Business model innovation for green urban infrastructure

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Abstract

Increasing population density, air pollution, and climate change put pressure on urban areas. Green infrastructure (GI) is increasingly recognised as a means to address these issues. However, piecemeal and asset-focused delivery, can limit the realisation of potential benefits. The vision for a comprehensive GI network which functions as a true interconnected infrastructure system, is one delivered at city-scale with an overarching strategic plan. Existing approaches are inadequate to deliver this, due to the lack of effective business models to join up stakeholders and value streams.

Using a case study of Newcastle upon Tyne, UK, this thesis shows that new and innovative business models (plans for how a GI system is delivered, who uses it and how it is financed and managed) are needed to enable the delivery of a city-scale GI vision. Effective business models for collaborative GI delivery will be where values (derived from benefit evaluation), stakeholders, and policy context intersect.

The value of GI is its environmental, financial and social benefits to humans. Testing evaluation approaches finds that values should be weighted according to relevance, and that functionality across the whole system should be considered. The policy context informs the power and governance structures that underpin GI delivery. A power relationship analysis is used to identify key enablers, opportunities and barriers. In particular, local plans and policies have the greatest potential to support GI delivery demonstrating the need to create a GI strategy at city-scale. Stakeholders may supply or benefit from the GI, or both, and this circular relationship is a key opportunity for GI delivery.

Where stakeholder interests intersect with GI values, the value proposition can be found; where they intersect with the policy context will be the power-holders and governance bodies needed to support GI delivery. Where the policy and values overlap are the key drivers for the project.

This research found that working in the value-stakeholder-policy intersection, developing business models that use collaborative co-production approaches, provides the best opportunity to achieve the vision for an effective, interconnected and strategically delivered GI system.

Dedication

For the rebels and mutineers.

For William, who was my friend; and for Molly, who looked after me.

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Chapter 1: Introduction

1.0 Urban challenges in the 21st Century

Urban, ***(adj.)***

a. Relating to, situated or occurring in, or characteristic of, a town or city, esp. as opposed to the countryside.

b. That constitutes or includes (part of) a town or city.

(Oxford English Dictionary, 2019 - note: emphasis author's own)

Throughout human development, there has been an ongoing shift away from rural, subsistence farming, through industrialisation and manufacturing economy, and finally a focus on tertiary industry. Concordant with this growth and change has been a shift from rural to urban living, and from working with the natural environment, to trying to control or even avoid it. This is quite at odds with low density settlements and subsistence farming.

Using Britain as an example, the shift away from primary to secondary industry required huge investment in infrastructure. It also necessitated not only private development of the technologies for manufacturing, but also a rise in public works for connectivity and in support of the urbanising population.

The current model of urban development underpinned by infrastructure is a product of years of human development. For example, an extensive network of Roman roads is still evident in contemporary British road placement. However, in its current form of development, large engineering projects, funded by capital investment to provide the infrastructure systems that we recognise today, are rooted particularly in the industrial revolution and Victorian development (Lawless and Brown, 1986).

A recurring theme from this is therefore the human desire to harness nature, to keep it contained, and to separate it from urban living.

Traditionally, the character of urban areas is to be removed from rural characteristics. Nature is controlled and limited to where it is most convenient for humans. We re-route streams to build houses, and keep flora and fauna limited to specific parks and gardens where they can be closely controlled and managed. Tree roots are given limited space, lest they interfere with utilities or cause uneven paving. In character, much of urban design has been about keeping nature at bay and producing artificial environments that best suit the immediate needs of humans as a species.

> "Every proposal to build a dam, to widen a highway, to cut down another forest, to turn wetlands into salable real estate, or to bury unwanted waste products is sure to have unintended consequences."
>
> *(Hardin, 1999, p. 41)*

As of 2018, 55% of the world's population live in urban areas (United Nations, 2018b) and this is expected to rise to 68% by 2050. Urban areas are expected to absorb most of the world's population growth with population projected to rise to 9.7 billion by 2050 (United Nations, 2018a). Thus, in the 21st century, humans live predominantly in urban areas, and to a 'developed country', economic growth involves industrialisation, mechanisation and a very human-designed way of living.

Increasing urbanisation will exacerbate challenges as well as opportunities for human society. The dense living model creates pressure for limited resources, especially for space and finance, as well as requiring larger capacities for different infrastructures to cope with rising demand. In addition to this, urban populations also face challenges from the changing climate.

Urbanisation, population growth and climate change act to create a vicious cycle across a range of city infrastructures and the links between them. For example, urbanised areas create urban heat islands which compound the impact of temperature rises (Chapman *et al.*, 2017). This can impact on human health, especially in countries with ageing populations. To mitigate this effect, cooling such as air conditioning is used; this increases energy use, which creates more carbon dioxide (CO_2) emissions, which increases the rate of climate change and temperature rises and thus the cycle is established. Extreme climatic events such as rainfall and storm surges threaten urban areas and their populations around the world (UNFCCC, 2019), including the UK where climate change is impacting on urban flooding and water quality.

According to the United Nations,

> "To combat these threats to sustainable development, numerous cities have taken steps to build resilience and address the growing climate-related risks posed to inhabited areas. Through initiatives such as 100 Resilient Cities and the Global Covenant of Mayors, leaders of cities have shown commitment to work together to address climate change and its impacts. Support from global organizations such as the World Bank, ICLEI, UN-Habitat, have also made

> various resources available to policy-makers, practitioners and even individuals willing to take action."
>
> *(UNFCCC, 2017)*

Therefore, there are a range of measures to create urban resilience and help cities adapt to and reduce the impact of climate change, including green infrastructure. Before exploring the benefits that green infrastructure can bring to urban areas in the face of climate change and how best to develop it, it is necessary to first explore in more detail the role it can play and the barriers to delivery.

1.1 The role of green infrastructure

> "Until recently, people just haven't been as interested in urban ecosystems. The typical city's combination of trees from all over the world seems haphazard, and illegitimate: not really nature."
>
> *(Johnson, 2016, p. xiv)*

Green infrastructure is underpinned by an ideology that the urban must work with the natural environment and cannot eschew it or deny its role. Green infrastructure offers opportunities to address challenges in urban areas by developing nature-based options in addition to, or instead of, traditional engineered infrastructure design. (See Chapter 2, sections 2.1 and 2.2 for further discussion of the scope and limitations of green infrastructure, and more detail on its definition).

Infrastructure development has focused on building structures to harness, manage or exclude natural processes, and solutions are often based around large engineering projects. Flood management has involved higher flood defences and canalising channels; transport infrastructure traditionally solves issues around congestion by building more roads; and air pollution has been controlled only by top-down imposed restrictions, such as taxes on emissions, and legal limits to particulate levels, with a limited effect. While innovation has been able to provide solutions to these various issues, the impetus to deliver them at an industry-wide level has lagged.

The fundamental concept underpinning green infrastructure is to work with natural processes in a mutually beneficial way. Now, more than ever, there is increased pressure to address environmental problems, such as climate change, plastic waste, air pollution, and flood management. With international climate agreements, the United Nations Sustainable Development Goals, and increasing public awareness and appetite for change – the so-called “Blue Planet effect” (Science Focus, 2019) – the status quo cannot continue.

1.2 Barriers to green infrastructure delivery

Despite the potential for green infrastructure to provide solutions to urban challenges, its implementation is not widespread. It has not been entrenched as ‘the norm’ for urban infrastructure systems, and there are some significant barriers to its delivery. These barriers fall into two main categories: design and planning issues; and finance and funding issues.

While a consensus has been established throughout 20th century planning and urban development that open space and parks are an inherently good thing, little attention has been placed on the quality and design of such spaces. Parks are frequently included in planning as an implied panacea to all problems caused by urbanisation. In reality, however, they can be either an asset or a detriment to the local area, depending on their placement, design, maintenance and use (Jacobs, 1961). Also, while humans instinctively recognise nature as a beneficial concept, the specific evidence and data available is more limited (see Chapter 2, section 2.2).

The main opportunity cost of investing in any specific infrastructure is the other existing or potential future infrastructure options. These can sometimes be changed later, depending on the lifespan of the infrastructure asset and the nature of the network or system. However, the change or retrofit of additional systems is usually more costly and can be operationally difficult. This high opportunity cost can make change in infrastructure systems slow and difficult and can lead to caution in adopting new technologies or approaches within the industry.

Another barrier to green infrastructure delivery is the competition for resources within urban areas. One particular challenge for green infrastructure development is that it competes with other potential land uses. One example would be putting office or retail buildings in a small open space that had previously provided ecosystem services for the immediate area.

Another common resource challenge is a limited supply of finance and funding for capital investment and operational expenditure. Although there are some examples of targeted delivery of green infrastructure, for example the Glasgow City Region

Green Network (GCV Green Network, 2019), such examples are very much the exception not the rule. Traditional methods of finance and funding are less available as we progress through late-stage capitalism. Innovative business models are needed to ensure guaranteed capital expenditure for current and future projects. The global financial crash in 2008 and the recession that followed have compounded this issue, and it is increasingly important to provide robust evidence to justify expenditure. Yet, in parallel, innovative business models have emerged across a range of industry sectors; market disruptors are emerging that upset the traditional "business as usual" way of doing things (Christensen *et al.*, 2015).

1.3 A green infrastructure vision for cities

In an ideal situation, a comprehensive network of green infrastructure across a city would be included and incorporated in the design at multiple scales, across the whole of the urban area, and connecting with peripheral rural areas. The system would have a strategic oversight plan in place in order to maximise connectivity and functionality, and it is through the performance of the green infrastructure system as a whole that benefits would be realised.

There are examples of green infrastructure best practice in various cities globally. Places that are developing high quality green infrastructure networks include Portland (Oregon), Seattle (Washington) and Philadelphia (Pennsylvania) in the USA; Malmo (Sweden), Copenhagen (Denmark) and Rotterdam (Netherlands) in Europe; as well as Melbourne (Australia) and the 'sponge city' Ningbo (China). While individual plans and developments vary in their detail, some common features of these cities include the overarching plans for green infrastructure development, the buy-in and funding from governance bodies as well as other key stakeholders, and the connectivity of specific developments to form an overarching network. This interconnectedness, and the network delivery over a whole city region are essential for effective green infrastructure that can deliver on its potential benefits.

While detailed descriptions of green infrastructure types, and its features and functions along with its definitions are discussed in Chapter 2 (sections 2.1 and 2.2), some of the key features are shown in Figure 1 to Figure 11.

Green infrastructure should form a strategic connected network, and work alongside existing infrastructure types within the built environment. The assets within the overall green infrastructure system should be multifunctional, for example providing aesthetic surrounds for human enjoyment, pollinator friendly planting to support biodiversity, and stormwater management, as in the green roof in Philadelphia, PA, USA, shown in Figure 1. It frequently takes the form of attractive landscaping (for example Figure 2, Figure 3, Figure 6, Figure 7 and Figure 8), though typically with additional functionality for storing or infiltration rain water, or other similar purposes. The management of rain water, or storm water is in integral part of green infrastructure, leading to the frequent use of the terminology blue-green infrastructure. The ‘green’ aspect of the name is drawn from both its use as a synonym to suggest environmental sustainability, and from the common presence of vegetation. However, vegetation need not be present in every case, as in Figure 5, which shows a drainage channel designed to filter and slow storm water, but that does not include planting.

Green infrastructure can be retrofitted to existing buildings and streets (see Figure 4), included as part of a new building development (Figure 1, Figure 3), or can in fact be the primary focus of a development, for example the conversion of a street in Copenhagen into a dual purpose park for human recreation and storage space for water in an extreme rainfall event (Figure 9), or the development of an ‘Eco city’ neighbourhood, as in Malmö (Figure 7).

Green infrastructure should also be sympathetic to its local context. While not forming part of a wider network, the Guadalmedina in Malaga, Spain (Figure 11) shows an interesting example of duel function blue-green space within a city. The river flows through the centre of Malaga, but is dry for much of the year. It is therefore used primarily for informal recreation, ahead of its original function as a river.

Another example of wet/dry dual functionality is shown in Figure 10, in Skradin, Croatia. Rainfall happens rarely, so artificial irrigation is required, but the infrequent sudden heavy downpours need to be managed to prevent flash flooding, therefore a rain chain and soak away have been added to one of the buildings.

Figure 1: Green roof on 'Thin Flats', a LEED certified housing development in Northern Liberties, Philadelphia, PA.

(Onion Flats, 2009)

Figure 2: A rain garden manages stormwater runoff in Philadelphia's Germantown section (Philadelphia Water Department, unknown)

Figure 3: Example of shallow vegetated stormwater facilities integrated within site planting, Lane Community College Health and Wellness Centre, Eugene, OR

(United States Environmental Protection Agency (EPA), 2015)

Figure 4: Green planting on a housing block, Vancouver BC, Canada

(NNECAPA, 2006)

Figure 5: Drainage channel for storm water control in Seattle, WA, USA.

(City of Seattle, unknown)

Figure 6: A Malmö rain garden

(Ludwig, unknown)

Figure 7: A green roof in Ekostaden [Eco-city] Augustenborg, a neighbourhood of Malmö, Sweden

(livingroofs.org, unknown)

Figure 8: Planting on a residential street, Copenhagen, Denmark.

Source: S.McGinty, used with permission.

Figure 9: Concept drawing for Sønder Boulevard, Copenhagen, Denmark in Dry/Cloudburst conditions.

(Ramboll, 2016)

Figure 10: Rain chain and soak away, alongside irrigation pipes in Skradin. Croatia.

Source: Author.

Figure 11: The Guadalmedina, Malaga, Spain.

Source: Author.

These examples of good practice, however, are not effective if they are replicated as isolated features. A true green *infrastructure* system must be interconnected and delivered to some sort of overarching strategic plan in order to deliver its benefits. Examples of effective green infrastructure planning are harder to find, though they are being developed. In the UK, the Glasgow City Region is developing its Green Network (GCV Green Network, 2019). Working to a visionary plan, this development aims over the medium term to develop and connect green spaces with a deliberate goal to gain social, environmental and economic benefits from it. The existence of this plan and the administrative organisations behind it mean gives it more weight and power than isolated or grassroots development of green infrastructure assets could deliver.

Similarly, in the USA, the New York City Green Infrastructure plan has been developed as the strategic plan to manage stormwater for the city, (New York City Department of Environmental Protection, 2016). The plan has increased the chances of successfully delivering the city's aims by creating an overarching strategy for the delivery and management of green infrastructure, with governance resources in place for its delivery. Planning and resource and a central interconnected vision are integral to the successful delivery of a green infrastructure network, and such a vision can communicate a common goal across a range of audiences.

In the UK context developing a comprehensive vision of green infrastructure should not be an add-on to existing plans, but instead embedded in local development strategies and local plans. While there are emergent examples of green infrastructure development across the UK, there is not yet widespread use of it at a strategic, city-scale level – Glasgow City Region being a notable example. Good examples of opportunities for green infrastructure to support wider strategic aims for cities are emerging though. Several cities within the UK, including London, Sheffield and Bristol, are moving towards using the United Nations Sustainable Development Goals as a benchmark for tracking their city's progress towards sustainability (Fox and Macleod, 2019; Valencia *et al.*, 2019), and a strategically planned and delivered green infrastructure network is an opportunity to address many of these goals.

1.4 Global relevance, research aim and thesis structure

This work has relevance on a global scale. It provides a starting point or template for other countries to follow for challenging large-scale issues around urbanisation, climate change, and challenging funding environments. Green infrastructure is relevant beyond Britain, and is already being used across North America, in northern Europe, and beyond. It provides opportunities to adapt to climate change, and to face challenges posed by increasing and rapid urbanisation. Often, green infrastructure networks can be incorporated at a low cost, relative to other infrastructure options. While it is not a panacea, it can make a significant contribution within the whole urban design.

The core aim of this research project is to explore and define what an innovative business model for effective green infrastructure system delivery would look like; and that this business model should form a 'toolkit' that allows a system-level green infrastructure plan to be implemented..

The objectives of the research are to:

1. Identify current opportunities and barriers to green infrastructure delivery
2. Understand the value of green infrastructure, how this is defined and captured
3. Assess the relevance and effectiveness of policies shaping green infrastructure delivery
4. Identify stakeholders with potential interest in a green infrastructure network, and consider how to align their priorities and needs
5. Develop an innovative business model archetype for effective green infrastructure delivery.

These objectives are achieved by addressing the following research questions:

1. What is preventing widescale green infrastructure development? What are the barriers and challenges, and how can these be overcome? What opportunities could be developed further?
2. What is the value of green infrastructure? How is this captured, quantified, and used? How can value capture be improved?
3. What are the key policy levers to support an effective business model for green infrastructure? How can the policy context shape delivery, identify stakeholders, and create opportunities and barriers for green infrastructure investment?
4. How are stakeholders identified? What are their priorities and needs? How can these be aligned with green infrastructure value?
5. How are these various elements used to build and shape new and innovative business model archetypes for green infrastructure delivery? Which opportunities can be capitalised on? How are barriers overcome?

The literature review (Chapter 2) provides an overview and critique of the current knowledge and research across a broad range of topics relevant to this cross-disciplinary project, addressing Objective 1, and setting the context for Objectives 2-5. Chapter 3 introduces the methods and approach used within the project, and introduces the case study area used throughout.

The analysis is then split by theme. Firstly, it examines the way value is assigned and how this can be done with various evaluation tools and approaches (Chapter 4), which addresses Objective 2.

Secondly, Objective 3 is explored through a detailed review of the policy sphere and opportunities created from this (Chapter 5). This is followed by a detailed analysis of stakeholders (Chapter 6), how they connect with values, and their role in forming opportunities and threats to infrastructure delivery. This addresses Objective 4.

Finally, Chapter 7 addresses Objective 5 by bringing these analyses together and synthesising the overall findings of the research project by exploring business models and how they relate to green infrastructure delivery. Chapter 8 concludes this thesis with a review of the key findings, identifying remaining knowledge gaps, and highlighting areas for future research.

The approach is unique in that it uses evaluation theory and evidence-based project planning to underpin business models for green infrastructure. While the infrastructure industry can be slow to innovate, and adopt new practices, the need for this rapid business model shift is essential, in order to support the delivery of strategic green infrastructure networks for cities.

Chapter 2: Evaluation, funding, and green urban infrastructure: a review of the current literature

2.0 Chapter introduction

Chapter 1 briefly introduced the rationale behind this research and identified that its approach is inherently interdisciplinary. It is therefore essential that the literature scope for this thesis must draw on a broad set of sources, from both academic and grey literature, including industry reports and policy documents. As green infrastructure delivery spans multiple theoretical disciplines, so the novel work presented in later chapters relies on bringing together knowledge from multiple domains, including civil engineering, environmental economics, urban planning, and business studies. This literature review presents and critiques key facts and current debates across several fields of study, intending to present a baseline knowledge relevant to the thesis.

A body of literature exists for the concept of green infrastructure itself, and section 2.1 introduces this and seeks to provide a working definition of the term within the bounds of this research. In addition, the opportunities that green infrastructure provides to face the challenges created by increasing urbanisation and climate change are discussed further in section 2.2.

The concept of evaluation, particularly as it pertains to infrastructure appraisal, is detailed in section 2.3. The literature on evaluation and appraisal provides information on approaches, frameworks, and tools that can be applied in new ways to be used for appraising green infrastructure specifically.

Finally, one must also consider the body of literature surrounding the study of business models. In particular, literature on business models for infrastructure, and of special interest is innovation within business models, to respond to current challenges and the changing nature of governance and capital investment.

2.1 Green infrastructure

2.1.1. Establishing a working definition

Each and every discipline of scientific thought, policy application, and public interest develops its own nomenclature, taxonomy, and shared understanding of meaning.

Where working across silos within or between disciplines, the language barrier can inhibit understanding and collaboration, and can, in the worst-case scenario, create confusion where terms are shared but with differing implicit understandings. In order to promote better understanding across a wider audience, language choice matters.

Green infrastructure is only not the only terminology applied to the concept being described in this thesis. Blue-Green Infrastructure (BGI) and Sustainable Drainage Systems (SuDS) are often both used to describe the same assets and networks, especially where they are focused on water management. For the purposes of this research, green infrastructure has been chosen as the terminology of choice as it implies a broader focus, encompassing a wide range of functions, and can be taken as an umbrella term that incorporates BGI and SuDS within its scope.

Over the past 10 years, green infrastructure has been gaining traction in urban development, particularly within planning, policy, and development. However, it does not prompt or inspire any great understanding in the public sphere (UK Green Building Council, 2015). While infrastructure itself is generally understood to be the systems that support civilisation, there is some confusion on the specific nature of green infrastructure. There is no single accepted definition of the term, although most definitions include similar concepts and keywords.

Green infrastructure began to come to the fore in academic and policy focus on landscape planning, as a new trend following on from the development of various schools of thought and ideological approaches in landscape planning, environmentalism, and climate change mitigation and adaptation. As an often-interdisciplinary approach, its narrative is one that may differ depending on its current use, but it is broadly aligned with the concept of ecosystem services and low impact development, and it can be used to address both an ideological approach and also to describe physical infrastructure components.

The definitions used by key organisations in green infrastructure policy and practice are shown in Table 1. While mainly from governing organisations and non-departmental public bodies, it also includes the definitions used by Benedict and McMahon, whose seminal work defines the broad perspective of green infrastructure as an ideological approach from a North American perspective, and underpins much modern use of the term.

Table 1: Definitions of green infrastructure

Author/Organisation	**Definition**
UK National Planning and Policy Framework (NPPF); (MHCLG, 2018, p. 67)	"Green infrastructure is a network of multi-functional green space, both new and existing, both rural and urban, which supports the natural and ecological processes and is integral to the health and quality of life of sustainable communities."
Natural England (2009, p. 7)	"Green Infrastructure is a strategically planned and delivered network comprising the broadest range of high quality green spaces and other environmental features. It should be designed and managed as a multifunctional resource capable of delivering those ecological services and quality of life benefits required by the communities it serves and needed to underpin sustainability. Its design and management should also respect and enhance the character and distinctiveness of an area with regard to habitats and landscape types. Green Infrastructure includes established green spaces and new sites and should thread through and surround the built environment and connect the urban area to its wider rural hinterland. Consequently it needs to be delivered at all spatial scales from sub-regional to local neighbourhood levels, accommodating both accessible natural green spaces within local communities and often much larger sites in the urban fringe and wider countryside."
Landscape Institute (2013, p. 3)	"GI is the network of natural and seminatural features, green spaces, rivers and lakes that intersperse and connect villages, towns and cities. Individually, these elements are GI assets, and the roles that these assets play are GI functions."
Benedict and McMahon (2001, p. 5)	"interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations"

Author/Organisation	**Definition**
Benedict and McMahon (2006, p. 12)	"the ecological framework needed for environmental, social and economic sustainability"
Intergovernmental Panel on Climate Change (IPCC, 2018a, p. 550)	"The interconnected set of natural and constructed ecological systems, green spaces and other landscape features. It includes planted and indigenous trees, wetlands, parks, green open spaces and original grassland and woodlands, as well as possible building and street-level design interventions that incorporate vegetation. Green infrastructure provides services and functions in the same way as conventional infrastructure."
United States Environmental Protection Agency (EPA) (2019)	"Green infrastructure is a cost-effective, resilient approach to managing wet weather impacts that provides many community benefits. While single-purpose gray [sic] stormwater infrastructure—conventional piped drainage and water treatment systems—is designed to move urban stormwater away from the built environment, green infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits."
European Environment Agency (2017, p. 1)	"Green Infrastructure (GI) is based on the principle that 'protecting and enhancing nature and natural processes […] are consciously integrated into spatial planning and territorial development'. Accordingly, the Green Infrastructure Strategy defines GI as 'a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services' in both rural and urban settings."
European Commission (2013a, p. 3)	"a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings."

All the definitions listed in Table 1 have commonalities, though it is apparent that there is no single definition on which all the involved organisations agree. Most mention green space, a network, and supporting or delivering benefits for communities. A notable exception to the green space is the definition from the EPA, which references only the use of green infrastructure for storm water management, and does not reflect its wider functions, nor the need for it to be a network or system. The Landscape Institute definition likewise has a significant omission in that it does not discuss the role of green infrastructure to serve, support, or provide functionality for communities. It does distinguish between assets and the network and mentions that the latter has a role through its functionality, but does not frame that functionality in any specific way.

Benedict and McMahon (2001) clearly take the stance that green infrastructure is a concept and an approach – an ideology to guide land use planning, sustainability, and policy decision making. However, in the UK context it has gained recognition primarily through its practical application, and it usually refers to the assets and resulting network, rather than describing the underpinning principles.

Taken together, the National Planning and Policy Framework, Natural England, and European Environment Agency definitions make the most comprehensive definition, with a lot of cohesion between the three. The key principles identified and acknowledged repeatedly by these, and most of the other definitions as well, are that green infrastructure is:

- **Nature based** – harnessing the natural world instead of, or in addition to, traditional ‘grey’ or ‘hard’ infrastructure. It can be manmade and engineered, as long as it is using nature as a core component.
- **An interconnected network**– although green infrastructure can refer to individual assets, as with any infrastructure system it should be part of an interconnected network.
- **Benefitting humans** – providing a function or service for human communities, whether directly or indirectly. These include sustainability, health, and quality of life, and might specifically deliver ecosystem services. These functions underpin the main benefits cited, which are discussed in section 2.2.

While green infrastructure is a system, in applied practice the focus is often on the individual assets within the network, so called structural and non-structural green infrastructure (Jayasooriya and Ng, 2014). These components form the basis for the green infrastructure system, and for stakeholders who do not have the remit to manage the entire network, an asset focus can nonetheless provide a bottom up approach to green infrastructure delivery. (The power, influence, and governance behind green infrastructure and the bottom-up and top-down approaches to its delivery are discussed further in Chapter 5.)

Table 2 shows an illustrative list of the main types of asset that commonly feature in an urban green infrastructure network. This list covers examples of green infrastructure assets applicable in the literature and in this research project but does not intend to be exhaustive. Although not included in all of the green infrastructure definitions, for the purposes of this research, it is essential to also include ‘blue’ assets, that is, those including water and water management.

Table 2: An illustrative list of green infrastructure assets.

Green infrastructure asset	**Definition/description**
Allotments/community gardens	Land managed for small scale, non-commercial agriculture, for the benefit of local communities
Green roof	Planted roof, either extensive or intensive, designed to store rain water and provide biodiversity.
Green spaces	Any open green space, public or private, including parks, gardens, open spaces, especially where a more specific definition does not exist.
Green wall	Vertical planted surface forming part of a buildings’ cladding
Hedgerows and shrubs	Medium-height planting, often in clusters or linear, which may provide habitats for wildlife as well as functions for humans.

Green infrastructure asset	Definition/description
Park	A predominantly green space, usually open to the public, with a recreational focus.
Private gardens	Gardens used for any purpose attached to a private dwelling, only relevant as green infrastructure if they include vegetation and permeable surfaces.
Sustainable Drainage Systems (SuDS), *including rain gardens; bio swales; retention and detention basins*.	Drainage systems designed to provide holistic management of water. A technical and engineered system, SuDS are often the green infrastructure asset most similar to a 'grey' infrastructure intervention.
Trees	Including isolated 'street trees' grown individually, as well as bigger areas of woodland and urban forest.
Wildlife corridor	An area of natural habitat that allows the movement of fauna through a built environment. Often follow the lines of roads and railways. They ideally connect other, larger, areas of habitat.
Wetlands	Any water or wetland feature, including ponds, rivers, lakes, marshland, and riparian zones.

Connected together in a network, the green infrastructure assets work to perform green infrastructure functions, which in turn provide ecosystem services (Landscape Institute, 2013). The link with ecosystem services is discussed further in section 2.1.2.

Opdam (2013) elucidates this asset-function relationship with the description,

> *"the green infrastructure, by supporting biophysical processes, provides functions that if valued by humans turn into services."*

(Opdam, 2013, p. 81)

It is the role of the assets within a wider network, the functions provided by the assets individually and collectively, and the way they are managed that better defines whether or not the asset in question is part of a green infrastructure system. This reflects the view of Benedict and McMahon (2006) that green infrastructure defines the approach and ideology rather than the physical assets themselves. This creates one of the main challenges in trying to measure the benefits of green infrastructure, as although an asset's functions may be quantifiable, its role within an interconnected network can be much harder to interpret. This is discussed further in section 2.2, and in Chapter 4.

2.1.1.1 Green infrastructure definition for this thesis

For the purposes of this research, the working definition of green infrastructure is that it is **a strategically planned network of interconnected natural and semi natural green spaces, features and wetlands (the *assets*), that are used to deliver ecosystem services and to support sustainable cities and communities (the *functions*)**. While green infrastructure is not limited to urban areas, this research does focus primarily on the urban context. Both the assets and the network are described as green infrastructure within this thesis, but it is the strategy, functionality, and realisation of benefits that make it an infrastructure system akin to any other.

2.1.2. Providing ecosystem services

Although a distinct research discipline from green infrastructure, ecosystem services underpin a large part of the discourse on green infrastructure benefits, whether implicitly or explicitly (see section 2.2 for further detail). Ecosystem services are defined as the functions that humans rely on that are provided by ecosystems, providing supporting services, provisioning services, regulating services, and cultural services (de Groot *et al.*, 2002b; Millennium Ecosystem Assessment, 2005). It is intrinsically linked to combining human and natural systems, particularly in the urban sphere. Ecosystems services is the leading theoretical approach within most green infrastructure focused work in northern Europe, and ecosystem services beyond the scope of green infrastructure are incorporated in the European directives that provide a key driver to green infrastructure delivery. There is no prescribed way to provide ecosystem services, but an effective green infrastructure system should be able to deliver many of the essential ecosystem services needed for a community.

De Groot *et al.* (2002a) is a seminal work in the study of ecosystem services, and defines not only the services provided by ecosystems, but also the relevant types of economic valuation across the range of services. This paper also identifies theoretical and empirical barriers to the economic valuation of ecosystem services, particularly how to value individual elements of an interconnected system and give appropriate weight and attribution across the network, and also that the different types of economic valuation available are often incompatible and so an overall value is difficult to provide.

More recently, Demuzere *et al.* (2014) have built on the initial starting point of de Groot's work and review the empirical evidence on the contribution of green infrastructure to climate change adaptation and mitigation. This paper looks at both the services and benefits of green infrastructure and maps where there is evidence for these across multiple spatial scales (city, neighbourhood, and sub levels).

There is development here of the concept of co-benefits, and how there need to be trade-offs in green infrastructure strategy to realise the benefits that are most relevant in the specific delivery context. They acknowledge that there is a huge influence on the potential green infrastructure benefits, depending on the context of the city or other area being assessed. The topography, climate, socio-economic, and urban form will all play a huge role, and green infrastructure cannot be delivered as a one-size-fits-all approach to addressing climate change adaptation and mitigation challenges.

Lafortezza *et al.* (2013) build on the concept of ecosystem services but argue that it is the use for supporting spatial planning that is the benefit of green infrastructure over ecosystem services, and contextualises green infrastructure as a tool to support spatial planning. Their argument is that there are already established drivers for green infrastructure in health, biodiversity, and spatial policy and practice, and that there is an inconsistent trend for ecosystem services to provide green infrastructure. However, it seems that this is perhaps more a limitation of a narrow concept definition of both green infrastructure and ecosystem services, and therefore limited by an adherence to arbitrary research and delivery silos, rather than highlighting a fundamental problem. Nonetheless, the fact that these barriers exist is indicative of a wider problem.

The ecosystem service concept has, however, been criticised for seeing ecosystems as something other, to do with biologists and ecologists and not part of daily life, (Opdam, 2013).

Opdam (2013) also discusses the limitations of ecosystem services to move out from the knowledge silo of conservation planning. He pushes for a broader term of landscape planning in order to be more accessible to a wider audience and so help facilitate community engagement of all stakeholders in landscape management, and not to limit it to the scientific community. He also critiques the overuse of the terminology of ‘sustainability’ and (rightly!) observes that through its overuse across such a wide range of interpretations it has become contextually meaningless and therefore breeds distrust and perhaps even contempt when engaging beyond a purely technical scientific audience. Arguably ‘landscape planning’ also better represents the role of humans in shaping the landscape and that humanity is a major influence within the ecosystem rather than simply a passive observer or user of the ecosystem while somehow separate from it.

These current debates in ecosystem services provide a core knowledge required for understanding the framing of the functions and benefits of green infrastructure, as discussed in section 2.2. They also illuminate some of the wider issues involved in interdisciplinary working across several areas of environmental science, built environment, civil engineering, and conservation.

2.1.3. The policy and operational context

There are many overlaps in green infrastructure from its growth in land use planning, resource management, climate change adaptation, and as a provider of ecosystem services. The focus, definitions and uses of green infrastructure vary between fields and also in different national and international contexts.

Mell (2014) raises concerns about the variability of different definitions, and that there is little consensus – particularly in the differences of definition between the USA and the UK. This concern is echoed by Sussams *et al.* (2015), who identify crucial knowledge gaps in green infrastructure in their paper, and particularly highlight the many and varied definitions. It is essential therefore, to understand that even while this research uses one definition for green infrastructure, (see section 2.1.1.), an understanding of the relevant literature, especially of the benefits of green infrastructure, must allow for flexibility within this definition, and to accept evidence from outside its narrowed scope.

In the USA, green infrastructure has largely been established as the latest ideology in land use planning, and provides an underpinning approach to land use planning challenges, but is not a solution in and of itself (Benedict and McMahon, 2006).

In policy and practice, green infrastructure in the US is largely focused on flood management, as evidenced by the Environmental Protection Agency (EPA) collation of resources on researching, designing, and evaluating green infrastructure, and by many practical city- or regional-level projects (United States Environmental Protection Agency (EPA), 2019). For example, Philadelphia using green infrastructure to reduce storm water volumes processed by its combined sewer system (Philadelphia Water Department, 2016), or a similar goal from the New York City Department of Environmental Protection (2016).

