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Resilient ecological solutions for urban regeneration

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There is a need for biological conservation at the global scale, and urban conservation has the potential to support the delivery of this wider goal. Despite historic trends, efforts are underway to protect and enhance the quality, quantity and accessibility of green infrastructure within cities, including biodiversity features within new developments. However, there are questions over their long-term persistence and function. This paper applies an urban futures resilience analysis to a case study site to illustrate how such concerns may be explored and addressed in practice. The analysis identifies vulnerable sustainability solutions and clarifies the aspects that may be improved. The results suggest that the resilience of these solutions is questionable, even though resilience has clearly been considered. In particular, future compliance with, and enforcement of, planning conditions is questionable. The resilience of these ecological solutions may be improved by including some redundancy, designing for low maintenance, incorporating microclimate buffers and locating features in areas unlikely to be subject to future disturbance. The establishment of endowment funds or other dedicated funding mechanisms should also be explored. The paper also recommends that a futures-based resilience analysis be included within the development planning process.

1. Introduction

The need for biological conservation at the global scale is clear, as rates of extinction, habitat loss and degradation show little sign of slowing (Butchart *et al.*, 2010). Local-scale conservation efforts within urban areas have the potential to support the delivery of this wider goal. This may be by way of the direct protection and enhancement of species of conservation concern or through the development of accessible green spaces where people are able to experience a range of species and habitats. Urban landscapes provide many opportunities for direct conservation and enhancement, particularly through the regeneration process (Sadler *et al.*, 2011). These include the protection of relict native habitats, the construction of natural habitat analogues (Lundholm and Richardson, 2010) such as brown roofs (Oberndorfer *et al.*, 2007) and artificial roosts (Williams, 2010), and changes to the management of amenity green spaces (Sadler *et al.*, 2011). It has also been argued that positive experiences with urban wildlife have indirect benefits for global conservation in the form of greater public support for related policies and campaigns (Dunn *et al.*, 2006). In addition, the ecological services provided by urban wildlife and green spaces are relevant to the delivery of numerous sustainability goals (MEA, 2005) related to quality of life, social cohesion and sense of place (Miller, 2005). Ensuring a diverse and accessible urban wildlife community should therefore be central to strategies for both global biological conservation and sustainable development.

The majority of the global population now reside in cities (UN, 2010) and the extent and density of urban areas are expected to continue to increase during this century (Irwin and Bockstael, 2007). Urbanisation is often characterised by high levels of impervious surfaces (McKinney, 2002), patch fragmentation (Luck and Wu, 2002; Zhang *et al.*, 2004) and heterogeneity in land cover type over time and space (Cadenasso *et al.*, 2007; McDonnell and Pickett, 1990). Despite considerable variability, increasing urbanisation generally results in a reduction in species richness (McKinney, 2008) and ecosystem services (Tratalos *et al.*, 2007). A reduction in the area and accessibility of urban green spaces during the latter half of the twentieth century has been reported for the UK in general (UKNEA, 2011a) and across Europe (Fuller and Gaston, 2009). However, there are indications that some losses are now being reversed (UKNEA, 2011b). Efforts have been made to compensate for losses and to enhance biodiversity within new developments (Defra, 2007), focusing on the planning, design and installation of habitat structures (DCLG, 2010; Williams, 2010). However, relatively little is known about the long-term persistence of these structures and their ecological function post-development (Sadler *et al.*, 2010). Recent high-profile failures of some artificial habitats (e.g. http://news.bbc.co.uk/2/hi/uk_news/england/london/8215035.stm) and analyses of post-mitigation success (e.g. Waring, 2011) highlight the need to consider whether such investments are sufficiently future-proofed.

This paper applies an ‘urban futures’ resilience analysis to a regeneration case study site in the UK in order to explore the vulnerability of a selection of ecological interventions (hereafter termed ecological sustainability solutions) that are commonly undertaken to deliver biodiversity goals within urban regeneration projects. The focus is on species of birds and bats that are protected under European and UK law and are frequently identified as targets for mitigation, compensation or enhancement during development schemes. While it is appreciated that a large number of ecological sustainability solutions may be included within regeneration projects, this paper focuses on three examples in order to illustrate how a futures-based resilience analysis can be applied in practice. The information available for these examples is therefore limited, reflecting the level of detail supplied in the various planning documents relevant to the case study site.

