Obsolescence types and the built environment – definitions and implications

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Abstract: In view of the literature to date as well as anecdotal conversations with practitioners and consultants in various sectors of the built environment industry, it is observed that the term 'obsolescence' is scarcely used or comprehended with its diverse implications. In the context of climate change impacts this term is even more uncommon. This paper describes implications of the term in the form of definitions and types of obsolescence from various perspectives, including the built environment and climate change. This study also briefly explains that obsolescence is a multi-faceted entity and the comprehension of its concept and implications can help to effectively manage the built environment in a sustainable manner, particularly to the face of climate change. This paper can stimulate both debate as well as further research in industry and academe, respectively.

Keywords: climate change; built environment; obsolescence; obsolescence types; sustainable development; sustainability.

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1 Introduction

1.1 Background

Whatever is human-made, tends to become obsolete over time due to physical factors such as chemical degradation, physical damage, etc. However, the process of obsolescence is not limited to materialistic and physical factors. Social, cultural, technological and political factors (such as technology innovation; variation in customer demands; change in existing legislation; social pressures; advancement of knowledge; inflation of currency; civil unrest or conflict of interests; etc.) can also drive obsolescence. Moreover, climate change is another and newest element which is acting as an additional driver of obsolescence in a number of ways – both directly and indirectly. This means some factors are climate change-related that are causing obsolescence while others are non-climate change associated. However, the literature review as well as anecdotes with professionals in various fields of the built environment revealed to the authors that not only the term obsolescence is not much common, but also that multi-dimensional and growing concept of obsolescence is seldom fully appreciated with its wide range of implications. Some implications are conventional that is age or breaking down of a component of a system renders the component obsolescent. But new factors such as how climate change and new environmental legislation are inducing obsolescence risks to various systems of the existing built environment are not as much realised. Generally, it does not appear to be recognised that increase in the requirement of adaptation, repair, overhauling, retrofitting, or refurbishment of a system is a direct indicator of increase in obsolescence.

1.2 Additional significance due to climate change

Physical and biological systems on all continents and in most oceans are already being affected by recent climate changes, particularly regional temperature increases recorded with a very high confidence level (IPCC, 2007a). Currently, the most widely accepted climate change scenarios or projections predict increases of between 1.1 to 3.5°C for the global annual average temperature by 2050s (Hulme et al., 2002). In addition for a longer time scale, according to the Intergovernmental Panel on Climate Change (IPCC), emissions of greenhouse gases (GHGs) will increase the average global temperature by

1.1 to 6.4°C by the end of 21st century (IPCC, 2007a), particularly when the fossil fuel driven carbon emissions have been on the accelerating increase since pre-industrial times and many folds even more so since 1970 (Boden et al., 2010). The built environment is potentially exposed to even larger rises in temperatures as the recent growth of large urban areas has created urban heat islands. For example, irrespective of global average temperature rise, over the past 30 years London Heathrow, Los Angeles, and Phoenix have all seen average temperature increases of at least 1°C locally (Crawley, 2008). Another example of substantial temperature rise is in the European Alpine Region which is amongst the areas most rapidly affected by climate change. In general, the mean temperature of this region has increased up to +2°C for some high altitude sites over the 1900–1990 period, thereby considerably affecting economic, environmental and socio-ecosystems (Balbi et al., 2013).

Furthermore, 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 sufficiently taken (CRED, 2005a, 2005b). As climate change begins to manifest itself in the form of increased frequency and intensity of various hazards, 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 droughts and wildfires (IPCC, 2001, 2007b). Thus, the systems and components (such as buildings and infrastructures) that constitute existing built environments around the globe face many folds more obsolescence risks than if climate change was not occurring. In other words, on the top of obsolescence occurring due to normal wear-and-tear and other such conventional drivers (e.g., technological innovations and developments – advancement and popularisation of renewable energy technologies (IPCC, 2012), climate change associated factors are going to accelerate the process of obsolescence even more. Moreover, legislative and mandatory instruments (examples given in later sections of the paper) influenced and driven by climate change are also introducing obsolescence risks to current systems of the built environment, and at the same time pressure is mounting to combat obsolescence via climate change mitigation and adaptation.