In the UK context, green infrastructure does not have such a fundamental emphasis on water management. While water is still an integral component of green infrastructure, it is accepted as being one of a wider range of concepts. Water management-focused aspects of green infrastructure in the UK tend to be encapsulated by the specific concept of Sustainable Drainage Systems (SuDS), and, especially in a rural or agricultural setting, through Natural Flood Management (NFM). Where city-wide programmes aim to address and incorporate water management at their heart, they are increasingly referred to as regarding blue-green infrastructure. From the UK perspective, green infrastructure focus in policy seems to have been at its peak in the mid-2000s, with many areas being required to develop a green infrastructure strategy, often as part of local plans, regional plans, and planning in other sectors.

In contrast, the European perspective has been largely driven by the concept of ecosystem services, introduced in section 2.1.2. There is a stronger presence of nature conservation and biodiversity fields within the European perspective, while the US view seems to draw more priority on environmental engineering and prominence of land use planning in policy and practice.

In order to gain a comprehensive understanding of the topic, all of these contexts must be considered when searching for evidence to support the use and benefits of green infrastructure.

As well as this broad understanding of the varying context of green infrastructure internationally, the specific policy context of green infrastructure within the UK, framed by the case study of Newcastle-upon-Tyne, is analysed in detail in Chapter 5 of this thesis.

2.2 Benefits of green infrastructure

As discussed in the previous section, 2.1, the classification of green infrastructure as an infrastructure system like any other is dependent on the interconnected network working to deliver ecosystem services, sustainability benefits, and supporting communities. Despite the essential role of the network, over and above the asset types, this section is structured according to these asset types. For the most part, the literature focuses on studies of particular types of asset, and so section 2.2.1 analyses the reported benefits according to this framework. The interconnected nature of the assets and therefore the benefits is then discussed in section 2.2.2.

The evidence base for the specific purported benefits is mixed, with different sources focusing on different potential benefits that green infrastructure can deliver. There are also disbenefits, costs, and opportunity costs involved, as with the delivery of any infrastructure system. In this section, the main benefits and disbenefits cited are critiqued, along with the evidence available to support them.

2.2.1 Benefits by asset type

This section of the chapter outlines some of the studied benefits of green infrastructure, grouped by the type of asset. While there is a consistent argument to be made that the individual assets need to be connected in order to form an infrastructure system, studies by type of asset form a large proportion of the body of literature into green infrastructure benefits. The amount of research available also varies between different asset types. For example, there has been much research into the benefits of allotments and community gardens, but less about the benefits of wildlife corridors. This is necessarily reflected in the varying lengths of each subsection. Largely this variable research is linked to the perceptions of benefits and user groups. Those assets with high use and benefits for human populations usually have more focus in the literature.

2.2.1.1 Allotments and community gardens

Allotments, of which there are estimated to be three million across Europe (Scott *et al.*, 2018), can be defined as semi-public spaces, which are used for growing plants, especially edible plants, for the consumption of the allotment gardener and their family. The specific purposes may vary across sites, but they all have this broadly in common. Community gardens tend to be less restricted to growing for food and may include a wider range of recreational activities.

As a key source of green space within an urban area, allotments and community gardens can offer a host of benefits like any effective green space. In this section, the benefits specific to their nature as semi-public garden spaces are explored. More general benefits of them as a type of green space are discussed later (see 2.2.1.11).

Allotments are traditionally a resource that has helped the working classes or those from deprived areas access opportunities for growing food, without needing access to a private garden. However, they are increasingly gentrified spaces, and the character as a male-dominated, working class space is changing, with more women and families taking part in allotment gardening, along with a shift towards more middle-class participation (Scott *et al.*, 2018). There is still a strong element of gatekeeping, and inequality of opportunity with regards to access to such spaces. This history of allotment gardening as a social resource is still evident in the focus of the benefits of allotments even now. The main benefits centre on health and wellbeing of humans, the provision of opportunities for contact with nature and for physical activity, and their role in social cohesion and contact within communities.

In one study (Webber *et al.*, 2015), allotment gardeners were found to have higher than the population average levels of wellbeing. In addition, the amount of time spent doing allotment gardening during the summer months was a good predictor of participant wellbeing. However, the study was limited, and so needs further research to validate this. Likewise, other studies have shown that allotment gardening can reduce stress and depression, as well as mental fatigue, provide social contact, and opportunities for personal achievement (Schmelzkopf, 1995; Milligan *et al.*, 2004;

Elings, 2006; Groenewegen *et al.*, 2006; Kingsley *et al.*, 2009; Phelps *et al.*, 2010; Cameron, 2014).

Some studies suggest that the key factor involved was the connection with nature (Webber *et al.*, 2015; Wolf and Robbins, 2015), rather than specifically allotment gardening itself, and so similar studies may find that any other nature-based recreation is as good as allotment gardening. Also, one study found that the interaction with plants specifically was important in determining any benefits (Yamane *et al.*, 2004). Nonetheless, it demonstrates that access to allotments provides an opportunity for contact with nature especially to those without a private garden (Swanwick, 2009). Allotments and community gardens therefore provide opportunities for contact with nature and wellbeing benefits, though they are not an exclusive resource for gaining these benefits.

As well as the wellbeing benefits for the general population, there were found to be significant benefits too for specific age groups within this. In older people, the benefits to wellbeing of allotment or community gardening were notable.

> "Allotment gardeners of 62 years and older had significantly better composite well-being scores than neighbors in the same age category, and they also scored significantly or marginally better than neighbors in the same age category on all single well-being measures. Younger allotment gardeners did not differ from younger neighbors in any of the well-being measures."
>
> (Van Den Berg *et al.*, 2010, p. 6)

Allotment and community gardening were also found to help combat social isolation in older people, and to help develop their social networks (Milligan *et al.*, 2004; Cameron, 2014). Among children too, the benefits of working on shared gardening projects were found to include improved self-esteem, and reduced stress and anxiety (Cameron, 2014). As well as wellbeing impacts, allotments and community gardens have physical health benefits. In particular, benefits on healthy eating, physical activity levels, and on indicators of physical health.

Allotments and community gardening are associated with an increased consumption of fruit and vegetables, a key factor in healthy eating (Alaimo *et al.*, 2008; Carney, 2012). One US study found that adults in households with at least one person partaking in community gardening,

> “consumed fruits and vegetables 1.4 more times per day than those who did not participate, and they were 3.5 times more likely to consume fruits and vegetables at least 5 times daily.”
>
> *(Alaimo et al., 2008, p. 94)*

Another that,

> “Eating fruit and vegetables in a ‘several times a day category’ increased from 18 to 85% for adults during the duration of the project (and from 24 to 64% for children)”.
>
> *(Cameron, 2014, p. 1013)*

However, causality is difficult to establish, with those who were previously eating more fruit and vegetables perhaps more attracted to partaking in community gardening.

Another key finding was that participants wished to consume more fruit and vegetables and were aware of the health benefits of doing so, but often lacked access to fresh produce. This is particularly important as increasing proportions of the urban population live in ‘food deserts’ with poor or non-existent access to fresh produce, and intersects with issues of deprivation and lack of mobility as well as the more direct benefits.

Allotments and community gardens are also associated with increased physical activity levels (Schmelzkopf, 1995; Milligan *et al.*, 2004; Groenewegen *et al.*, 2006; Phelps *et al.*, 2010; Cameron, 2014). The benefits of physical activity are usually greatest with moderate activity sustained throughout the year. Allotment gardening provides the opportunity for this, with different plants and maintenance tasks needing attention at different times of year. The self-expression and personal achievement felt by participants helps to sustain interest, and therefore activity levels, long term. In fact, gardening in particular is associated with long term participation in physical activity, which maximises the potential benefits compared to short term engagement (Magnus *et al.*, 1979; Blair *et al.*, 1991; Cameron, 2014).

However, the type of gardening task, and the pre-existing fitness level and ability of the participants will affect intensity of the physical activity involved, and therefore the extent to which it impacts overall physical activity levels may vary considerably (Cameron, 2014). Other types of physical activity may be more beneficial overall, as they offer more opportunities for higher intensity or more frequent exercise (Magnus *et al.*, 1979).

Nonetheless, allotment gardening does provide opportunities for regular physical activity throughout the year, and this is associated with reduced risk factors for coronary heart disease, Type II diabetes, hypertension, stroke, osteoporosis, and some types of cancer, as well as reduced mortality, and lower blood pressure (Milligan *et al.*, 2004; Cameron, 2014).

In particular, allotment gardening offers opportunities for physical activity to help with illness or disability management (Elings, 2006; Kingsley *et al.*, 2009; Cameron, 2014), and in hospital settings (Wolf and Robbins, 2015), and is associated with positive health indicators in older people especially (Van Den Berg *et al.*, 2010).

As well as the positive health benefits, there are some negative health benefits associated with allotments and community gardening. Injuries during gardening are not uncommon, and in particular there are considerations about the misuse of tools, including lawn mowers (Powell *et al.*, 1998; van Duijne *et al.*, 2008; Cameron, 2014). There are also issues of allergies, exposure to pollen or toxic plants, and to pathogens in the soil (McMullen and Gawkrodger, 2006; O'Connor *et al.*, 2007; Cameron, 2014). The latter may be of particular concern in allotments and community gardens over private gardens, as these sites frequently make use of previously derelict land (Alaimo *et al.*, 2008).

There are also a range of social befits that are associated with allotment and community gardens. In particular, better social and cultural integration (Schmelzkopf, 1995; Milligan *et al.*, 2004; Groenewegen *et al.*, 2006; Phelps *et al.*, 2010; Cameron, 2014), and improved family cohesion (Carney, 2012; Cameron, 2014). Though these are not the only available opportunities for social or family cohesion, they can provide key opportunities, in combination with the health benefits to individuals, it is certainly a key resource for a community.

There are also eductional opportunities, especially of understanding local ecosystems (Demuzere *et al.*, 2014). This helps to promote the environmental benefits of green infrastructure, and thus encourage the long term and sustainable management of allotments and community gardens.

Both allotment sites and community gardens are often built on otherwise-unused land (Alaimo *et al.*, 2008), for example the derelict spaces around railways or between developed sites. This helps to connect them within wider networks of wildlife corridors. They also provide key areas of green space within the urban environment, which can help to perform some of the same ecosystem services and environmental benefits of, for example, parks. These include promoting and supporting biodiversity; climate change mitigation; and urban waste minimisation (Scott *et al.*, 2018). Biodiversity in particular is known to be supported and promoted in urban areas by allotments, cemeteries and parks, and that they are especially beneficial for insects and birds and for pollination and seed dispersal (Gómez-Baggethun and Barton, 2013).

Of course there is also the benefit of their most basic function, in providing food through urban agriculture. While this is usually very much on a small scale and has direct benefits to individuals, families, and neighbourhoods, it nonetheless reduces some of the reliance of a city on the wider surrounding areas, and can also be a market disruptor to wider economic trends (Scott *et al.*, 2018). At a more basic economic level, the presence of community gardens is associated with higher property values in a neighbourgood (Wolf and Robbins, 2015), although this may lead to gentrification, which has its own associated socio-economic issues.

2.2.1.2 Green roof

Green roofs, involving planting vegetation on flat roofs, are associated with many benefits, especially environmental benefits (Rowe, 2011). However, they also have limitations, and the ability to retrofit them in existing urban areas depends on the existence of suitable flat roofs with appropriate structural integrity to support the desired roof type (Land Use Consultants and Green Roof Consultancy, 2010). The benefits that can be realised from a green roof will vary according to its size and vegetation type, so this is hugely influential and potentially very limiting in realising those theoretically potential benefits. A green roof is also more expensive than a conventional roof at the construction stage, although they typically have a longer lifespan and the full cost over the life of the roof will be less for a green roof than a conventional one, based on current valuation scenarios (Clark *et al.*, 2008). This extended lifespan, of 40-45 years for a green roof compared to 20 years for a conventional flat roof, also means that over time there will be fewer roofing materials being consigned to landfill (Rowe, 2011).

One of the main uses for green roofs is to provide vegetation that can contribute to air purification, both cooling urban air and helping to remove pollutants, especially particulate matter (Clark *et al.*, 2008; Rowe, 2011), and these benefits can be realised at individual street scale (Alexandri and Jones, 2008; Baik *et al.*, 2012), at neighbourhood scale (Currie and Bass, 2008), and at municipal scale (Yang *et al.*, 2015).

Green roofs can be either extensive or intensive. Extensive roofs are typically grass-based, and are often the cheapest to construct and maintain. Intensive roofs include wider range of vegetation, such as shrubs, and as such need a greater investment of roof strength, and maintenance over their lifespan. Air pollution benefits can come from both types of roof, though greater impacts might be found from intensive roofs.

> "Grass on roofs (extensive green roofs) could augment the effect of trees and shrubs in air pollution mitigation, placing shrubs on a roof (intensive green roofs) would have a more significant impact. By extension, a 10-20% increase in the surface area for green roofs on downtown buildings would contribute significantly to the social, financial and environmental health of all citizens."
>
> *(Currie and Bass, 2008, p. 409)*

Research has found that green roofs are particularly good at removing NO_x from the air (Clark *et al.*, 2008), and that they also indirectly may reduce CO_2 emissions because their cooling effects can reduce energy demand for building heating and cooling (Rowe, 2011).

However, there are also some limitations in practice. It is suggested that green roofs are not as effective at reducing air pollution, especially particulate matter, in urban street canyons when compared to street-level greening (Pugh *et al.*, 2012). Although, there is some evidence that in general over the urban area they may be as effective at pollutant reduction as urban forest, but that they do so at a much greater installation and maintenance cost than an urban forest (Rowe, 2011).

Research also suggests that green roofs may be effective at reducing noise pollution (Oberndorfer *et al.*, 2007; Rowe, 2011), and there is a “linear relationship between the percentage of roof space covered with vegetation and the reduction in sound pressure on the opposite side of the building from the noise source or street canyon." (Rowe, 2011, p. 2105).

Green roofs are also useful for their impact on urban heat islands, providing urban cooling (Oberndorfer *et al.*, 2007; Rowe, 2011; Jones and Somper, 2014). In general, green roofs are cooler than their conventional roof equivalents (Bowler *et al.*, 2010; Demuzere *et al.*, 2014), though the specific temperature differences will vary depending on the time of day, season, antecedent, and current climatic conditions and the volume of water stored. The cooling action works through evapotranspiration as well as through reflecting sunlight (Demuzere *et al.*, 2014; Santamouris, 2014). With high leaf area index planting, green roofs can produce an effect equivalent to using high albedo paint (Santamouris, 2014; Norton *et al.*, 2015), though it is most effective with a well-irrigated roof.

Alexandri and Jones (2008) found that the greatest cooling effects were found in the hottest, driest climates, for example, their study included Riyadh, Saudi Arabia. It is encouraging that the greatest effects were also found in the areas that have the greatest need. However, even though some street canyon scale effects were evident, the study also found that the greatest cooling was at rooftop level and therefore that the cooling was most effective at urban scale. This also supports the findings of Santamouris (2014) that there is an impact of green roofs on urban heat islands at a city scale.

The cooling effect of green roofs can affect buildings as well as the air. The layers of substrate can increase building insulation as well as offering cooling through evapotranspiration (Oberndorfer *et al.*, 2007; Santamouris *et al.*, 2007; Sailor, 2008; Cameron *et al.*, 2012). This can in turn reduce building heating and cooling costs in winter and summer. However, this impact may only be noticeable in buildings with poor existing insulation (Castleton *et al.*, 2010; Demuzere *et al.*, 2014). Nonetheless, this may be an important consideration when retrofitting green roofs to older buildings that may not have high levels of existing insulation. There is also the advantage that the insulating effect can reduce summer cooling requirements, but without increasing winter heating burden (Santamouris *et al.*, 2007), unlike some other types of green infrastructure asset (see 2.2.1.8, 'Trees and urban forest').

Despite this broad range of studies considering the impact of green roofs on urban cooling, which include both modelling results and empirical studies, it is still difficult to quantify the specific impact that green roofs may have as a strategy for cooling in temperate climates. The variables involved are many, with complex relationships, and there are arguably insufficient data to provide specific recommendations (Bowler *et al.*, 2010; Cameron *et al.*, 2012). Despite the difficulty in elucidating the specific relationships, the weight of evidence overall suggests that there is strong reason to believe that green roofs can have a beneficial role in providing urban cooling, particularly in areas or times of great heat stress, and that this benefit can be maximised with careful design choices for structure, vegetation, and maintenance regimes.

Another key benefit of green roofs is their contribution to management of storm water and run-off reduction (Oberndorfer *et al.*, 2007; Rowe, 2011; De Sousa *et al.*, 2012; Qin *et al.*, 2013; Jones and Somper, 2014). Compared to a conventional roof, green roofs can reduce up to 60-70% of storm water volume, and through attenuation can delay and prolong the discharge from that roof, contributing to a reduced discharge peak for the area (Qin *et al.*, 2013). Another study suggested that run-off reduction can range from 50-100%, depending on the roof type, and that the roof design and maintenance, the antecedent conditions, and the intensity and duration of the rainfall will all impact its performance (Rowe, 2011). Green roof performance for stormwater management is not consistent: it is most effective in small to medium rainfall events (Demuzere *et al.*, 2014), and in events with a late peak in the flow profile (Qin *et al.*, 2013).

Green roofs are also good for managing water quality. This effect is twofold. Their direct impact is that their vegetated surfaces can filter pollutants within run-off, and reduce the proportion of run-off that comes from streets with potentially high pollutant levels (Rowe, 2011; Demuzere *et al.*, 2014). However, the extent to which they can do this is highly dependent on roof design, antecedent conditions, and rainfall intensity and duration (Demuzere *et al.*, 2014), and some studies also fail to provide any indication that they can improve water quality (Rowe, 2011), and even that pollutants in green roof run off may be higher than a control roof (Hathaway *et al.*, 2008).

Secondly, green roofs can have an indirect impact on water quality by reducing combined sewer overflows (CSOs) (Rowe, 2011; Demuzere *et al.*, 2014). In urban areas with combined sewers, periods of heavy rainfall can result in CSOs, which reduced water quality in the affected areas. By reducing total run-off volume and delaying the peak flow through attenuation, this may help to reduce incidences of CSOs. Although it must be remembered that green roofs are most effective in small to medium rainfall events, while CSOs are typically associated with bigger storm events.

In summary, there are some benefits of green roofs on managing stormwater volumes, especially in low to medium intensity rainfall events; but the impact of green roofs on water quality is limited and suggests that while there may be some benefits, it is on a very small scale.

Green roofs deliver many benefits to wildlife, especially birds, and are good for biodiversity (Oberndorfer *et al.*, 2007; Chiquet *et al.*, 2013). They increase the available urban habitat, and are especially noted for supporting biodiversity among generalist species, especially insects (Williams *et al.*, 2014). This has further indirect benefits to humans, such as increasing pollinators. However, there is little evidence on the value of green roofs for rare or endangered species, nor for vertebrates, and little evidence on how they compare to ground-level habitats (Williams *et al.*, 2014). Without further, more informative, evidence, Williams *et al.* (2014) argue that biodiversity benefits should not be a key driver for policy nor investment in green roofs, and that further research needs to be done into their impact.

This limitation in evidence is unsurprising, given the scale and complexity of modelling or measuring impact of green roofs within an entire urban system. While there is some evidence that they work best when used in conjunction with other green features (Wang *et al.*, 2013), thus supporting the argument for an interconnected green infrastructure network, there is also some suggestion that in practice they often fail to deliver on the maximum potential benefits that are theorised (Rogers, 2013). The location and design of a green roof can vary hugely from site to site, and in order to realise the potential benefits, care must be taken to match the design to the local characteristics and climate.

2.2.1.3 Green wall

Green walls, like green roofs, are able to provide areas of vegetation in a dense urban environment without increasing the footprint of green space. While there is less research and evidence available on their benefits, it may be assumed that some of the general benefits of increased urban vegetation found in research on green roofs, parks, and trees will have some relevance here as well.

Looking specifically at research on green walls, Alexandri and Jones (2008) found that they provide urban cooling, and may reduce some urban temperatures by up to eight degrees Celsius. They can provide a similar level of urban cooling without taking up as much street space as trees (Norton *et al.*, 2015).

Green walls also contribute to the removal of air pollution, potentially reducing NO_2 concentrations by up to 40% and PM_{10} up to 60% in street canyons (Pugh *et al.*, 2012; Demuzere *et al.*, 2014).

The last main benefits centre on the role of green walls as a habitat for birds. In their research, Chiquet *et al.* (2013) found that birds use green walls for nesting, food, and shelter, albeit mainly in the upper portion of the walls. There was also an increased abundance of birds observed on other, non-vegetated, roofs near the green walls. Use of green walls included some species of concern, though use by all birds depended on the time of day, the season, and the vegetation type.

2.2.1.4 Hedgerows and shrubs

Hedgerows and shrubs generally consist of mid-height woody plants, distinct from trees in their size more than plant type. Hedgerows are less common in urban areas due to the extended space implicitly needed. Nonetheless, where they do exist they combine the benefits of shrubs with the advantages of greater extent and likely increased connectivity with other green spaces.

Shrubs offer similar benefits to other vegetation types, including air purification, pollutant removal, and cooling (Nowak *et al.*, 2006; Baró *et al.*, 2014; Wolf and Robbins, 2015). There is less research available on shrubs specifically, and much of their value has been researched in the context of the wider urban forest (Nowak *et* *al.*, 2006; Baró *et al.*, 2014). They were also found by Wolf and Robbins (2015) to be good for noise abatement in urban areas.

Hedgerows and shrubs may also be contributors to carbon sequestration. Along with trees, they provide greater levels of carbon sequestration than annual plants (Cameron *et al.*, 2012), and in a domestic garden shrubs and trees may contribute around 16% of the total carbon storage (Jo and McPherson, 1995).

The direct contribution of urban forests, including shrubs, to overall climate change mitigation is, however, low. They do have some role to play as part of a wider set of measures, and have an important role as an indirect contribution through urban cooling creating reduced energy demand and consequently lower GHG emissions (Baró *et al.*, 2014).

Despite these small contributions, the overall evidence of hedgerows and shrubs impact on wider green infrastructure benefits is low. Further research may need to be conducted in order to isolate these benefits, perhaps as part of detailed study into the types of trees and plants that offer the greatest benefit in different urban contexts.

2.2.1.5 Parks

Parks provide a key source of green space in urban areas, and there is a large body of literature on their benefits, across environmental, social, and economic spheres. They can come in a range of sizes, and while there may be some access restrictions, they are generally open to the public for some of the day, and free at the point of use. Some parks, especially with a sports focus, may have significant impermeable surface (e.g. tennis courts or running tracks), but generally they include large areas of grass, shrubs, trees, and other vegetation.

A key function of parks, especially large parks, in urban areas is that they can provide a cooling effect, both within the park itself but also that extends beyond its boundary and into the surrounding built up area (Demuzere *et al.*, 2014; Doick *et al.*, 2014; Klemm *et al.*, 2014). Studies showed a gradual increase in temperature moving away from large green areas (Demuzere *et al.*, 2014). One study on Kensington Gardens, London, UK, found that the excessive night-time temperatures of the urban heat island were abated by proximity to the park, and that this effect was greatest when most needed, on warm, still nights (Doick *et al.*, 2014).

Other environmental benefits of urban parks include their role in protecting biodiversity, and ecological functions (American Planning Association, 2003). However, the biodiversity in park is not as rich as in an allotment garden (Speak *et al.*, 2015). Parks can also play in a role in storm water management, through providing permeable surfaces and vegetation to reduce run-off and provide attenuation (American Planning Association, 2003).

Natural landscapes have been found to have health benefits (Cameron, 2014; Lamond and Everett, 2019), and the largely vegetated landscape of most urban parks is found to be as good for providing these health and wellbeing benefits. Access to parks is associated with good physical health (Fields in Trust, 2018), as well as improved wellbeing and better mental health (Guite *et al.*, 2006; Pretty *et al.*, 2007; Mitchell, 2013; Cameron, 2014; Peschardt, 2014; Fields in Trust, 2018). Mitchell (2013) found that regular use of natural environments was associated with a lower risk of poor mental health, even when controlled for demographic or socio-economic factors. There is some evidence that even very small 'pocket parks' can offer a restorative effect that is good for wellbeing (Peschardt, 2014). These health benefits may have particular importance for more vulnerable groups in society: Takano *et al.* (2002) found that older people with access to walkable green space (both parks and tree lined streets) lived longer than those without such access. It was, however, unclear what socio-economic factors may also dictate this relationship, nor what influence past medical history may have had on individuals' ability to access green space.

There are also other confounding factors, and while there appears to be a relationship between health and wellbeing and access to parks, it is difficult to establish causality. There is some suggestion in the literature that the health benefits of parks may vary according to the emotional attachments that users have to the space (Cameron, 2014). In cases of exercise in green space being good for wellbeing, it is unclear what proportion comes from the exercise, regardless of the setting (Pretty *et al.*, 2007). In addition, there is some evidence that people prefer informal green space to formal parks, and therefore these may be better for wellbeing (Rupprecht *et al.*, 2015).

Nonetheless, parks do have an important role to play for health and wellbeing as part of an urban green infrastructure network. They have been shown to be good for the health and wellbeing of all sections of the community, regardless of economic status (Fields in Trust, 2018), and can in fact provide important access to green space for those sections of the population who have limited or no access to private green space (Conedera *et al.*, 2015). As such they can help to reduce inequalities, and in particular health inequalities in mental wellbeing (Mitchell *et al.*, 2015; Fields in Trust, 2018).

> "Socioeconomic inequality in mental wellbeing was 40% narrower among respondents reporting good access to green/recreational areas, compared to those with poorer access."
>
> *(Mitchell et al., 2015, p. 80)*

Many of these health and wellbeing benefits are related to the opportunities that parks provide for physical activity and active recreation (American Planning Association, 2003; Baró *et al.*, 2014; Cameron, 2014; Byrne *et al.*, 2015; Lindberg and Schipperijn, 2015; Hirsch *et al.*, 2017). Proximity appears to be key for access to physical activity, with people living close to parks more likely to use them for active recreation and people living further away from parks more likely to be overweight, and less likely to be meeting minimum physical activity guidelines (Cameron, 2014). However, Lindberg and Schipperijn (2015) found that there are gender imbalances in the use of parks, with men and boys more likely to use the space for physically active recreation than women and girls. This research also suggests that park design could be utilised to reduce these inequalities, but does not provide examples of how this could be done. Likewise, Lamond and Everett (2019) found that interaction with and understanding of such spaces will vary according to local contexts and cultural practices, and thus benefits of parks cannot be assumed to be universal, without more detailed understanding of how and why users interact with the space and its features.

Other inequalities may arise through park placement or design. While public access that is free at the point of use makes parks relatively accessible, they are easier to use and used more by the immediately local population. In parallel to this, the presence of a park increases property values (Panduro and Veie, 2013), and can increase the popularity of an area (Hirsch *et al.*, 2017). These factors in combination can contribute to gentrification, meaning socio-economic imbalances occur in accessibility to parks (Kabisch and Haase, 2014).

There is a need for considered design in parks in order to maximise their potential benefits. In a study of a Swedish greening programme, Littke (2015), found that some people regarded highly managed, formal parks as less ‘good’ than informal green space, and felt that urban green space was not inherently natural, therefore not ‘nature’. This may limit the extent to which they are useful for wellbeing, as that is associated with contact with nature (Cameron, 2014). That said, poorly maintained parks and parks with lots of understory beneath trees are often perceived as unsafe (Baró *et al.*, 2014), contradicting the Swedish study that suggests a less ‘manicured’ park is preferable. A more manicured park, however, will have fewer environmental benefits (which come from having a range of vegetation types), but will likely feel safer to humans (Baró *et al.*, 2014). This balance of maintenance for maximum environmental benefits while maintaining the space as desirable as humans may also be under threat as the quality of parks in the UK has been declining over time (Fields in Trust, 2018), as budgets are reduced for park maintenance.

The design of parks and their distribution is also important, as they help to shape urban form, can buffer incompatible land uses (American Planning Association, 2003), and can be good use of formerly derelict space (Littke *et al.*, 2015), although it must account for the land use, culture and character of the neighbourhoods surrounding that repurposed space if it is to be beneficial to the area. Parks can offer a variety of ecosystem services, but which, and how well, will depend on their placement, size, design, maintenance and uses (Liu *et al.*, 2018), and in particular the vegetation types chosen will influence the types of service that can be realised (Mexia *et al.*, 2018)

Finally, urban parks can also provide various economic benefits to cities. Their total economic value to an individual is estimated to be £30 per year, including “benefits gained from using their local park or green space and non-use benefits such as the preservation of parks for future generations” (Fields in Trust, 2018, p. 6). In addition, the cumulative impact of health benefits of parks creates an estimated £111 million per year, based on reduced GP visits (Fields in Trust, 2018). Economic benefits also stem from tourism, with iconic parks being a potential attraction to visitors (Gómez-

Baggethun and Barton, 2013), and through increased house prices (Panduro and Veie, 2013). However, while good quality parks can increase house prices, based on hedonic pricing, poor quality parks can also decrease property value. This again reinforces the need for good design, strategic placement, and a comprehensive maintenance plan to maximise the benefits available from urban parks.

2.2.1.6 Domestic gardens

Domestic gardens are usually attached to people's houses and limited to use by the household, or perhaps shared between a small numbers of residents in multi-unit buildings. Many houses, especially in the UK context, have front and back gardens, with the latter more likely to be used for recreation and the front more aesthetic. They form a significant part of the makeup of the overall urban green space: between 35% and 47% of total urban green space in the UK (Sjöman and Gill, 2014), and in Britain, an estimated 62% of garden space is vegetation (Data Science Campus, 2019). Domestic gardens provide the main opportunity for contact with the land for many people (Swanwick, 2009).

They can insulate houses against extreme temperatures, thereby contribute to urban cooling, and reducing domestic heating and cooling costs (Cameron *et al.*, 2012; Demuzere *et al.*, 2014). However, the variation in vegetation extent and type will influence the energy load, so all gardens and buildings will be different. This makes it difficult to estimate the impact on the wider urban environment (Cameron *et al.*, 2012).

Gardens help to mitigate flooding, and often are a key source of permeable surfaces in urban areas (Cameron *et al.*, 2012). There are issues arising from the increasing trend to pave over front gardens for parking.

> "We have revealed a 22.47% increase in impermeable domestic front garden cover, and an average required increase of 26.23% in attenuation storage volumes across Southampton's high-risk flooding hotspots between 1991 and 2011. These increases have negative implications for ecosystem services, especially with regard to flood regulation."
>
> *(Warhurst et al., 2014, p. 338)*

Domestic gardens also provide habitats for wildlife, and social opportunities for encounters with nature, which is good for wellbeing (Cameron *et al.*, 2012; Wolf and Robbins, 2015). However, they also increase the presence of non-native and invasive species, and use of pesticides and fertilisers can be detrimental to the environment (Cameron *et al.*, 2012).

There is some evidence that domestic gardens are a contributor to carbon storage in urban areas, (Jo and McPherson, 1995; Demuzere *et al.*, 2014), but gardening activity can increase GHG emissions (Cameron *et al.*, 2012).

2.2.1.7 Sustainable Drainage Systems (SuDS)

Sustainable drainage systems (SuDS) are constructed systems designed to manage rainwater, usually in urban settings, sustainably. Typical features include rainwater harvesting systems, pervious pavements, bioretention systems, swales, detention basins, soakaways, and infiltration basins (Woods Ballard *et al.*, 2015). SuDS and other low impact development for water management can reduce surface run-off during rainfall events (Sjöman and Gill, 2014; Woods Ballard *et al.*, 2015; Ahiablame and Shakya, 2016), although the size and capacity of the SuDS design and intensity and duration of the rainfall event will dictate the efficacy of this (Ahiablame and Shakya, 2016). Green infrastructure options have been shown to be more robust at water management than their ‘grey’ counterparts in some cases (Casal-Campos *et al.*, 2015), and SuDS perform best in low intensity and short duration rainfall events (Tao *et al.*, 2017). However, their performance in high intensity events means that SuDS should ideally not be the only type of flood management in place in an urban area. SuDS are also beneficial for storage of excess water for later use in times of insufficient supply, for discharge peak attenuation and for groundwater recharge (Chow *et al.*, 2014; Voskamp and Van de Ven, 2015). The reduction in surface water run-off then reduces the risk of CSOs (De Sousa *et al.*, 2012; Flynn and Traver, 2013), which is beneficial to water quality.

SuDS, particularly rain gardens, also have an impact on water quality through removing some pollutants from stormwater run-off, and mitigation of fresh water eutrophication (Flynn and Traver, 2013; Wang *et al.*, 2013; Woods Ballard *et al.*, 2015). However, rain gardens are associated with some environmental disbenefits in the construction phase (Flynn and Traver, 2013).

SuDS offer benefits to both people and wildlife, including increased amenity values (Chow *et al.*, 2014; Woods Ballard *et al.*, 2015), restoration or preservation of vegetation and wildlife (Scholz, 2013), and through urban cooling via evapotranspiration (Voskamp and Van de Ven, 2015). They are also an economically viable method of stormwater management (Jayasooriya and Ng, 2014), and are economically feasible at a neighbourhood level (Johnson and Geisendorf, 2019).

These benefits for humans extend to health benefits, with areas around green infrastructure installations for stormwater management in Philadelphia, Pennsylvania, USA showing population level health improvements when compared to control areas in the same city (Kondo *et al.*, 2015). This study also showed positive impacts of crime reduction on the same scale.

The design of SuDS used is important (Woods Ballard *et al.*, 2015), and using a mix of features in a SuDS system will have the best effect for managing stormwater run-off,

> "Swales perform best during a storm event with an early peak, permeable pavements perform best with a middle peak, and green roofs perform best with a late peak."
>
> *(Qin et al., 2013, p. 577)*

Some research indicates that a combination of green and grey infrastructures offer the most robust combination for flood management and that the greatest contribution of SuDS to climate adaptation occur when they are implemented in combinations (Voskamp and Van de Ven, 2015).

2.2.1.8 Trees and urban forest

Trees, which in combination with shrubs and other vegetation form the urban forest, have a lot of benefits to offer urban areas and their populations, across environmental, social, and economic sustainability (Duinker *et al.*, 2015).

Environmental benefits include air quality improvements, urban cooling, carbon storage, biodiversity, and flood management. Air quality can be improved through trees and shrubs (Nowak *et al.*, 2006; Cameron *et al.*, 2012; Baró *et al.*, 2014; Demuzere *et al.*, 2014; Hartig *et al.*, 2014; Duinker *et al.*, 2015). In particular, they have a role in the reduction of particulate matter (PM) (Nowak *et al.*, 2006; Demuzere *et al.*, 2014; Hartig *et al.*, 2014).

