Sustainable development and climate change induced obsolescence in the built environment

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Abstract

Climate change impacts, which are increasingly threatening to sustainability, are expected to be growingly experienced to various degrees around the globe in a number of ways such as global warming, more floods, stronger storms. Conversely, what is being built now shall predominantly be around as a substantial part of our built environment for decades to come, which due to aforesaid climate change factors are bound to suffer various degrees of obsolescence in different ways. Before climate change induced obsolescence accelerates and it is too late, actions need to be taken now to design and develop measures to tackle this problem. Failure to act now will mean that the costs of tackling climate change related obsolescence in future will be much higher. In view of these concerns, this paper present a conceptual model of how obsolescence can potentially occur to various degrees over time in built environment in relation to factors such as climate change. With examples this article relates climate associated obsolescence with the performance of buildings and infrastructures. The article also distinguishes between internal and external obsolescences, and shows that climate change impact on the built environment is preliminarily external. This paper also briefly discusses linkage between obsolescences and the role of maintenance and refurbishment. The paper reports on the peripherals of the short-term research underway at the University and future research potentials.

1.0 Introduction

Any constituent (such as a building or infrastructure) of the Built Environment grows to become obsolete or suffers increasing obsolescence over time. There is a host of factors which play a role either alone or collectively to cause obsolescence. Examples of these factors are not only conventional such as aging, wear & tear, but also, rather contemporary factors including energy consumption efficiency, environmental pressures such as reduction of carbon / greenhouse gases emissions, legislation / regulations, change of use, clean and waste water management, water quality and resources, land use, land contamination / soil quality, changing occupier / end user demands, sustainable waste management, ecological concerns, health & safety, and climate change. These factors can be categorised in different groups from various perspectives. However, the main focus of this paper is those factors which can be addressed under the banner of climate change category either in the context of climate change mitigation and / or adaptation. However, the paper's scope is not a specific constituent type of the built environment (e.g. a certain building type or infrastructure class) or a specific constituent itself (e.g. a given commercial building, a given hospital, a specific stretch of railway or road network, etc.). The paper is to consider obsolescence in a broad sense around various climate change phenomena.

Currently, the most widely accepted climate change scenarios or projections predict increases of between 1 to 3.5^{o}C for the global annual average temperatures (Crawley, 2010). On the top of global warming as a result of climate change, over the past few decades, there has been a significant trend towards increasingly larger urban areas. This concentration of transportation infrastructure and buildings often results in urban heat islands – increasing of the cooling loads on buildings. For example, London Heathrow, Los Angeles, and Phoenix have all seen average temperature increases of at least 1^{o}C over the past few decades (Crawley, 2010). Further more, floods, storms, droughts, and extreme temperatures strike communities around the globe each year. The top ten disasters of 2004, in terms of the number of people affected, were all weather and climate-related. These types of disasters have occurred throughout history but with total damages amounting to US$130 billion from just these ten events, it is clear that the necessary steps to reduce disasters have not yet been taken (CRED, 2005a; 2005b). As climate change begins to manifest itself—in the form of increased frequency and intensity of hazards such as floods, storms, heat waves, and drought—the need for communities to address climate risks is becoming urgent. The coming decades are likely to bring, among other changes, altered precipitation patterns so that many areas will experience more frequent floods and landslides, while others will experience prolonged drought and wildfires (IPCC, 2001; IATF, 2010). This simply will also lead to increase degree of obsolescence both in buildings as well as infrastructures of our built environment around the world.