2. Methodology

2.1 Case study site: Luneside East

Luneside East is a post-industrial site in Lancaster, UK, proposed for mixed-use regeneration. In 2004, it was Lancaster City Council’s (LCC) largest single regeneration project, with a

vision to transform the largely vacant and derelict site into a vibrant, well-used and integrated quarter (LCC, 2004). The site (owned by LCC) is ~6.6 ha in area and is bounded by a mainline railway (owned by Network Rail), a disused railway embankment (owned by LCC), a river and an established residential area (Figure 1). The land cover is typical of many brownfield sites, with built structures of varying integrity, contaminated soils and a mix of bare ground, ephemeral vegetation, scrub and semi-mature trees (Rogers *et al.*, 2012). The site has outline planning permission (granted in 2001), an environmental statement (2001), a development brief (2004) and a masterplan design code (2007). These documents were used to inform the analysis in this paper, although it is acknowledged that the plans are currently under review.

2.2 The urban futures resilience analysis methodology

The urban futures methodology addresses the question: will today’s sustainability solutions deliver their intended benefits whatever the future brings? The analysis is divided into four steps (Boyko *et al.*, 2012; Rogers *et al.*, 2012). In step 1, the sustainability solutions are listed and their intended benefits are described. This step is particularly important because

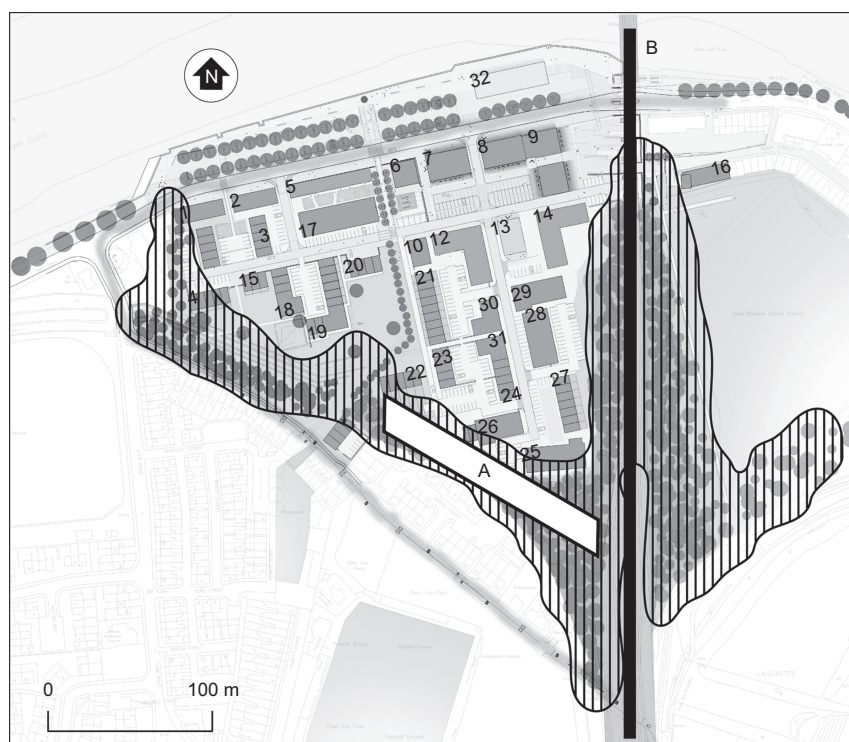


Figure 1. Plan view of proposed site layout (modified from the Luneside East masterplan design code (LCC, 2007: p. 11, Figure 12) and reproduced by permission of Lancaster City Council). The hashed area indicates a major tree network expected to facilitate

bat movement through the site. The white area labelled A indicates the embankment of a disused railway line and the black strip labelled B indicates the embankment of a mainline railway

clarity on the nature of each solution and its intended purpose underpins the validity of subsequent steps in the analysis. The prerequisite conditions for the delivery of each intended benefit are outlined in step 2, including the key patterns and processes that need to be in place if each solution is to function effectively. Step 3 provides an analysis of whether these necessary conditions are likely to remain in place in the future. To provide a structured approach to this analysis, the following plausible, robust and divergent future scenarios have been defined for UK urban areas.