1.3 The case of UK as an example

The case of UK is presented here as an example. By the 2050s, the UK is predicted to have an increase in average summer mean temperatures of up to 3.5°C; escalations in the frequency of heat-waves/very hot days; increases of up to 20% in winter precipitation; and possibly more frequent severe storms (Hulme et al., 2002). 70% of UK buildings in the 2050s have been built by 2010, which due to aforesaid climate change factors will suffer from various types of obsolescence. If the investment in these buildings, which was approximately £129 billions in 2007 in the UK alone (UK Status online, 2007), is to be protected, actions need to be taken now to assess likely obsolescence of the existing UK built environment; and adaptation and mitigation strategies to be adopted that will continue to support the quality of life and well-being of UK citizens. Failure to act now will mean that costs of tackling climate change associated obsolescence in future will be much higher (CBI, 2007). Other countries around the globe face similar issues, although there may be some variation in nature and quantity of climate change, and the way climate change impacts manifest themselves in relation to the resources and governance of a given country. Irrespective of any specific country, in order to render a given built environment more sustainable; concepts, definitions, types and implications of obsolescence need to be clearly understood.

1.4 Aims and objectives

This paper aims to indicate some new insights building up on existing conventional concepts of obsolescence. The paper does this by defining and classifying obsolescence from different angles, which particularly include: the built environment, climate change (both direct and indirect influences), and even non-climate change perspectives. A detailed systematic nomenclature of obsolescence is developed and described for one area in which there is presently no literature of a comprehensive degree for the built environment. Not only examples are used throughout the paper, where appropriate, to elaborate on old and new dimensions of obsolescence, but a number of case studies are also presented to demonstrate how different types of obsolescence can simultaneously co-exist in the same scenario of a built environment. Also, links are briefly drawn between obsolescence and the sustainability philosophy.

2 Common definitions

2.1 What is obsolescence in general?

The word obsolescence comes from the Latin word ‘obsolescere’ which means to grow old. Obsolescence means the process of becoming obsolete or obsolescent; falling into disuse or becoming out of date. Obsolescence can also be referred to as 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 or condition. It is depreciation in value, impairment of desirability and/or usefulness caused by new inventions, current changes in design, improved processes of production, or external factors that make a system less desirable and valuable for a continued use (Definitions.Net, 2013; Hornby and Cowie, 1989; MFL, 2013; Nwoko, 2010a; Word Net, 2013).

Some literature have been found to define obsolescence in different and limited manner. For instance, some literature defines obsolescence as a loss in the utility of an asset due to the development of improved or superior equipment, but not due to physical deterioration (Investorwords.com, 2013). Thus, conventional meaning of obsolescence – that is, due to physical wear and tear – has been excluded from this definition. Whereas some literature may consider only physical deterioration while others only financial depreciation in connection to obsolescence. However, this paper deems and describes the concept of obsolescence with much more holism, which includes not only conventional meanings of the term but also contemporary implications such as socio-economic and environmental, as explained in later sections of the paper.

2.2 Definition of the built environment

The term built environment means human-made surroundings that provide a setting for human activity, ranging in scale from personal shelter to neighbourhoods and large scale-scale civic surroundings. In summary, whatever is human-made is the built environment. In a similar manner, the world that is not human-made or anthropogenically influenced can be referred to as the natural environment. The relationship between built and natural environments can mathematically be expressed as follows:

$$\text{Total Environment} = \text{Natural Environment} + \text{Built Environment}$$

or,

$$\text{Built Environment} = \text{Total Environment} - \text{Natural Environment}$$