Specifically for the UK, by 2050s the UK is expected to experience: increases in average summer mean temperatures (predicted to rise by up to 3.5^{o}C) and frequency of heat-waves / very hot days; and increases in winter precipitation (of up to 20%) and possibly more frequent severe storms (Hulme et. al., 2002). Also, in 2050s approximately 70% of UK buildings will have been built before 2010. Thus, if the investment in these buildings, which was approximately £129 billion in 2007, (UK Status online, 2007), is to be protected, action needs to be taken now to assess the vulnerability and resilience of the existing UK built environment, and plan adaptation / mitigation interventions, that allow to continue to support the quality of life and well-being of UK citizens. Failure to act now will mean that the costs of tackling climate change in future will be much higher (CBI, 2007). The UK will also miss out on the commercial opportunities that will emerge on the pathway to a low carbon economy (CBI, 2007). Thus, there is a growing need for long-term investors, managers and other stake holders to be able to assess how resilient their real estate assets are to new regulations and changing occupier demands (Goodland, 2008), which, in fact, reflect on various types of obsolescences, including the climate change induced obsolescence.

The biophysical properties of the urban environment are distinctive with a large building mass (350kg.m^{-2} in dense residential areas) and associated heat storage capacity, reduced greenspace cover (with its evaporative cooling and rainwater interception and infiltration functions) and extensive surface sealing (around 70% in high density settlement and city centres) which promotes rapid runoff of precipitation

(Handley, 2010). Climate change amplifies this distinctive behaviour by strengthening the urban heat island (Gill et. al. 2004). This correspondingly leads to amplify climate change induced obsolescence in the built environment (as explained with examples in Section 4.0). So it can be safely presumed as a general rule that the more the density of a built environment, correspondingly there is to be more the obsolescence, irrespective of drivers and reasons. For instance, London is one of the top most parts of the total UK built environment in terms of a range of elements such as geographical size, value, economy, human population, diversity, ecology and heritage. Furthermore, London is the capital of the UK and located near the North Sea, stretching around an estuary, and the River Thames running through it, thereby further adding significance and sensitivity to the city in hydro-logical context e.g. increased potential of pluvial, fluvial, tidal and coastal floods. Collectively along these wide-ranging elements, the overall London share in the total obsolescence over time in the total UK built environment, most probably is to be larger than anywhere else in the UK, and probably one of the largest shares throughout the world.

2.0 Obsolescence definition and types

2.1 Definition

In English language the word Obsolescence means the process of becoming obsolete; falling into disuse or becoming out of date (Word Net, 2010). In other words, obsolescence is the state of being which occurs when a person, object, or service is no longer wanted even though it may still be in good working order (Wikipedia, 2010).

2.2 Financial Obsolescence and Functional Obsolescence

In the context of built environment, obsolescence can be defined as depreciation in value and / or usefulness due to an impairment of desirability and / or function caused by new inventions, current changes in design, improved processes of production, or external factors that make a property or infrastructure less desirable and valuable for a continued use. Thus, irrespective of reasons / causes, financial obsolescence means loss in value where as functional obsolescence is loss of usefulness, effectiveness, efficiency or productivity. The financial obsolescence is also termed as social or economic obsolescence, and functional obsolescence as technical obsolescence. (Cooper, 2004; Montgomery Law, 2010; Leeper Appraisal Services, 2010; Richmond Virginia Real Estate, 2003; Nky Condo Rentals, 2010: SMA Financing, 2009).

2.3 Internal Obsolescence and External Obsolescence

Irrespective of whether obsolescence is in value or function or both, internal obsolescence in a component or built asset is due to factors that exist with in the component or built asset. For instance, general wear and tear, fatigue, corrosion, oxidation, evaporation, rusting, leaking of gas / water or any other fluid like coolant, breaking, age, etc. Where as external obsolescence is temporary or permanent impairment in value or usefulness of a built asset due to factors outside the system such as change in existing or advent of a new environmental legislation; social forces / pressure groups; arrival of new technology; enrichment of knowledge e.g. asbestos is no longer allowed to be used in the built environment; fluctuation in demand; inflation of currency; etc. In summary, external obsolescence could be due to any external factor from a large employer in the area shutting its doors to a zoning change through a property located under an airport flight pattern to even a house in one's neighbourhood that seem to attract broken down cars. (Landmark Properties, 2009; Salt Lake County, 2004; ESD Appraisal Services, 2010; Drew Mortgage, 2006)

2.4 Climate change induced obsolescence

Irrespective of whether an obsolescence is internal or external and financial or functional, if a given obsolescence is due to impacts of climate change (e.g. more intense and more frequent rainfall, stronger and more frequent hurricanes, heat-wave, flooding, etc.) is referred to as Climate Change Induced Obsolescence by the authors (Butt et. al., 2010). More examples of climate change impacts are listed in Section entitled 'Obsolescence impacts on Maintenance and Refurbishment'. Those examples also demonstrate that climate change related obsolescence is predominantly external, rather than internal.