- (a) Policy reform (PR). Government action is promoted in an attempt to reduce poverty and social conflict, although behaviour change is slow. There is a belief that markets require strong policy guidance and legislation/regulation to address inherent tendencies toward economic crisis, social conflict and environmental degradation. The tension between continuity of dominant values and greater equity for addressing key sustainability goals is not easily reconciled.
- (b) Market forces (MF). The self-correcting logic of the market predominates, with individualism and materialism as core human values. Well-functioning markets are thus considered key to resolving social, economic and environmental problems. This scenario assumes that the global system in the twenty-first century evolves without major surprise and incremental market adjustments are able to cope with social, economic and environmental problems as they arise.
- (c) Fortress world (FW). Powerful actors safeguard their own interests and resources at the expense of an impoverished majority who must live in ghettos. The world is divided, with the elite in interconnected, protected enclaves and an impoverished majority outside. Armed forces impose order, protect the environment and prevent collapse.
- (d) New sustainability paradigm (NSP). An ethos of 'one-planet living' pervades and a fundamental questioning of progress emerges in light of sustainability goals. New social-economic arrangements and fundamental changes in values result in changes to the character of urban industrial civilisation rather than its replacement.

These four scenarios were selected from the six scenario variants developed by the Global Scenarios Group (www.gsg.org) (Raskin *et al.*, 1998) and adapted to reflect a UK urban context, as part of the urban futures project (www.urban-futures.org). For each intended benefit, the necessary conditions are considered in the context of an extensive characteristics list developed to describe each future scenario (Boyko *et al.*, 2012; Rogers *et al.*, 2012). In the final step, if the necessary conditions are unlikely to be supported in some of the future scenarios then the solution is classed as vulnerable,

prompting a revision of plans for its design, construction and maintenance. An example of how this methodology may be applied in practice is provided below, drawing on Lunsdale East regeneration as a case study.

3. Results

3.1 Ecological sustainability solutions suggested for the Lunsdale East regeneration site

Biodiversity concerns are referred to within the LCC core strategy (LCC, 2008) and several ecological sustainability solutions were proposed for the site following an environmental impact assessment (EIA) (Entec, 2001). These were intended either to mitigate/compensate for impacts on local biodiversity or to deliver ecological enhancements. These solutions and their intended benefits are most clearly stated within the Lunsdale East environmental statement (Entec, 2001) and a selection are summarised in Table 1. The analysis presented here is limited to the solutions with clearly stated intended benefits. This is vital because, without clarity on the purpose of each solution, its vulnerability cannot be assessed.

3.2 Conditions necessary for the solutions to deliver their intended benefits

3.2.1 Bats

A bat (Chiroptera) survey was undertaken to inform the EIA, as all bats are legally protected at European level under the EU 1992 habitats and species directive. All bats and their roosts are also legally protected in the UK under The Conservation of Habitats and Species Regulations 2010, with reckless or intentional disturbance in England an offence under the Wildlife and Countryside Act 1981 (as amended) and the Countryside and Rights of Way Act 2000. In addition, bats have a dedicated species action plan as part of the Lancashire biodiversity action plan. The survey identified common pipistrelle bats (*Pipistrellus pipistrellus*) commuting or foraging in several parts of the site and the possibility that some buildings may contain winter hibernation roosts. The associated development impacts, proposed solutions and their necessary conditions are now outlined.