This implies that if the natural environment is taken away from the total environment around humans, what is left behind is the built environment. The phrase built environment is also widely used to describe the interdisciplinary field of study which addresses the design, construction, management and use of the human-made surroundings and their relationship to the human activities which take place within them over time. This does not necessarily mean only buildings, structures, canals, bridges, housing stock and offices, but also individual commodities that are used in these buildings and structures, industries and their associated manufacturing and processing plants, technologies (embodied/physical and disembodied/non-physical), inventories and stock, and supply chains. Whereas these industries could be in the service sector (e.g., education, planning), the product sector (e.g., cars, farming equipment) or a combination of both the sectors. For instance, a transport company serves its customers with travelling (which is a service) but also sells them food and beverages while travelling (which is a product). These are just a few examples merely to present a flavour, whereas obsolescence risks are posed to all situations with varying degrees, in different time scales, in a number of ways, of various types, and with diverse implications (Dubos and Saleh, 2010; Fitzpatrick, 2011; Herald et al., 2009; Iansiti and Khanna, 1995; Iselin and Lemer, 1993; van Jaarsveld and Dekker, 2011; Ji-wen et al., 2010; Johnson, 2012; Kumar and Saranga, 2010; Miao, 2011; Romero Rojo et al., 2009; Slade, 2006; TLS Ltd., 2013; Zanon and Verones, 2013). Obsolescence types and implications are defined and described in later sections of the paper.

2.3 Obsolescence and the built environment

In the context of built environment, obsolescence can be defined as depreciation in value and/or usefulness of a human-made system as a whole (e.g., a building, transport infrastructure, etc.) or its component (e.g., a boiler of the building) due to an impairment of desirability and/or function. This loss of value or amenity could be from a multitude of causes such as: new inventions, current changes in design, technological development, improved process of production, change in use or end-user demands, climate change (e.g., global warming). Other social factors may also play a role, for instance, instability in politics of a country or tightening of environmental legislation can render a part of a given built environment, e.g., a property or built asset less desirable and valuable for a continued use.

It is generally not age as much, but change that is the chief cause of obsolescence. Many ancient buildings are still useful and may perhaps serve their functions better because of their age. For instance, churches, mosques, shrines, monuments and historical buildings are known to have been constructed many centuries ago and are deemed even more functional and useful in their old age in their respective usage when compared with when they were originally constructed. In summary, obsolescence in buildings refers to the gradual process (or a condition) of a building of not being able to meet up with the contemporary standards in terms of functionality, statutorily, physically, and/or economically with in a particular place or time causing the building to be obsolescent (Nwoko, 2010a).

3 Implications and types of obsolescence

There is a wide range of types, aspects and implications of obsolescence. A few main types are listed below with a systematic categorisation to explain various facets and implications of obsolescence. These implications also include climate change-related (both direct and indirect) and non-climate change-related obsolescence in the built environment context.

3.1 Financial and functional obsolescence

Irrespective of 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 (depending on the driving cause), and functional obsolescence as technical obsolescence (Cooper, 2004; Farlex Inc., 2013; LAS, 2013; MFL, 2013; NKY Condo Rentals, 2013; RRE, 2013; wiseGeek, 2013a, 2013b). Sometimes a whole system may become functionally obsolete, although mostly obsolescence induces embedded parts of a complex system where the design life of the system typically exceeds 20 years (Kumar and Saranga, 2010). This obsolescence in part, if not fully, is generally due to technological advancements of embedded parts of a complex system and has even been referred to as the ‘dark side’ of innovation (Gravier and Swartz, 2009). The functional obsolescence is a major parameter affecting technical installations and influences the value of an office building (Allehaux and Tessier, 2002). Another scenario is that of a building might be structurally fine but unable to generate enough income to keep it running in the present state, which can be referred to as a case of financial obsolescence (Nwoko, 2010a). On the contrary, it would be a matter of functional obsolescence if the same building cannot perform to the required level due to some structural defect appearing in the building, e.g., precipitation leaking through the roof.

Suppose a developer has set a residential area along a coast. The houses are new and modern. If mortgages become unaffordable due to, for instance, rise in interest rates (Patriarca, 2012), then these houses despite being new and modern, can be hit by financial obsolescence. Similarly another scenario could be for being in a coastal region, if there is a flood event, e.g., due to flood bank bursting, the insurance premium may become unbearable and this can be yet another financial obsolescence scenario. Alternatively, if due to constantly rising sea levels, the current flood defence heights may not sufficient to protect these properties. Therefore irrespective of the financial implications this may bring to the housing stock, these defences are going to be suffering from obsolescence. In this case the flood defence is functional obsolete, which could propagate further to render the housing stock functionally obsolete if these defences failed to effectively contain the seawater.