> "A 10 x 10 km grid in London with 25% tree cover could remove 90.4 tons of PM_{10} per year."
>
> *(Nowak et al., 2006, p. 110).*

However, the effect may be limited (Cameron *et al.*, 2012; Baró *et al.*, 2014), especially where dense planting restricts airflow and so prevents effective particulate dispersal (Demuzere *et al.*, 2014; Hartig *et al.*, 2014). Thus, placement and vegetation type are both essential for creating an effective urban forest with benefits that outweigh the disadvantages. Another key issue for air quality is that an increase in trees in an urban area can increase the pollen and other allergens in the air, as well as trees issuing bio volatile organic compounds (BVOCs). However, some tree species do this more than others, so careful species selection can mitigate this to some extent (Demuzere *et al.*, 2014; Hartig *et al.*, 2014).

Despite the variation in species ability to deliver air quality improvements, the management of the canopy cover of the urban forest may be a viable strategy to deliver clean air standards in a cost effective way (Nowak *et al.*, 2006; The Nature Conservancy, 2016).

Urban trees can also affect the air quality indirectly, by reducing energy demand through delivering urban cooling, which is delivered through a combination of shading and evapotranspiration, which can be a cost effective way of managing the urban heat island (Hartig, 2008; Cameron *et al.*, 2012; Demuzere *et al.*, 2014; Doick *et al.*, 2014; Duinker *et al.*, 2015; The Nature Conservancy, 2016). However, it is unclear which tree species or types are the best for cooling particular types of buildings in various environmental contexts, and the quantification of specific benefits remains uncertain (Cameron *et al.*, 2012; Rahman and Ennos, c. 2015). The placement of trees must be carefully considered, as shading can be detrimental in some situations, and it is important particularly in cooler climates where shading can reduce heat all year round, thus increasing winter heating burden and energy use (Demuzere *et al.*, 2014; Duinker *et al.*, 2015).

Trees and the urban forest are good for carbon and climate change (Nowak and Crane, 2002; Nowak *et al.*, 2006; Cameron *et al.*, 2012; Demuzere *et al.*, 2014; Duinker *et al.*, 2015).

> "Total carbon sequestered in urban trees in the USA is estimated to be 700 x 1012g."
>
> *(Cameron et al., 2012, p. 131)*

However, there does remain uncertainty around the figures for carbon storage by urban trees on average (Rahman and Ennos, c. 2014a), and its contribution is very small when compared to global forests (Cameron *et al.*, 2012). There is also a time lag between the planting of new trees before they can begin to contribute carbon sequestration benefits. It is estimated to take between three and ten years for a newly planted tree to become carbon neutral, and they are not able to effectively offset carbon emissions at the current rates (Nowak and Crane, 2002; Cameron *et al.*, 2012; Baró *et al.*, 2014).

Trees are good for run-off reduction and stormwater management in urban settings through attenuation, which slows peak flow and can prolong a lower run-off rate to avoid or reduce flooding (Cameron *et al.*, 2012; Duinker *et al.*, 2015). However, there is still uncertainty around the exact water run-off figures possible from different tree types in different contexts (Rahman and Ennos, c. 2014b). Nonetheless, stormwater management benefits may provide sufficient financial argument for investing in street trees (Stovin *et al.*, 2008).

The final key environmental benefit of the urban forest is its ability to support and promote biodiversity (Duinker *et al.*, 2015). However, the exact benefits will again depend on the species type, and the tree layout, planting context, and relationships with the rest of the urban green infrastructure network. In addition, disbenefits can be introduced through poor tree choice, as some species are less desirable in urban areas.

The urban forest is also able to provide a range of social benefits. Human beings in general like trees (Duinker *et al.*, 2015), and they are considered the second most important feature of a park after grass (Arnberger and Eder, 2015). Trees generally enhance urban aesthetics and provide education opportunities; they can provide important structural functions for households and can help contribute to a sense of place (Barau, 2015; Duinker *et al.*, 2015). Trees can also be unpopular. People dislike understory vegetation, and dense planting can increase the fear of crime due to shading and reduced sightlines, although some of the negative impacts can be reduced through careful maintenance and management (Johnston, 2012; Duinker *et* *al.*, 2015). This species selection and maintenance is important, but it is often overlooked in funding and finance plans for new trees, which can reduce the benefits that are realised, and make trees less beneficial than their theoretical potential (Pincetl *et al.*, 2013).

Despite the increased fear of crime in poorly maintained urban forest, there is evidence to suggest that the presence of trees helps to reduce crime, even accounting for varying social-economic or demographic contexts (Cameron, 2014; Duinker *et al.*, 2015; Kondo *et al.*, 2017).

> "[…]domestic violence increased by 25-35% in housing estates in Chicago where large landscape trees were removed from the view of some housing blocks but not others (for communities with similar housing stock, and social-economic background). The authors related the level of aggression encountered to enhanced stress and anxiety in those dwellings where there was no view of greenery."
>
> *(Cameron, 2014, p. 1012)*

It is suggested that this may be due to the ability of urban trees to improve wellbeing and lower levels of stress and anxiety (O'Brien and Snowdon, 2007; Arnberger and Eder, 2015; Duinker *et al.*, 2015), which lead to reduced aggression and violence. This also links to the ‘broken windows’ theory of crime, which theorises that a rundown area with signs of petty crime and vandalism will be prone to more of the same (Aiyer *et al.*, 2015), thus a well-landscaped city area including trees may help to avoid this.

Cameron (2014) suggest that while beneficial, streets with trees do not cross the threshold needed to be classified as a restorative environment for stress, yet there is evidence that trees do promote good health, and aid fast recovery from physical illness and injury (Duinker *et al.*, 2015). Again, the species selection is essential. While trees in urban areas have been seen to reduce incidences of asthma (Duinker *et al.*, 2015), perhaps through improving air quality, some species of plants are harmful to humans, and increased pollen rates may worsen air quality and increase asthma incidences at certain times of year. More plants and associated wildlife also can increase the use of pesticides and fertilisers as part of their management, which can be harmful to people (Demuzere *et al.*, 2014).

Trees and urban forests are able to offer a range of economic benefits. They can increase property values, create employment through demand for management and maintenance, support business activity, and enhance tourism (Duinker *et al.*, 2015). These benefits are not without their costs – including potential gentrification and social displacement, increased maintenance costs, and greater demand on local infrastructure by tourists. Nonetheless, the ecosystem services provided by urban forests are an important economic factor for a city. For example, Rumble *et al.* (2015), estimated that the total value from urban trees in Glasgow, UK, in 2013 was £4.5million per year.

Interestingly, urban trees can prolong the life of other infrastructure, especially in hot climates. The shading of streets by trees reduces the breakdown of asphalt under sunlight, thus prolonging the useful life of road surfaces and reducing costs for repair and replacement (Duinker *et al.*, 2015).

Species choice and location is the most important factor in the ability of urban trees to deliver on their potential benefits, with larger trees able to provide greater benefits than small ones (canopy cover and leaf surface area are key), and mature trees better than saplings (GreenBlue Urban, 2018). The forest biomes across a global scale are increasingly fragmented, and so with correct design and management, urban forestry could help to infill gaps in global forest zones, and therefore offer benefits to humans on a greater scale (Reinmann and Hutyra, 2017)

2.2.1.9 Wildlife corridor

While wildlife corridors form a key element of a green infrastructure network, they are hard to identify and define as a specific asset in an urban area. They can be mapped using land use classifications, but research on them is limited. The focus of most studies on specific assets is more focused on those that are deliberately constructed and/or managed as an individual asset, like parks or trees. Wildlife corridors, however, tend to be identifiable by their nature of being strips of extended green or green-blue space that extend over some distance, and ideally connect to other areas of green space. Road and railway edges are often also wildlife corridors, as are riparian habitats following urban watercourses (Scott Shafer *et al.*, 2013). Despite being little understood, they are key, and evidence shows that, for example, an interconnected system of parks and open space is more beneficial than creating parks in isolation (American Planning Association, 2003).

2.2.1.10 Wetlands, ponds, rivers and streams

Wetlands and ponds, along with rivers, streams, and canals all provide green infrastructure functions in urban areas, though it is the wetlands and ponds that provide the most ecosystem services to humans.

> "Ponds and wetlands are features with a permanent pool of water that provide both attenuation and treatment of surface water runoff. They can support emergent and submerged aquatic vegetation along their shoreline and in shallow, marshy (wetland) zones, which helps enhance treatment processes and has amenity and biodiversity benefits."
>
> *(Woods Ballard et al., 2015, p. 485)*

They may be naturally occurring or manmade, and may form a key part of a SuDS system (Fletcher *et al.*, 2015). For the purpose of finding evidence of the benefits of wetlands, any of these types were considered.

Wetlands are important for the water balance in urban areas (Gómez-Baggethun and Barton, 2013), and yet the ecosystems provided by wetlands are often the most underappreciated and therefore undervalued of all urban ecosystem services in an area (McInnes, 2014). Consequently there have been failures in green infrastructure planning to recognise the value of wetland ecosystems, and the supporting services they provide. In particular, they are key for provision of biodiversity, soil formation, and nutrient cycling (McInnes, 2014), and wetlands have been found to offer nitrogen retention in arid and semi-arid climates, which no other bio-retention scenarios were able to offer (Houdeshel *et al.*, 2015).

Wetlands in urban areas also provide key cultural services and are a valuable social asset, aside from their environmental benefits (Vollmer *et al.*, 2015). Naturally occurring or artificially constructed watercourses are invaluable to the wider green infrastructure network in urban areas, with stream corridors forming the skeleton network of green infrastructure in many cities (Scott Shafer *et al.*, 2013), and often providing wildlife corridors. This suggests that they are an underutilised asset within strategic green infrastructure planning at city scale, and could be a key opportunity and policy driver if used appropriately.

2.2.1.11 Green spaces

Green space in urban areas does not always fit into the neat definitions of the specific assets listed above, and some of the key research into the benefits of green space only define it in broad terms. This section of the chapter aims to capture some of the green space benefits not already included in other asset classes.

Urban residents in dense cities were found in one study to use green spaces infrequently, but for long bursts of time, and for a range of reasons (Qureshi *et al.*, 2010), and green space of all kinds was found to be an essential resource for physical activity (Schipperijn *et al.*, 2010). There is particular political interest in green space because of its potential health and wellbeing benefits, which include reducing mortality, stress, and mental fatigue; and they are associated with lower mental distress and higher wellbeing at a community level (Schipperijn *et al.*, 2010; White *et al.*, 2013; Wolf and Robbins, 2015). Tzoulas *et al.* (2007) established links between ecology, human health, and green infrastructure. Their work is seminal, and cited 336 times. It is the first work to explicitly tie together the intuitive interconnectedness between human and ecosystem health, which makes green infrastructure potentially a key feature of public health policy

Urban green space is also vital for reducing socio-economic inequalities. Access to green space in rural areas is associated with more affluent, white, and middle and upper class groups. Younger, less affluent people and those in Black and Minority Ethnic (BME) groups are less likely to access rural green space, but are more likely to be urban dwellers. Hence urban green space can offer key opportunities for more social equality in accessing green spaces and their resultant benefits (Swanwick, 2009).

However, there may also be issues of gentrification and social displacement associated with access to greenspace, as proximity to green space has a positive impact on housing prices (Votsis, 2017), although this is also influenced by the type and quality of green space as well as the distance to the city centre.

2.2.2 Multiple benefits

It is clear from the literature reviewed in section 2.2.1 that there are a range of benefits found across studies that look at specific types of green infrastructure asset.

While there are a range of different benefit types, common themes emerge across all of the research. These benefits (and the disbenefits and limitations) of green infrastructure can be broadly summarised along environmental, social, and economic categories, aligning them with sustainability. This summary is shown in Table 3.

As well as the common themes in the literature with regard to the types of potential benefit, there is one overarching issue: the potential benefits are dependent on the design and implementation of green infrastructure assets, both in their individual context but also their role in the wider green infrastructure network.

One of the key advantages of green infrastructure is that they can be used to realise multiple benefits from the same asset. However, this is not without compromise. The ideal network of green infrastructure assets will vary for every city according to the local challenges and uses. Some of the potential benefits are in direct contradiction (for example, understory vegetation can be a vital habitat for wildlife, but unpleasant and damaging for the human experience). Trade-offs must be made between different assets in order to maximise the co-benefits.

This itself provides a challenge in that the mix of stakeholders found in a dense urban environment is likely complex, and having the oversight, power, and resources to form a strategic network is unlikely (see section 2.4.4 on stakeholders for further discussion). Hence, while multiple benefits of green infrastructure may often be heralded as one of its particular advantages, it can make it difficult to properly target delivery against the whole contextual requirements. It is also difficult to pinpoint attribution or causation of any particular intervention or asset and the benefit being realised across a whole area, making it difficult to evaluate the benefits.

Nevertheless, there is a burden of responsibility at a strategic planning level to ensure that the delivery strategy of a green infrastructure network is best placed to maximise the benefits and target them to specifically where they are needed.

Table 3: A summary of the thematic green infrastructure benefits and disbenefits

	Environmental	Social	Economic
Benefits	Air quality	Social cohesion	Tourism
	Urban cooling	Mental health	Business activity
	Stormwater management	Wellbeing	Land and property values
	Water quality	Physical health	Energy costs
	Noise abatement	Physical activity	Amenity value
	Biodiversity	Education	Employment
	Carbon storage	Reduced inequalities	
	Carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions	Crime reduction	
	Ground water recharge and water balance		
Limitations/ disbenefits	Bio volatile organic compounds (BVOCs)	Gentrification and social displacement	Increased maintenance costs
	Allergens/pollen	Fear of crime	
	Invasive species		
	Water contamination		

Attempting to deliver a green infrastructure network across a city scale is therefore not without its challenges. Realising the maximum potential benefits in the urban context is therefore even more complex.

The following sections of this chapter will elucidate the ways in which the value of such a complex system can be captured through evaluation practice; how that can influence the values given and the stakeholders involved; and finally how value and stakeholders are drawn together in the mechanism of business models.

2.3 Evaluating green infrastructure

Evaluation is a key part of delivering a project, intervention or policy. Summative evaluation, which is used to define outcomes and impact, is how a project is deemed successful or otherwise (HM Treasury, 2011). Often considered only at the exit stage of a project, an evaluation strategy is ideally considered at its inception. This allows for planning at every stage to be held in the context of what is realistic, measurable and attributable to the particular intervention or project. While the ambition of a project may be a scope beyond the measurable, it allows this to be recognised in the context of what is demonstrable to stakeholders, and manages expectations of the rigour and confidence of evidence that can be anticipated for various impacts. Done properly, evaluation can add a key dimension to the implementation of a project or programme, its delivery, and its impacts on a large scale (Rotem and Bandaranayake, 1983; Stufflebeam, 2000; Linnan and Steckler, 2002; Kazi, 2003; Haji *et al.*, 2013; Chih and Zwikael, 2015; Hansen, 2016).

Evaluation frequently is designed to assess the outcomes and impacts of a project. While there is some confusion in the distinction between outcome and impact, as they are informally used synonymously, in evaluation they each have a distinct meaning. Outcomes are broadly any change that can be seen as a direct result of the project or intervention. They require an element of pre-post intervention comparison and are usually short term and tangible.

Impacts are less tangible and longer term. They are the "*so what?*" of the outcomes. An outcome for example might be that a target population increases their physical activity beyond the five times 30 minutes recommended by Public Health England (Bull and the Expert Working Groups, 2010). The impact then might be that those people are now healthier. Attribution is notoriously difficult to assign at impact level.

Evaluations can be undertaken *ex ante* or *ex post*. Ex-ante evaluations are delivered before a project or intervention is delivered with a similar purpose as an impact assessment (Banks, 2000; Mergaert and Minto, 2017). That is, ex-ante evaluations look to identify the likely outcome of an investment or policy before it is made, which is a crucial factor when creating a business model. For example, an ex-ante evaluation which demonstrates a positive return on investment of green infrastructure would be used to support a business case for investment in green infrastructure. Ex-post evaluation takes place within three years after a project or intervention and assess actual or observed outcomes and impacts. An ex-post evaluation is therefore used to assess the success of an initiative, how well it was delivered and its results, including value for money and return on investment (Mergaert and Minto, 2017). In a green infrastructure context for example, an ex-post evaluation of SuDS would assess the impact it had on flood management and whether it created a positive return on investment. Ex-post evaluations are enhanced when baseline data is collected before an intervention

Naturally, when designing an ex-ante evaluation, the observed results from ex-post evaluations of delivered projects are used to inform the potential impacts and benefits of a new project. For example, if undertaking an ex-ante evaluation as part of a business case for green walls in a new urban development one would seek to understand the impacts of and return on investment from other green wall developments which have been evaluated ex-post.

Traditionally in the UK neoliberal context, evaluation is carried out for policies, programmes and projects in standard ways using a limited range of tools led predominantly by economists. These approaches exist to justify investment and to test the success of a project, programme, or policy. There are both supporters and critics of using a primarily economic approach – but it is the norm set by policy makers and other major funders, for example government departments or Lottery funding.

Policy evaluation in the UK is governed by the principles outlined in two key documents: The Green Book, and The Magenta Book. The Green Book: *appraisal and evaluation in central government* is guidance published by HM Treasury (2018) “for public sector bodies on how to appraise proposals before committing funds to a policy, programme, or project.” The Magenta Book, also published by HM Treasury (2011), provides “guidance on what to consider when designing an evaluation.”

Any policies, programmes or projects commissioned by regional or national government, or underpinned by a policy from these, will likely be required to provide justification, and possibly also an outcome evaluation based on the principles in these documents. Therefore, in terms of large project delivery, like infrastructure projects, this appraisal and evaluation approach is key. While values that are both monetary and non-monetary are of relevance, the main basis of most evaluation design is to capture value in some quantifiable way. Often this also requires monetisation, using financial values as a proxy to add comparability to any quantifiable value involved. Using evaluation and assigning monetised value to non-market goods helps the public to understand their value, and helps to include them in wider situations where comparisons with other monetised values are needed. (Vandermeulen *et al.*, 2011). Some values remain outside of the scope of current methods for quantification however, and these values struggle to be captured or compared in evaluation.

2.3.1 Valuing non-market assets

Valuing non-market assets is essential to be able to capture and compare them alongside traditional market assets, and compare them to project costs, in an economic evaluation. Because many environmental costs and benefits fall outside of traditional economics and markets, an entire discipline exists to focus on how these are captured. This can provide key opportunities for the benefits and values of green infrastructure to be captured and included in an evaluation.

Field and Field (2002) outline some of the key challenges in valuing environmental benefits, and also highlight the established economic tools for trying to assign value to non-market goods, such as willingness to pay and willingness to accept.

The neoliberal foundation of traditional economic appraisal approaches is that markets can provide a value for all goods and services and that these can be compared to draw out benefit-cost ratios (BCRs) and other finance-based comparators. But it has been established for some time that when it comes to natural environment it is often the case that one is dealing with non-market values, and approaches have been developed to standardise these in such a way that allows comparison to be made with the market goods.

The key approaches developed often come out of the need to account for externalities and indeed climate change can be categorised as an externality. Much of the impetus for green infrastructure is the mitigation of and adaptation to climate change.

Contingent valuation (including willingness to pay, willingness to accept, and hedonic pricing), opportunity costs and social return on investment (SROI) are all key in this branch of economics.

Of particular interest for green infrastructure, especially with regard to ecosystem services, is the part of environmental economics concerned with Natural Capital Accounting (NCA). NCA aims to align natural resources with other capital assets in an economy.

Within the field of ecosystem services, value is often sought using these economic principles and yet it remains a controversial contemporary debate within the field. As critics assert that it is fundamentally incompatible with the ideology of ecosystem services; that it undermines socio-cultural value by simplifying it merely to a financial value (Costanza *et al.*, 1997; Costanza *et al.*, 1998; Toman, 1998; Gómez-Baggethun *et al.*, 2010; Gómez-Baggethun and Ruiz-Pérez, 2011). Some, for example Jaffe (2010), question the practice of valuing anything but the direct benefits as a way to resolve some of issues of attribution and excessive commodification.

Because the intrinsic value of natural assets and ecosystems cannot always be adequately captured through simplified financial valuation, it is nonetheless essential to try to do so as there is no other practical way of drawing its role into decision making. The ideological concept of using green infrastructure to provide ecosystem services already makes an anthropocentric argument for valuing green infrastructure based on its provision for humans, so framing these values in economic terms is aligned with this approach.

However, economic framing has been shown in several studies to influence human decision making (Sheldon and McGregor, 2000; Liberman *et al.*, 2004; Sheldon *et al.*, 2004; Bauer *et al.*, 2012; Common Cause Foundation, 2013; Schultz *et al.*, 2016). This suggests that ascribing financial value to ecosystem services, green infrastructure, or indeed nature itself at a fundamental level may actually have a detrimental effect on the altruistic outlook and reaction to nature and conservation.

> “Non-market transactions value are difficult if not impossible to incorporate into basic GVA [Gross Value Added] calculations.”
>
> *(Natural Economy Northwest, 2008)*

This approach of using related ways of valuation of non-market assets can be very useful for green infrastructure and it can also borrow tools and techniques from public health and behavioural economics.

Vandermeulen *et al.* (2011) present an argument for the economic value of green infrastructure however they focus solely on cycle route development in isolation and have dubious use and extrapolation of data to build a cost benefit ratio. There is no consideration of the co-benefits, little mention of context, and while they assert that their method is replicable, there is little to convince the reader that this is true. However, it does illustrate well the complexity and challenge of calculating a BCR.

Some of the hardest to value (potential) benefits of green infrastructure are in the public health arena. As multiple benefits cited typically include physical and mental health and wellbeing, but these are notoriously difficult to measure and attribute at the sub-clinical and population levels.

Also, as seen in later chapters when incorporating these ways of valuing health and wellbeing alongside the direct measurable benefits of green infrastructure, they are measured using a vastly different scale of benefit that brings confusion when compared alongside direct monetary benefits.

These various methodological shortcomings and inadequacies have led to customised approaches for valuing green infrastructure; albeit with focus varying depending on the priorities and policy interests behind the approaches. Because it is still relatively young as a discipline there is not (yet) an established approach to the appraisal of green infrastructure. Of these custom approaches, some are focused on specific green infrastructure features, while others (attempt to) account for a range of multiple benefits. The various available tools and their advantages and limitations are discussed further in Chapter 4.

2.3.2 Capturing quantifiable values

The size, scale, and scope of a project should naturally inform the size, scale, and scope of its evaluation. There are different approaches to take, depending on the requirements of funders, who may specify particular types of evaluation, or who are only concerned about particular measures of value. For example, Department for Transport projects require transport appraisal to use the *webTAG* tool, to frame appraisal around specific values of interest to them (Department for Transport, 2018). In contrast, a private sector investor may only be concerned about return on investment over a set time period.

There are a range of different approaches available with which to frame an evaluation, different specific values that may be of interest, and in some cases pre-existing tools designed for those approaches and values. Figure 12 attempts to illustrate what these different elements might include, and how they relate to each other within a comprehensive evaluation trying to quantify value. This is intended as an illustrative, rather than exhaustive, list but covers the main approaches and values relevant to infrastructure appraisal in the UK context. Further discussion of these concepts, and how they fit together, follows below.

There are multi directional links between values, approaches, and tools. Some tools are used to generate specific values required by a certain approach. Some values provide the inputs for tools. While some approaches do not use tools, but are informed by one or more values. The following sections highlight some of the key strengths and weaknesses of the approaches, values, and tools.

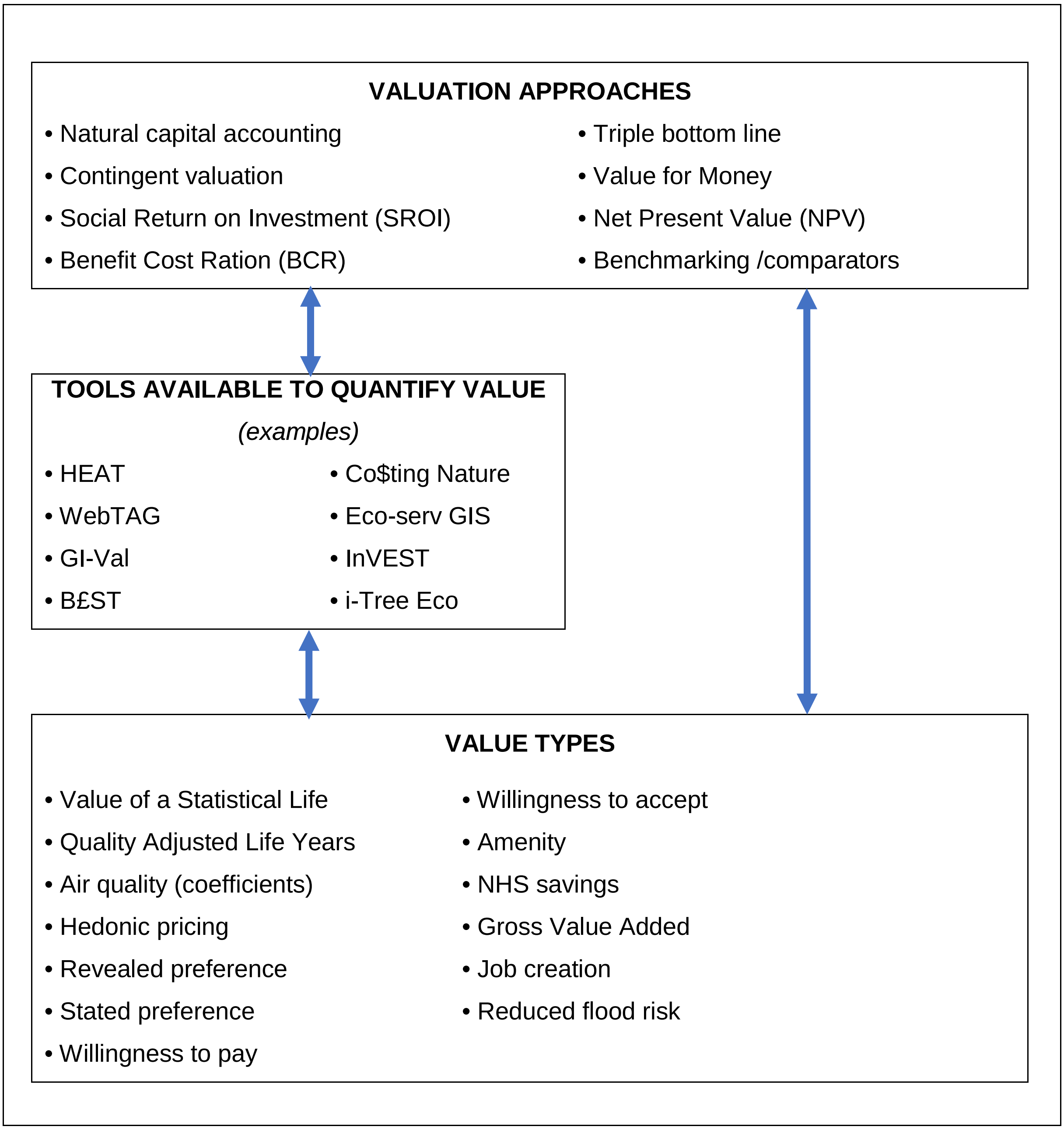


Figure 12: Evaluation approaches and values.

2.3.2.1 Valuation approaches

These economic measures equate financial gains to project outcomes (expected or measured). Using these standard approaches allows comparisons to be made between different projects and having a common approach keeps things simple. However, one criticism of these standard valuation approaches is that the level of simplification needed for interpretation across themes can lose some of the key details in order to provide a summary value or values. This carries a risk of losing some nuanced details of ‘what works’, and also relies on trust in the accuracy of the appraisal or evaluation. When only a pared down result is presented there is trust placed that the underlying work is true. This can be further complicated by differences in ideology, known unknowns, and methodological decisions in the process, which can, and are, biased and can potentially even be subjectively manipulated to push a particular agenda (Lucas, 1976; Lawson, 1997; Vedung, 1997).

Transparency of methodology can help to avoid such accidental or deliberate manipulation of information, and the current cultural shift towards transparent methods and open data will hopefully help to improve this situation.

Another key limitation is that these approaches usually present a summary figure to demonstrate value, when in reality the likely value may be better represented by a range, to reflect the uncertainties or sensitivity testing involved. This single value summary style suggests a level of precision that may not reflect the true level of certainty. Nonetheless these valuation approaches remain the established norm for appraisal and evaluation of infrastructure and other projects in the UK, and in other similar delivery contexts.

2.3.2.2 Value types

Values, whether they can be easily captured and quantified or not, are important. These are frequently anthropocentric – the services provided by ecosystem services are potential values that could be realised by an effective green infrastructure system. There is a broad overlap between the types of value that could be captured in an evaluation, shown in Figure 12, and the benefits of green infrastructure that were identified in section 2.2.

Some values are easily monetised. Either they have an inherent financial (monetary) value, or they can be expressed in such economic terms (monetised). This is convenient and makes them easy to compare with project costs, enabling the calculation of a BCR and Value for Money (VfM) assessments of the project or infrastructure scheme as a whole.

2.3.3 Evaluation of complex systems

Whilst the theory of evaluation is straightforward, cities and their infrastructures are inherently a system of systems. Green infrastructure is just one of these systems, which itself has multiple assets and interdependencies (Benedict and McMahon, 2006; Bouch, unknown).

Assessing the efficacy and value of a system is just as, or more, important than any individual component within that system. This creates an opportunity for further development of the assessment of green infrastructure as one of many systems in urban areas, and research can capitalise on the growing interest in looking at a network and its interactivity and connectivity (Urban Foresight, 2018).

Yet, complex systems-of-systems are difficult to appraise or value, (Brown and Robertson, 2014). Because of the inherent complexity, it has even been suggested that wider indirect benefits of green infrastructure should not be included in an evaluation, and that only direct benefits are relevant (Jaffe, 2010). In some cases, for example the benefits of green infrastructure for stormwater management, direct benefits are sufficient to provide an argument for investment, but this is not always the case. Despite this criticism, realist evaluation design is increasingly focused on capturing value in complex systems (Gerrits and Verweij, 2015; Wong, 2018).

The systems approach is not particularly new, and can even be said to stem back to the *Gaia Hypothesis* (Lovelock, 1979), which conceptualises the whole earth as a series of interconnected systems. Despite some of its limitations, taken as a metaphorical descriptor *Gaia* is nonetheless visible in its influence and principle in the current concepts of systems of systems, and indeed the concept of the circular economy.

In social interventions, particularly given the growing interest in recent years in behavioural economics, evaluating complexity is becoming increasingly necessary. For example, when looking at the outcomes of social behaviour interventions for people with complex needs, reflexive communities of practice fit into a narrative of outcome measurement for evaluation, and the need to prove benefit to funders (Lowe *et al.*, 2016). This type of social impact intervention is similar to a green infrastructure network is that it operates within a complex system, with components that may or may not act in a predictable manner.

There are a range of evaluation approaches which can be delivered in experimental or academic context to effectively encourage green infrastructure investment, from public or private sectors, though only evaluation approaches which inform effective business models for such investment should be used. Fundamentally, the underlying question when evaluating green infrastructure interventions, as with all investment decisions, is,

> "Will a certain investment lead to added value?"
>
> *(Opdam, 2013), p.91.*

2.4 Understanding business models

The study of businesses, how they operate and how they're influenced by internal and external factors has been the subject of study since large scale production required the need to understand productivity. It is not new, though the approaches and focus of study have shifted and changed over the years. There is no single agreed form of creating or describing a business model, with different approaches being developed within different business specialisms (Zott *et al.*, 2011). However, in simple terms it can be described as being the structure or way in which a business delivers value to its customers (or users), thus creating and transferring value (Teece, 2010).

From the early 20th Century focus on manufacturing industry, much study regarded productivity: workers, motivation and business practices. From the Hawthorn Effect, Type A and B workers, and the introduction of production line practices, made mainstream by Henry Ford, there was an internal focus in business in how to refine and improve practice for increased production and higher outputs and revenues (Handy, 1993; Needham and Dransfield, 2000).

At its most fundamental level, business can be defined with the four factors of production: capital, enterprise, land, and labour. However, this simple model was devised for an economy based predominantly on manufacturing (secondary industry), whereas in the UK context, the economy has shifted to predominantly service and knowledge sectors (tertiary industry). The components of this most simple business model have more limited applicability now, though they do still translate approximately. The basic need for capital exists, with value flowing through business activity – goods and/or services translating that capital investment into revenue and profit. Enterprise is needed, in its abstract form it relates to entrepreneurial spirit, the value proposition and the unique selling point of one business over another. Land, which traditionally focuses on natural resources, is not always relevant for tertiary sector as it is for manufacturing, though business facilities such as digital space are needed. Labour is usually smaller scale in tertiary industry compared to secondary, yet is still an essential. Labour may focus more on the knowledge and skills of smaller numbers of workers, rather than the physical labour of larger numbers.

Alongside this shift in the economy from secondary to tertiary industry, so also the ways of typifying, describing and analysing business activity have changed. Thus, the study of business has shifted from reflecting mostly internal factors in a static state, to understanding both internal and external factors, and looking at process and flows in a more dynamic way. In particular, the shift in recent years towards concerns of the circular economy changes the focus of business activity on one single business to the whole supply chain.

The most fundamental and possibly most well-known approach to understanding the internal and external influences on a business is a SWOT analysis (see Figure 13). Strengths and Weaknesses form the internal factors, while Opportunities and Threats are the external factors. Throughout this thesis, there is a focus particularly on the opportunities and threats (generally referred to as challenges) for green infrastructure, as these represent fundamental ways of understanding where a business sits relative to its environment.

In order to keep aware of, and on top of, the external influences on a business, the process of horizon scanning (also called environmental scanning) was developed – again using a matrix approach, this time dividing the key influences into interest and power (Johnson et al. 2005; Mendelow, 1981). This is discussed further in section 2.4.4 below.