- (a) Artificial bat roosts. The most current proposals include the installation of 'bat boxes' (artificial bat roosts) to compensate for possible loss of winter hibernacula, but do not specify their type or location. However, it is clear that any compensation for the loss of possible winter roosts (see Table 1) should include artificial roosts in structures that are undisturbed, with a cool and stable temperature. Disturbance may include physical movement, predation, poisoning from pest control or building treatment products, high-frequency noises, artificial lighting and changes in temperature or humidity. The artificial roosts

Ecological solution	Intended benefits	Post-development retention mechanisms
A Bat hibernation boxes	Compensation for possible loss of winter hibernation roosts within existing buildings on-site	Condition to be checked every 5 years by an ecologist. Planning controls used to ensure the required management, repair and replacement is undertaken
B Expansion and management of semi-natural vegetation as bat foraging habitat	To enhance the foraging habitat for the common pipistrelle (<i>Pipistrellus pipistrellus</i>) with new habitats created to complement those retained as part of the disused railway embankment	Planning controls to ensure the implementation of a management plan in perpetuity, with checks every 5 years New habitats to be monitored annually for first 3 years by an ecologist
C Bird nesting boxes	Enhancements for local priority bird species such as swifts (<i>Apus apus</i>), house martins (<i>Delichon urbica</i>), house sparrows (<i>Passer domesticus</i>) and starlings (<i>Sturnus vulgaris</i>)	Condition to be checked every 5 years by an ecologist. Planning controls used to ensure cleaning, repair and replacement

Table 1. Proposed ecological sustainability solutions for the Luneside East development, their intended benefits and evidence that retention (post-development) has been considered. This summarises information from the LCC environmental statement (Entec, 2001)

must also be accessible to the bats and be retained on-site as features. Assuming these conditions will be met during installation, the success of this solution would be dependent on these conditions continuing indefinitely into the future.

- (b) Bat foraging habitat. The proposed increase of, and enhancement to, foraging areas within the site are primarily intended to benefit bats that are active during the spring, summer and autumn. During this period, common pipistrelles typically roost in warm inhabited buildings, and the EIA report concluded that modern houses outside the boundary of the site were the most likely location of summer roosts for the bats recorded as foraging on-site. For the enhanced foraging areas to be successful, they must be available to common pipistrelles following completion of the Luneside East development. This requires that local summer roosts continue to be present, that bats can commute from these roosts to the Luneside East feeding areas and that the foraging habitats produce sufficient quantities of their insect prey.

3.2.2 Birds

Although no nesting sites were recorded as part of the EIA, enhancements are currently proposed to support several species that are listed within the Lancashire biodiversity action plan (Table 1). These birds are protected at European level under the EU 1992 habitats and species directive and the 2009 birds directive. They are legally protected in the UK under The

Conservation of Habitats and Species Regulations 2010, with intentional killing, injury or damage of the birds, their eggs or active nests an offence in England under the Wildlife and Countryside Act 1981 (as amended) and the Countryside and Rights of Way Act 2000.

The success of the bird nesting boxes proposed as ecological enhancements depends on conditions similar to those required for artificial bat roosts. Boxes must be retained on-site, accessible to the birds and remain undisturbed. All species that are intended to benefit from these enhancements at the Luneside East site require nesting sites that are out of direct sunlight (Williams, 2010). Some require unobstructed flight paths to the nests and others, such as swifts (*Apus apus*), require a site free of climbing plants that may give access to predators. Again, these conditions must continue to be present indefinitely into the future if the nest boxes are to function as intended.

3.3 Performance of the Luneside East ecological solutions within the urban future scenarios

The analysis indicates that, under certain scenarios, it is questionable whether the habitat features of interest will remain undisturbed, whether microclimates will be preserved and functional connectivity maintained (Table 2). Habitat management is considered unlikely to be undertaken in two of the scenarios and its presence is questionable in a third. It is only in the NSP scenario that all the conditions necessary for

Necessary conditions for the success of proposed solution	Scenario			
	PR	MF	FW	NSP
Habitat features not intentionally disturbed ^{ABC}	√	?	√	√
Habitat features not accidentally disturbed ^{ABC}	?	?	?	√
Microclimates (light, temperature, moisture) are maintained ^{AC}	?	?	?	√
Functional connectivity is retained ^{AC}	?	?	?	√
Habitats are managed to deliver their intended ecological function ^B	?	×	×	√

Table 2. Summary of results from a futures-based sensitivity analysis of key local conditions. Superscripts A, B and C indicate the solutions listed in Table 1 that these conditions relate to. √ indicates where a condition is expected to be supported within a particular scenario, ? means that it is unclear whether the condition will be supported and × indicates that support for this condition is unlikely

these sustainability solutions to function are likely to be present. The reasoning behind these results and implications for specific solutions are now discussed.