3.0 Conceptual Model of Obsolescence and Building Performance

At the University of Greenwich (UK) in a short-research project the factors that affect building/infrastructure obsolescence (i.e. failure of the built asset to meet the demands, requirements and expectations of the end users) are examined and how their influence may be affected (positive and negative) by climate change is considered. A conceptual model of building/infrastructure obsolescence (based on that produced by Finch, 1996) has been developed (Figure 1) that suggests the changing UK climate will accelerate the rate at which a built asset becomes obsolete, requiring greater performance improvements from maintenance and refurbishment actions and a foreshortening of maintenance and refurbishment cycles. The collective consequence of these factors will be greater (than expected) life cycle costs.

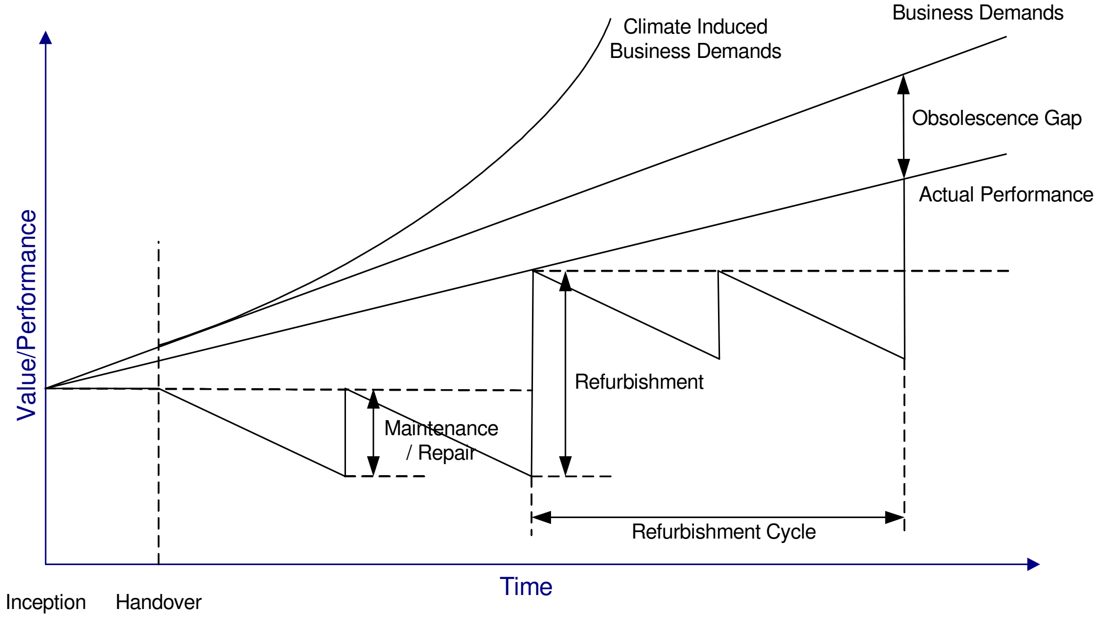
The purpose of this research in the next stage will be to begin to quantify the above. To do this the research team is to build future built asset life cycle scenarios across a range of 'typical' built assets that relate climate change induced obsolescence (both causes and affects) to adaptation and mitigation measures that can be costed as part of the routine maintenance and refurbishment cycle for the asset. From these scenarios it is hoped to be able to predict the potential impacts of climate change induced obsolescence on life cycle costing models.