Throughout the 1980s and into the 1990s, the understanding of business and business models became focused on process over and above static elements. Most relevant to this research project being Porter’s Value Chain (Porter, 2004), see Figure 14. In a post-industrial economy, this value flow and process-based approach is essential for understanding the elements that comprise a business model. The value flow approach is discussed further in section 2.4.2 and in Chapter 4, applying this business-focused approach in a unique way to understand the value of green infrastructure.

Strengths	**Weaknesses**
Helpful factors about a business, product, or project, with an **internal** origin.	**Harmful** factors about a business, product, or project, with an **internal** origin
Opportunities	**Threats**
Helpful factors about a business, product, or project, with an **external** origin.	**Harmful** factors about a business, product, or project, with an **external** origin.

Figure 13: Component elements of a SWOT analysis

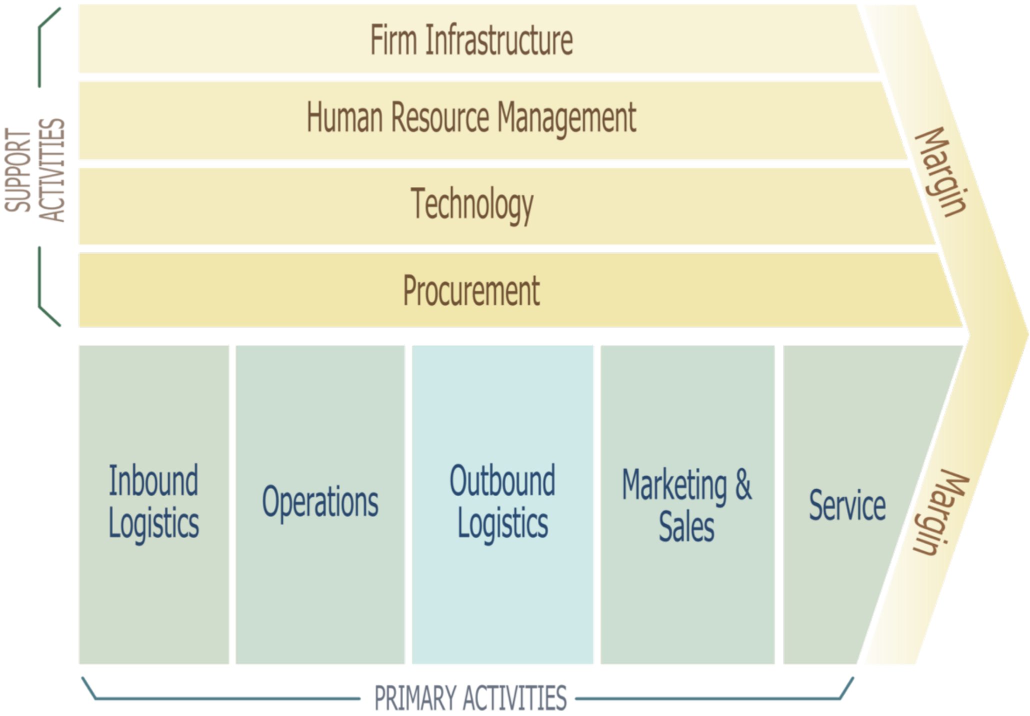


Figure 14: Porter's value chain (Porter, 2004)

Business Model Canvas

Key Partners
Who are our Key Partners? Who are our key suppliers? Which Key Resources are we acquiring from partners? Which Key Activities do partners perform?

MOTIVATIONS FOR PARTNERSHIPS: Optimization and economy, Reduction of risk and uncertainty, Acquisition of particular resources and activities

Key Activities
What Key Activities do our Value Propositions require? Our Distribution Channels? Customer Relationships? Revenue streams?

CATEGORIES: Production, Problem Solving, Platform/Network

Key Resources
What Key Resources do our Value Propositions require? Our Distribution Channels? Customer Relationships Revenue Streams?

TYPES OF RESOURCES: Physical, Intellectual (brand patents, copyrights, data), Human, Financial

Value Propositions
What value do we deliver to the customer? Which one of our customer's problems are we helping to solve? What bundles of products and services are we offering to each Customer Segment? Which customer needs are we satisfying?

CHARACTERISTICS: Newness, Performance, Customization, "Getting the Job Done", Design, Brand/Status, Price, Cost Reduction, Risk Reduction, Accessibility, Convenience/Usability

Customer Relationships
What type of relationship does each of our Customer Segments expect us to establish and maintain with them? Which ones have we established? How are they integrated with the rest of our business model? How costly are they?

Channels
Through which Channels do our Customer Segments want to be reached? How are we reaching them now? How are our Channels integrated? Which ones work best? Which ones are most cost-efficient? How are we integrating them with customer routines?

Customer Segments
For whom are we creating value? Who are our most important customers? Is our customer base a Mass Market, Niche Market, Segmented, Diversified, Multi-sided Platform

Cost Structure
What are the most important costs inherent in our business model? Which Key Resources are most expensive? Which Key Activities are most expensive?

IS YOUR BUSINESS MORE: Cost Driven (leanest cost structure, low price value proposition, maximum automation, extensive outsourcing), Value Driven (focused on value creation, premium value proposition).
SAMPLE CHARACTERISTICS: Fixed Costs (salaries, rents, utilities), Variable costs, Economies of scale, Economies of scope

Revenue Streams
For what value are our customers really willing to pay? For what do they currently pay? How are they currently paying? How would they prefer to pay? How much does each Revenue Stream contribute to overall revenues?

TYPES: Asset sale, Usage fee, Subscription Fees, Lending/Renting/Leasing, Licensing, Brokerage fees, Advertising
FIXED PRICING: List Price, Product feature dependent, Customer segment dependent, Volume dependent
DYNAMIC PRICING: Negotiation (bargaining), Yield Management, Real-time-Market

Figure 15: The business model canvas (Osterwalder, 2010)

The most recent significant development in the presentation and articulation of business model processes is the business model canvas (Osterwalder, 2010). Shown in Figure 15, this brings together key elements needed in a business model, providing a versatile tool for shaping and framing business model innovation.

The use and role of business model approaches and literatures is drawn upon in Chapter 7, which adapts the basic tools and frameworks to suit strategic green infrastructure delivery.

2.4.1 Business models for infrastructure delivery

Given the aim of this thesis is to influence how green infrastructure is delivered in practice, it is also important to consider how business models work for infrastructure specifically, as much of the business literature is focused on more traditional provision of goods and services. Infrastructure projects require a whole-life delivery plan, with finance and funding options to support their initial development as well as ongoing management and maintenance costs throughout the anticipated life span of the assets. They also require a plan for the end of their useful life, perhaps including decommissioning or replacement of the assets. The mechanisms involved in these elements form the business model or finance model for the infrastructure system.

The literature on economics often rules that infrastructure falls outside of traditional business models, instead being treated as a separate asset class. It is an external factor, outside the usual market forces, and provided to correct externalities (Bryson *et al.*, 2014b). Current thinking, however, increasingly frames infrastructure in terms of the services it provides rather than the physical asset networks themselves, bringing infrastructure provision back into more traditional approaches to business models and market forces. This is especially prevalent in the privatised utilities sector. Referring again to the four factors of production, capital, enterprise, land, and labour, infrastructure may be consigned to existing only as part of the capital needed for production (Needham and Dransfield, 2000). However, this fundamental business model can be adapted to apply to the provision of infrastructure if it is considered as a fundamental service and a business in its own right. Infrastructure systems require capital, the investment that starts the value chain. The value proposition, the services provided, and the management and delivery structures around these, form the Enterprise. Land is needed whether in its literal form, for systems like transport networks and green infrastructure, but also the space for digital systems, both in terms of the physical distribution and also the server space needed to support digital infrastructures. Finally, Labour is also needed for provision and maintenance of the infrastructure. Again, this includes for the physical assets, but also applies to digital infrastructures as well. Thus, despite not being designed for this type of business originally, the most basic business models still has relevance. It is this adaptation of business models and analysis tools that will support the development of innovative business models throughout this thesis.

Although sometimes an ephemeral concept in terms of its definition and use, business models exist for all types of infrastructure development, just as they do for businesses that offer any other goods and services (Bryson *et al.*, 2014b). Varying definitions for business models exist, but the commonalities across them all are that it models how a business does what it does and how it makes money from doing that, in other words what system of activity is used to create value (Weill *et al.*, 2005; Zott and Amit, 2010). Fundamentally, how does a business take the essential operating factors of capital, enterprise, land, and labour (Needham and Dransfield, 2000), and translate them into a functional operation. An infrastructure business model includes four elements – defining the need (the drivers and rationale); ownership (the stakeholders); the financial model (the value proposition, and how it is monetised); the solution (the resulting infrastructure system or asset itself) (Bryson *et al.*, 2014a).

Business models have existed for infrastructure development for as long as there have been infrastructure systems. In a form recognisable today, the rapid and widespread growth of infrastructure investment in the UK started in the industrial revolution, where limited companies were established to raise capital from shareholders (Rolt, 1957). By the late Victorian era, and into the early part of the 20th Century, there was a rise in the interest in social security, and investment in 'public works' developed for the benefit of wider society. A very centralised, top-down approach, infrastructure was considered a public good, and largely funded by government (O'Brien and Pike, 2015). This centralised, government-led investment in infrastructure was challenged by the rise of free-market ideology of neoliberal economics, and the widespread privatisation of many public services, including infrastructure service provision, like railways and utility companies. Since this time, business and financial models for infrastructure provision have become increasingly fragmented, including public-private partnerships and private finance initiatives. Following the global financial crash, innovation has become increasingly common in business models (Bryson *et al.*, 2014b), with market disruptors also emerging to challenge business as usual investment. Although, an interesting counterpoint to the increasingly fragmented delivery of infrastructure, the launch in 2015 of the National Infrastructure Commission has brought the strategic oversight of infrastructure back to a more central point; arguably due to the need to have some centralisation in counterpoint to this.

Infrastructure systems have differing characteristics than most goods and services, and so have unique demands and challenges for business models (Bryson *et al.*, 2014b). The definition of infrastructure for iBUILD, the project under which this research sits, is

> "the artefacts and processes of the inter-related systems that enable the movement of resources in order to provide the services that mediate (and ideally enhance) security, health, economic growth and quality of life at a range of scales."
>
> *(Dawson, 2013)*

While an infrastructure business model is defined as,

> "The system of physical artefacts, agents, inputs, activities and outcomes that aim to create, deliver and capture economic, social and environmental values over the whole infrastructure life cycle."
>
> *(Bryson et al., 2014b)*

An infrastructure system cannot be viewed as simply the component assets themselves, but the whole system needs to be considered across its full lifecycle. Challenges stem from the typically long lifespan of an infrastructure system; the potential need for different business models at different stages; a strong lock-in and opportunity cost from decision making; and the high capital investment requirements (Bryson *et al.*, 2014b). Although it is arguable that these are less problematic in a green infrastructure system compared to, for example, a road or railway development. Typically, the upfront costs of green infrastructure are smaller than traditional 'grey' infrastructures, and the opportunity costs are likely smaller for smaller physical assets of a green infrastructure network compared to, for example, an electricity network.

Other challenges for infrastructure business models, including green infrastructure, are that the values crosscut social, environmental, and economic sectors, and therefore lead to a complex stakeholder network. Also, the value is predominantly in their role as a ‘public good’, and therefore they do not easily sit within traditional value streams, as a direct consumer-focused good or service might be (Bryson *et al.*, 2014b). Business models cannot be static, but must change and adapt according to market changes and other external and internal factors

2.4.2 Assigning values

Another key element of a business model is the value proposition or value stream, whether monetary or otherwise. For the purpose of a business model, being able to monetise the value proposition can offer a key source of revenue funding for operational expenditure, however, effective business models can also mechanise finance and funding for non-monetary values, or indirect values.

Indirect value in particular is hard to capture through traditional business models (Bouch, unknown). This has particular relevance for infrastructure systems, especially green infrastructure, as the socio-economic or environmental services that are provided by infrastructure are a source of value, but this is not traditionally captured for investors. As discussed in sections 2.3.4 and 2.2.2, values can be derived from a green infrastructure system which will be of relevance to a range of stakeholders, some of which may be direct but many of which will not. Yet these are still important values and an example of infrastructure providing essential services. Use of evaluation is key to help identify and elucidate the value that can be created for a city from an infrastructure system, although the links between evaluation practice, often only done after a project or programme has been delivered, and business models, generated in advance of a project, are weak and underutilised. Linking the two together more comprehensively may well be able to provide new opportunities to identify and use alternative value propositions and support innovative business models. Ultimately, the value proposition can be informed by, and help to shape, the finance and funding options available for an infrastructure system.

2.4.3 Finance and funding

An essential element of any business model is its financial model. That is, the finance and funding that are in place to support the business activity. Finance refers to,

> “the financial models that organise how the revenue (or funding) sources are turned into capital.”
>
> *(O'Brien and Pike, 2015, p. 3)*

While funding,

> “Funding is the primary stream of revenue required to offset costs or to support leveraging options.”
>
> *(Bryson et al., 2014a)*

Together these allow for the capital needed to implement an infrastructure system, while the revenue streams provide the funding needed. In other words, the finance supports the capital expenditure while the funding supports the operational expenditure. A business model requires both, and for an infrastructure system, typically the large upfront capital investment means that part of the revenue stream needs to pay for not only the ongoing maintenance and management of the system, but also to repay finance loans or investors as well (Sloman *et al.*, 2014).

Infrastructure is essential to underpin an effective civilisation, but typically outside the remit of conventional market forces in a capitalist system. Due to the changing nature of finance and funding for infrastructure, private investment is now essential, especially for capital investment, and requires financialisation of the infrastructure system (O'Brien and Pike, 2015). However, private sector investors generally expect a high return on investment, with a clear value proposition and a profitable benefit-cost ratio (Bouch, unknown). This means that many traditional financial models are difficult to apply to infrastructure systems, including green infrastructure, as they rely on direct monetisation of some aspect of the goods or services provided by the system. Infrastructure is typified by its indirect, intangible, long-term and non-monetary outcomes and impacts, which creates a barrier to using traditional finance mechanisms (Roelich, 2015).

Financialisation reflects, and is reflected by, the increasing fragmentation of stakeholders and delivery models, despite the increasingly centralised strategic oversight for urban infrastructure (O'Brien and Pike, 2015), although the centralised oversight is found less in green infrastructure than other systems. The fragmentation of investment and therefore also stakeholders offers benefits and challenges. Innovation in business models can take advantage of the broader range of interests of a wider group of stakeholders. However, the smaller scale does generally prefer short-term and tangible returns on investment (whereas at national government level, greater upfront costs may be acceptable for a longer-term payoff, if the overall benefits are sufficient). Even where there is a global economic argument for something being good value in the long term, this does not translate well into a case for smaller scale private sector investment. For example, climate change will cost billions in damages if unchecked, but that will be spread across many countries, industries and stakeholders. Private investors lack the motivation to invest now to avoid the costs that may only have a small impact on them specifically (Gouldson *et al.*, 2015). This smaller scale prioritisation of direct issues also can lead to geographic inequalities, with unequal investment meaning only certain parts of a population might benefit from an infrastructure investment (O'Brien and Pike, 2015), which is contrary to the role of infrastructure systems to provide a service across a whole area.

One of the underlying issues in ascribing a finance model to an infrastructure system is that infrastructure is often argued to be a separate asset class, and not a good or service, thus leaving it outside of market-based economics entirely (O'Brien and Pike, 2015). This can create an opportunity in that it allows for innovative investments, for example Australian and Canadian pension funds investing in infrastructure for long term returns (O'Brien and Pike, 2015). However, regulation and market failure keep governments involved in infrastructure provision, even if not directly, which can also provide a challenge to seeking traditional private finance. It is a heterogeneous, inflexible market with small returns over long time period, making infrastructure investment less attractive than other markets for investors (O'Brien and Pike, 2015).

Even with direct government involvement as a key stakeholder in an infrastructure model, innovation in finance models has been evident. For example, the development of Public Private Partnerships (PPPs) and Private Finance Initiatives (PFIs) under the Blair government in the UK both created new opportunities for large scale investment for public works (O'Brien and Pike, 2015).

This type of finance model is typically targeted at creating a specific infrastructure asset, thus supporting an infrastructure centred approach. The alternative to this approach is the enterprise centred approach, which,

> “demonstrates how monetary, and non-monetary, value arising from enterprise/infrastructure interdependencies, can be captured and used, in conjunction with cost reduction, to achieve the value/cost ratio necessary to support development and implementation of novel, and successful, business models “
>
> (Bouch, unknown)

And it is based on this ideology that future investment can best capitalise on opportunities.

Other forms of large-scale funds for investment that support an enterprise-based approach are becoming increasingly common. Social investment bonds and the European social fund make finance available based on social accounting ideology, and the new green finance initiative has been developed to reflect the need for changing drivers for finance and funding to enable climate change adaptation and mitigation. Social accounting offers opportunities to capture the social costs not easily monetised, and may include more individual impacts, for example having more free time, rather than larger scale economic impacts, such as the cumulative economic cost of journey times (Affleck and Gibbon, 2015).

The European Social Investment Fund offers funding underpinned by this ideology, providing funds for programmes based on their ability to deliver social good, especially through improved social inclusion and reduced poverty (European Commission, 2013c). While not directly relevant for green infrastructure, it nonetheless demonstrates the willingness for investment on indirect benefits with an overall social benefit.

Social investment bonds (SIB) were also developed as a solution to capture value in programmes that were based on providing a socially-relevant service, and were hailed as a good idea (Liebman, 2011; Marsh *et al.*, 2011; Warner, 2013). They are based on the concept of payment by results for improved social outcomes – one of the pilot schemes being aiming to reduce recidivism in prisons. However, the SIB concept is not without its critics (McHugh *et al.*, 2013; Ainworth, 2014). Payment by results relies on the ability of essential service provision to continue even if the criteria for the SIB returns are not met. SIBs were judged not to be suitable for financing Birmingham’s Be Active scheme, for example, because despite its huge economic value, these values were long-term and not in the easily monetised areas that SIBs depend on (Marsh *et al* 2011). Thus, while seeming to offer a solution for creating finance and funding for socially necessary goods and services, they still rely heavily on the same shorter-term monetised returns as conventional private finance.

Another innovative area of potential finance and funding, particularly relevant for green infrastructure, is developing in the insurance industry. Investment in green infrastructure can enhance insurance value, especially where the green infrastructure system is expected to improve resilience to the threat of increasing weather extremes due to climate change. The underpinning concept is that the insurance industry is offsetting future costs by investing in systems to prevent damage to property, rather than waiting and paying out on insurance claims after damage has been sustained (Green *et al.*, 2016).

Based on a similar ideology, that global finance and investment sectors must change and adapt in response to future global challenges like the changing climate, provides the driver for the green finance initiative. Launched in July 2019, the Green Finance Initiative aims to create 'greener' financial markets as well as to create finance opportunities for the development of 'green' programmes, designed to adapt to or mitigate climate change (HM Government, 2019). While it is too soon to know how well this programme will work at a city-scale, in theory at least it provides a key opportunity to find sources of finance for green infrastructure investment.

Fundamentally, all of the finance and funding mechanisms available rely on finding the value in what an infrastructure system is providing. This value proposition element of a business model will inevitably shape the financial models that are suitable, and capturing values, including non-traditional values, from a green infrastructure system will create opportunities for innovation in business models.

2.4.4 Stakeholders

Another key element in the business model is the stakeholders. The precise definition of a stakeholder is an essentially contested concept within the academic literature (Miles, 2011). The key elements within most definitions is that stakeholders are all the individuals, organisations, or groups that affect, and are affected by, a business, project, or in this case, an infrastructure system.

Stakeholders are important as they affect decision making, can form the customer or beneficiary base, and can provide opportunities or challenges to delivery. For example, stakeholders can even lead to total project failure (El-Gohary *et al.*, 2006). In the case of infrastructure systems, stakeholders include users of the system, but also land owners, decision making authorities including local or even national government, and any other influential groups or organisations in the local area, or in the industry. For utilities, stakeholders would include service providers and homes and businesses. In the case of green infrastructure, stakeholders will be influenced by the geographic reach of the green infrastructure network, but in the case of something like flood management, could include individuals and organisations in the whole of a catchment, to some extent. Thus, in order to understand the specific people and groups involved in the stakeholder mix, and to assess the extent to which they can or should be interested in the green infrastructure network, some identification process of the stakeholders and their level of interest is required.

Knowledge of effective stakeholder management is often fragmented, and it crosses a broad range of different industries, depending on the nature of the project involved (El-Gohary *et al.*, 2006). Stakeholder management is an essential part of wider infrastructure project management, with communication channels key, especially during the construction of new or expanded infrastructure systems.

For green infrastructure particularly, the stakeholders can be a very diverse mix with sometimes conflicting wants and needs from green infrastructure provision within limited urban space (Ugolini *et al.*, 2015). While interest is increasing towards green infrastructure as a potential solution for urban challenges, the systems of governance and implementation for an effective green infrastructure network are not particularly established (Lawrence *et al.*, 2013; Besse, 2014).

The knowledge and communication gap between academic and delivery organisations, especially for green infrastructure, is prevalent and presents a main threat to green infrastructure network delivery (Ugolini *et al.*, 2015). Overcoming this is essential for effective delivery of green infrastructure systems; and stakeholder identification, communication, and management is essential for overcoming this challenge. In green infrastructure particularly, the network of stakeholders can be so complex that it poses a challenge to stakeholder management (Ugolini *et al.*, 2015) thus an effective system for identifying stakeholders and assessing their needs is essential.

Across business for the past 40 or more years, horizon scanning or environmental scanning have been used to identify opportunities and challenges for a business or project, and can be used to identify potential stakeholders and assess the level of interest and influence on a project or business (Mendelow, 1981; Armstrong and Taylor, 2000; Government Office for Science, 2017; Hines *et al.*, 2018). Given the complexity of stakeholders in a green infrastructure system, this type of mapping exercise provides a key opportunity to identify stakeholders and their influence, as well as informing other opportunities and threats that exist in the policy sphere, and other influential factors for delivery of an effective green infrastructure network.

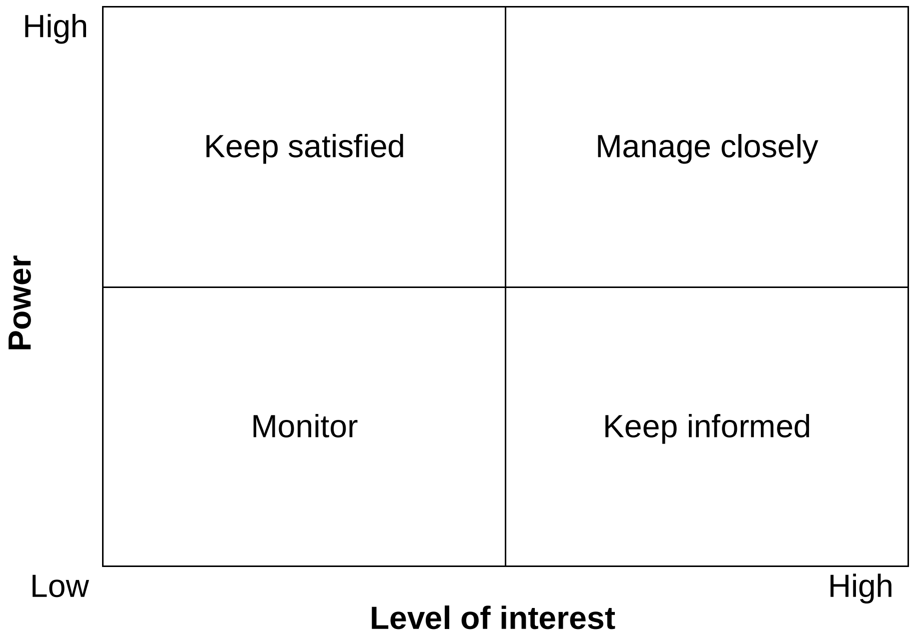


Figure 16: Stakeholder Power/Interest matrix - adapted from Johnson et al. (2005) and Mendelow (1981)

Using the stakeholder concept to conduct environmental scanning and identify stakeholders includes recognising the inequalities in power and influence between different stakeholders. Scoring can be applied to create a matrix showing the stakeholders grouped by their relative power and influence, and allowing them to be grouped by type to make for easier targeting of management and communication (Mendelow, 1981). Figure 16 shows a simplified outline of this type of matrix, and the typology of stakeholder management that should be applied to the different groups, depending on the matrix quadrant that they fall into. This type of scoring and grouping can also be used to assess the relative power and influence of policy documents on green infrastructure delivery (see Chapter 4 for more detail on how this can be used in practice and adapted to suit different uses).

As well as identifying stakeholders, it is useful to also understand their primary motivations and concerns. This can be key for finding links between the interests of the stakeholders, and the opportunities relevant to them in terms of the value proposition in the green infrastructure business model.

Among businesses, it has always been difficult to get them to make decisions based on a strategic big picture of environmental benefit, against the day to day concerns of costs and regulations and compliance. Environmental issues are largely seen only as those for which there is a mandatory need to comply with limitations or rules on supply chains, disposal of waste, and creation of by products such as pollution. Purvis *et al.* (2000) highlight that even when people in positions of management have a personal interest in the wider environmental issues of the day, they still feel limited in their work role and they only focus on those environmental issues that have some regulatory link to their particular industry. Yet there is little or no regulatory compulsion for individual businesses to develop green infrastructure, therefore it must be promoted according to the interests and priorities of those businesses by some benevolent external party. Matching the interests of stakeholders to the relevant value propositions is essential for the delivery of an effective green infrastructure business model.

Within a purchasing or procurement process, systems are often structured to favour overall low cost ahead of ‘value for money’ thus an inferior but cheaper design is much easier to justify at the point of purchase, and is not conducive to green infrastructure development (New *et al.*, 2000). If, for example, a new housing development is built, it is cheaper for a developer to plant small, immature trees. They may even get some additional revenue from selling houses at a higher price if the area looks nice (due to the attractiveness of the greening measures). However, for the benefit of urban shading and cooling, a larger species or more mature plantings will offer greater benefits. But the additional cost of this would be borne by the developer, but the benefits will be received by the future householders. This disconnect in costs and benefits is a key challenge in developing business models for green infrastructure. A way of sharing the costs and benefits between all the stakeholders involved may offer a more equitable arrangement, but examples of this working in practice are rare.

2.4.5 Archetypes and innovation

Drawing together the value proposition with the stakeholders, and the finance and funding mechanisms, shapes the business models needed for green infrastructure delivery, underpinned by the conceptual question *"who benefits and who pays?".* The ways in which these elements can fit together are many and varied, though there are a few key business model archetypes that lend themselves to infrastructure delivery and green infrastructure delivery specifically.

A green infrastructure system is inherently complex due to the ideal scale of linked assets across a whole urban area. In addition, they frequently involve inter-disciplinary working, some of which is normalised while other elements are more unusual. Developers are used to working with planners and within planning frameworks. Similarly, engineering is an essential component of this, as is the adherence to the environmental regulations. But the developers perhaps are less linked to the operational and strategic needs of a transport network, though that too may fit within planning or regional development policy. Traditionally environmental sector issues such as ecology or biodiversity now also need to be considered, while also meeting local and national pollution criteria. Add in the stakeholders in the form of local businesses and residents (current and future) and the complexity increases further. In addition, all of the actors within this matrix will have their own private motivations and interests as well as those that are representative of their professional role. Then, if there is to be a coherent green infrastructure driver, some external motivating factor is pushing for green infrastructure to be the solution to multiple challenges across the wide range of stakeholders. No wonder the situation is complex.

Likewise, the literature on increasing the sustainability elements of business models is fragmented, with relevant sources across a range of disciplines, but no coherent narrative that yet draws them together (Bocken *et al.*, 2014). Business model innovation is needed to shift the focus of value propositions from the easily monetised and onto the more social and environmental benefits as values to a city region as a whole. Despite the complexity inherent in the delivery of such a network, there are successful examples of business model types that can deliver green infrastructure (Bocken *et al.*, 2014; Toxopeus and Polzin, 2017).

Finance mechanisms identified by Roelich (2015) and O'Brien and Pike (2015), as discussed in section 2.4.3, demonstrate innovative opportunities for green infrastructure investment and consequently can inform and shape business models for delivery. One key recent example of innovation in business models for green infrastructure delivery was the creation of the Newcastle Parks and Allotments Charitable Trust in 2019, which took over the management of parks and allotments in Newcastle city region that had previously been under the remit of the city council. Funding cuts rendered ongoing management untenable, and shifting the land and its management to a private charitable trust allows for the freedom of governance to capitalise on new value streams, but maintaining the protections of the public land that provides essential ecosystem services (Bradford-Keegan, 2019).

Another key opportunity for innovation in green infrastructure delivery is the concept of creating shared value (CSV) (Porter and Kramer, 2006), it is good for capitalising on business interests with links to corporate social responsibility, but it goes further than this, developing the concept of distributing the benefits and costs through a wider network of people. Networks of shared goals are an important opportunity for business model innovation (Breuer and Ludeke-Freund, 2014). One of the main uses of CSV is that it allows the inclusion of environmental costs and benefits into existing economics, in ways that it is otherwise difficult to do (Gieseke, 2011).

This type of portfolio working is increasingly common, and it reflects the distributed potential benefits, and thus is a key opportunity for green infrastructure investment, albeit with its own challenges such as fragmented governance and planning. The knowledge gaps and challenges for green infrastructure delivery even within the scope of business model innovation mean further research needs to be done to better identify and capitalise on innovation.

2.5 Chapter conclusion

This chapter has provided a working definition of green infrastructure for the project as being both a systematic network that provides ecosystem services, and a term for the assets that exist within that network. It has acknowledged that the concept of ecosystem services is integral to the understanding of green infrastructure in this context, and recognises that in consideration of policy and practice, the two concepts are inextricably linked.

It then provided a summary of the main benefits and disbenefits of green infrastructure and critiqued some of the evidence for these. It identified that there are different ways of grouping the benefits and that this is done differently across different users, and there is no single standard practice adopted for categorisation.

It is clear that the body of literature on green infrastructure and its benefits is substantial. Yet knowledge gaps remain, including in some key areas of fundamental information. While it is clear that there are many benefits of green infrastructure, the evidence for them is not of a consistent standard. Often the quantified benefits cited are theoretical or modelled, and not based on real observations. Likewise, there are no standardised ways of measuring these benefits.

In addition, there is a poor understanding of the co-dependencies, conflicts, trade-offs, and issues of double counting, and also of how multiple benefits work together. Issues of geographic scale of green infrastructure systems, and how far reaching benefits can be based on the size and scale of the network, remain speculative at best. The scalability of multiple benefits could mean that the whole green infrastructure system has value greater than the sum of the individual assets, but it is not currently established how this could be measured or tested.

The second half of this chapter, sections 2.3 and 2.4, focused on the evaluation and funding of green infrastructure. It introduced the key concepts of evaluation and appraisal, and discussed the opportunities and limitations for evaluation, and identified some of the key challenges in evaluating complex systems. Finally, the implications of using valuation to inform business models, and how business models for green infrastructure delivery might be structured were discussed. This is developed further in Chapter 7.

Again, knowledge gaps remain in the literature, and the role of evaluation to inform business models is still under-explored, as evaluation is an inter-disciplinary concept that is not particularly prevalent in the literature. Particular gaps include how values can be defined and quantified through evaluation methods to fit into the value proposition part of a business model; how values and stakeholders fit together in green infrastructure systems, to inform business models; and which types of business models would work for the finance and funding of green infrastructure.

Chapter 3: Research design: the overarching methodological framework, and case study development

3.0 Chapter introduction

The previous chapter of this thesis identified several key knowledge gaps in the literature on the benefits, evaluation, values, and delivery of green infrastructure. These gaps are:

- Inconsistent evidence for benefits of green infrastructure
- No standardised method for measuring benefit
- Poor understanding of multiple benefits, their interrelation, and relationships.
- No exploration of scale of green infrastructure assets or networks
- Poor understanding of matching potential benefits to the value proposition within business models
- Little exploration of overlaps between values (from benefits) and stakeholders
- No standard set of business models for effective green infrastructure delivery.

A final notable limitation was that there is no precedent for evaluation to inform green infrastructure delivery, and no use of evidence-based project planning for green infrastructure delivery. Yet, many of the barriers to more effective delivery lie in a lack of translation of the potential benefits (the value) of green infrastructure into actual delivery. There is no established route for theory to be used in practice, nor for translating knowledge of green infrastructure into delivery. This research project uses an evaluation perspective, following the concept of evidence-based project planning, to address some of these gaps, and therefore work towards an improved business model for green infrastructure delivery.

This chapter discusses the methods and research approach taken in this project, as well as introducing the case study of Newcastle upon Tyne, which is used as an illustrative example throughout the thesis – including an audit of the current green infrastructure provision, and flood modelling for parts of the city. These are intended to provide contextual information, and provide inputs for the development of green infrastructure business models in later chapters, and are not presented as results of this research in their own right.

3.1 Theoretical approach to the research

As the practice of green infrastructure delivery is inherently cross-disciplinary, so too is the methodological approach to this research; using approaches from evaluation practice, infrastructure appraisal, and business studies together to inform business model innovation for green infrastructure delivery. These tools and approaches, used in combination, can be developed into solutions for the challenges currently facing green infrastructure delivery. The multidisciplinary approach used throughout this thesis is as much a source of novelty in the research as the resulting business model innovation, developed in Chapter 7.

The application of cross-cutting research and analysis to inform future delivery is aligned with the practice of evidence-based project planning. From the late 1990s, evidence-based project planning emerged as a key trend in public service provision, from healthcare and education, to transport, urban policy, and even planning (Davies and Nutley, 2000; Krizek *et al.*, 2009). Conceptually, it ties together research (often from evaluative research of past projects) with future delivery planning, underpinned with the central concern: “what works?” (Davies and Nutley, 2000). In this thesis, a business model framework is used in lieu of a specific project plan. This allows the information to be formed into a high-level delivery plan structure, which can then be applied to a range of contexts.