3.2 Internal 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 *within* the component or built asset. Factors could include:

- general wear and tear
- fatigue
- corrosion
- oxidation
- evaporation
- rusting
- leaking of gas/water or any other fluid like coolant
- breaking
- breakdown/failure
- age, etc.

External obsolescence is temporary or permanent impairment in value or usefulness of a built asset due to factors *outside* the system. Factors that could derive external obsolescence either individually or in various combinations include:

- changes in existing or advent of a new environmental legislation
- social forces/pressure groups
- arrival of new technologies (Clavareau and Labeau, 2009)
- technological innovation (Pantano et al., 2013)
- knowledge advancement
- labour market and unemployability (e.g., specific skill set not available) (Rio, 2010)
- inflation of currency
- rise in interest rate (Patriarca, 2012)
- sharp rise in fuel and/or energy prices (Alpanda and Peralta-Alva, 2010)
- fluctuation in demand, supply, inventory, etc. (Teunter et al., 2011).

In summary, external obsolescence could be due to any external factor such as a large employer in the area shutting its doors due to a zoning change, through to a property being located under an airport flight path, to even a particular house in one's neighbourhood that seemingly attracts broken down cars (American Appraisal, 2013; DMA, 2006; NAI Landmark, 2013; SLC, 2013). However, boundaries between internal and external factors of obsolescence for a given setting may not necessarily always be physical, they can also be virtual.

3.3 Permanent and temporary obsolescence

Permanent obsolescence is irreversible. For instance, when adverse health impacts of asbestos were proved, use of asbestos in the buildings became illegal, rendering the asbestos use in the construction industry permanently obsolete. On the contrary, factors which are not permanent such as temporary civil unrest in a society, loss of power for days, or flooding can cause a *temporary obsolescence*. For instance, the Berlin Wall in Germany was a barrier constructed in early 1961, that completely cut off (by land) West Berlin from surrounding East Germany and from East Berlin. Following a series of radical political changes, in 1989 the wall was eventually demolished after nearly three decades from its first construction (HCD of CIA's Information Management Services, 2011). The east/west division via the wall can be referred to as an example of temporary obsolescence, although, relatively a long one.

On the other hand, since the invention of the telephone in 1870s by Alexander Graham Bell, the humble phone has undergone numerous changes on terms of size, shape and design. A relatively recent design is the one which used to have a 'rotary dial'. The rotary dial has been gradually replaced by the 'push-button dial'. Nowadays, a rotary dial phone is thought of more as an antique item. Thus, the rotary dial phone is not in use in our current built environment any longer and this is permanent obsolescence. Similarly, like Asbestos, another example is that of poly-fluorinated chemicals (PFCs) which are toxins and used in manufacturing of outdoor clothing to render them stay warm and dry when worn outdoors in the rain. These toxins are now found in the environment and in the blood of humans. Greenpeace has called on the outdoor clothing industry to ban PFCs from production and to further develop fluorine-free alternatives. There are a number of initiatives, even at the governmental levels, already taking place (Greenpeace (Germany), 2012). Once these toxins are banned, their use will become permanently obsolescent for the outdoor clothing industry.

3.4 Planned and unplanned obsolescence

A planned obsolescence is an intentional obsolescence and an unplanned obsolescence is an unintentional or natural obsolescence. Planned obsolescence is also known as built-in obsolescence. It is the conception, design, and production of a commodity with an intent of it being useful, functional or popular for a certain period of time, after which it becomes obsolete, that is, unfashionable or no longer functional. In some cases this type of obsolescence is to ensure that consumer will have to buy the commodity multiple times, rather than once. The strategy of planned obsolescence is common in the markets for information goods such as software programme and textbooks (Bulow, 1986; Fitzpatrick, 2011; Johnson, 2012; Miao, 2011; Rouse, 2013; Slade, 2006; Waldman, 1993). In the context of developments (such as buildings, bridges, etc.) an evaluation of the implementation of development-viability-appraisal models in the UK planning system has been carried out by Crosby et al. (2013). This evaluation reveals that due to spatial and temporal variation in the capacity of development sites to generate financial surpluses for planning obligations, policies that set rules or fix targets on planning obligations without regard to prevailing site and/or market conditions, can reduce the supply of developments and/or be prone to rapid obsolescence.