4. Discussion

4.1 Vulnerability of proposed ecological sustainability solutions

4.1.1 Artificial bat roosts

Bats rarely cause nuisance to householders and therefore the intentional disturbance of an artificial roost is considered unlikely. However, in future scenarios such as MF, in which materialism and individualism are valued over environmental concerns and planning enforcement is expected to be weak, artificial bat roosts may be removed if the structure or droppings impact the aesthetics of a building.

Accidental disturbance is considered to be a reasonable risk within three of the scenarios. In the PR scenario, policies to meet social sustainability goals (e.g. encouraging flexible building use) may result in warmer or inconsistent hibernation roost temperatures, undermining their success. In addition, apparent ‘holes’ (roost entrances) in a building envelope may be inadvertently sealed during routine maintenance to ensure good thermal performance. Artificial lighting of the roost or roost entrance is considered a risk in several scenarios, preventing or disturbing access for bats (see Waring (2011) for case studies where this has occurred elsewhere). In the PR scenario, this lighting may be intended to encourage walking as an alternative to night-time car use while, in the MF scenario, lighting may be used as a tool for raising the visual profile of the development or illuminating advertising boards. Artificial lighting of roost entrances may also occur in the FW scenario, but in this case may be used to

increase site security or the perception of safety. The proposed planning conditions to require monitoring and maintenance of roosts on a five-yearly basis are unlikely to be enforced in either the MF or FW scenarios, as values and priorities lie elsewhere.

4.1.2 Bat foraging habitat

The current proposals imply that winter rather than summer roosts will be created as on-site compensation. Any new foraging habitat created on the Luneside site would therefore be used in the summer by bats that are roosting off-site in adjacent residential areas. However, roosts within off-site buildings are considered vulnerable in three of the four scenarios as they may be unintentionally lost during building renovation or changes to the immediate built environment. The loss or isolation of off-site roosts would make on-site feeding areas redundant from the perspective of bat conservation. For several UK bat species (including the common pipistrelle), unlit tree lines are important commuting routes between roosts and foraging areas. The bat survey and consultant’s report included within the EIA identified the trees along the disused railway embankment and along the active railway line as particularly important in this respect (Figure 1).

In the current analysis, the function of the disused railway embankment as a commuting route is considered vulnerable in three of the four scenarios. Future tree losses may occur if their canopies are managed in the PR scenario to improve passive solar gain for adjacent buildings, in the MF scenario to maintain a desirable view or in the FW scenario as a local supply of fuel. In addition, artificial lighting may also increase in these scenarios, thus threatening the accessibility of foraging areas (Stone *et al.*, 2009).

Feeding areas are considered vulnerable to disturbance or degradation in three scenarios. Although planning policy in PR would generally support their retention, the loss of these areas may be permitted if it contributes to achieving targets for higher residential density and social equity. In the MF scenario, if the land value of these foraging areas were to be high, planning decisions would be likely to favour development over conservation. Should these foraging areas remain undeveloped, they are likely to be vulnerable to gentrification, typified by amenity planting with non-native species, frequent maintenance and low insect productivity (Donovan *et al.*, 2005). Low land values would likely result in the abandonment of habitat management and potentially a reduction in foraging quality over time. The proposed planning conditions to monitor and maintain semi-natural vegetation in perpetuity are unlikely to be enforced in either the MF or FW scenarios, as values and priorities lie elsewhere.

4.1.3 Bird nesting boxes

As with the bat hibernation boxes, bird nesting boxes may be intentionally removed in scenarios where planning enforcement is weak and aesthetics are prioritised over the environment. Bird nesting boxes are potentially more vulnerable than artificial bat roosts, particularly those for house martins (*Delichon urbica*) and starlings (*Sturnus vulgaris*), which may be considered a nuisance due to their droppings and noise respectively (Williams, 2010). Again, accidental disturbance appears to be a greater threat, with exposure of nests to direct sunlight (following changes to tree or building cover) being of particular concern. Although the monitoring and repair of these features is inexpensive, a planning condition to ensure their maintenance on a five-yearly basis is unlikely to be enforced in either the MF or FW scenarios, as priorities lie elsewhere.