As well as the evaluation approach forming the ideology and principles herein, this research also draws on urban geographies, strategic planning, environmental economics, and business studies literature, concepts and philosophies. The approaches used range across geographical analysis, policy review, project appraisal and business model design. As such, the language and framing are open to confusion. Specific jargon in one field may have a different connotation in another. This, combined with the intention that the research is of interest across all of these disciplines, and with practical delivery teams outside of academia, means that this thesis is written to be understood by an educated, non-academic audience, and language choices at times draw on “layman's terms" to ensure clarity across disciplines of working.

Rationale	Activities and outputs	Outcomes	Impacts
A changing economic and policy context means conventional infrastructure delivery is becoming outmoded and is not fit for purpose for effective green infrastructure delivery.	Green audit of a case study urban area, creating a map of existing GI and assessing its quality. A critique of current appraisal approaches and tools, to identify opportunities and gaps. Case study testing of current appraisal approaches at a specific case study site. Value and stakeholder mapping, to match potential value to beneficiaries. Identifying business model archetypes suitable for GI delivery Recommendations for overcoming barriers to GI implementation and for evaluating benefits.	Better understanding of GI benefits, including the links between some of the benefits. Better understanding of how to evaluate GI. Improved understanding of the spatial and temporal nature of GI benefits. Improved business models for GI delivery	Increased implementation of GI Reduction in instances of GI components being lost to cost cutting Improvements in urban area resulting from GI (e.g. flood risk, air quality, amenity, etc)

Figure 17: a logic model showing the underpinning theory of how project appraisal can lead to improved business models for green infrastructure delivery

This interdisciplinary approach to combining evaluation theory and practice, and applying it in new ways to infrastructure provides an opportunity to overcome some of the challenges of delivery. A logic model showing the project rationale, its activities and outputs, outcomes, and its overall impact, is shown in Figure 17. In the current time of increasing political unpredictability and the ever more challenging funding environment, the need to provide evidence for all investments has never been more essential.

3.2 Research structure

To reiterate, as identified in Chapter 1, the central aim of this thesis is to explore and define what an innovative business model for effective green infrastructure system delivery would look like.

The objectives and research questions are shown in Table 4 alongside the relevant thesis chapters where each of these is addressed. Some chapters address themes and data relevant to more than one research question.

Table 4: Project objectives, research questions, and where they are addressed within the thesis

Objective	Research questions	Relevant thesis chapter(s)
1. Identify current opportunities and barriers to green infrastructure delivery	What is preventing wide scale green infrastructure development?	Chapter 2
	What are the barriers and challenges, and how can these be overcome?	Chapter 2
	What opportunities could be developed further?	Chapter 2; Chapter 7
2. Understand the value of green infrastructure	What is the value of green infrastructure?	Chapter 4
	How is this captured, quantified, and used?	Chapter 4

Objective	Research questions	Relevant thesis chapter(s)
	How can value capture be improved?	Chapters 4
3. Assess the relevance and effectiveness of policies shaping green infrastructure delivery	What are the key policy levers to support an effective business model for green infrastructure?	Chapter 5
	How can the policy context shape delivery, identify stakeholders, and create opportunities and barriers for green infrastructure investment?	Chapter 5; Chapter 6
4. Identify stakeholders with a potential interest in a green infrastructure network, and consider how to align their priorities and needs	How are stakeholders identified?	Chapter 6;
	What are their priorities and needs, and how can these be aligned with green infrastructure value?	Chapters 6; Chapter 7
5. Develop an innovative business model archetype for effective green infrastructure delivery.	How are these various elements used to build and shape new and innovative business model archetypes for green infrastructure delivery?	Chapter 7
	Which opportunities can be capitalised on; and how are barriers overcome?	Chapter 7

The literature review addressed the initial objective and research questions, identifying the barriers to green infrastructure delivery. From the literature it also emerged that the structure of a business model provides a framework to understand how different elements can come together to enable green infrastructure delivery. From this approach, it was also identified that while there are multiple elements of a business model, it is through the value and stakeholder elements that most barriers to green infrastructure sit, and where there is most scope for innovation and to overcome challenges. Therefore, this thesis uses this business model approach to frame the evidence-based project planning, exploring the challenges and opportunities within value streams and stakeholder analysis.

3.2.1 The business model concept

The research has been developed across several areas, aligning broadly with the different elements needed for a business model. This thesis focuses not on the specific design or build of green infrastructure assets, but rather the systems and processes that inform its delivery, especially as a network. Particularly how the value proposition and the stakeholder relationships can shape this delivery. This approach enables the development of relevant business model archetypes, which then forms a high-level structure that can be applied to specific delivery contexts.

As has been discussed in Chapter 2, section 2.4, business models consist of several key components. A simplified business model is shown in Figure 18.

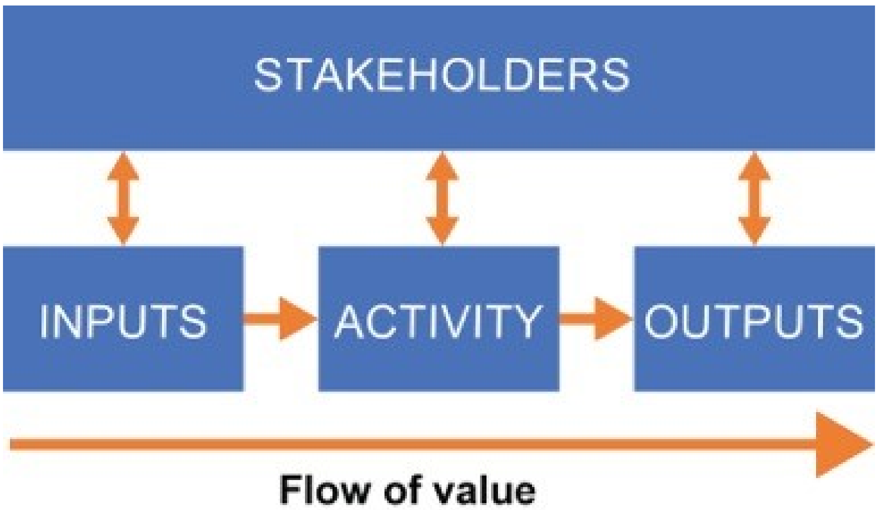


Figure 18: Basic components of a business model

There are different schools of thought and many approaches to what is or is not included in a business model, but for the purposes of this thesis, a basic business model is based on the *business model canvas* (Osterwalder, 2010), which was shown in Chapter 2, section 2.4. This is simplified further in Figure 18 in order to create a flexible template and allow for innovation and new ideas. It is intended to identify core components and create a framework for these, without being too prescriptive. The related components from Osterwalder's model, and how they relate to the simplified model are shown in Table 5.

The core activity of a business uses the inputs and translates those into outputs, thus creating a flow of value through the business model. For the case of an infrastructure business model, this might be taking inputs of investment, capital, and physical resources, building the physical assets and creating the management structure for the infrastructure system itself. The outputs then become the services that the system provides to its users. It is through the stakeholder relationships and the roles of value, that innovation for green infrastructure business models is explored.

Table 5: Simplified business model: content of core elements

Basic business model component	**Related components of the business model canvas**
Stakeholders	Key partners; Customer relationships; Customer segments; Distribution channels
Inputs	Key resources
Activities	Key activities; Cost structure
Outputs	Value propositions; Revenue streams
Flow of Value	Key resources > Key activities> Cost structure > Value proposition > Revenue streams

3.2.2 Understanding value

A key element of a business model, and of this research, is to understand the role of value. The literature on green infrastructure refers to benefits (and disbenefits) of green infrastructure (see Chapter 2, section 2.2), and these benefits form the value concept within a business model. Therefore, the language of value (whether positive or negative) is used for the remainder of this thesis. Some of the values can be framed in monetary terms, while others are non-monetary, and include wider social and environmental values. It is not easy to capture non-monetary values, and ways in which the value of a green infrastructure network can be identified, captured and quantified are explored in Chapter 4, including a detailed rationale of this methodology. Taking the approach of critiquing existing methods for project appraisal, Chapter 4 identifies the opportunities and challenges for drawing out value from green infrastructure, especially focusing on non-traditional values and opportunities for new value streams to be brought into the business model.

This process included a systematic review and critique of available appraisal tools, and then highlighted three tools to test with realistic data, based on the simulated scenarios of green infrastructure in Newcastle (see section 3.3 for further detail on the development of the scenarios and the use of Newcastle as a testbed). The tools shortlisted for testing were CIRIA's *B£ST*, *GI-Val*, and the *multiple benefits toolbox*.

The testing used a new development of regeneration in an existing city brownfield site, *The Helix* (see section 3.3). The strengths and weakness of the three tools were each considered separately as ways of evaluating the green infrastructure credentials of a development option. This realisation of value, and the approaches for doing so were later used to inform the value proposition – that is, how the potential values of green infrastructure can be realised, depending on the relevance to various stakeholders within the business model.

3.2.3 Identifying stakeholders

Stakeholders within a business model can play many different roles. Identifying these stakeholders and understanding their roles is key to identify and capitalise on a range of interested groups. Stakeholders are also key to translating a potential value into an actual value, as it is through the worth to a person or group that the value proposition is realised.

Identifying stakeholders was conducted in several stages. A policy review was conducted in Chapter 5 which identified groups and organisations, and analysed their power and influence within the sphere of green infrastructure delivery. This power and influence shapes the governance and policy perspective for green infrastructure delivery, and was crucial to understand the sphere in which a green infrastructure system might be delivered. These stakeholders predominantly formed delivery organisations, regulators, key funders, and other power holders that can influence delivery.

However, not every type of stakeholder fits within the remit of a policy review, and thus further identification and analysis of stakeholders was conducted, and the methods, results and findings from this process are detailed in Chapter 6.

3.2.4 The value proposition: where stakeholders and values meet

The final phase of the research focused on using this newly generated data on value and stakeholders and developed these to inform alternative business model approaches relevant to the green infrastructure sector. The work on innovative business models in infrastructure also forms part of the wider research project of iBUILD, from which this project drew its funding.

In this current political and economic climate there is a strong need to draw on non-traditional or innovative business models in order to access funding and finance opportunities for new ways of working. This research highlights further opportunities where this innovation can be used, and consequently enhances the delivery of green infrastructure in practice.

3.3 Newcastle upon Tyne: a testbed for innovation

This thesis is fundamentally concerned with the process and application of tools to inform practical delivery and as such draws loosely on the concepts of testbeds and 'living labs' – testing the theory in a real-world setting to ensure that it is fit for purpose and realistic. Using this type of 'living lab' is a methodology that is increasingly common, especially for the development of smart cities, and the crossover of digital technology with real world applications (Schaffers *et al.*, 2011; Mitchell Finnigan *et al.*, 2018; Newcastle Helix, 2019; Urban Foresight, 2019).

While the data burden used in this research does not go so far as building a full parallel of the city, it nonetheless creates a comprehensive case study in which the values, stakeholders and business model information can be contextualised, and development scenarios can be simulated. The case study appears throughout the project for testing the concepts raised and providing simulated data and real-world examples to fill in the processes as well as providing a frame for the results to be understood.

Newcastle upon Tyne, UK, was chosen to be the target geographic area for the case study. It is an example of a mid-sized city with a combination of ‘green’ areas as well as a compact central business district (CBD). It also has some issues common to many urban areas, including surface water flooding, air pollution, and economic challenges.

Newcastle upon Tyne is a city of 280,000 people (Census, 2011), in the North East of England. At around 11,300 hectares, the city comprises a compact urban core area, and surrounding residential areas, and substantial areas of green belt land, especially to the north and west of the city. A focus for future development of the city is this urban core area, as identified in the *Core Strategy and Urban Core Plan for Gateshead and Newcastle* (Newcastle City Council and Gateshead Council, 2015), and shown in Figure 20, alongside the overall local authority boundary for Newcastle City Council as a whole.

Newcastle, like any city, faces a range of environmental challenges. Environmental challenges that have been identified as issues for Newcastle include flooding, especially during intense heavy rainfall; air quality, with identified air quality management zones in place; and an urban heat island effect, making the city warmer than the surrounding areas (Newcastle City Council and Gateshead Council, 2015). These challenges are set in the context of an uncertain political and financial future given the austerity agenda and the UK’s decision to leave the European Union.

Green infrastructure delivery typically takes one of two forms. Either it is focused on retro-fit – that is, creating new green infrastructure assets within the existing urban form – or it focuses on incorporating green infrastructure into new developments. Although the green infrastructure assets themselves may be the same, the context around delivery differs between new development and retrofit.

Newcastle offers a good opportunity to review both these distinct delivery types. The CBD of the city is a compact area with mixed commercial development from a range of eras. From the historic Georgian facades of Grainger Town to the modern developments. The dense city centre has some existing elements of green infrastructure, potentially with scope for additional development, through green infrastructure retrofit.

Additionally, there are pockets of redevelopment and regeneration happening within the city. A key site is the large, 10-hectare former brewery site, which is part way through a large regeneration project. This site, known as *The Helix*, is a mixed residential, commercial and educational site, with business and research focused on science, technology, engineering and maths (STEM). The site is home to the National Green Infrastructure Facility and has significant green infrastructure assets incorporated into its design.

While an effective green infrastructure network would ideally be comprehensively and holistically fitted into a city or area, these two sites offer the opportunity to specifically examine the opportunities and challenges of the two main types of green infrastructure delivery.

Thus, within the case study of the city overall, there were also two neighbourhood-level areas of particular focus, allowing for exploration of issues that were unique to particular delivery settings. This concept is shown in Figure 19, and the development of these detailed focus areas is explained in sections 3.3.3 and 3.3.4. Figure 20 shows the map of Newcastle, with each of these focus areas identified.

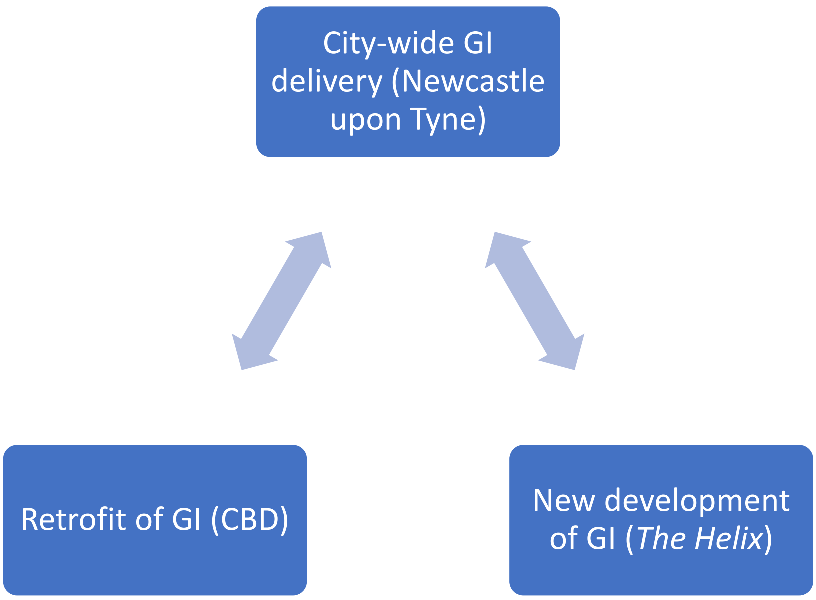


Figure 19: Case study structure for capturing two key forms of GI delivery

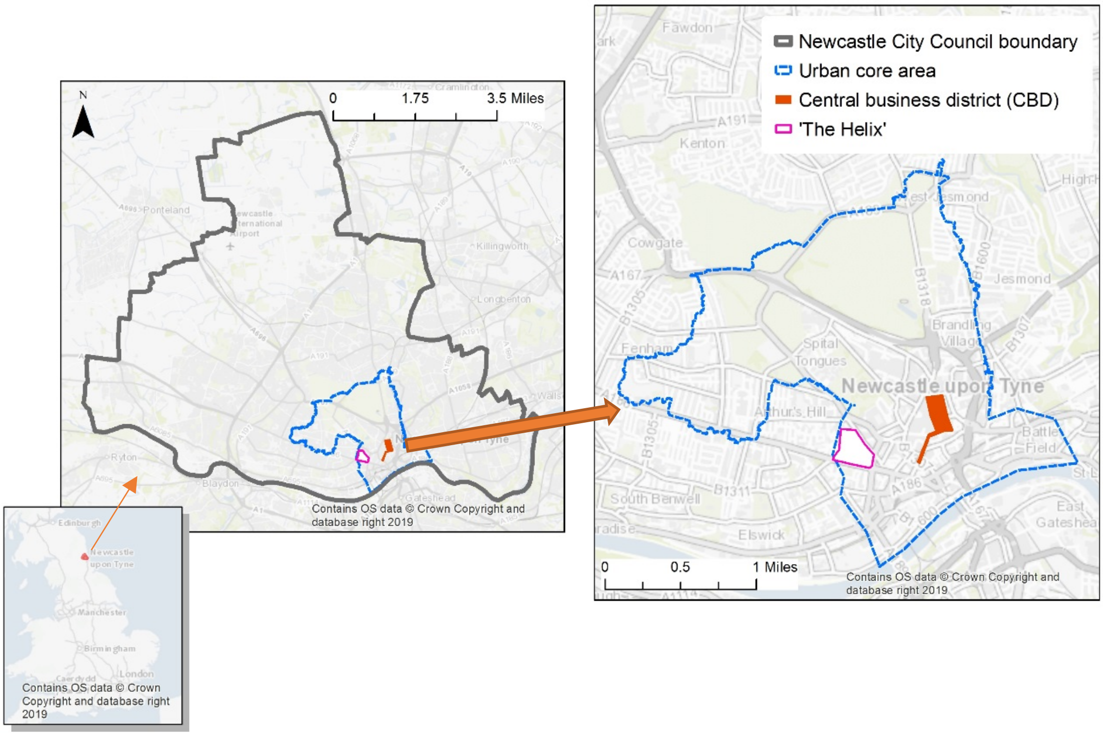


Figure 20: Location of Newcastle upon Tyne and its case study sub-sites

3.3.1 A green audit for Newcastle

In order to understand the existing green infrastructure network within the city, and to identifying key opportunities for green infrastructure development, a green audit was conducted for Newcastle. A green audit aims to collect and collate a host of information on the existing green assets of the target area, combining primary and secondary sources. It then synthesises this information to provide an overall assessment of the current extent and quality of its green infrastructure network, its limitations, and the opportunities for development.

The extent of the existing green infrastructure network across the city was mapped. In addition, the baseline level of green infrastructure within the CBD was assessed, using primary data collection as a way of understanding the situation in which green infrastructure retrofit was developed. As the regeneration site was in its early stages at the time of starting the research, its existing green infrastructure could not be identified. Therefore, data from the development plans were used to simulate realistic data for potential final scenarios for the finished site.

3.3.2 Current green infrastructure network

A desk-based review was conducted searching for relevant information on existing green infrastructure assets as well as any additional information on the quality and functionality of these assets. Secondary data were shared by Newcastle City Council and other interested parties and supplemented by online searching. Several key data files were already held within the department from provisional scoping work done by colleagues and as part of other projects. These files were sourced from stakeholders including Newcastle City Council. The files formed a partial picture of the green infrastructure assets within the city area, from officially published datasets.

Data have been validated using background maps, aerial photography including Google Earth, and site visits to the area. Where possible, these data have been traced back to their original publisher to verify sources and check that it is the most up to date version available.

In addition to finding the most recent versions of the data sets discussed above, a systematic search of data published by the UK government, regional governance bodies, and non-governmental organisations was conducted. Using the web repository for official data, data.gov, this review used key words to search for other relevant data in the case study area. Keywords and phrases used are listed in Table 6. All searches included the word ‘Newcastle’.

Table 6: Keywords used in search for data on data.gov website

Keyword text used		
Newcastle	Green	Greenspace, “green space”
Tree/trees	Park	allotment
Open space	cemetery	“Wildlife corridor”, “green corridor”

This systematic search included the dataset for Tree Preservation Orders (TPOs) within the Newcastle administrative area. This can provide a partial picture of the location of trees within the area. However, it is limited in both data quality and information contained. Only trees with associated TPOs are recorded, therefore this cannot provide information on other trees. In addition, while the data are publicly available, the dataset is caveated with a statement on quality. It is known that the tree locations are not always precise, and it is not intended to be a live dataset therefore it is only indicative and not definitive. The TPO data is available as a Web Feature Service (WFS) layer, which can be added to GIS mapping.

As well as the systematic review of official data, access to other publicly available data was sought. Treezilla (Forest Research, 2019) a citizen science project that aims to map every tree in Britain, has used publicly submitted data to plot the location of five trees within the case study area of Newcastle, which have been included in the data sources for mapping the existing green infrastructure assets in the city.

These data were then collated, digitised where necessary and used to create a map of the existing green infrastructure network within the city, using ArcGIS and QGIS software.

Newcastle forms part of the Tyne river catchment, shown in Figure 21, but due to reasons of governance, only the green infrastructure within the administrative city boundary has been considered. It must be remembered that the green infrastructure network within the city is part of a wider structure of natural and manmade systems, but it is beyond the scope of this research to consider these wider scale systems in detail.

Figure 22 shows a map of the existing green infrastructure assets in Newcastle upon Tyne. These were collated from a variety of sources, predominantly via partners at Newcastle City Council. The map shows the quantity and extent of the network but not its quality or function. Additional detail on green space types was available for the urban core, see Figure 23.

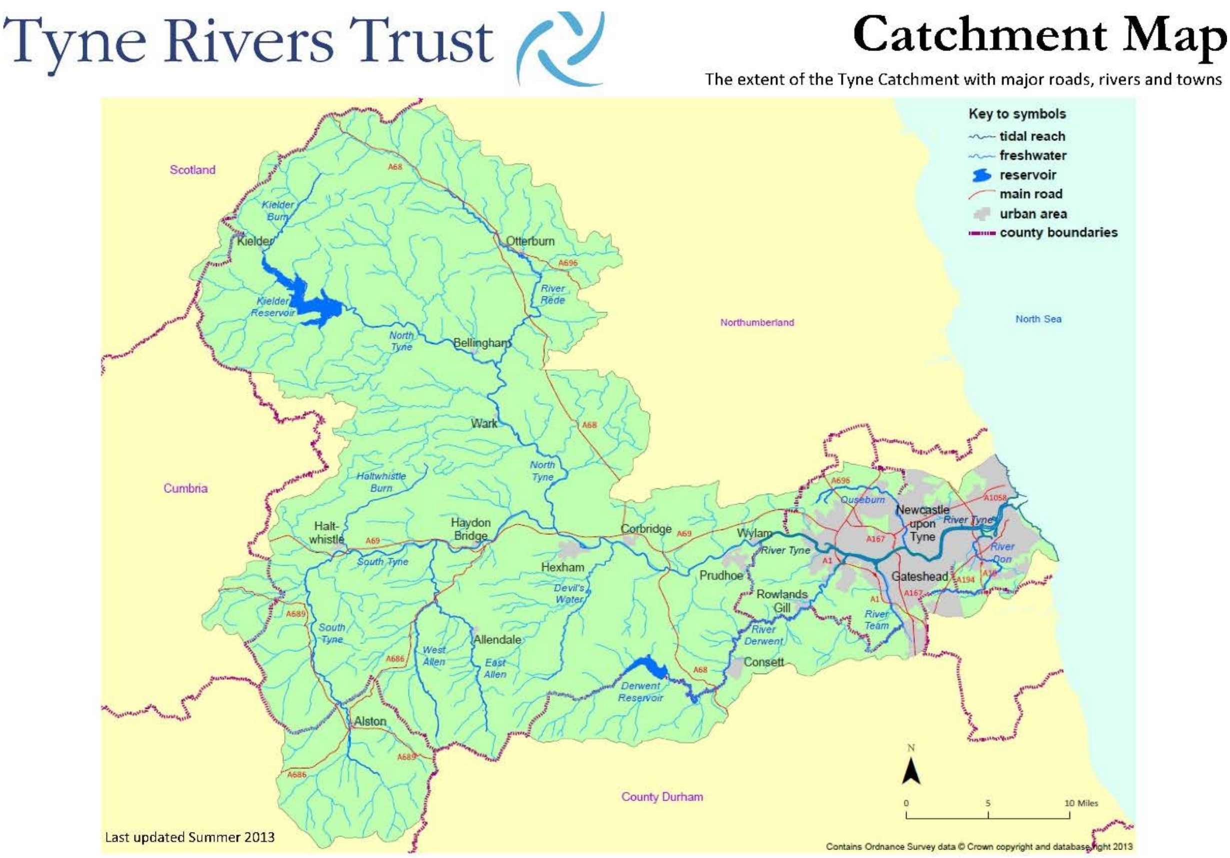


Figure 21: Tyne catchment map, showing location of Newcastle (Tyne Rivers Trust, 2013)

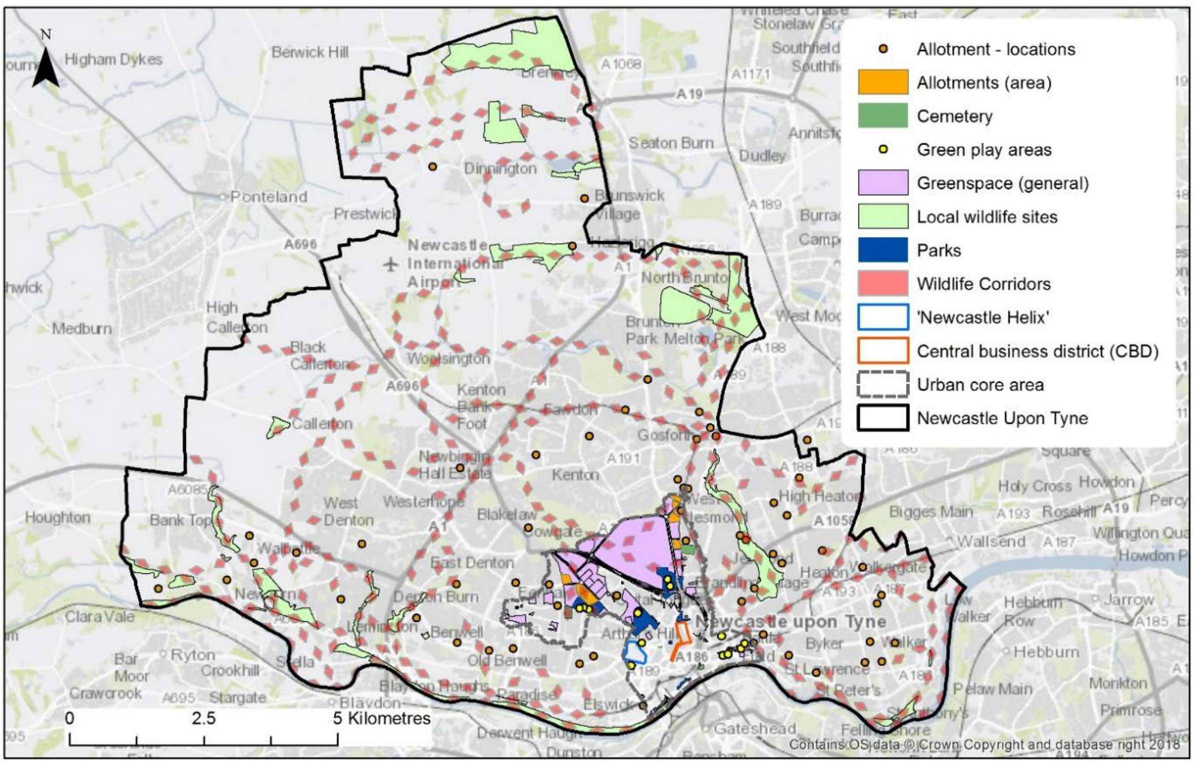


Figure 22: Map of green infrastructure extent within Newcastle city boundary

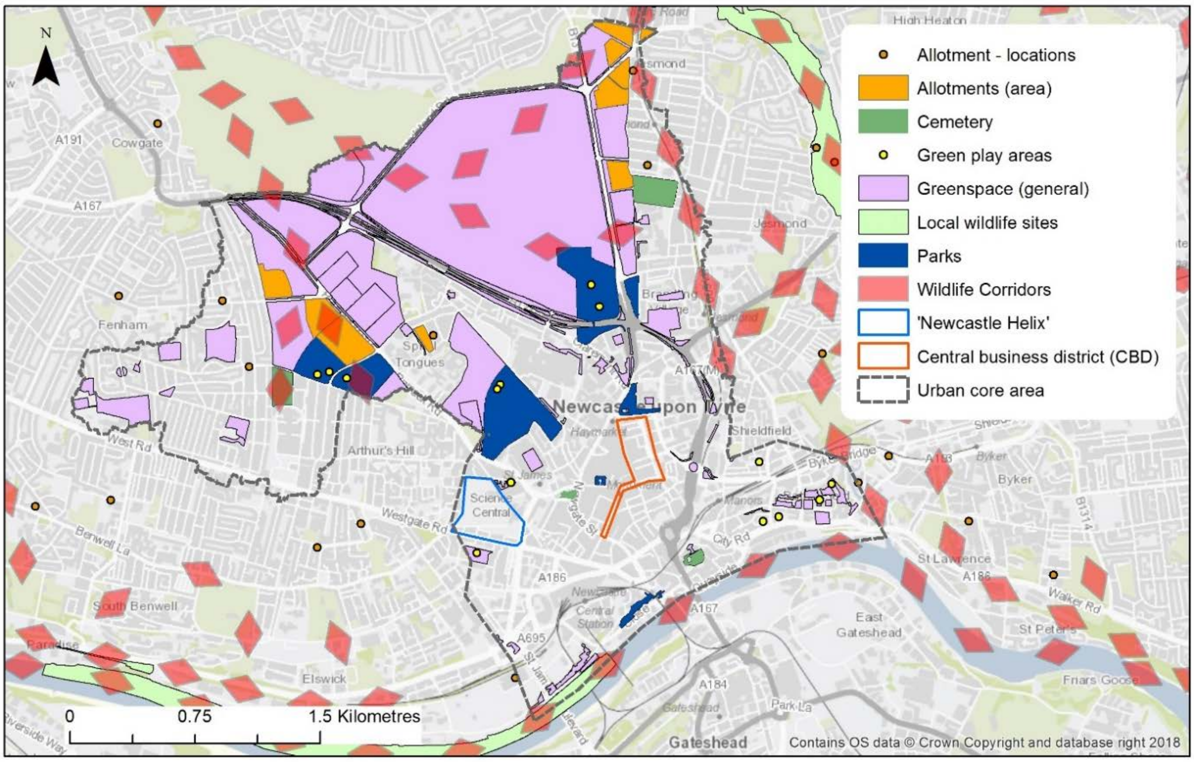


Figure 23: Green infrastructure within central Newcastle

The data show obvious gaps, particularly when comparing the quantity of data available for the urban core compared to the wider local authority area. Without a complete dataset, it is difficult to judge whether this is sufficient to call it a functioning network or not. River valleys, such as the Ouseburn and Jesmond Dene to the east of the city provide some blocks of green space with wildlife habitat functions. In addition, the north and north east of the city boundary both form rural-urban fringe and provide more habitats at Gosforth Park, and north of Newcastle International Airport.

Within the core area of Newcastle, more data are available. In terms of open space, the Town Moors offer obvious open space with associated functions and benefits. Wildlife corridors follow the metro line at the eastern boundary of the core area, and the River Tyne at the south boundary. In addition, wildlife corridors run through the Town Moors and formal parks at the north and west of the city centre.

Again, the quality and function of these potential green assets is relatively unknown without further investigation, but the limited spatial distribution of these assets likely reduces their function as a coherent, strategic network. The city centre area itself appears to be extremely limited in terms of green infrastructure assets, thus primary data were collected to further investigate this.

3.3.3 Green infrastructure retrofit: the central business district

The secondary data collection mapped the extent of the green infrastructure network and the range of assets types. However, there was little information available on isolated assets, nor on the quality and functionality of the assets. Conducting primary research following green audit best practice allowed for the collection of this type of information and provided further detail on the existing green infrastructure network. In addition, the aim of conducting a primary data stage of the green audit was to identify opportunities for green infrastructure retrofit for economic development of the CBD. This economic development was also a key priority for city council stakeholders at the time of the research. The main CBD was chosen for a detailed audit of the potential to retrofit elements of a green infrastructure network. In particular N*orthumberland Street* was identified as a priority. The 400-metre-long pedestrianised street is a key part of the city's shopping district, and is home to major high street brands including *Marks and Spencer*, *Primark* and *H&M*. It offers fast food outlets and coffee shops, banks, and the main entrance to the city centre shopping mall, *Eldon Square*.

Different green audits are conducted for different purposes, for example they may form part of an environmental impact assessment (EIA). For the purpose of collecting primary data on the location, quantity and quality of existing green infrastructure assets, various examples and literature were sought (Benedict and McMahon, 2006; Land Use Consultants and Green Roof Consultancy, 2010; Lennon and Scott, 2014). In particular, those conducted by the Victoria Business Improvement District (BID) area (Arup, 2014) provided an example of a data collection pro forma and process that matched the needs of this research. The pro forma designed for use in this research was adapted from several of these sources, and can be seen in Appendix A. The data collected are shown in Table 7, with a brief description of the purpose.

Primarily adapted from the green infrastructure audit Best Practice Guide, (Arup, 2014), the pro forma was tested in a pilot phase during May 2016, and then further data were collected throughout the summer of 2016.

Table 7: Primary data collected in green audit

Data type	Purpose
Survey date; surveyor initials; Weather	Metadata on when the data were collected, who by, and the weather conditions. Weather conditions and seasonality may impact perception of green infrastructure – e.g. deciduous trees more attractive in summer; visual appeal of features nicer in sunshine than rain.
Site name; Location; Size	Information to identify the site, so that it could be later converted into GIS data.
Photo (or sketch plan)	Visual record of the green infrastructure type, placement and condition. Could be referred to later for further detail.
Site category	This question categorised the space, and identified the type of green infrastructure present. These included a range of potential types, such as: planter or raised bed; street tree in pit; green wall; green roof; grass verge; hedge or shrubs; parks or community gardens and allotments; and wetlands.
Condition	This was used as a subjective assessment, indicative of the condition of the green infrastructure feature. It was categorised as: Good ("Looks neat, well-managed, signs of active management and maintenance."); Moderate (Some signs of active management, but not in ideal condition); or Poor (No signs of active management/derelict or seems neglected). Well managed green infrastructure may be more able to offer benefits than neglected assets can.
Current management	If it was possible to tell, the type of any current management was noted. This was used to further inform the condition, but also to suggest whether the site was managed in order to exploit potential benefits. Some conditions of green infrastructure are required for particular benefits to be realised. For example, green roofs are more effective at flood control if they are irrigated; and allowing grasses to flower provides habitat for pollinating insects.