As opposed to planned obsolescence, there has not been found as much literature defining unplanned obsolescence in particular. This is probably because, when obsolescence is unplanned, it is simply taken for obsolescence. It is only when it is intentional then the term 'planned obsolescence' is used to distinguish it from the obsolescence, which is generally unplanned in nature. For instance, Patterson (2013) is the only refereed journal literature that due to the nature of the article, has been found to use both the terms in the same article as a basic requirement to differentiate between the two concepts. In some built environment scenarios, planned and unplanned obsolescences may simultaneously be happening. For instance, irrespective of degree of planned obsolescence in electronic gadgets, Grahame (2011) states that the world is facing a terrifying era of unplanned obsolescence, where the pace and popularity of personal electronic communication has reached an unsustainable rate of change.

3.5 Climate change induced obsolescence

Irrespective of whether obsolescence is internal or external and financial or functional, if a given obsolescence is due to impacts of climate change it is referred to as *climate change induced obsolescence* by the authors. The climate change associated obsolescence can be direct or indirect as described below:

3.5.1 Directly induced climate change obsolescence

Obsolescence that is caused by direct influence of climate change factors is termed as *directly induced climate change obsolescence*. For instance:

- Current air conditioning systems in built environments may not be as effective due to global warming or extreme heat-waves which are a resultant of climate change. Thus, global warming or extreme heat-waves may bring about obsolescence in a given building's air conditioning system as a direct influence of climate change.
- These extreme heat-waves may also have direct adverse affects on structure or fabric of buildings. Similarly, prolonged droughts can adversely impact foundations of buildings due to extreme dryness. Moreover, due to rising levels of GHG emissions in the atmosphere, the interaction of poor air quality with facade of a given building can induce obsolescence in terms of reducing refurbishment cycle of the building facade.
- Similarly, due to water level rise in water bodies as a result of climate change, estimated flood levels are higher than before. This implies that current level of electrical cables, power points, and appliances from the ground in a given built environment may not be high enough any longer to defend against flooding should it happen. This is direct induction of climate change associated obsolescence in the flood defence mechanism.
- As one of climate change impacts, the rainfall is on the increase in both frequency and intensity. In many cities combined sewer systems were not designed to cope with this fact. Thus, pluvial flood events are happening more frequently, which is an

indicator of increase in the directly induced climate change obsolescence in existing combined sewers. To overcome this increasing obsolescence risk, as an adaptation measure, the grey infrastructure needs to be replaced by blue and green infrastructure appropriately, e.g., water-sensitive urban design (WSUD) (Ashley et al., 2013; Stride, 2013).

3.5.2 Indirectly induced climate change obsolescence

Obsolescence that results from climate change factors in an indirect manner is referred to as *indirectly induced climate change obsolescence*. For example:

- Irrespective of to whatever degree, one of the reasons of climate change acceleration is anthropogenic activities such as GHG emissions which include carbon dioxide. This has contributed in shaping environmental legislation such as European Union (EU) Directive of Energy Performance of Buildings (2002/91/EC) (EC Energy (ManagEnergy), 2013; EU, 2002); EU Climate and Energy objectives; and legally binding carbon reduction targets set up by Climate Change Act 2008 (DECC, 2009; HM Gov., 2011; Legislation.gov.uk, 2013). Such environmental legislations, in the form of legal pressures to reduce carbon footprint, have begun to cause indirectly induced climate change obsolescence in existing buildings. A more specific case in this regard is described in Section 4.1.1 below.
- Similarly, the advent of carbon capture and storage (CCS) technology in line with carbon cut demands and targets (Butt et al., 2012) is at the verge of introducing substantial amount of obsolescence to existing fossil fuel power plants operating without CCS. This will be a case of indirectly induced climate change obsolescence.
- Introduction and application of clean energy technologies is on the increase. The cost of these substitutes is presumed to decrease with cumulative use because of learning-by-doing and widening of the use like it happened with, e.g., computers. In some cases these clean technologies are being adopted voluntarily and in others due to mandatory factors like carbon cap, carbon tax, and cap-and-trade regarding control on aggregate emissions from a fossil fuel (e.g., coal). In both the categories, climate change is a fundamental and original driver either wholly or partly. This can be deemed as indirectly climate change induced obsolescence that has started to happen varyingly in a number of aspects of industrial economies, buildings, and our life styles in general – which are currently predominantly based on fossil fuels one way or another as a matter of 'carbon lock-in' (Chakravorty et al., 2012; Ji et al., in press; Unruh, 2000).

4 Discussion with case studies and examples

4.1 Case studies and examples

4.1.1 The UK built environment, energy, and climate change

This case study is specific to residential or domestic built environment of the UK. The (relatively recent) Climate Change Act 2008 enshrines the target of reducing UK's GHG emissions by at least 34% by 2020 and 80% by 2050. At the same time, it has been calculated that, at today's level of demolition, two thirds of the houses existing today will still be standing in 2050. With 27% of the UK carbon footprint coming from domestic sector, it is obvious that a crucial element of achieving the target will be the mass retrofitting (i.e., refurbishing to very high levels of energy efficiency) of the existing housing stock throughout the country. As there are around 25 million houses, this means that over 500,000 homes a year need to be retrofitted for the next 40 years (Hewitt, 2010). Thus, a substantial degree of obsolescence is creeping in the UK housing stock due to climate change pressures. In this case, the obsolescence is not only 'indirectly' climate change-related for it is being driven via the environmental legislation in the form of Climate Change Act; but also external for it is occurring in the houses due to external factors. This obsolescence is not planned either. Furthermore, this obsolescence is expected to be permanent (if not retrofitted); functional or technical if new energy efficient technologies are not employed; and also financial or economic in terms of rental values (if any) and escalation of operational costs e.g., due to gas and electricity bills. Creeping up of prices of utility services has been widely and clearly noticed in the last few years.

This case study reveals that obsolescence for a given scenario can happen at the same time in more than one way or have more than one form. In this scenario the obsolescence is simultaneously climate change associated, permanent, environmental, external, technical, and financial. Thus, obsolescence is a multi-faceted concept. In summary, due to future temperature change, the need for adaptation (in other words, requirement of tackling obsolescence) of the existing housing stock is on the increase on various fronts including heating, cooling, ventilation, domestic hot water provision, lighting and other appliances (Gupta and Gregg, 2012; Wilde et al., 2011).

4.1.2 Urban drainage infrastructure and escalating flood risks

Flooding is becoming a paramount issue not only in Europe but around the globe for all countries irrespective of being developed or developing (Chen et al., 2012; Sun et al., 2011). City growth and increases in heavy rainfalls, both together and alone are increasing flood events and flood risks (Davies et al., 2008). In all, around 357,000 properties in Wales, or about one in six buildings, are at risk of flooding. More than 357,000 people live in 220,000 properties that are at risk of flooding from rivers or the sea, 97,000 of which are also at risk of surface water flooding. A further 137,000 properties are susceptible to surface water flooding alone (EA Wales, 2009). As for the UK overall, pluvial flood risk accounts for approximately one-third of flood risk in the UK. Approximately 2 million people in UK urban areas are exposed to an annual pluvial flood risk of 0.5% or greater ('1-in-200 year' event). An additional, 1.2 million people can be put at risk by 2050 due to a combination of climate change and population growth (Houston et al., 2011). These cases indicate risk of obsolescence is increasing within the UK built environment due to increasing surface-water flood events which themselves are down to two main reasons:

1. escalating urbanisation (due to population increase and economic growth)
2. increased rainfall (both in frequency and intensity) due to climate change.