4.2 Resilience of selected ecological solutions proposed for Luneside East

Resilience is a term increasingly used in discussions about sustainable development, but is applied differently depending on the context of its use (Folke *et al.*, 2010; Pickett *et al.*, 2004). Walker *et al.* (2004: p. 1) define resilience as ‘the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks’. In this paper, resilience is defined as the capacity of a sustainability solution to continue to deliver its intended benefits, despite changes to its environmental, social, economic or political context.

The results of the selective analysis described in this paper suggest that none of the ecological solutions proposed for Luneside East is particularly resilient, even though some consideration has clearly been given to sustaining their intended benefits post-development (Table 1). The difficulties

in ensuring the long-term maintenance of biodiversity compensation and enhancements are well known among practitioners and issues such as the governance and management of urban green space have been explored in the academic literature (e.g. Hermy, 2011; James *et al.*, 2009). The futures-based resilience analysis illustrated here may be a particularly valuable tool for improving the communication of these vulnerabilities among key decision makers. The next step is to explore how these solutions might be modified to improve their resilience, so that they deliver their intended benefits in any envisaged future.

4.2.1 Suggestions for improving the resilience of the proposed ecological solutions

While modification of the proposed solutions is not within the scope of this paper, some general approaches are considered below. Intentional disturbance is the threat to the functioning of habitat features that is perhaps the most difficult to respond to. Increased legal penalties for removing bat/bird boxes may be sufficient deterrent in some cases, but their effectiveness relies on feedback loops that may be degraded in some scenarios (e.g. residents may fail to report wildlife crime and responsible agencies may fail to act). A more reliable approach may involve designing these features in a manner that makes them more difficult to disturb, less likely to cause nuisance and easier to maintain. This could be as simple as integrating bird nesting boxes or artificial bat roosts into the building fabric (e.g. using bat bricks) rather than attaching them to outside walls (see Williams, 2010). Ensuring that people are aware that solutions are vulnerable to disturbance can be achieved through management agreements that specify community participation or warning signs incorporated into specific features that will be visible during building maintenance. However, in scenarios where development decisions are market led, awareness of such tensions may make little difference.

The strategy of locating key features in areas where conflicts are less likely to arise may be successful, particularly where this includes the transfer of ownership to a community land trust or where these features are likely to be valued and protected by multiple decision makers. In the case of Luneside East, the active railway embankment immediately adjacent to the site would appear to be ideal for providing resilient access for bats to foraging areas. The topography and adjacent land use makes future development pressure unlikely, while the dense vegetation would probably be valued by both residents as a screen from noise and the landowner as it impedes public access to the railway track. However, establishing a broader connected tree network would provide some useful redundancy, as tree lines in the surrounding landscape are still considered vulnerable. Similarly, locating artificial winter roosts throughout this network creates a diversity of accessible roost options, so should a roost be damaged or isolated, bats

may respond by switching to a local alternative. In addition, creating artificial summer roosts on-site would have the benefit that the function of new on-site feeding areas is not reliant on bats roosting in off-site areas, which may be more vulnerable to loss or isolation.

Maintaining microclimates (such as temperature and moisture) within a particular range is crucial to the success of many ecological solutions. There is a need to buffer against extreme changes and it is clear from the analysis that feedback loops reliant on well-resourced and ecologically motivated planning authorities are particularly vulnerable. Alternatives include locating sensitive ecological features on sites where adjacent land use or topography is unlikely to change or to include lighting, thermal or moisture buffers as part of the solutions themselves (e.g. lighting shields around roost entrance, moisture-absorbent substrates and ceramic heat sinks).

In future scenarios where resources are under pressure or public values are unresponsive, habitat management may be much reduced. Design may again play a useful role in improving resilience, with a focus on designing for longevity and low maintenance. Additional mechanisms to support long-term maintenance may also be explored, such as establishing endowment funds or the management of ecological features (e.g. as commercial woodland) to generate funds in perpetuity.