Data type	Purpose
Land cover/habitat types	This question was used to illustrate the type of setting that the green infrastructure feature being assessed was in. For example, whether it was set on a highway or paved area, a green area, or as part of a building, including if it was a roof or wall.
Functions	Green infrastructure is only truly an infrastructure system if it provides services to human society and urban structure. Therefore, it is important to understand the functional use of a green infrastructure asset. For example, this could include recreation, biodiversity, or flood management functions, or any of the ecosystem services that green infrastructure may provide.
Scope for enhancement	As well as adding new green infrastructure features in a retrofit, existing features can also be improved to increase their functionality or better realise their potential benefits. Any apparent ways that this could be done to existing features was noted for this question.
Barriers to delivery; any other considerations; ease of delivery; estimated cost of delivery.	As a follow up to the previous question on scope for enhancement, any obvious barriers or challenges to delivering changes or improvements can be noted. In a busy city centre for example, there could be issues of access for deliveries or wayleaves for utilities. Issues around building ownership may also be included. Based on this assessment, the likely delivery of any improvements can be categorised as easy, moderate or challenging, and the likely cost can be identified, if known. This serves to prioritise potential enhancements, for example identifying ‘quick wins’ – easy, inexpensive changes that can be made to improve the green infrastructure network quickly.

The pilot test of the data collection was conducted alongside a ‘walkabout’ with key council stakeholders. This allowed informal interview opportunities to further improve the data collection process. It was a key opportunity to identify potential for green infrastructure retrofit within the CBD, particularly in order to promote economic growth.

Data were collected via the designed pro forma using pen and paper, after discussion at key locations on the context and quality of existing green infrastructure. Photographs of green infrastructure assets were taken to support the written information. These data were supplemented by further desk research – for example, mapping was used to establish plot size. The primary data were collated into a spreadsheet initially, and then mapped using both QGIS and ArcGIS.

In addition, recommendations were sourced from secondary sources about the necessary conditions needed for particular types of green infrastructure asset. These were then compared against the sub-plots in the case study zone, and recommendations made about the apparent suitability for retrofit. Particular attention was also paid to how the elements would interact with each other and how they could form a network rather than simply remaining discrete features.

The Core Strategy and Urban Core Plan for Gateshead and Newcastle identifies that:

> "The success of the Urban Core is […] fundamental to our long-term vision of achieving sustainable economic growth. Development that meets the needs for office space and retailing are particular priorities for the Urban Core."
>
> *(Newcastle City Council and Gateshead Council, 2015, p. 32)*

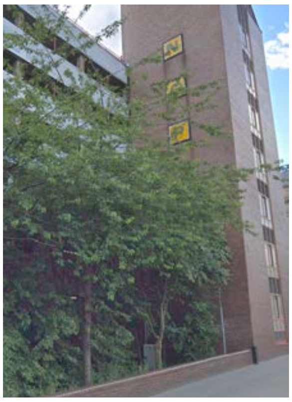
A green infrastructure strategy for the city could provide some opportunities to address these environmental and economic challenges. The CBD is particularly important for this economic growth, and opportunities have been identified by project stakeholders to improve the main shopping streets through green infrastructure retrofit. Thus, it forms the focus for the primary data section of the green audit.

The main part of the CBD, shown in Figure 26, was used for this data collection. There is a very limited provision of any green infrastructure assets, particularly on the main shopping high street, Northumberland Street, and few more on its surrounding streets. Northumberland Street runs broadly north-south, with Haymarket metro station at the northern end, and links to Market Street and Grey's Monument at the southern end. This is the main 'high street' in the city, and therefore essential for its economic success and attractiveness to both businesses and shoppers. The green infrastructure features that do exist in this area provide limited benefit, and contribute little to an overall network. An illustrative selection of the green infrastructure assets within the CBD is shown in Table 8.

Where there are street trees, these are small and set into the ground with very limited capacity to capture or store rainwater. Planters near the northern end of the street provide a decorative element, but are not cohesive with the rest of the street furniture. Two sections of green wall are on the side of, and privately owned by, *Marks & Spencer.* These do seem to provide some level of water storage, and certainly enhance the visual amenity. They help to differentiate the facade of the building and help to create a sense of place.

Table 8: Sample of green infrastructure assets assessed during primary data collection

GI asset	**Discussion**
	Planters at the north end of the street provide some visual greening and may contribute to wellbeing and enjoyment. They have no apparent function for environmental management.
	One of just five trees on this street. Trees have limited space to grow. The known benefit of trees for shade and cooling, and for rainwater retention is usually calculated for mature trees. These trees therefore do not deliver the maximum benefit compared to their potential.
	Many of the street trees on *Northumberland Street* have very limited open ground around them. Covering the base of trees with impermeable materials limits their ability to access rainwater and limits the space for water to run off during a rain event.

GI asset	Discussion
	Some of the trees on the street are located close to seating areas. However, there is little cohesion, and the placement of seating, trees, and other street furniture follows no discernible pattern.
	There are two sections of green wall on *Marks & Spencer*. This is adjacent to the recently redeveloped entrance to the *Eldon Square* shopping centre (part of the roof of this is visible in the top left of the image). The green wall provides visual amenity and helps to create a sense of place.
	New planting on *John Dobson Street*, forming part of a transformation of this through route. Two south bound lanes of traffic were removed to create a cycle way, which these new saplings help to delineate from the roadway.
	During the works on John Dobson Street, some existing mature planting was kept. The new trees increase and enhance this mature planting and help to form a more cohesive network of assets.

There are more green infrastructure assets on the parallel street, *John Dobson Street.* This is not primarily a commercial street but a through route that forms an essential part of the CBD. During the course of this research, *John Dobson Street* has undergone extensive redevelopment, which has preserved and enhanced its green infrastructure provision. However, the southern end of this CBD was devoid of any green infrastructure.

Figure 24 summarises the green infrastructure provision in the CBD, as collected from the green audit primary data. The assessed condition of these assets is then shown in Figure 25.

Figure 24: Types of green infrastructure in Newcastle central business district

Encouragingly, the majority of the green infrastructure assets assessed were considered to be in good condition. However, most of the assets were individual street trees, of which the majority were small (20 small or very small trees, compared to 17 medium trees and just 8 large trees). The benefits of green infrastructure from urban trees are maximised through the use of large specimens, and high levels of leaf canopy. Most of the trees in the CBD were small, with small canopy coverage, and limited room to grow further (see Table 8 for examples of the size of trees and limited canopy cover). The green infrastructure assets in the CBD were mapped, as is shown in Figure 26.

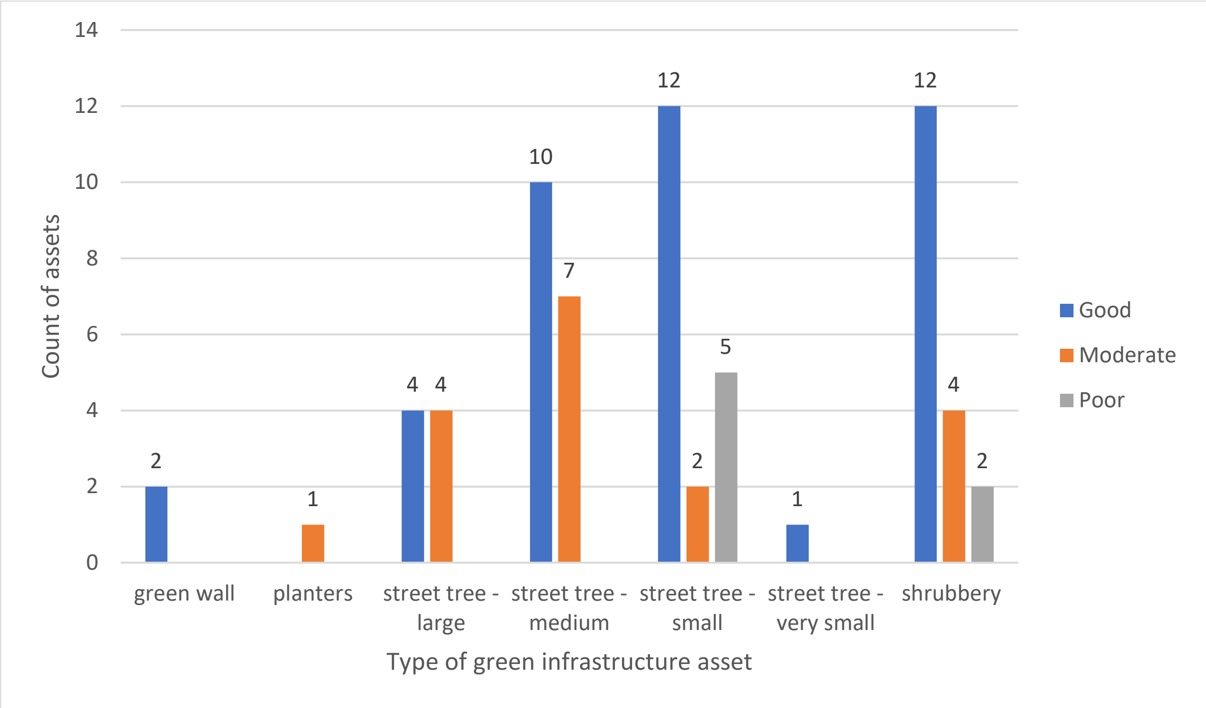


Figure 25: Green infrastructure assets in Newcastle central business district, assessed by condition

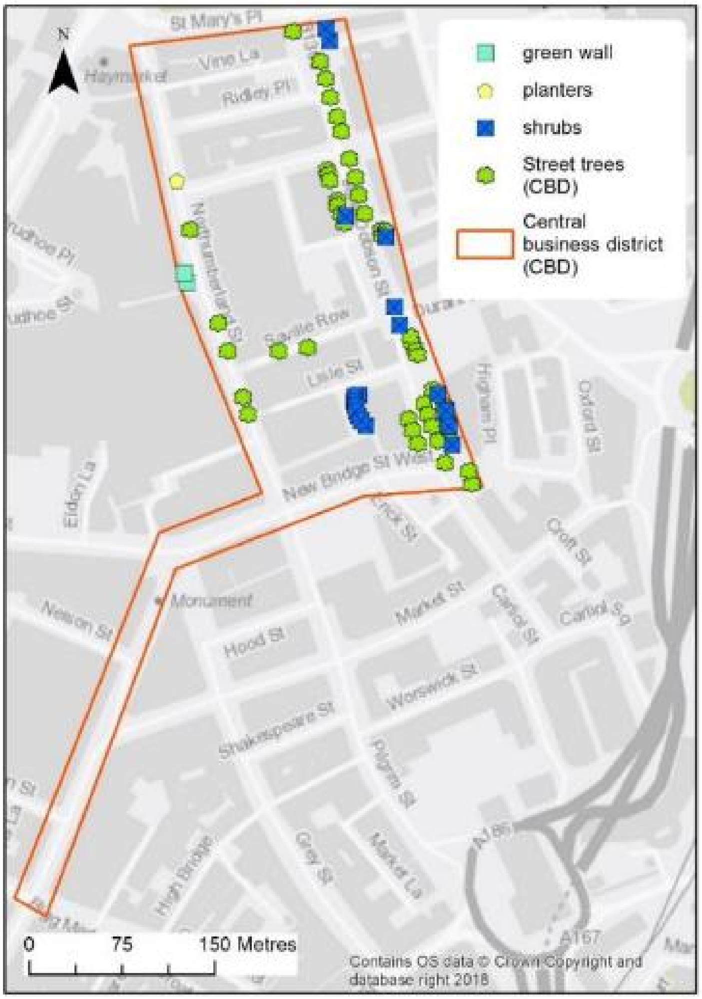


Figure 26: green infrastructure within the central business district

The additional data collected on the existing green infrastructure assets is shown in the following tables, Table 9 to Table 12. These all allowed multiple responses, and so the count does not add to the total number of assets (n=66). The percentages are calculated based on this total.

The types of land cover that each asset was set in is shown in Table 9. This showed that most of the existing green infrastructure in the CBD is adjacent to roads, and usually on a paved area.

Table 9: Land cover forming setting for green infrastructure asset

Land cover/habitat type(s) present	**Count**	**Percentage**
Highway	48	73%
Pavement/paved area	30	45%
Building	19	29%
Scrub/shrubs	18	27%
Roof or wall	2	3%
Other	5	8%

Table 10 shows the main functions that were apparent for each of the assets. All of them served some visual or amenity purpose, while just four provided any function for wildlife, and only two offered some flood management use.

Table 11 shows the potential enhancements to the existing assets that could be made, where relevant. There was scope for installation of wetland features or rain gardens to improve 11 of these green infrastructure assets. This was predominantly in areas with clusters of shrubbery. In addition, some of the building-adjacent sites of shrubs and trees would have been suitable to locate green walls or climbing plants, thus increasing the surface area of leaf canopy without adding to the footprint of the assets.

Table 10: Main function of existing green infrastructure asset

Functions of green infrastructure assets	Count	Percentage
Visual/amenity	66	100%
Public use: informal recreation	9	14%
Wildlife	4	6%
Flood management/water storage	2	3%

Table 11: Scope for enhancements to existing green infrastructure assets

Scope for enhancements	Count	Percentage
Wetland features/rain gardens	11	17%
Green wall or climbing plants	8	12%
Floristic annual planting	1	2%
Food growing: fruit trees/vegetables	1	2%
Water storage feature	1	2%

However, there were also barriers to delivery of some of these enhancements, shown in Table 12. Most commonly, improvements to existing green infrastructure assets would be restricted by building type – especially with listed buildings or facades that add character to the CBD. In some areas, there were obvious restrictions due to utilities, and this was also informed by the expert advice from stakeholders during the pilot phase of the data collection. A detailed review of the wayleaves for the CBD has not been done as part of this exercise.

Table 12: Potential barriers to delivery enhancements to existing green infrastructure assets

Barriers to delivery	Count	Percentage
Building constraints (e.g. listed buildings)	11	17%
Isolated/poor visibility	8	12%
Utilities or wayleaves	6	9%
Current use	4	6%
Misuse/poor ambience (e.g. vandalism, feels unsafe, etc)	1	2%

To summarise this primary data, there are some green infrastructure assets within the CBD, however, these are generally small, some of them are not in good condition, and they are also poorly connected. There is no obvious linkage or network between the individual assets. Many of the assets could be easily improved, though there are some restrictions to this.

One key issue to the creation of a functional network of green infrastructure assets, needed to call it an effective infrastructure system, is the total lack of connectivity between the different assets, apparent in the mapping of the assets shown in Figure 26. These gaps reduce the functionality of any individual green asset as it cannot form a network without proximity to other nodes. There are not insignificant green infrastructure features in all directions surrounding the city centre, but without sufficient links these cannot have maximum benefit for the central area, despite this being a major source of stakeholders and need. Potential development routes to connect the CBD with existing areas of green infrastructure have been suggested, though not tested for feasibility. This development, and the challenges and opportunities available, are discussed further in Chapter 6, in terms of the role of different stakeholders, and in Chapter 7 in terms of developing business models.

3.3.4 New development of green infrastructure: The Helix

The Helix is a development zone on the edge of the city centre. The regeneration of this area is already underway, and the site development plan, shown in Figure 27, is a long term one, and some parts of the design are yet to be built. At around 10ha in size, the area is a regeneration of the former site of the *Scottish and Newcastle* brewery and surrounding industrial land. It will form a mixed development of residential and commercial space. The project is a joint venture between a consortium of partners, including Newcastle University and Legal and General, and represented by the Newcastle Helix group. It will host an intensive zone of businesses and university research with a focus on science, technology, engineering and maths (STEM). It will focus on 'Big Data' and the use of smart technology and feed into the *Internet of Things* concept, as well as showcasing sustainability and smart grid technology (Newcastle Helix, 2018).

The Helix offers a large, neighbourhood-level, new development in which to look at the impact of green infrastructure at different scales and using different tools.

Two scenarios of simulated data were developed, based on the same masterplan, but assuming different amounts of green infrastructure exist in different imagined finished sites. Using the 2017 masterplan of the site as a baseline for the buildings, roads and general site layout, with the supplementary documents from the planning applications illustrating how the finished development might look.

The first, Scenario 1, was a “best case” scenario. That is, an aspirational level of green infrastructure quantity and quality. This assumed a large number of green infrastructure assets, with maximum functionality of those features; for example, any planting functioning as a high specification rain garden rather than simply as decorative bedding plants. The second, Scenario 2, forms a “worst case”, imagining the bare minimum of low functioning green infrastructure. For example, very few green infrastructure assets are incorporated, with a focus on decoration and low maintenance over technical functionality. However, this scenario still accounts for green infrastructure assets developed on the buildings so far.

Figure 27: Masterplan for 'The Helix', (March 2017 version)

Figure 28: 'The Helix', mock-up of buildings

Source: Hawkins\Brown, 2015. Proposals for urban sciences building. Accessed via Newcastle City Council, Planning applications, planning reference: 2015/0248/01/DET.

Also, the development conditions attached to the planning permission require certain levels of sustainability. The nature of the site as an innovative testbed and home of the National Green Infrastructure Facility (Newcastle University, unknown) will require a certain level of technical green infrastructure feature installation. Within this minimal scenario, it can be assumed the minimum necessary features will be developed, with low quality or poorly matched to the context. This is what might be considered by critics to be ‘greenwashing’, - that is, presenting the illusion of strong environmentally sustainable credentials, but with little strategic value and little thought to the long-term maintenance and role of these features beyond aesthetic. Table 13 explains how each of the two scenarios were developed with their varying green infrastructure assets, while the characteristics of the two scenarios are summarised in Table 14.

3.3.5 Flood modelling at The Helix

One of the key applications of green infrastructure is for flood control and stormwater management, and so comparisons between the two scenarios was also made in terms of how each one might perform in a flood event.

Flood modelling for both scenarios was conducted using the CityCAT flood modelling tool (Glenis *et al.*, 2018), in order to understand how the differing levels of green infrastructure might impact the hydrological response in a storm event. The literature identifies that green infrastructure performs better in smaller flood events, and less well in larger storm events. Table 15 and Table 16 show summary data of how the two scenarios performed in different flood conditions.

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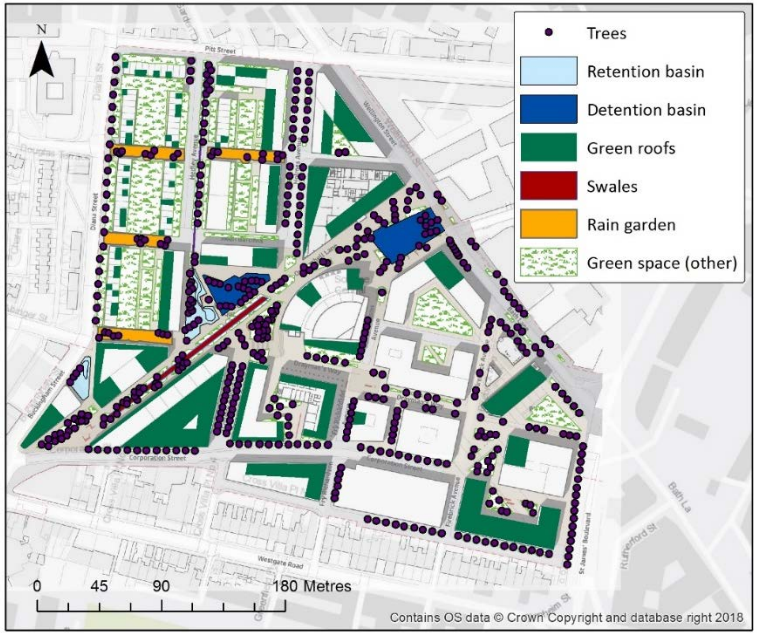
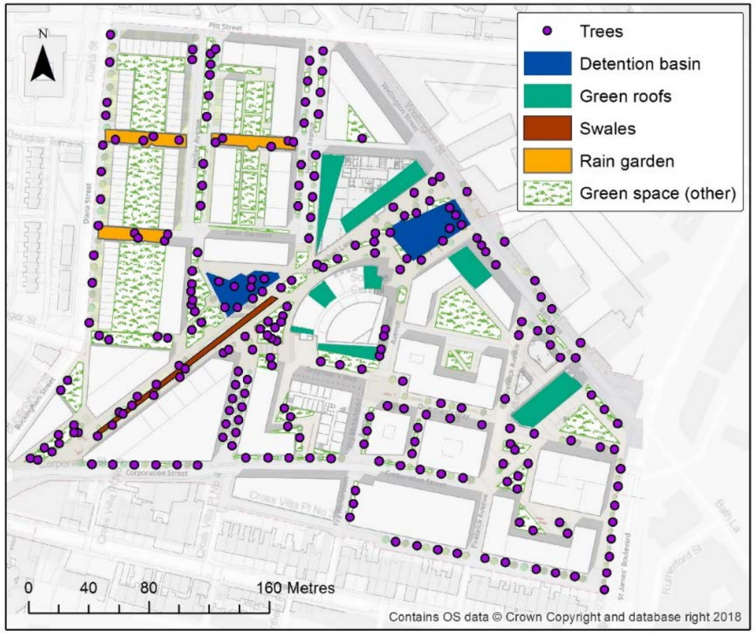
Table 13: Scenario development for The Helix

Asset type	Scenario 1 development	Scenario 2 development
Green roofs	Assumes all of the green roofs visible in the imagined aerial view of the site, Figure 28, will be built. [Note: This plan is not an exact match for the most up to date plan in terms of building shape, however it was used as a guide to illustrate the potential extent of green roofs on the site.] The green roofs have all been assumed to be extensive rather than intensive.	Using the aerial view (Figure 28) as a starting point, the green roof coverage was reduced to only include those buildings already constructed with green roofs at the time of creating the model, plus additional green roofs for the flagship buildings currently at building stage. It was estimated that green roofs would be less of a priority for the residential section of the site in Scenario 2. The green roofs have all been assumed to be extensive rather than intensive.
General green space	Based on the areas of visible greening on the masterplan. Any green areas on the plan that were not already identified as one of the other types of green infrastructure asset were categorised as general green space. The private garden spaces, front and back, associated with the residential area are assumed to be predominantly green, permeable surfaces.	Based on the areas of visible greening on the masterplan. Any green areas on the plan that were not already identified as one of the other types of green infrastructure asset were categorised as general green space, albeit less generously than S1. Private garden spaces associated with the residential area are assumed to be predominantly green, permeable surfaces for back gardens, with some paving for front gardens, assuming off-street car parking made with impermeable materials will be prevalent.

Asset type	Scenario 1 development	Scenario 2 development
	Assumes more generous areas of green space than S2, with bigger green areas around houses and around other features like the main swale.	
Green walls	Although some green walls already exist at the site, and more are potentially planned, none of the tools being tested had functions for incorporating these in the appraisals, so they have not been included in the digitised green space for the inputs.	
Rain gardens	The site masterplan shows areas of mixed green and blue space in several sections, which for the purpose of building these scenarios have been assumed to depict rain gardens. All four of these areas have been designated as rain gardens.	The site masterplan shows areas of mixed green and blue space in several sections, which for the purpose of building these scenarios have been assumed to depict rain gardens. Three of the four green-blue sections on the masterplan have been assumed to be rain gardens. These are central to the residential area. The fourth area is simply landscaped green space without deliberate structure or planting to make it a rain garden. This decision follows the logic that Scenario 2 will only have a minimum of functional green infrastructure assets, and that while rain gardens may be important to creating the character of the residential quarter, they are less essential in the transition between residential and commercial space.
Retention and	Includes both retention and detention basins. The retention basins include vegetation around the perimeter.	There are no retention basins included. Two ‘squares’ intended as communal public space on the masterplan have been designated as detention basins.

Asset type	Scenario 1 development	Scenario 2 development
detention basins	Two ‘squares’ intended as communal public space on the masterplan have been designated as detention basins.	
Swales	Includes multiple bio-swales, vegetated swales intended to convey stormwater and allow for some infiltration and slower flow than that of storm water over the surrounding impermeable surfaces. These were located on the south west end of Oystershell Lane and running along Hedley Avenue. They are assumed to connect with the retention basin at Knowledge Square.	Includes only the bio-swale on Oystershell Lane. Poor connectivity to the other green infrastructure assets.
	Note: A testbed swale has since been developed on Holmes Avenue, as part of the National Green Infrastructure Facility, however this was not incorporated into either scenario, as they were developed before this was built.	
Trees	Assumes that all of the trees in Figure 27 will be planted, that these trees will be planted with sufficient space to grow to maturity, and that species and layouts will be appropriate for maximising water storage and infiltration. Assumes that Scenario 1 trees would have a canopy radius of 1.5 metres at maturity.	Assumes that in reality around half the number of trees would end up being planted, and that the species selection would create a smaller canopy cover at maturity. Assumes that Scenario 2 trees would have a canopy radius of 1 metre at maturity.

Table 14: Scenario summaries

Characteristic	Scenario 1	Scenario 2
Green roofs	1.3ha	0.3ha
No. trees	493	246
Other green space	1.4ha	1.3ha
Site map		

<u>Note</u>: Scenarios were digitised according to Table 13, using ArcGIS software, version 10.5, to overlay new shapefiles of the green infrastructure assets on top of the masterplan, and matched to the existing base map of the city, from the OS base maps. The maps use British National Grid projections.

In order to create the green space input files for CityCAT, there was no distinction between the types of green infrastructure asset, with the total surface area being used to create the inputs, and all the green space assumed to be permeable. Obviously, some nuance on the performance of different green infrastructure assets is lost, but the simplification was necessary to effectively run the flood model.

The average flood depth of each time step generated in the flood modelling are shown in Table 15, along with the differences in these depths in Table 16. These tables show that although flood depths of over a metre exist in the flood models, the differences in the green infrastructure scenarios are only of the order of 1-2cm depth. This could make a difference when it is the critical depth between overtopping curbs or barriers, but it is not a huge change in the total quantities of water involved. In order to understand the impact over a longer time period, perhaps against average rainfall for a specific month or a whole year, additional simulations would need to be run. This falls outside the scope of this research, but the role and use of such flood simulations are discussed further in Chapter 7, section 7.3, and in Chapter 8 section 8.2.

Table 15: Mean max depth for each rainfall and green infrastructure scenario

	Average maximum depth (m) for each rainfall return period			
	R3	R9	R15	R27
Baseline	1.848	1.929	1.961	2.161
S1	1.834	1.917	1.948	2.148
S2	1.835	1.918	1.949	2.149

Table 16: Differences in flood depths between scenarios

	Difference in depth (cm):			
	R3	R9	R15	R27
Baseline to S1	-1.38	-1.25	-1.34	-1.31
Baseline to S2	-1.26	-1.13	-1.25	-1.20
S1 to S2	-0.12	-0.12	-0.09	-0.11

3.4 Chapter conclusion

To conclude, this research uses a novel approach to address the barriers to effective green infrastructure delivery. It reflects the inherently cross-disciplinary nature of green infrastructure practice and draws on this to find innovative ways to address the challenges.

Using principles of evidence-based project planning, the research takes this developing evidence base to feed into a business model framework. It then identifies that the key opportunities for business model innovation, through detailed analysis of stakeholders and values.

As identified in the literature review (see Chapter 2, section 2.4), the key elements of a business model include the partners, resources, activities, value propositions, customers, channels, revenue streams and cost structure. To develop innovative business models for green infrastructure, this research will use this evaluation practice to inform value propositions and revenue streams, and to identify key stakeholders, whether these are partners, governance and regulation influencers, or customers and channels. This chapter explains this overarching theoretical framework, and reiterates the aim, objectives and research questions first identified in Chapter 1. These are then shown alongside the relevant chapters that address the research questions in detail. The process of evaluation and identifying benefits and values is explored further in Chapter 4. Identifying stakeholders is done through this desk research, including the policy review, which is presented in more detail in Chapters 5 and 6.

Through doing this, this project will address some of the research gaps identified in the literature review and offer a better understanding of green infrastructure benefits; of how to evaluate green infrastructure; and of the network conditions needed for an effective green infrastructure system.

In order to ensure that the research is practicable and realistic, it is underpinned by a city-wide case study. Data are shown for the extent of the existing green infrastructure network across the whole city. In addition, two key areas of focus are also included: for the CBD of the city, to represent the context of green infrastructure delivery via retrofit in existing urban areas; and for *The Helix*, a regeneration site, to represent the green infrastructure delivery when it forms part of a new development. Baseline data for the green infrastructure network, and development scenarios for including it in a new development are used.

This chapter includes the results of the primary data collected through a green audit of the city, and secondary data identifying the current extent of green infrastructure. This green audit showed that there are limited green infrastructure assets within the central business district of the city, despite this being a major centre for employment and social activity. While there are some significant blocks of green space with functional purpose around the city, these are largely isolated. A strategic network of connections between these is likely to improve the network's overall functionality.

For the new development, two potential green infrastructure scenarios were created. Both include green infrastructure, but one has a greater quality and quantity of green infrastructure assets than the other. The differences between each scenario, and how they performed in flood conditions, were small. This suggests an interesting line of enquiry for further research into the relative scale of green infrastructure compared to its relative performance, but this is outside the scope of this project at this stage. The following chapter, Chapter 4, concerns the value of green infrastructure, addressing objective 2, and builds on these simulated development scenarios for the city.

Chapter 4: Assigning value in green infrastructure systems: approaches, tools, and challenges

4.0 Chapter introduction

The value of green infrastructure, which is drawn from its benefits and the usefulness of these to human society, is a key element of defining and shaping an effective green infrastructure system. Together with the stakeholders (see Chapter 6), they form fundamental elements of a business model for green infrastructure delivery. Objective 2 and its associated research questions all focus on value, how it is defined, captured, quantified and used. This chapter addresses these research questions in order to inform a business model framework.

Objective 2: Understand the value of green infrastructure

- What is the value of green infrastructure?
- How is this captured, quantified, and used?
- How can value capture be improved?

As discussed in Chapter 2, section 2.2, some of the benefits of green infrastructure are direct and tangible, while others are indirect or intangible. These benefits form the basis of the value, through their worth to humans. In order to fully maximise the opportunities for green infrastructure delivery, it is important to be able to capture and quantify as many of these values as possible. Additionally, Chapter 2, sections 2.3 and 2.4.1 identified that appraisal, valuation, and finance and funding options are easiest to employ when a quantified value can be converted into a monetary or monetised form. This enables direct comparisons to be made between costs and benefits. Not all of the benefits are easily monetised, but techniques from environmental economics and other disciplines can be drawn on to create proxy values for non-market goods and services. Some of these techniques are already established in infrastructure appraisal, for example for transport schemes, and so there is a strong precedent for using this type of approach to elucidate and quantify the value of green infrastructure.

This chapter is structured around identifying and testing tools that are currently available for green infrastructure project appraisal. Several of these have been developed, but as yet there is no dominant approach. Identifying and quantifying green infrastructure value is key for developing a business model for delivery.

This phase of the research is done in three parts, firstly by identifying and critiquing the tools available for green infrastructure appraisal, before then shortlisting some of these. These shortlisted tools were most appropriate for the appraisal of a site with a reasonable quantity of green infrastructure – thus they were tested using the development scenarios for *The Helix*, introduced in Chapter 3. They were not used for assessing the retrofit of green infrastructure in an existing area, as this would have been a less effective way of testing the capability and suitability of the tools. However, they could also be used for this purpose assuming the relevant input data were available. Finally, these shortlisted tools were tested using these scenarios for *The Helix*, and the results discussed in terms of what they show about the available tools, and about green infrastructure value capture: how the values can be captured; and ways in which this value capture could be improved.

4.1 Tool critique

This phase of the research project involved a critique of current green infrastructure appraisal approaches and tools, to identify opportunities and challenges for delivery. In particular, with an aim of highlighting opportunities that are currently underexplored. This was vital in order to highlight the current strengths and weaknesses of the evaluation process and to understand how this influences the delivery of green infrastructure projects. The tools critique aims to provide a shortlist of the most suitable tools that are then tested on a case study site.

Evaluation tools specific to green infrastructure are limited, and there is no obvious leading tool used across the industry. Some appraisal tools, for example CIRIA's *B£ST* (see Table 17 for more detail), were publicised within the industry on release. Others have been created as part of academic research projects, and are less well publicised, as their widespread knowledge and use is not a key aim. Some of these tools were encountered in the literature review, within the search for infrastructure appraisal and evaluation generally (see Chapter 2, section 2.3). However, for the purpose of ensuring a comprehensive review of all of the relevant tools, a specific search was conducted at this stage of the research. The search to identify these specific green infrastructure evaluation and appraisal tools was conducted through web searches, academic literature, and on expert advice from people in the industry. Key search terms used included:

- green infrastructure,
- appraisal,
- valuation,
- evaluation,
- ecosystem services,
- SuDS.

This search process identified 15 tools that were potentially relevant for the appraisal of a green infrastructure project. These tools are listed and briefly described in Table 17. It summarises the tool, its approach, the type of inputs and outputs, and any restrictions on use.

One useful resource for this process was the tool assessor created by a research project looking at the appraisal of ecosystem services (Ecosystems Knowledge Network, 2016).This has been an invaluable source for finding relevant appraisal tools and providing groundwork for discovering some of the available established approaches.

In addition, searching for 'Natural Capital Accounting' elicited a lot of information on the process of asset valuation of green space and other natural resources. However, while Natural Capital Accounting methods provide useful insight and background, this is a step removed from the focus of this research, and it is only tangentially relevant to green infrastructure evaluation specifically, therefore this route was not further explored in this research project.

The specialised ecosystem services or green infrastructure tools available fall into two broad categories. They predominantly use either a spreadsheet-based format that ascribes values to the functions and benefits realised by a green infrastructure feature or project. Alternatively, they take a spatial analysis approach, using GIS software to incorporate the spatial context of green infrastructure assets and based on this spatial extent aims to illustrate and explain the extent of benefits or functions that can be realised.