Thus, the existing sewer systems (which are predominantly combined in the UK) are becoming inadequate in terms of their capacity and performance. Thus, obsolescence is 'seeping' into the existing sewers networks due to both climate change-related and non-climate change associated aspects. In order to overcome this increasing obsolescence risk, mitigation measures need to be taken. For instance, London is a very old city which has had a combined sewer system for centuries. The proposed Thames Tideway Tunnel in London which is a storage and transfer tunnel – the width of three London buses – will be constructed under the River Thames to capture many millions of tonnes of sewage that regularly flows into the capital's river and which can now occur after as little as two millimetres of rainfall (Stride, 2013).

Another case is that of an innovative technology regarding flood warning. A new 'Flood Alert' free application has been launched via the iPhone technology to help families and businesses get prepared for potential flooding in their area. The technology uses live flood warning data feeds of the Environment Agency (EA), enabling users to quickly, efficiently, and conveniently receive flood alerts relating to their current location, as well as up to two extra locations of interest such as a workplace or local town. It can also display alerts by county, local authority or EA region (HGL, 2013; CIWEM, 2013a). Like computers/laptops have become a norm of life in the modern world, as time moves on and electronic gadgets like iPhone become a norm of life for almost everyone in the society, some of conventional flood warning mechanisms will be turning obsolescent to an extent, if not entirely. This is an example of technical or functional obsolescence (due to technological development) waiting to happen, just like computers eventually replaced the previous paper-based spread-sheet systems by the e-based approach.

4.1.3 Renaturalisation of watercourses – Cheonggyecheon stream in Seoul, South Korea

The stream was formed during the Joseon Dynasty in order to provide drainage for the city. It lasted for hundreds of years until the 1940s, when the city became so populated that a shanty town popped up around the stream and began polluting the area. The stream was gradually covered over with concrete, and by 1976 a 5.6 km elevated highway stretch was built on top of it. Considered as an example of 'successful industrialisation and modernisation', the highway remained there until 2003, when city planners tore it down to revitalise the area and help Seoul remake itself as a modern environmentally friendly city. The Cheonggyecheon Renaturalisation/Restoration Project took two years and cost around $281 million, but it has created a thriving stretch of green public space in the middle of the city. Among many sustainable benefits this renaturalisation project has brought, from flood risks perspective, it specifically provides flood protection for up to a 200-year flood event that can sustain a flow rate of 118 mm/hr (Robinson and Hopton, 2011; Meinhold, 2010). This scenario is a case which indicates that the elevated highway stretch was hit by obsolescence and of various types and facets including, climate change-related, permanent, external, and even environmental quality and sustainability also played a role in rendering the highway stretch obsolescent.

4.2 Discussion

Obsolescence generally happens in part although there may be cases of total obsolescence. Firstly, the stage of complete obsolescence is reached when the old buildings and layout have little or no value as they stand. If all goes well, clearance and redevelopment follow quickly but there may be factors that prevent this. Firstly, the site may have insufficient value to justify demolition of the old structures and its replacement by something new. In order words, the economic pressure may not be enough to propel renewal. Secondly, the pattern of redevelopment may require changes in the size and shape of the site that may not readily be secured. This arises where comprehensive renewal is needed to meet modern traffic conditions and the existing small units of development have to be amalgamated for rebuilding purposes. In these circumstances, it is often necessary for individual obsolescent building to remain until the whole areas are capable of total clearance. Thirdly, it happens that a building is totally worn out and judged by contemporary standard, is no longer fit for occupation. But because of the shortage of accommodation, it continues to command a use and income. It retains therefore, a value, sometimes, a high one, and is not strictly obsolete from an economic point of view, although it may be so regarded in social terms (Nwoko, 2010b).