4.3 Resilience and the development planning process

Building resilience into a sustainability solution requires awareness that the drivers of its future success may be social, environmental or economic. It may therefore be necessary for professional input from a range of disciplines (e.g. legal, financial, design and communication). This is particularly true when identifying the conditions that need to be in place for a solution to function and for considering how the solution might be modified. Various attempts have been made to conceptualise urban areas in a manner that includes the human and ecological components on equal footing, to facilitate collaboration between disciplines (Alberti *et al.*, 2003; Folke *et al.*, 2005). Conceptualisation of cities as social-ecological systems and improving the collaboration between disciplines is a key ingredient to integrating ecological conservation into urban planning (Niemelä, 1999) and providing a strong basis for managing system resilience (Folke *et al.*, 2010). The urban futures resilience analysis methodology has therefore been developed to support broader systems thinking, to be as accessible as possible (avoiding discipline-specific language and concepts) and has been tested using a wide variety of sustainability solutions, as discussed elsewhere in this special issue). In principle, any sustainability solution could be analysed in this way as long as sufficient information is available to define the solution, its intended benefits and the

condition necessary for these benefits to be delivered in the future.

As sustainability has become a key goal in urban planning policy (Bramley *et al.*, 2006), it follows that resilience management for sustainability should play a prominent role in the planning process. Attempts to improve the longevity of ecological compensation and enhancement measures are evident in both urban planning policy and practice, yet their effectiveness is often questionable. Implicit within related planning conditions are assumptions about resources, values and governance; that is, that in the future funding will be available for the required management and there is the will and capacity to enforce these conditions. This is illustrated in Table 10.3 of the Luneside East environmental statement (Entec, 2001: p. 98), which states that 'planning controls should be used to ensure that the area (of semi-natural vegetation) is managed in perpetuity'. The implication is that a condition for continued management will be attached to any consent for development and monitored by LCC in perpetuity, yet there is no guarantee that LCC will have the capacity to do this in the future. Declines in the quality of green infrastructure reported in recent decades (DTLR, 2002) and reports of poor post-development compliance of mitigation features to planning conditions (e.g. Waring, 2011) indicate that the current system of ecological governance is failing. While there appears to be a broad awareness among practitioners that some mitigation and enhancement measures may be temporary, there are few tools that allow these concerns to be demonstrated to a diverse audience. It is therefore suggested that consideration of future-proofing should be explicitly included within the Royal Institute of British Architects' outline plan of work (RIBA, 2007) and that evidence of a resilience analysis be required as part of planning submissions for development consent.

As a cautionary note, careful consideration needs to be given to the appropriate level of resilience to incorporate into a particular sustainability solution. Increasing the resilience of one desirable component of a system may compromise the resilience of others (Folke *et al.*, 2010). A balance is therefore required between future-proofing particular sustainability solutions and retaining the flexibility to adapt the regeneration site in the future.

5. Conclusions

In this paper, resilience is defined as the capacity of a sustainability solution to continue to deliver its intended benefits, despite changes to its environmental, social, economic or political context. Recent reports raise concerns as to whether the ecological sustainability solutions often implemented as part of regeneration projects will continue to deliver their intended benefits in the long term. Their performance

may rely on questionable assumptions about resources, values and governance in the future and it is argued that there is a need for a tool that can make these vulnerabilities explicit.

The urban futures resilience analysis method illustrated here provides a structured approach to identifying vulnerable sustainability solutions and to clarifying the aspects of each solution that may need to be improved. The results of this selective analysis suggest that none of the ecological solutions proposed for the Luneside East case study is particularly resilient, even though some consideration has clearly been given to sustaining their intended benefits post-development. In particular, the effectiveness of planning conditions and enforcement is questioned, given future scenarios where political and financial priorities may lie elsewhere.

In terms of improving the resilience of these ecological solutions, the inclusion of some redundancy, designing for low maintenance, including microclimate buffers and locating features in areas unlikely to be subject to future disturbance may be particularly effective. The establishment of endowment funds or other dedicated funding mechanisms should also be explored.

Ensuring that current investments in sustainability solutions will continue to deliver their intended benefits into the future should be at the heart of sustainable development. It is thus recommended that resilience analysis techniques such as the one presented here be explicitly included within the development planning process.

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