Table 17: Green infrastructure appraisal tools

Tool	**Description**
ARIES (Villa *et al.*, 2014)	A spatial analysis based tool. The user side of the tool does not yet exist in a publicly available format. The programming aspect uses modelling tools, and the ultimate aim is that it will offer this powerful modelling approach to non-technical users, widening the audience able to use it. It will be an artificially intelligent system of modelling for the valuation and management of ecosystem services. As it is not yet available for use, it is not relevant for testing in the scope of this project.
Burnley Method (McGarry and Moore, 1988)	A method used for calculating the monetised amenity value of trees. It was developed in Australia to overcome limitations of UK-focused methods. It is based on the tree size and base value, but modified by life expectancy and suitability for the location. It is limited to trees, and even then only their function as an amenity. This is too focused for the scope of this project case study, but is useful for feeding into valuation of individual green infrastructure assets.
CAVAT (Doick *et al.*, 2018)	A method used for valuing amenity trees (those not grown as a crop, e.g. for timber or orchards), either individually or collectively. Individual value assessments use the so-called 'full method', and can be used for example to calculate the replacement value needed for compensation. Valuing a collection of trees is done using the 'quick method' and is used to value trees for asset management purposes. It attempts to overcome some of the limitations of the Helliwell system. It tries to include the concept that ecosystem services are provided by trees, but does not calculate these specifically. It is widely used by local authorities and other governance bodies in the UK, and considers the range of benefits provided by amenity trees, including ecosystem services. However, it is limited to tree value, and cannot be used to value other types of green infrastructure asset.
CIRIA B£ST (CIRIA, 2016)	The Benefits of SuDS Tool (B£ST) from CIRIA is a free to use tool, developed in Microsoft Excel, for quantifying and monetising the value of a SuDS project using the environmental economics frameworks of triple bottom line accounting, and using the ecosystem services framework. It is accessible and usable by a non-analytically technical user, although the accuracy and robustness of the user input values require a certain level of technological understanding of SuDS.

Tool	Description
	The outputs are monetised, and a cost benefit ratio can be estimated if project costs are known. The benefits that are valued are based on the performance of the drainage system, and also allows for the valuation of additional features that form part of the scheme, for example trees or green walls. The values that have been sourced are published within the tool, along with appropriate references. They can be overwritten by the user should more detailed values be known in the context. This transparency offers a critical opportunity to ensure the tool is being used as accurately as possible. The tool is designed for use at a scheme-level scale, and for comparing proposed design options or valuing a single project option. It is not aimed at the strategic city scale, although it does have a predominantly urban focus. It has an ongoing schedule of development, and the latest update was released in February 2018.
Co$ting Nature (King's College London *et al.*, unknown)	An open access, spatially based tool for analysing ecosystem services, and designed for natural capital accounting and supporting decision making at policy level. Their approach is one of costing nature, rather than valuing it (i.e. actively avoiding a 'Willingness to Pay' ideology). It is designed for assessing a baseline level of nature provision and for modelling options ahead of plans being delivered. The tool provides extensive datasets for use, but the user can also use their own data if it is better suited to the local context. Different scenarios can then be modelled for their relative impacts on the ecosystem service provision. It works best at a large scale: regionally or nationally.
Eco-serv GIS (Winn, 2015)	Developed by Durham Wildlife Trust with others, this is a GIS toolkit for mapping ecosystem services at a county scale. Its approach is a spatially analytical one, underpinned by the ecosystem service function concept. This includes functions across provisional, regulating and cultural contexts. The existing green infrastructure network can be mapped (and/or modelled if needed), as well as supporting information like population statistics. The output maps can be used to identify gaps in green infrastructure provision, or to plan strategic development of a green infrastructure network in line with other planned development.

Tool	Description
	It is used at a regional scale, so is perhaps less relevant in this project, which uses a case study at sub-city level.
GI-Val (The Mersey Forest *et al.*, 2010)	This tool is an Excel based calculator. It is designed to cover a range of green infrastructure assets and functions. It is monetised and grouped by the type of benefits being realised, as defined by the ecosystem service functions. The values table is published, allowing these to be updated or overwritten if and when the best available evidence is updated. It is free to use, and can be used for a range of spatial scales, but particularly city scale or smaller.
Helliwell (Helliwell, 2008)	A method used for valuing trees, based on solely on their visual amenity function. It can be useful for comparing trees to one another, but the lack of transparency on how the base price for a tree is derived limits its use for showing an absolute value of a tree. It does not cover any other types of green infrastructure asset or function.
i-Tree Eco (USDA Forest Service, 2006)	A specific tree-focused web tool for evaluating urban trees. Unlike other tree valuation approaches, i-Tree Eco is concerned with the role of trees beyond amenity, and can estimate their role across a range of ecosystem service provisions. The software is open access and required inputs include tree data, alongside air pollution and meteorological data.
InVEST (Natural Capital Project, 2016)	InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) is a set of several open source software models that allow the modelling of ecosystem services provision for a particular area of interest. It allows the impact of different scenarios to be modelled, and is designed for this to be used to support decision making about natural resources. User inputs mapping the area of interest are needed, but the tool is now available even to non-technical users as its current version allows use outside of the ArcGIS environment. However, there are further uses and more practical applications of the tool if the output maps are then used in GIS software for further interpretation.
LUCI (LUCI, 2016)	The Land Utilisation and Capability Indicator (LUCI) is designed to assess how a landscape is currently providing ecosystem services and also what its maximum potential for ecosystem service provision would be. Another spatial approach, this tool will rely on ArcGIS software. Still in prototype format, this tool is not yet publicly available.
Multiple benefit toolbox (Blue-Green Cities, 2015)	This tool is spatially-based, using GIS (ArcGIS with spatial analyst needed, which can be a significant cost if not already available). Aside from software costs, the toolbox is free to use, but it is no longer being developed and not supported. It was designed as part of a research project, but not developed further. The user guidance is limited,

Tool	Description
	but ad hoc support may be available from some of the researchers involved in the project. It values multiple benefits of green infrastructure, and uses a ranking system and scores rather than monetised values.
Natural Capital Planning tool (Hölzinger *et al.*, 2018)	It is a spreadsheet based tool, and can offer an ecosystem service impact score and guidance. Its approach is to assess the impact of proposed developments on the natural capital and the ecosystem services provided over the long term development of that proposal. It uses a systematic approach to assess 10 different ecosystem services over a timescale up to 25 years. This tool was not publicly available for use until 2018, therefore could not be used for the case studies in this project.
SENCE (Environment Systems, 2016)	Run in-house by the consultancy service, SENCE (Spatial Evidence for Natural Capital Evaluation) is based on spatial analysis. Its approach is to assess the current provision of ecosystem services from a particular landscape or natural capital asset. This will enable informed decisions to be made for development, accounting for “hidden” functions of land in addition to obvious functions that a new development might be aiming to create. The principle is that it will enable better evidence-based decisions about land use. The consultancy has expertise particularly in geoinformatics and earth observation, and their analysis has been used usually for larger scale landscape management rather than city-based development as in this project case study.
Viridian (Viridian Logic, 2016)	A consultancy service that uses its own propriety software and approach for analysing ecosystem service provision and green infrastructure. It takes a spatial approach, but further detail on the methodology is not open access. They go beyond ‘opportunity mapping’ with mathematically based hydrological modelling to include the complexity of water flows in an ecosystem.

Both approaches form a basis for decision making and evidence-based project planning. It is arguable the quantitative and monetised approaches have the most relevance for project appraisal in the context of funding and finance. They can provide a business case and allowing for the role of green infrastructure to be more genuine infrastructure type, as these are more in line with conventional infrastructure appraisal. However, a key advantage of a spatial approach is that it is useful for technical design and strategic planning.

Selection of a subset of the tools to use with case study data considered a mixture of practical and theoretical concerns. Firstly, the shortlist includes only those that are available in the public realm and free at the point of use, including the availability of any essential software to run the tools. Prototypes and proprietary approaches offer interesting learning opportunities but will not be a priority for testing while fully developed options exist.

For practical reasons, it was assumed that tools which ran using common software packages could be assumed to have no additional software costs involved. When considering the usability of the tools both in this research, and their potential for use in industry, it is reasonable to expect that web tools, Microsoft Excel, and free code-based options (for example, models built using Python) would all be cost effective. The scope of this research project included existing access to GIS software, with spatial analyst functions. However, this is a limitation of use and applicability within the context of practitioners given that software costs can be a significant barrier, especially where proprietary GIS software is required.

The tools used must also be able to include multiple types of green infrastructure assets. A focus on one specific type is not necessarily a barrier as long as others are also incorporated. But where the tool or approach is limited to one very narrow aspect then it is not as relevant to concept of whole-scheme appraisal or whole network analysis of a green infrastructure system. An awareness of these asset-specific tools may be of use when informing the inputs into another system however.

From a theoretical perspective, the two key approaches that emerge from a review of all the tools is that they either approach it from a project appraisal style point of view, with predominantly quantitative summary of the extent and impact of a network of green infrastructure assets. Alternatively, the other key approach is through a spatial analysis perspective. Therefore, it is important to ensure that the shortlisted tools for testing represent both of these main theoretical perspectives. A summary of the tools and their key features is shown in Table 18.

Table 18: Potential appraisal tools for testing, with their key features

	Tool:	ARIES	Burnley method	CAVAT	**CIRIA B£ST**	Co$ting Nature	Eco-servGIS	**GI-Val**	Helliwell	i-Tree Eco	InVEST	LUCI	**Multiple benefit toolbox**	Natural Capital Planning tool	SENCE	Viridian
Access	Free to use		X	X	**X**	X		**X**	X	X	X		**X**			
	Proprietary														X	X
	Prototype/ restricted	X					X					X		X	X	X
Underpinning approaches	Spatial analysis	X				X	X			X	X	X	**X**		X	X
	Monetised	X	X	X	**X**			**X**	X	X				X		
	Ecosystem services	X			**X**	X	X	**X**		X	X	X		X		X
	Natural capital accounting					X								X		
Format	Spreadsheet				**X**			**X**						X		
	GIS					X	X				X	X	**X**			
	Modelling	X									X					?
	Consultancy service														X	X
Stage/ purpose	Planning /baseline				**X**	X	X	**X**			X	X	**X**	X	X	
	Evaluation				**X**					X			**X**			
	Management	X					X				X	X	**X**	X	X	
	Valuation	X	X	X	**X**			**X**	X	X				X		
Coverage	Multiple green infrastructure	X			**X**	X	X	**X**			X	X	**X**	X	X	X
	SuDS-specific				**X**											
	Tree-specific		X	X					X	X						

*Note: **Bold** text signifies tools chosen for shortlist*

Given the funding context and the aim of this research to add weight to the business case then the two calculator-based approaches that are within this neoliberal delivery context are obvious candidates. One, *GI-Val*, is apparently the most comprehensive in terms of the breadth of focus and for its holistic approach to benefit. However, *B£ST* has been designed primarily for SuDS but incorporates other green infrastructure features as well. The fact that it has the weight of a formal industry body in the shape of CIRIA means that it is certainly in contention to become the mainstream option for green infrastructure appraisal.

The prevalence of spatial approaches cannot be ignored, despite their separation in form from traditional policy appraisal approaches. A third tool for testing must therefore be one that takes this spatial approach.

In practical terms, some are easily discounted as they are proprietary tools run by consultancy services for paying customers, thus making them inaccessible in this research context. Similarly, open source is particularly important, or at least data and programming transparency, as it is important to understand how the mechanisms work and for this to be open to critique. Thus of the tools that take a spatial approach, the practicable shortlist consists of the *multiple benefits toolbox*, *Co$ting Nature* and *InVEST*.

Of these, the *multiple benefits toolbox* lends itself most readily to the criteria for this case study testing. In particular, informal contact with the development team behind the toolbox, and access to its code and development make it a versatile option.

4.1.1 CIRIA B£ST

A spreadsheet-based tool, this is based on the approach commonly used in governmental infrastructure appraisal, for example similar in approach to the department for transport web-based transport appraisal guidance (webTAG). It considers a range of potential benefits and the user ascribes relative weighting, specific to the appraisal timescale, and largely monetised values are drawn from a range of sources and applied to the project specific inputs to give a benefit cost ratio for a project.

Used in this way, *B£ST* is designed to allow either for the consideration of an investment into a SuDS project, or a comparison between potential options. *B£ST* acknowledges that the benefits of SuDS can go beyond the immediate water management functions and is also underpinned by the reality that in context a SuDS design can be part of a wider blue green approach.

Policy-wise this approach fits with a neoliberal investment context and is clearly designed within the existing infrastructure investment system operational in the UK. That is not to suppose that it does not have other roles or that it can't be applied elsewhere. The relative conservatism of the approach makes it excellent for using within this research project and makes it likely to be popular with conventional establishments such as major developers or local regional and national governance bodies.

This tool offers the capability to assess a range of value types, though only some of these were relevant to the context in which they are being tested for this research. Table 19 shows the full list of values it can calculate, and identifies those most relevant to *The Helix* context. Table 20 then shows a summary of the types of inputs, mechanisms for quantifying value, and output forms for each of these relevant value areas. These specific underlying mechanisms shape how the values are captured and quantified, and differ from the other tools, creating different results even for similar types of value.

However, it is not without its limitations. The data requirements involved for the inputs can be large. Some of the sections require technical knowledge, which might be available to an engineer designing a SuDS project, but that would not necessarily be known to a developer interested in understanding the potential green infrastructure value of a new project at the planning stage. Yet the functionality of the tool should ideally serve both these types of users. Likewise, some aspects of the inputs and calculations use proxy data, and are based on underlying assumptions around confidence and future inflation. While perfectly normal practice for infrastructure appraisal, these present knowledge barriers that make it harder for non-specialists to understand and interpret the results, and could lead to confusion or inaccurate results. Ultimately this can shake confidence and public perceptions of the value of green infrastructure as it is difficult to communicate uncertainty and nuance to a wide audience. Detail on the sources for input values within the tool, and information on some of the underlying assumptions and calculations can be found in the values library of the B£ST spreadsheet (CIRIA, 2016).

Full details on the inputs, source data, decision rationale, and other supplementary data is also shown in Appendix B. In this analysis, 100% confidence was used for the quantity and valuation of the green infrastructure assets being inputted into the tool. While this represents a higher degree of confidence that could be expected in a real world project, more accurate levels were difficult to accurately predict. Therefore it was judged that as the main use of the outputs would be to compare the scenarios, the confidence levels themselves were less important, so long as they were consistent between the different scenarios. It must be remembered when considering these outputs that they are likely to be higher values than an actual project of this type would likely deliver.

Table 19: Types of value that can be assessed using B£ST, and relevance to The Helix

Value type	Relevant to ***The Helix*?**	Rationale
Air quality	Yes	Relevant to the city centre location of The Helix, within an air quality management zone and adjacent to main roads.
Amenity	Yes	Relevant to the mixed residential/commercial use of the site, and its aim to have a unique sense of place. The site plans include extensive landscaping.
Biodiversity and ecology	No	Not an essential habitat location or designated site.
Building temperature	Yes	The site includes extensive green infrastructure, including trees, green roofs, and water bodies. It is in a built-up area and the planting will provide some shading to the buildings.
Carbon sequestration	Yes	The site plans include significant tree planting.
Education	No	Although there are university buildings on site, and it is a key resource for research, the values in B£ST are based only on nature-based school trips, which do not form a key part of the plans.
Flooding	Yes	The site is on a key route between the upper catchment and the River Tyne. Previous flood events have impacted the site.
Groundwater recharge	No	Not a particular priority for this location.

Value type	Relevant to *The Helix*?	Rationale
Health	Yes	The city centre location and the potentially large number of users of the site, along with its extensive tree planting and landscaping mean it will be a key opportunity for contact with nature among residents, workers and visitors. Active travel to and from the site (part of its sustainable travel goals) will also increase opportunities for physical activity.
Pumping	No	No additional wastewater pumping stations expected/planned.
Recreation	No	The green infrastructure will encourage casual outdoor recreation and physical activity. However, it is not primarily a leisure site. These benefits are already being counted under Health. Avoid double counting.
Rain water harvesting	No	No significant rainwater harvesting is planned.
Treating wastewater	No	The size and scale of the green infrastructure is not expected to have a significant impact on the quantity of wastewater being treated.
Water quality	No	There are no particular water quality concerns associated with the site.
Crime; Economic growth; Enabling development; Tourism; Traffic calming	*n/a*	*B£ST can include these values in its summary form if external evidence/other research has been done to supply the inputs. It cannot (yet) calculate these itself.*

(CIRIA, 2016)

Table 20: Input types, mechanisms used, and output types for values, used by B£ST

Value	Inputs	Mechanism for quantifying value	Output type
Air quality	Vegetated SuDS (excluding trees), area of coverage for • Green roof intensive • Green roof extensive • New basins (total incl. surrounding) • Area of other vegetative SuDS e.g. rain gardens, swales • Total contributing vegetative SuDS area Trees, number of trees • Small • Medium • Large • Note: size of species at maturity.	Vegetation pollutant removal levels (tonnes/year/ha) Tree pollutant removal levels from ranges (tonnes/year/tree): • SO_2 • NO_2 • O_3 • PM_{10} • CO	Net present value (NPV) (multi-year assessment, user defined time period; 3.5% discount rate)
Amenity	**Street improvements through greening** Estimated no. of residents living in green streets;	Quantified as £/resident/per month (Low, medium or high value chosen from value library depending on quantity and quality of greening, e.g. size of trees, and presence of other planting.)	Net present value (NPV) (multi-year assessment, user defined time

Value	Inputs	Mechanism for quantifying value	Output type
	Permanent body of water Estimated no. of homes overlooking ponds	Quantified as £/month/resident household (Low, medium, or high value chosen from value library)	period; 3.5% discount rate)
	Property price increase as a result of enhancements to parks Average house price, £ • Detached • Other houses • Flats City public park enhancement / Local public park enhancement / Public open green space enhancement: • No. of detached houses <450m from park • No. of other houses <450m from park • No. of flats <450m from park	Property price premium for each type of housing applied, (adjusted for local average house price for housing type) combined with proximity of housing type to enhanced parks.	Net present value (NPV) (One-off benefit for a specific year).
Building temperature	Green Roof Size for all buildings (m^2) Green Roof Size for buildings using air conditioning (m^2) Annual number of heating degree days (Degrees Celsius)	Energy saving to buildings through installing green roofs for heating (Kwh): • Energy savings through electricity • Energy savings through gas	Net present value (NPV) (multi-year assessment, user defined time period; 3.5% discount rate)

Value	Inputs	Mechanism for quantifying value	Output type
	Annual number of cooling degree days (if air conditioning is used) (Degrees Celsius) Proportion (%) of properties heated through electricity Proportion (%) of properties heated through gas	• Carbon Savings through not generating electricity over evaluation period • Carbon Savings through not generating gas over evaluation period Energy saving to buildings through installing green roofs for cooling (kwh): • Energy savings • Carbon Savings through not generating energy over evaluation period	
Carbon sequestration	Number of trees planted • Deciduous - Small • Deciduous - Medium • Deciduous - Large • Conifer - Large	Carbon sequestered, using estimated using values from Sacramento Municipal Utility District (2016), in tonnes; and present value of carbon.	Net present value (NPV) (multi-year assessment, user defined time period; 3.5% discount rate)
Flooding	Average annual damage (AAD) from flooding, to property and other damage	Converted to NPV for the total number of years in evaluation period	Net present value (NPV) (multi-year assessment, user defined time period; 3.5% discount rate)

Value	Inputs	Mechanism for quantifying value	Output type
Note: Flooding can also accept inputs from externally generated values, including: value based on willingness to pay; value calculated from Flooding Grant in Aid calculator; and, reduction in lost travel time.			
Health	**Impact of increased physical activity on avoided costs** Number of adults more physically active	Avoided local authority public health costs, £/person/year	Net present value (NPV) (multi-year assessment, user defined time period; 3.5% discount rate)
	Emotional wellbeing Estimated no. of adults having a view over green space from house Estimated no. of adults with freshwater or wetland within 1km of home Estimated no. of people using non-countryside green space monthly or more	Value of contact with nature, £/person/year	
Note: Health can also accept inputs from estimating the health benefits of walking or cycling, using the value of reduced mortality that results from specified amounts of walking or cycling; using the World Health Organisation HEAT tool to estimate the impact on physical health by increased walking and cycling (http://heatwalkingcycling.org/)			

(CIRIA, 2016)

4.1.2 GI-Val

This tool was born out of intensive research into the benefits and evidence for green infrastructure. The background research done in the initial stages of this project group and define the benefits of green infrastructure (Natural Economy Northwest, 2008). This evidence gathering is also used as the basis for the categories in this approach, which is a key strength of this tool.

The tool uses a calculator format with an Excel spreadsheet to allow user inputs on the projects and context. It houses its own values library based on other research (listed in a transparent fashion) and shows a series of outputs.

The outputs show a range of quantified benefits across ten areas of green infrastructure benefit, as well as producing a summary sheet of cost benefit ratio and one of all economic value. As with *B£ST*, this takes a quantified monetised approach, which fits with the policy and funding context most commonly found in the UK, Europe, and North America.

The *GI-Val* tool includes specific calculators across a range of value types, based on specific functions. The full list of value types and functions is shown in Table 21 and a summary of the specific value types used for *The Helix*, alongside each of the specific calculation tools, is shown in Table 22. These specific underlying mechanisms shape how the values are captured and quantified, and differ from the other tools, creating different results even for similar types of value. Full detail of all the tools used within GI-Val, and the input data and their sources are included in Appendix B.

Table 21: Value types and functions underpinning GI-Val

Value type	Key functions
Climate change adaptation & mitigation	Shelter from wind
	Reduction of urban heat island effect
	Cooling through shading and evapotranspiration
	Carbon storage and sequestration
Water management & flood alleviation	Interception, storage and infiltration of rainwater
Place & communities	Catalyst for community cohesion and pride
Health & wellbeing	Provision of attractive opportunities for exercise
	Stress and mental illness alleviation
	Healing time reduction
	Air pollution removal
Land and property values	Setting for higher value residential and commercial properties
Investment	Setting for inward investment
Labour productivity	Attraction and retention of high-quality staff
	Labour productivity improvement
	Reduction of absenteeism from work
Tourism	Tourism attraction
Recreation & leisure	Provision of recreation opportunities
Biodiversity	Provision, protection and enhancement of natural habitats
Land management	Production of food, timber and industrial crops
	Land management

(The Mersey Forest *et al.*, 2010)

Table 22: Value types, functions and tools within GI-Val, used for The Helix

Value groups	Functions	Tools	Inputs required
Climate change adaptation & mitigation	Reduction of urban heat island effect	Reduction of peak summer surface temperatures	Project area (ha) Total area of greenspace (ha)
	Cooling through shading and evapotranspiration	Reduced energy consumption for cooling	Net additional area of green roof % building(s) air conditioned Yearly air conditioning use
		Avoided carbon emissions from building energy saving for cooling	Calculated automatically from tool 1.5.
	Carbon storage and sequestration	Carbon stored and sequestered in woodland and forests	New trees planted (broadleaf/conifer)
Water management & flood alleviation	Interception, storage and infiltration of rainwater	Energy and carbon emissions savings from reduced stormwater volume entering combined sewers	Land cover; Annual rainfall
Place & communities	Catalyst for community cohesion and pride	Willingness to pay for a view of urban green space	Percentage of local households with a view of green space Number of local households with a view of green space
Health and wellbeing	Provision of attractive opportunities for exercise	Reduced mortality from increased walking and cycling	Number of households: within 300m; within 1200m; beyond 1200m Number of local residents within 300m; within >301 and <1200m; beyond 1200m Existing pedestrian/cycle routes; New pedestrian/cycle routes; Upgraded pedestrian/cycle routes Average number of trips per resident per year (split by within 300m; 301m - 1200m beyond 1200m.) Total trips per year for residents (split by within 300m; 301m – 1200m; beyond 1200m)

Value groups	Functions	Tools	Inputs required
Land and property values	Setting for higher value residential and commercial properties	Residential land and property values uplift	Potential number of properties benefiting New green space created (Of which high quality 'city park'/ quality 'local park') Green space enhanced (Of which high quality 'city park'/quality 'local park') Average property price % of properties with green space <450m currently and benefiting
Labour productivity	Reduction of absenteeism from work	Savings from reduced absenteeism from work	Number of workers encouraged to walk or cycle to work by green infrastructure scheme
Biodiversity	Provision, protection and enhancement of natural habitats	Willingness to pay for protection or enhancement of biodiversity	Total area of green space Area designated for nature and wildlife conservation: (local designation or similar; national designation or similar)
Land management	Land management	Employment supported by land management	Number of jobs created/safeguarded for management/maintenance of site

(The Mersey Forest *et al.*, 2010)

4.1.3 Multiple benefits toolbox

Many of the approaches for valuing green infrastructure are spatially based using assessment of the scope of green infrastructure, benefits and functions which is arguably more useful in terms of scoping a project or for evidence-based project planning, though perhaps does not address the business case for investment. This is a barrier to wider scale green infrastructure implementation.

The *multiple benefits toolbox* uses a spatial approach to both visually express the extent of green infrastructure benefit, but also to a certain extent quantify this. It does not provide objectively comparable results, as *B£ST* and *GI-Val* do, but it can be used to provide relative comparisons between different scenarios. The specific value types, the required inputs and the underlying mechanisms behind the tool are shown in Table 23. It is provided as a toolbox within the ArcGIS environment, but its mechanism is visible, and its programming is viewable, written in SQL and Python languages.

Table 23: Value types, inputs and mechanisms for the multiple benefits toolbox

Value type	Inputs required	Mechanism for calculating output
Access to Greenspace	Ordnance Survey (OS) MasterMap Topographical Layer OS Integrated Transport Network (ITN) Polyline Link Layer	The model takes the vegetated surfaces defined by OS MasterMap Topographical Layer; performs a cost distance calculation along the road network for two cases: For all areas of Greenspace larger than $50m^2$; and for areas greater than $500m^2$. Distances to area of greenspace between 50 m^2 and 500 m^2 are multiplied by two to recognise their reduced utility.
Air Pollution (PM_{10})	OS MasterMap Topographical Layer OS ITN Polyline Link Layer	The model assigns a PM_{10} concentrating to roads, depending on the road type. Euclidean Allocation is performed distributing the pollution based on distance from source. A percentage of the pollution from is removed for particular land cover types.
Carbon Sequestration	OS MasterMap Topographical Layer	The model selects the natural surfaces and assigns a sequestration rate depending on the surface.
Flooding	OS MasterMap Topographical Layer	Uses six different return periods. Identifies land use category from MasterMap. Each land use has its own

Value type	Inputs required	Mechanism for calculating output
	Point Data of building types The Return Period of Event 1 in years A raster of maximum flood depth for each cell during Event 1	depth damage curve. The damage from each return period is then use to calculate the annual risk of damage in £/m^2.
Habitat Size	OS MasterMap Topographical Layer	Identifies areas of greenspace from the MasterMap, that are connected, and then measures the total area of that habitat. The total area is assigned to each cell in the raster. Manmade surfaces and gardens are excluded.
Noise	OS MasterMap Topographical Layer OS ITN Polyline Link Layer A raster containing elevation data (Digital Terrain Map)	The model assigns a noise level to each road based on type. Noise is then distributed using a Cost Distance calculation. Noise is reduced by terrain, buildings, and vegetation.

Note: All of the benefit calculating functions also need a specified name and location for the output raster, and a raster to define the processing extent of the model.

(Blue-Green Cities, 2015)

4.1.4 Summary of tool critique

Each of these three tools will be used to assess the contribution to the green infrastructure network of two potential development scenarios at the regeneration site, *The Helix*. Comparisons will be made between each of the scenarios with the tools, and then also between each of the tools.

These comparisons will contribute to the critique of available appraisal approaches, and also will help the identification of potential stakeholders and benefits, as well as providing an illustration of the spatial and temporal extents of different benefits.

The identification of stakeholders and benefits is particularly relevant for the following stage of the project (see Chapter 6 and Chapter 7).

4.2 Evaluating the green infrastructure of *The Helix*

Case study testing of real, publicly available evaluation frameworks was conducted for two reasons. Firstly, to investigate whether any current evaluation approaches were 'fit for purpose' for good quality green infrastructure appraisal at the city- or sub-city scale. Secondly, in order to explore the spatial extent of the benefits and disbenefits of green infrastructure, and to understand whether there was an ideal quantity or spacing of green infrastructure assets within a network to realise optimum benefit. The two development scenarios for *The Helix*, detailed in Chapter 3, section 3.3.4, were used to generate the inputs for each of the appraisal tools. Some of the inputs remained static between scenarios (e.g. size of local population), while others changed according to the green infrastructure development (e.g. number of trees). Full details of the inputs used for each scenario and appraisal tool are included in Appendix B. A notable omission from *B£ST* and the *multiple benefits toolbox* is the calculation of flood value, due to lack of the necessary input data.

Although detailed flood modelling has been conducted for the two scenarios (see Chapter 3, section 3.3.5), completing these flood models requires specialist software and skills. The purpose of this test of appraisal tools is in order to understand their use for a broad range of potential green infrastructure stakeholders, including, for example, community-level partners and not for profit groups, as well as more traditional engineering and infrastructure providers. The focus therefore has been to complete as much of the appraisal as possible with data that might be readily available to all of the potential users. For example, census data are available online, site characteristics should be discoverable by a stakeholder with some involvement. For the purposes of representing this range of stakeholder specialism, the detailed flood damages inputs have been omitted from this appraisal work. For *GI-Val*, which calculates some flood impact from characteristics of the amount and size of green infrastructure features, flood impact results are included.

Once these initial scenarios were tested, comparisons between the different evaluation approaches were made. In addition, it was possible to look at the relationship between the scale of a green infrastructure network and the resultant scale of benefit, and whether this relationship was linear, and if there was a 'critical mass' that will bring maximum benefit. Conversely it was also considered whether there was a limit where marginal gains became insignificant.

4.2.1 Appraisal using B£ST

4.2.1.1 Scenario 1: High levels of green infrastructure

Four of the benefit areas available within *B£ST* were practicable and usable within the scope of this project: amenity; air quality; building temperature; and health. Potential double counting was flagged between amenity and health, and between building temperature and health. However, further review of these suggested no issue of combining building temperature and health. There is potential overlap between the element of amenity value that comes from street greening, and the health benefits. This component of the amenity value was omitted, to avoid double counting the benefit.

A notable omission from the appraisal is flood value, due to not having the average annual damage figures available as an input for the site.

Already the context is shaping the type of appraisal possible, and which elements of potential benefit are included and therefore what can be realised in terms of potential value. Other values may be applicable in terms of matching potential stakeholders with the benefits that are relevant to them. However, a limitation of this type of appraisal is that access to the relevant input information is essential to be able to calculate outputs. The value of the potential benefits of Scenario 1 are shown in Table 24.

Health benefits provide the greatest value in this scenario, forming around half of the total economic benefit. This reflects the wellbeing and physical health benefits of green infrastructure, but is also very large due to the differing nature of the types of monetised benefit available. Health includes elements such as increased walking and cycling, which can then be monetised through using value of statistical life. As an economic measure, this can create very high outputs, as human life is valued very highly. However, the different underlying ideology between this and, for example, the energy savings from regulating building temperature, means that the scale of benefit is wildly different between different assets.

Table 24: Estimated value of 'The Helix' Scenario 1, using B£ST

Value type	**Estimated value (NPV, £)**
Air quality	£29,410
Amenity	£746,243
Building temperature	£133,411
Carbon reduction	£8,271
Carbon sequestration	£4,212
Health	£1,896,193
Total	**£2,817,740**

This is a challenge in any economic assessment and not specific to *B£ST*. Due to the difficulty in comparing the benefits across types, some of the more interesting comparisons can instead be made for the same type of benefit between differing scenarios. This is discussed further in section 5.4.

4.2.1.2 Scenario 2: Lower levels of green infrastructure

As with the appraisal of Scenario 1, the appraisal using *B£ST* shows vastly different levels of value for the different types of benefit, see Table 25. Again this is partly due to differing methodology and underlying mechanisms for value.

The highest benefit area for Scenario 2 is the amenity value. This aligns with the potential criticism that light-touch greening has little effective delivery of any benefits other than being decorative in nature. While amenity value is a valid benefit, it is difficult to match this to stakeholders willing to pay for it. It does not provide as broad a range of benefits, nor is it as easy to monetise this value as it might for something like an avoided cost (such as through flood damage or building heating costs).

Table 25: Estimated value of 'The Helix' Scenario 2, using B£ST

Value type	**Estimated value (NPV, £)**
Air quality	£10,734
Amenity	£734,276
Building temperature	£30,554
Carbon reduction	£1,882
Carbon sequestration	£1,028
Health	£574,443
Total	**£1,352,918**

4.2.2 Appraisal using GI-Val

4.2.2.1 Scenario 1: High levels of green infrastructure

The scenario appraisal using *GI-Val* shows that the main areas of benefit that can be easily realised are land and property values, and health and wellbeing, shown in Table 26. Other areas where monetised benefits are attributed include climate change adaptation and mitigation, labour productivity and biodiversity.

The user guidance for *GI-Val* is clear that the gross value added (GVA), land and property value, and other economic values should not be summed to a total value as they are too different to be grouped as like values.

Table 26: Estimated value of 'The Helix' Scenario 1, using GI-Val

Value type	**GVA value**	**Land and property value**	**Other economic value**
Climate Change Adaptation & Mitigation	£190,383	n.a.	£7,335
Water Management & Flood Alleviation	£377	n.a.	n.a.
Health & Wellbeing	£179	n.a.	£3,079,270
Land & Property Values	n.a.	£17,295,925	n.a.
Labour Productivity	£630,146	n.a.	n.a.
Biodiversity	n.a.	n.a.	£1
Land Management	£46,245	n.a.	n.a.
Total economic value of benefits	**£867,328**	**£17,295,925**	**£3,086,605**

Note: These three figures should not be added together, as they represent different kinds of value.

These outputs show that the biggest monetised values are not necessarily related to the most contextually relevant of the benefits, in terms of project aims when developing the green infrastructure network. Instead what these figures are primarily showing is that the scale of potential benefit is much larger in view of land values and health. The underlying economic mechanisms behind this type of appraisal ascribe more value to these benefit areas than to, say, flood damage estimates for example.