4.0 Obsolescence impacts on Maintenance and Refurbishment

There is growing evidence that climate change is real, already observable, and threatening to undermine development. Therefore, climate adaptation continues to rise on the agendas of researchers, practitioners and decision-makers. On the other hand, the onus of adaptation to climate change directly lies with or impacts on maintenance and refurbishment of the existing built environment. Even future developments are not safe from climate change unless adaptation is not integrated into not only in there design but also maintenance and refurbishment cycles, both in the form of practice as well as costs. Thus, any effective planning and development process will need to take climate adaptation into account and, conversely adaptation efforts themselves will often require development interventions, via maintenance and refurbishment, to succeed.

While climate impacts are increasingly observed, the debate over managing adaptation has progressed very slowly. However, as the authors have shown in the figure, that adaptation management is expected to accelerate rapidly and exponentially soon. Thus, one of the reasons of the acceleration shall surely be increased realisation which is yet to fully to catch up with the reality. Relatively current slow realisation is in part due to confusion about relationship between adaptation and development – a definitional problem that has hindered not only project design, but also the allocation of funding to adaptation efforts. Notwithstanding the difficulty in developing a concise operational definition, failure to clarify this relationship has meant that funding mechanisms create redundancies or leave gaps in the landscape of critical adaptation, development, maintenance and refurbishment activities (WRI, 2010).

Figure 1. Model of the Maintenance – Refurbishment life cycle



Common examples of climate change factors (both cause and / or affects) that have already begin to cause obsolescence to the built environment and have substantial potential to further increase climate change induced obsolescence in future, are:

- Flooding (fluvial, tidal and pluvial due to more frequent and more intensive rainfall);
- Coastal flooding due to sea level rise;
- Over-heating (due to global warming as average annual global temperature is rising);
- Corrosion (due to acidic rain, more frequent and more intensive storms / hurricanes);
- Coastal corrosion;
- Drying out of water bodies such as lakes;
- Ultra-violet (UV) sun rays due to ozone layer depletion;
- Resources depletion e.g. deforestation;
- Wildfire;
- Drought;
- Landslides;

- Hurricanes;
- Environmental pollution e.g. GHG emissions;
- Environmental and legislative pressures e.g. to reduce carbon emissions;
- etc. etc.

Below are a few examples described to indicate how climate change impacts have potential to cause obsolescence and consequently adding burden on maintenance and refurbishment:

Flooding risks to residential and commercial properties

UK coastal waters have warmed by about 0.7^{o}C over the past three decades. In addition, the average sea level around the UK is now about 10 cm higher than it was in 1900. Globally, sea level could rise by 18 to 59 cm by the end of the century. Rising sea levels would swamp some small, low-lying island states and put millions of people in low-lying areas at risk of flooding (Directgov, 2010). Consider an existing residential area near by a coastal line or along a tidal river stretch. Given that these residences would be containing items such as electric cookers, microwave oven, refrigerators and freezers, washing machines, dishwashers, tumble dryers, carpets, vacuum cleaners, cars, radio and CD players, CDs / DVDs, Hi-Fi stereo, video equipment, televisions, telephones and answer machines, computers and peripherals, toys, power distributions and accessories, sentimental value items, etc. (Cooper, 2004). Climate change includes more rain and more flooding. Thus, if a pluvial, fluvial or coastal flooding occurs, all these listed items if subjected to flood water are to become obsolete. Not to mention damage that flooding will cause to the fabric of buildings and houses. Thus, if refurbishments take place post-flooding, the cost could be incredible, depending not only on degree of flooding intensity but also other factors such as how dense the residential area is, how well planned it is, etc. In the context of adaptation, a number of steps could be taken either at individual property level or communal level, for examples, raising and strengthening flood banks and their regular maintenance to control their obsolescence. In planning applications for various developments, Environment Agency in England and Wales is consulted on flood risk assessments seeking implementation of flood resistant and resilient approaches (ODPM, 2001; 2005; 2006; DCLG, 2007; DEFRA, 2005a; 2005b). Whereas if a given development is new and in planning stage finished floor levels can be set above 1 in 100 year flood level plus allowance for climate change and 300mm freeboard for hard flood defences and 500mm for soft flood defences (ODPM, 2006; DCLG, 2007). The same discussion also implies in principle to commercial properties though additional losses due to flooding include disruption of businesses. Thus, flooding is a potential source of external obsolescence directly increasing maintenance and refurbishment requirements and costs.