Social and cultural responses to climate change and environment issues appear to be rapidly emerging force driving climate change obsolescence. As more businesses and organisations are adopting sustainability as a core operational goal, it is finding expression in practical steps to demonstrably reduce their environmental impacts. This may be achieved by steps such as waste reduction, energy efficiency, and resources conservation, but also by larger and more strategic measures such as ‘green’ leases, upgrading buildings, moving to ‘greener’ buildings. There is an emerging and increasing demand for sustainable offices in the UK although as yet location and availability remain paramount (Dixon et al., 2009). As businesses increasingly demand a more sustainable built environment, and society more critically examines such claims, the less sustainable parts of the built environment may suffer obsolescence to varying degrees. As dramatic as predictions of long term climate change impacts are; the threat of loss of tenants or rental income (i.e., financial or economic loss) due to climate change induced obsolescence, might become a much more powerful driver of climate change adaptation and mitigation. Thus, obsolescence in general and climate change-related in particular encapsulates all three fundamental dimensions of sustainable development, i.e., social/ethical, economics and environment. Therefore, climate change interventions in terms of both adaptations and mitigations are required not only at strategic levels but also need to be incorporated in maintenance and refurbishment cycles of present as well as future built assets to render them sustainable.

In a number of cases, not only that various types of obsolescence occur simultaneously but also there are cases where obsolescence may happen in the form of a ‘chain-reaction’. In this regard, an example is briefly described from the aerospace industry as follows: A chemical legislation known as REACH was introduced in 2007 and the European Chemical Agency (ECHA) has created a candidate list of substances of very high concern, which can cause cancer, persist in the environment, or build up in the body. Several chrome-based substances, which are vital to aircraft manufacture, are on the list and could be banned from use in the EU by 2017. Thus, there are risks of permanent obsolescence lurking against not only several chrome-based substances but also significant parts of the supply chain, as well as a number of manufacture and maintenance processes and systems of the industry (Else, 2013). This can be referred to as a ‘knock-on-effect’ or ‘chain-reaction’ obsolescence.

Low-cost, high-grade coal, oil and natural gas – the backbone of the industrial revolution – will be a distant memory by 2050. Much higher cost remnants will still be available but they will not be able to drive our growth, our population and, most critically, our food supply, as before. Conventional food production is dependant desperately on oil for insecticide, pesticide, and fertilisers, and for transportation over thousands of miles. Modern agriculture is an industry that converts oil into food. With the depletion of oil reserves, it is not easy to imagine, how many types and to what varying degrees obsolescence can hit different industries, sectors and in fact, all walks of life in general (CIWEM, 2013b). This explains obsolescence hazards and risks that our life in general and the built environment in particular face today, some of which are already happening (as explained in aforesaid case studies and examples) and others are in the pipeline, waiting to happen.

5 Concluding remarks

This paper reveals that obsolescence as a concept may not be as uncommon as the term itself. The authors specifically attempted to highlight implications of the term by developing and defining a detailed nomenclature of obsolescence types. The concept has been presented in different contexts including built environment, finance, function, maintenance and refurbishment, technology innovation, civil unrest, and climate change. It is also explained that obsolescence may generally happen in part, such as a component of the system becomes obsolescent, although in some cases a system may entirely become obsolescent. This may also depend on how the boundaries of a given system and its components are defined.

Obsolescence being considered from various perspectives, the paper establishes that it is a multi-dimensional item. It may generally take place in such a way in a given built environment scenario that various obsolescence types and aspects may be happening at the same time in the same scenario. It can involve all of the three principal dimensions of sustainable development or sustainability philosophy, i.e., social/ethical, environmental and economic/financial.

This research study can help the diverse audience from the environmental field in general, and the built environment in particular, to better conceive what obsolescence is and how it can occur in different ways such as socially, environmentally, economically, temporally, spatially, technologically, and even climatologically. Comprehension of varying implications and different dimensions of obsolescence will assist asset managers as well as environmental practitioners and consultants to consider the built environment from different angles to assess and then manage obsolescence. Thereby, be more able to render the built environment more sustainable for now and future. Therefore, it is anticipated this study, which presents innovative concepts of obsolescence across a wide spectrum in the changing world of today, has a potential to attract interest, debate and further research from practitioners and researchers, in industry and academe, respectively.

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