Acid Rain

The term 'acid rain' refers to both wet and dry deposition of acidic pollutants that may damage material surfaces including corrosion of metals and deterioration of paint and stone (such as marble and limestone). These materials constitute our built environment. Thus, acid rain effects can significantly reduce the societal value of buildings, bridges, cultural objects (such as statues, monuments, and tombstones) as well as leading to increased maintenance and refurbishment costs (EPA, 2007). Since air emissions are escalating and correspondingly more acid rain, therefore maintenance and refurbishment costs are likely to be much higher in future than they are now to keep built environment constituents from suffering climate related external obsolescence. Similarly, acid rain also adversely impacts vegetation or plant life. This means open space green areas as well as any other vegetation in the built environment can also be affect by acid rain, thereby increasing their maintenance amount, frequency and costs.

Sea ports

Climate change can impact ports in a variety of ways. For instance, increases in power and duration of storm surges; coastal flooding and changes to erosion pattern can impact infrastructure and dredging requirements; wave attack at higher sea levels can increase the vulnerability of structure over time, as can increase in frequency and duration of storms (Shipping Industry News, 2009). All such potentials and incidents if happen have strong likelihood to cause obsolescence to various degrees which may require increased levels and frequencies of maintenance.

Electric power systems

Over the past 100 years the average global temperature has risen by around 0.75^{o}C and the sea level increases by 3mm a year. There is a consensus on the impact of this climate change phenomena on the planning and operation of electric power systems. For instance, winds are growing in strength, resulting in a greater frequency of operations interruption (falling trees, avalanches, etc.). Furthermore, due to the increasing incidence of heavy precipitation, lines and substations are often flooded, damaged and destroyed. Repairing the resultant damage is often time-consuming. Also the temperature of permafrost layers is rising. As a result the bedrock is becoming loose. This in turn increases the risk of landslides, which also damage and destroy lines and substations. There are many cases of extreme weather which have caused enormous damage to electric power systems, e.g. the ice storm in Canada (1998) or the hurricane “Lothar” in Western Europe (1999). Considering the climate change and resultant maintenance at the planning stage are therefore highly relevant. (Moser et. al., 2008).

Erosion of Estonia coast

Estonia has a long (3,800 km) coastline due to numerous peninsulas, bays and islands (over 1,500). Frequency of storm days varied greatly during the second half of the 20th century with a minimum in the 1960s and a maximum during the last two decades. The results of the Mann-Kendall test show a statistically significant increasing trend in annual storminess over the last half century. This increase is probably associated with increased westerlies and cyclonic activity in Northern Atlantic in winter resulting in a warmer winters in Northern Europe and an ice-free Baltic Sea near the Estonian coast. This has and is resulting in extensive erosion and alteration of deposition coasts, such as sandy beaches, appears to be largely due to the recent increased storminess in the eastern Baltic Sea (Orviku et. al., 2003). Keeping in view the length of the coastline it is obvious all developments (irrespective of their types and nature) are being and to be affected in the form of external obsolescence owing to the climate change, consequently increasing need of maintenance and refurbishment requirements.

Ocean acidification

The absorption of atmospheric carbon dioxide (CO_2) into the ocean lowers the pH value of the waters. This is called ocean acidification which could have important consequences. The ocean uptake of anthropogenic CO_2 has been observed to have increased (Feely, et. al. 2008). This means that there is potential of corrosion / rusting of all human made structures which come in contact with ocean waters e.g. oil rigs, under sea pipe systems / infrastructures, tunnels, sea current / tidal energy turbines, piers, etc. This can be seen as a potential of more external obsolescence as a result of climate change, and more frequent maintenance may be required.

Enhanced cooling / air conditioning in buildings

The1990s was the warmest decade in central England since records began in the 1660s. Summer heat-waves are now happening more frequently and in winter there are fewer frosts. Globally, over the past century, the average temperature of the atmosphere near the earth's surface has risen by 0.74^{o}C. Eleven of the 12 hottest years on record occurred between 1995 and 2006. The scientific consensus is that global temperatures could rise between 1.1 and 6.4^{o}C above 1980 – 1999 levels by the end of 21st century. The exact amount depends on the levels of future greenhouse gas emissions. (Directgov, 2010). This happening phenomenon is already demanding our current residential and commercial built environment for extra cooling to achieve comfort zone during heat-waves in particular. This could also affect our road infrastructure for heat-waves could have adverse affect on roads charcoal and quality. Various industrial processes may also be affected due to ambient temperature rise. All of these scenarios are resulting and will increasingly result in external obsolescence, thus demanding more maintenance and refurbishment incurring more costs.

Change in vegetation zones

A change in climate would have an affect on the world's vegetation zones which means change in the boundaries between grassland, forest and shrubland. This change in vegetation zones could cause famine in arid area such as Africa that depends on a certain type of crop. The change in vegetation would cause mass movement of people away from arid regions. This could cause huge over-crowding in towns and cities (ECA, 2010). Thus, urban environment would be even more populated than already is, which could increase obsolescence of the existing built environment for these were not designed for this much population in the first place. Thus, this would increase maintenance and refurbishment requirements, frequency and costs.

Permafrost thawing and impact on infrastructure

The Artic has shown the most rapid rate of warming in recent years and continues to be a climate change hot spot (Folland and Karl, 2001). The Artic is extremely vulnerable to projected climate change, with major impacts anticipated physical, ecological, sociological and economic factors (Anisimov and Fitzharris, 2001). Many of such impacts have already been detected and are likely to continue in the future (Serreze et. al., 2000). The term "permafrost" refers to any subsurface materials that remain below 0^{o}C for at least two consecutive years (Anisimov and Reneva, 2006). The permafrost regions occupy 25% of the Northern Hemisphere's terrestrial surface, and more than 60% of that of Russia (Anisimov and Reneva, 2006). In Usa Basin, Northeast of European Russia, alone about 75% of the Basin is underlain by permafrost terrain with various degrees of continuity (isolated patches to continuous permafrost). The region has high level of urban and industrial development (e.g. towns, coal mines, hydrocarbon extraction sites, railway, pipelines). About 60% of all infrastructure is located in the 'high risk' permafrost area. Most of the permafrost-affected terrain will likely start to thaw within a few decades to a century. This forecast poses serious challenges to permafrost engineering and calls for long-term investments in adequate infrastructure that will pay back over time (Mazhitova, et. al., 2004).

Every fifth emergency at West Siberian pipelines is caused by thawing of permafrost. This is the conclusion given by the Greenpeace's study of socio-economic and natural consequences of the climate change (Rus Business News, 2009). The Russian Office of Greenpeace informed that 1,900 disasters occur every year in the oilfields of Ugra. Uneven ground subsidence when the permafrost thaws and squeezing the foundations out when the soil freezes, were identified as the main causes of technological breakdowns. There are similar problems faced by the gas producing companies in Yamal. Maintaining the working order of pipelines and the liquidation of deformations caused by changes in permafrost costs producing companies 55 billion roubles a year. Specialists reckon that costs of preparing sites for property development in the West Siberia may grow by 3 to 56% due to the need for additional thermo-stabilisation measures. (Rus Business News, 2009). Thus, like in other exemplary scenarios of climate change impacts mentioned above, in permafrost case too, maintenance and refurbishment are to take the onus of climate change impacts thereby increasing maintenance costs substantially.

5.0 Discussion and concluding remarks

Irrespective of reasons or causes of obsolescence, the prime affect of it is reduction in performance and, consequently, not appropriately meeting demands, requirements and expectations of the end user of a given building, structure, infrastructure or any other constituent / unit of built environment. It is maintenance and refurbishment which attempts to eradicate obsolescence, to whatever degree this may be, to avoid rebuilding / redevelopment. Thus, the onus of obsolescence, in terms of closing an obsolescence gap (Figure 1), lies on maintenance and refurbishment. Consequently, as the afore listed climate change impacts intensify and become more frequent over time, the climate change induced obsolescence correspondingly will increasingly lead to substantially more expensive maintenances and refurbishments and yet more often, thereby reducing maintenance and refurbishment cycles' length and escalating frequency and costs. Furthermore, if enough measures / interventions are not implemented in time, this could even lead to redevelopment i.e. demolition and fully rebuilding at the same place or even geographical relocation of the new resultant development, which could raise additional siting / relocation issues in a whole host of sustainability seeking efforts. Whether obsolescence compromises performance of a system, or increases maintenance and refurbishment amount and frequency, or even result in rebuilding / redevelopment, in all cases it eventually stresses finances and economy of an organisation. Thus, further research is needed to relate climate change induced obsolescence factors (both causes and affects) with in-time maintenance and refurbishment cycles such that the given built environment scenario does not loose its performance both as a physical built asset as well as operational, and continues performing efficiently with cost-effective maintenance and / or refurbishment. In the literature review, no evidence has been found of such a research in a holistic format.

This research project is investigating how climate change is to cause obsolescence and consequent affects on built environment, which predominantly comprises buildings and infrastructures. The former category includes offices / commercial buildings, structures (e.g. tunnels, bridges, dams, etc.), residential buildings (e.g. houses, flats, etc.), schools, churches, factories; and the latter predominantly comprises utilities, energy and transportation. Thus, built environment is not only physically built assets but also contains other aspects such as facilities, products, materials, commodities, services, energy, comfort, health & safety, and operational facets (McClure and Bartuska, 2007; Wikipedia, 2009). All such aspects and facets of a unit / constituent (e.g. a given building or an infrastructure) of a built environment are collectively termed as overall performance of the unit / constituent, by the authors. That is performance comprises both a given built asset itself (e.g. fabric of a building) as well as various operational / functional elements such as cooling / heating in the building.

As stated earlier, this underway research project is establishing causes and effects regarding obsolescence and specifically in the climate change context. Then those factors (both causes and affects) shall be further investigated to find which crucially relate to the overall performance of built environment (inclusive of both, buildings and infrastructures). Thus, the project is to address not only physical aspects of the built environment but also operational facets. The identified factors shall be categorised in a holistic set of logical groups and sub-groups particularly along the sustainability dimensions i.e. social, environmental and economic (Kiaie et. al., 2010; Plows et. al., 2003). Later the project shall investigate which of these factors are more frequent and influential / sensitive for various scenarios e.g. a certain aspect of maintenance / refurbishment like boilers / heating system, a certain industry like oil refinery, a certain set of buildings such as houses, etc. From the review of literature to date (e.g. Allehaux and Tessier, 2002; Jones and Sharp, 2007; Acclimatise, 2009) the research project establishes that especially from the perspective of climate change there is lack of knowledge, models, and holistic approaches towards integrating maintenance and refurbishment cycles with the performance and life-cycle of a given built asset / building or infrastructure. On the other hand, in 2005 built asset maintenance and refurbishment accounted for approximately 45% of the total UK construction output (DTI, 2006); employed 1.17 million individuals and represented approximately 6.2% of the UK's Gross Added Value (Dye and Sosimi, 2006). In view of such facts, in summary, this research is identifying knowledge gaps to establish bases for future research to develop a holistic obsolescence assessment around climate change impacts in the form of a conceptual framework, then a knowledge-base procedure, which shall be translated into a computational methodology and then eventually an expert system. The holistic assessment approach is to consider both functional as well as financial obsolescences yet around climate change impacts only.

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