This makes it incredibly difficult to make meaningful comparisons between the different types of potential value, though within values, differences between scenarios or sites can be seen. This is reflective of a wider problem common to all types of monetised appraisal, in that certain commodities or assets are valued on different scales than others.

4.2.2.2 Scenario 2: Lower levels of green infrastructure

The appraisal for Scenario 2 using *GI-Val* shows large values for health and wellbeing, and land and property value benefit areas, shown in Table 27. Again, this is a reflection of the larger scales of figures available for these types of benefit in the underpinning methodology and is not necessarily a good representation of the context of the site itself. This is a limitation of this type of cross-cutting monetised appraisal.

Health in particular has a high value, which is linked to the fact that value is in part calculated through the statistical value of human life, which returns high values as human life is in turn highly valued.

Table 27: Estimated value of 'The Helix' Scenario 2, using GI-Val

Value type	GVA value	Land and property value	Other economic value
Climate Change Adaptation & Mitigation	£43,424	n.a.	£1,662
Water Management & Flood Alleviation	£153	n.a.	n.a.
Health & Well-being	£41	n.a.	£3,079,270
Land & Property Values	n.a.	£17,295,925	n.a.
Labour Productivity	£630,146	n.a.	n.a.
Biodiversity	n.a.	n.a.	£0
Land Management	£46,245	n.a.	n.a.
Total economic value of benefits	**£720,008**	**£17,295,925**	**£3,080,932**

Note: These three figures should not be added together, as they represent different kinds of value

4.2.3 Appraisal using multiple benefits toolbox

4.2.3.1 Scenario 1: High levels of green infrastructure

The *multiple benefits toolbox* is an ArcGIS toolbox, which uses spatial analysis to assess the extent of benefits for green infrastructure. In theory, it also allows these to then be combined into a multiple-benefit analysis. However, partly due to it being an unsupported proof of concept, rather than a supported tool, its use was problematic.

The output maps for some of the potential benefit areas are shown in Appendix B (Figure 55 to Figure 58). As with *B£ST*, a notable omission is the calculation of flood benefit, as the return period data and flood extent was not known.

Habitat size (Figure 55), shows that the larger an area of green open space, the more suitable it is as a habitat. A lot of the open space within *The Helix* site is adequate to create habitat, according to this appraisal. Other significant areas of habitat within the city include the Town Moors. However, the appraisal tool is arguably overly simplified, as it highlights the large green space of the football pitch at St James' Park as a key habitat site, which is arguably untrue given its highly managed characteristics and the lack of free access to the site for fauna.

Access to green space (Figure 56), shows the relationship between green areas and also key access roads. This is quite a simplistic assessment, and has no way of accounting for the quality of green space, nor any potential access limitations (such as private gardens versus public parks).

The assessment of air pollution (PM_{10}), is based on the combination of road types (using average air pollution rates for the type of roads) and the prevalence of green space for reduction of air pollution (Figure 57). However, this only shows the broad pattern of roads, and it is difficult to discern whether any of the green space provides relief from this air pollution. As discussed in the literature review, there is also a limit to the air filtering properties of different types of planting, with some road planting also worsening the impact of air pollution. The toolbox is not designed to include this type of detail in its assessment.

Carbon sequestration (Figure 58) shows the areas of green space that are able to provide this. Within the city area, most of this benefit is coming from the larger green space of the Town Moors. However, within *The Helix* site, there is an impact from tree planting – although this is subject to a time lag, as it relies on the trees planted being appropriately managed and reaching maturity.

4.2.3.2 Scenario 2: Lower levels of green infrastructure

Appraisal of Scenario 2 using the *multiple benefits toolbox* in ArcGIS produced four output areas, which are included in Appendix B. The habitat size (Figure 59) shows some provision of new habitat space within *The Helix* site. However, this does not link to the other key habitat areas within the city, nor does it extend beyond the site in any way.

Access to greenspace (Figure 60), merely demonstrates the link between open space areas and key roads. As with Scenario 1, it does not account for any difference in accessibility due to ownership issues. The greenspace within *The Helix* site seems to have little impact on the overall city-wide access to green space.

Air pollution (Figure 61), uses road traffic base averages to estimate air pollution. The greening of *The Helix* in this scenario seems to have little impact on the overall air pollution for the city.

Figure 62 shows that there is a small but limited impact of Scenario 2 on the carbon sequestration at *The Helix*. This effect comes from the tree planting at the site, so will be slow to be realised given the time lag needed for the trees to mature.

4.3 Discussion

The purpose of the tools critique and testing using simulated data was to critique the existing evaluation approaches for green infrastructure and to identify how these can create opportunities and barriers for finance and funding. In this section, comparisons are made between the scenarios, to explore the impact of extent and scale of green infrastructure; and between the tools to explore strengths and weaknesses of these existing approaches. Finally, the overall conclusions of how these elements work together and what can be learned about green infrastructure delivery opportunities are considered.

A comparison of the level of green features for the two green infrastructure scenarios at *The Helix* are shown in Table 28, and the difference between the high and low green infrastructure levels are illustrated on the difference map, Figure 29.

There is almost twice as much green space in the high green infrastructure scenario (Scenario 1) than there is in the low green infrastructure scenario (Scenario 2).

Table 28: Comparison of green features at 'The Helix' for scenarios 1 and 2

Green features:	Scenario 1	Scenario 2	Difference
trees (number)	493	246	247
tree canopy (m^2)	3,485	772	2,713
Retention (m^2)	968	-	968
Detention (m^2)	1,849	1,849	0
Green roof (m^2)	13,392	3,001	10,391
Rain garden (m^2)	1,778	1,297	481
Swale (m^2)	687	518	169
Green space (other) (m^2)	14,073	12,953	1,120
Total green space (m^2)	**36,232**	**20,390**	**15,842**

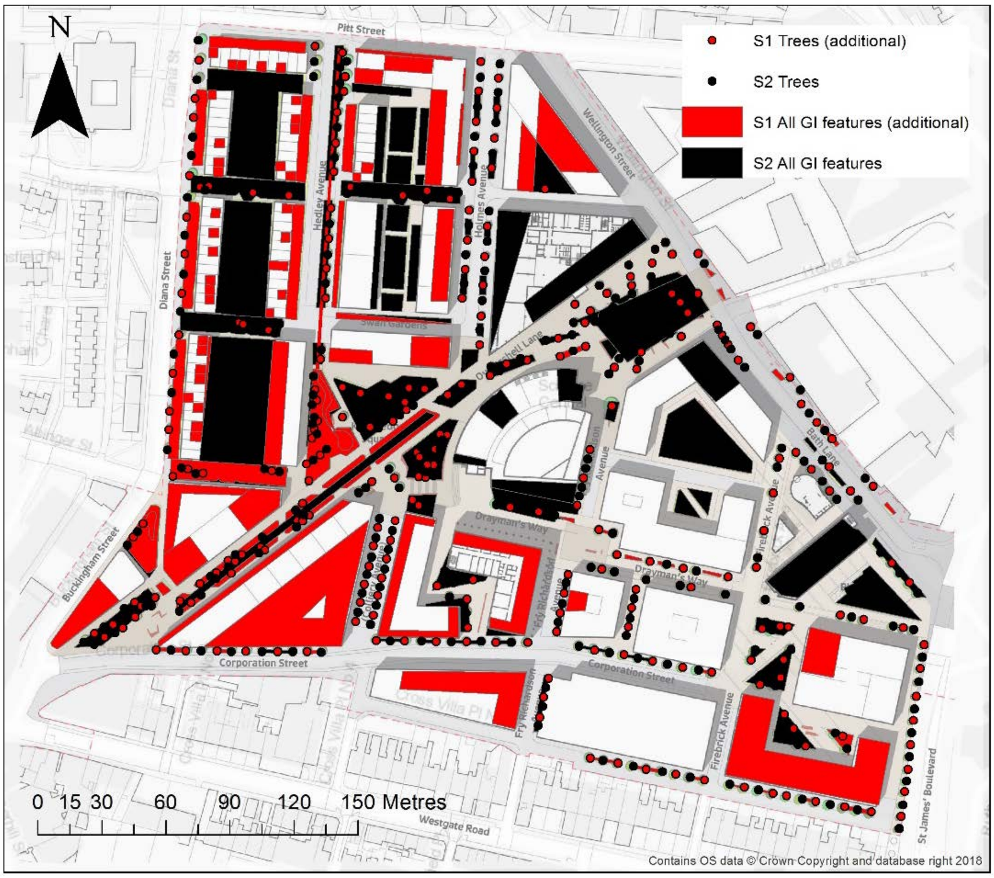


Figure 29: Difference map, highlighting additional green infrastructure from Scenario 1 to Scenario 2

Particularly notable is that not only are there twice as many trees planted in Scenario 1, but these also are assumed to be managed better and given more space to grow, thus there is a more significant tree canopy cover in Scenario 1 (albeit with a time lag for trees to reach maturity).

There is also an assumption of more functionality in the green infrastructure features in Scenario 1 than in Scenario 2. For example, Scenario 1 includes retention basins, and has more rain gardens and more swales. This means that as well as having more green features, this scenario has potential for greater capacity and effectiveness.

4.3.1 Comparison of scenarios: using quantitative approaches

Comparing the results of the two scenarios with the different appraisal tools shows an interesting relationship between the input and output values. Table 29 summarises the differences in green infrastructure benefits between the two scenarios when they are compared using *B£ST*. The difference in green infrastructure inputs for the scenarios shows a relationship where Scenario 2 has approximately half the amount of green infrastructure of Scenario 1, but this relationship is not obviously reflected in the outputs of the appraisal. Likewise, the outputs from *GI-Val* show an uneven relationship between Scenarios 1 and 2, shown in Table 30 (output values by benefit type) and Table 31 (outputs summarised by value type). The scale of green infrastructure inputs is not obviously reflected in the outputs.

In order to explore this unclear relationship further, sensitivity testing was conducted to illustrate the relationship between inputs and outputs in more detail. This sensitivity testing used the Scenario 1 inputs and outputs as a baseline for each tool, and then compared this with two extreme alternative inputs. The first used one tenth the quantity of green infrastructure as its inputs, while the second used ten times the inputs. These extremes were not designed to be realistic in terms of practical delivery, although the total area of any single green infrastructure asset was capped at 10ha, as this was the total size of the whole site. All of the input data regarding the site size, population and housing type remained the same, including the extent of new walking and cycling routes.

Table 29: B£ST results comparison for 'The Helix' scenarios 1 and 2

Value type	**S1: Estimated value (NPV, £)**	**S2: Estimated value (NPV, £)**	**Difference (£/%)**	
Air quality	29,410	10,734	18,676	36%
Amenity	746,243	734,276	11,967	98%
Building temperature	133,411	30,554	102,856	23%
Carbon reduction	8,271	1,882	6,389	23%
Carbon sequestration	4,212	1,028	3,184	24%
Health	1,896,193	574,443	1,321,750	30%
Total	**2,817,740**	**1,352,918**	**1,464,822**	**48%**

Table 30: Results comparison for 'The Helix' scenarios 1 and 2, using GI-Val, by benefit type

Value type		**Scenario 1**	**Scenario 2**	**Difference**
Climate Change Adaptation & Mitigation	GVA value	£190,383	£43,424	£146,959
	Other economic value	£7,335	£1,662	£5,673
Water management & Flood Alleviation	GVA value	£377	£153	£224
Health & Wellbeing	GVA value	£179	£41	£138
	Other economic value	*no difference*	*no difference*	n.a.
Total economic value of benefits	GVA value	£867,328	£720,008	£147,320
	Other economic value	£3,086,605	£3,080,932	£5,673

Table 31: Results comparison for 'The Helix' scenarios 1 and 2 using GI-Val

Type of value expression	Scenario 1	Scenario 2	Difference (£/%)	
GVA value	£867,328	£720,008	£147,320	83%
Land and property value	£17,295,925	£17,295,925	£0	100%
Other economic value	£3,086,605	£3,080,932	£5,673	99.8%

The scale of difference in outputs from this sensitivity testing for *B£ST* is show in Table 32 and for *GI-Val* in Table 33. Note that neither includes the total values, but only those by benefit type. This is because the detail sought in the sensitivity testing is not apparent in the totals.

Table 32: Sensitivity testing for B£ST

Value type	Baseline: Scenario 1	Test 1 (1/10th)	Test 2 (x10)	Difference	
	£	£	£	Test 1	Test 2
Air quality	29,410	2,658	255,160	9%	868%
Building temperature	133,411	13,341	1,018,141	10%	763%
Carbon reduction and sequestration	12,482	1,192	99,236	10%	795%
Amenity	746,243	746,243	746,243	100%	100%
Health	1,896,193	1,896,193	1,896,193	100%	100%

For some of the benefit types, there is no difference in output values between the extremes tested, this is reflecting that the value is reached through the inputs of households, businesses, target population, and other factors based on the beneficiaries, with the green infrastructure having little relevance other than a binary yes/no regarding its existence. This is the case for land management, labour productivity, land and property values, and some of the health and wellbeing benefit (that based on non-GVA values), for *GI-Val*. For *B£ST* the unaffected benefits are amenity and health, for the same reasons. The quantity and quality of the green infrastructure is not relevant for these factors, rather the target population of beneficiaries creates these benefits, with the green infrastructure simply existing.

Some of the benefits in both accurately reflect the extreme scales of the sensitivity test. The biodiversity and some health benefits (those based on GVA) from *GI-Val* perfectly reflect the 10%:1000% scale of the change in inputs. Likewise, the other benefits also reflect a similar scale. Here the relationship is not exactly aligned, but it accurately reflects the scale of the inputs. This suggests that where benefits are directly related to the amount of green infrastructure assets in the inputs, the relationship between input and output is broadly linear.

Table 33: Sensitivity testing for GI-Val

Value type		**Difference compared to baseline (Scenario 1)**	
		Test 1 (1/10th)	Test 2 (x10)
Climate Change Adaptation & Mitigation	GVA	16%	861%
	Other economic value	14%	913%
Water Management and Flood Alleviation	GVA	9%	266%
Health & Wellbeing	GVA	10%	1000%
	Other economic value	100%	100%
Land & Property Values	Land and property value	100%	100%
Labour Productivity	GVA	100%	100%
Biodiversity	Other economic value	10%	1000%
Land Management	GVA	100%	100%

4.3.2 Comparison of scenarios: using spatial approaches

Figure 30 to Figure 33 show the difference in habitat, access to greenspace, air pollution, and carbon sequestration, measured using the *multiple benefits toolbox*. Access to greenspace is slightly higher in Scenario 1 than 2, reflecting the additional amounts of green infrastructure in that scenario. Similarly, the greater quantity and size of (matured) trees in Scenario 1 has a visible impact on the carbon sequestration potential between the scenarios. Habitat is likewise greater in Scenario 1 than 2. Air pollution, however, shows no discernible difference – suggesting that the difference in green space between the two scenarios is not great enough to have an impact on this more indirect benefit

Understanding the spatial implications of a green infrastructure network, and its relation to other environmental systems (such as a river catchment) as well as the wider built environment (both its layout, and its other infrastructure systems) is essential for effective green infrastructure delivery. As such, a spatial appraisal of the network and its interactions is needed. Ideally, data can be presented simultaneously on the interdependencies of green infrastructure, its benefits, the stakeholders, and other urban features and infrastructures. However, no single tool seems able to capture and present all of this information currently. Flood modelling is useful to understand the impact of green infrastructure scenarios on surface water flooding, but this is just one of many potential benefits. The *multiple benefits toolbox* attempts to capture and quantify a range green infrastructure benefits through spatial analysis, but it is merely a prototype tool, and is already outdated. The results are insightful but not comprehensive, and the tool is impractical for long term use. Overall, while the results from these spatial approaches are illustrative and provide interesting insight into the potential role of green infrastructure at a city or neighbourhood scale, neither is effective on its own for providing a comprehensive understanding of the value of potential green infrastructure benefits.

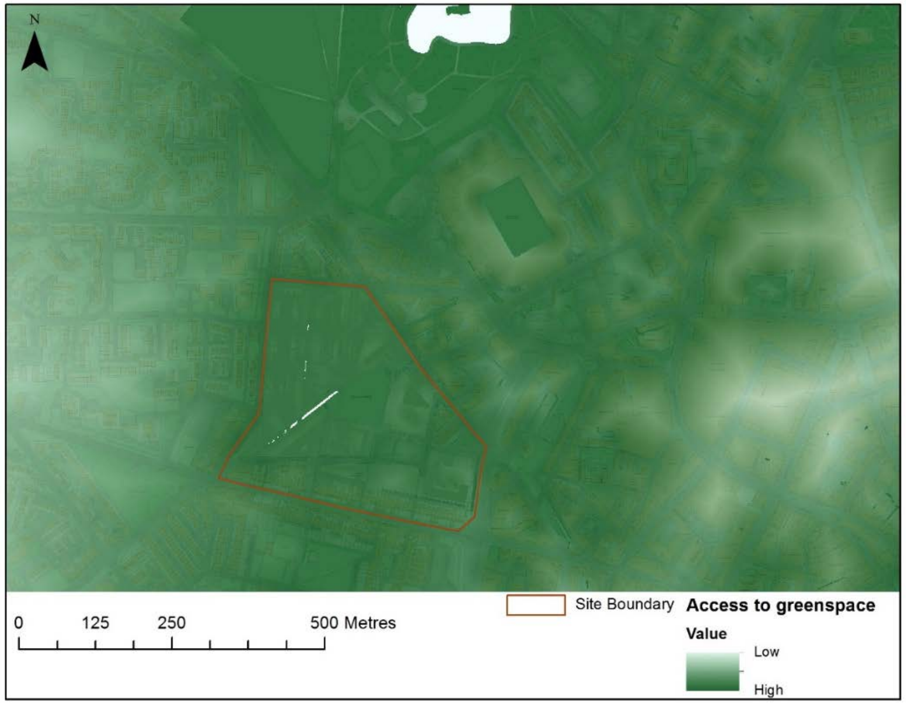
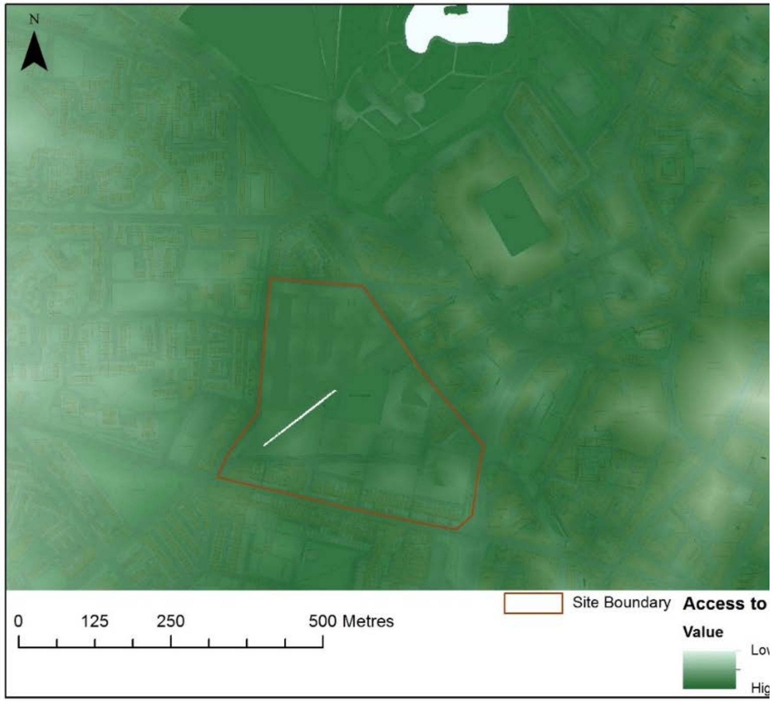
	Scenario 1	Scenario 2
Access to greenspace		

Figure 30: comparison of access to greenspace benefits between scenarios 1 and 2

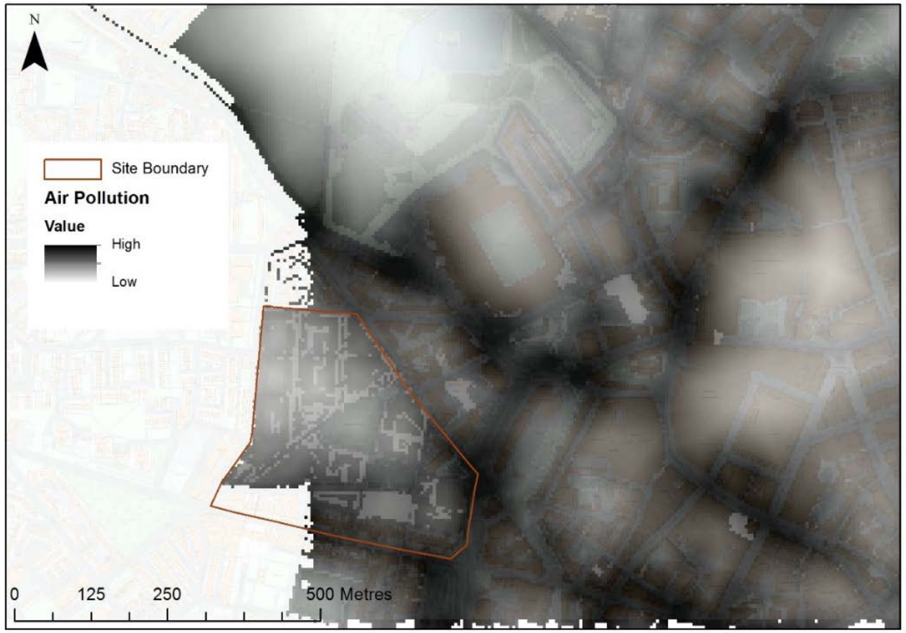
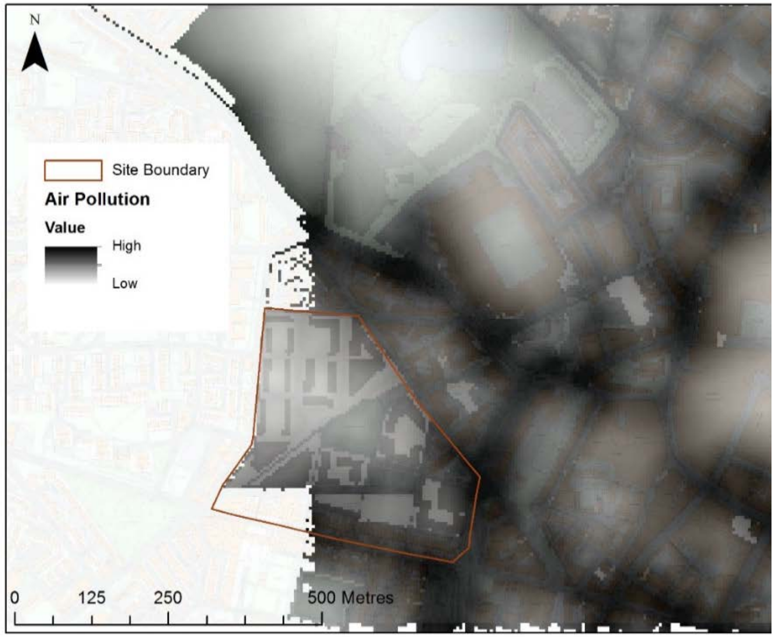
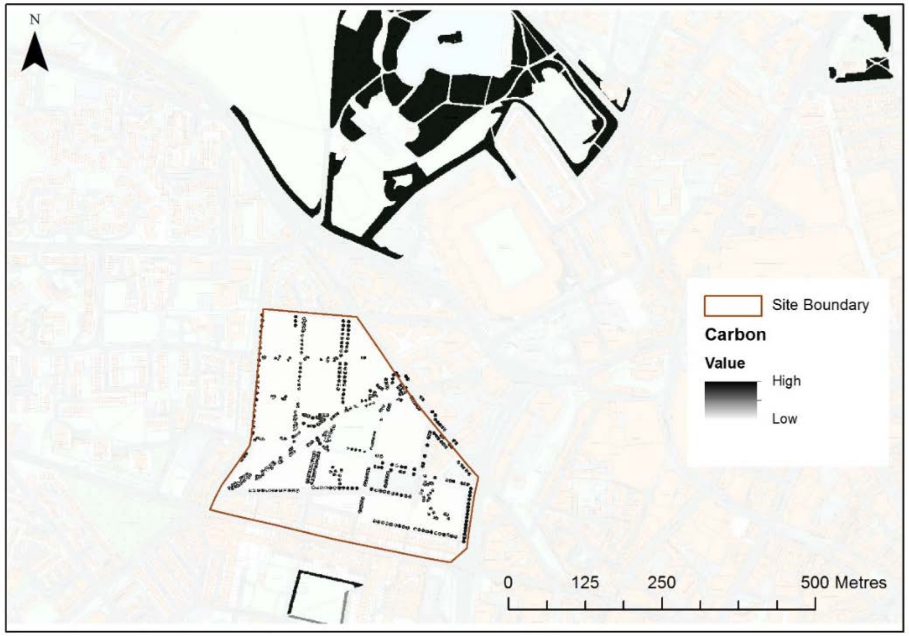
	Scenario 1	**Scenario 2**
Air pollution		

Figure 31: comparison of air pollution benefits between scenarios 1 and 2

Carbon sequestration

Scenario 1



Scenario 2

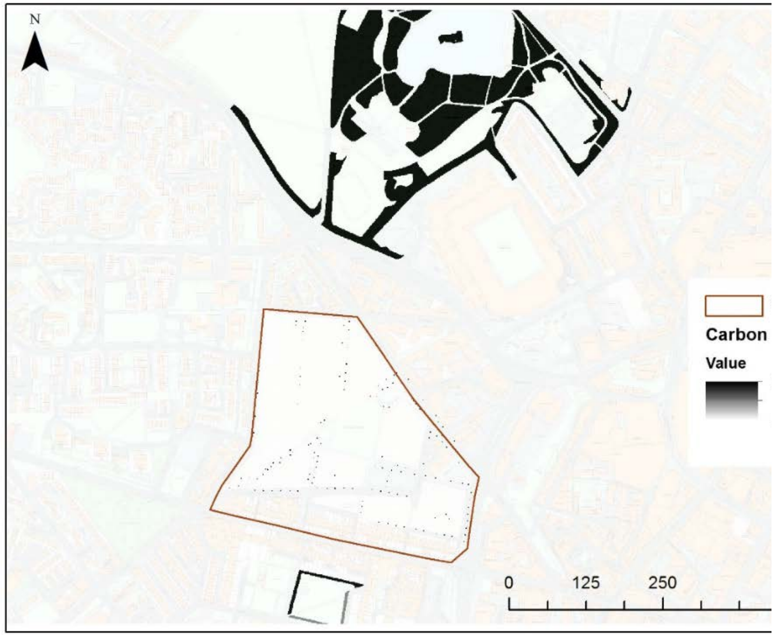


Figure 32: comparison of carbon sequestration benefits between scenarios 1 and 2

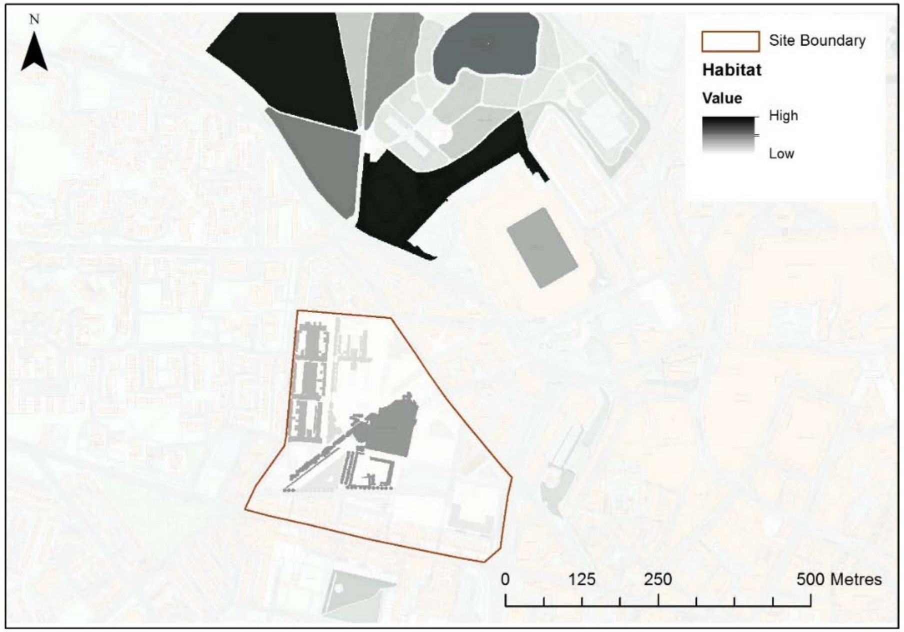
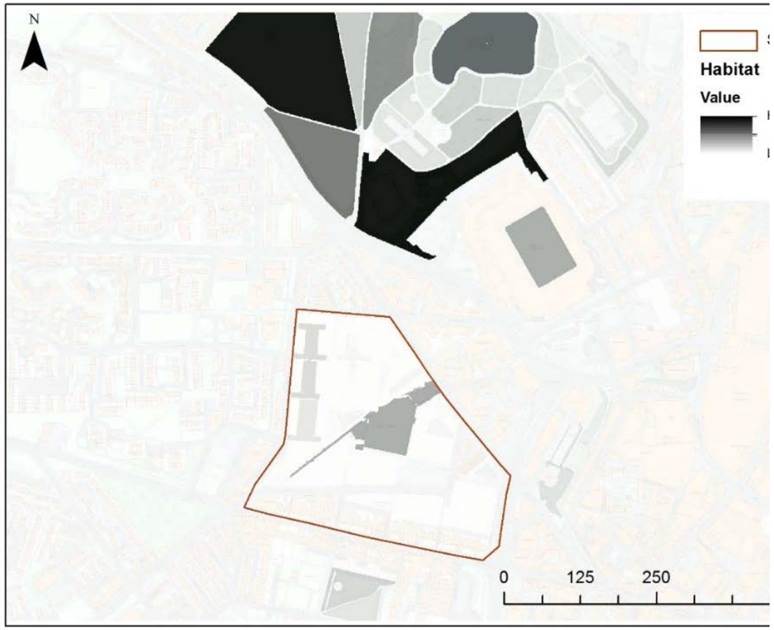
	Scenario 1	Scenario 2
Habitat		

Figure 33: comparison of habitat benefits between scenarios 1 and 2

4.3.3 Comparison of tools: based on practical use

This section of the chapter compares the results for each type of tool between Scenarios 1 and 2, and also assesses the relative merits of each of the tools themselves.

Each of these tools allows for the presentation of data on the benefits of green infrastructure and its value to a wider audience; particularly one whose interests may not be affected by the ideology that green infrastructure is inherently beneficial. All three tools allow for the synthesis and display of complex information into a more condensed form. They enable the comparison of green infrastructure benefits with costs and allow a wider audience to see and understand the potential benefit which is a valuable first step towards enabling it to be used as a valid infrastructure option like any other engineering solution. However, as with any evaluation where complexity is simplified, it must be done with caution to avoid misinformation, and with good intent to get realistic information from it.

GI-Val and *B£ST* have similar approaches and are best for making economic assessments, similar to other types of infrastructure appraisal. The mechanisms of each tool are similar, and they share many of the same underlying values in their method of calculation. The differences between the tools are significant enough to give different output values, however, as long as the mechanisms and calculations are understood to be imperfect, and to have limitations, it is difficult to argue that either one produces 'better' outputs than the other. In order to select one tool to use, the decision must be made instead regarding practical values like the ability to find and calculate relevant inputs. Due to its establishment in industry and the availability of CIRIA for continued support and development, *B£ST* is likely to be the tool that continues to grow and be used more widely, especially if it continues to be developed to meet the changing needs of users and their interests.

However, for the purposes of assessing value across a wider network and at a whole city scale, both these tools are limited by their (current) inability to handle spatial data. And they cannot easily present or highlight stakeholder interests that form out of spatial proximity rather than from thematic overlap. Thus these quantitative tools are useful, but would be best used alongside spatial presentation of data, to maximise the understanding of the green infrastructure network and its opportunities and challenges for delivery.

That said, finding an effective spatial tool is difficult. Many of them are proprietary tools or require high level skills in GIS and analysis of spatial data, making them inaccessible to a wider audience. Some of them also focus on asset management and project planning and lack the evaluation focus needed for this type of infrastructure appraisal.

The *multiple benefits toolbox* used in this analysis has produced some interesting spatial analysis of the benefits of green infrastructure, including the surrounding areas beyond the immediate project focus. However, it was a proof of concept output from a research project, and not designed to be a functional and supported analysis tool in the long-term. There are limitations in its functionality, and not all of the available input data is easily compatible with the formats required, leading to further data cleaning and adjustments of the programming of the tool itself to cope with changes in the taxonomy of the input data. The output maps are interesting, but are limited to showing single benefits, with the functionality of the multiple benefits analysis largely not working. They also reflect only relatively simple relationships from limited inputs, so for example pollution is drawn from proximity to roads, and the relative impact of green space is not very nuanced. Further research into the relationships between the proximity to green space and air pollution could help to model this relationship more accurately, but this would be a significant undertaking and is outside the scope of the current tool. The maps provide interesting outputs that are an excellent summary of areas of influence of a green infrastructure network and can be a useful contribution to the wider discussion, but by themselves are not sufficient to provide detailed analysis of the impact of an existing or proposed green infrastructure scheme.

The future development plans for *B£ST* include developing spatial analysis (CIRIA, 2018). Before this functionality is available, assessing in some way how the spatial distribution of green infrastructure delivery and potential value related to the area is essential, even if this is relatively basic and done manually. This allows for a more detailed understanding of the stakeholder-value relationship and can highlight opportunities and challenges that a quantitative and thematic approach alone may miss. This interaction of stakeholders with value is explored further in Chapter 6.

One of the key limitations of the quantitative tools used is the variable influence of the quantity and quality of green infrastructure inputs on the output values. Anyone looking merely for a return on investment for a new development can be focused simply on the binary nature of there being green space in existence, and the emphasis on the suitability and quality of any particular asset is lost. From the literature it is clear that not all green space functions as green infrastructure and that an effective network is necessary to maximise the potential benefits, yet this is not accounted for in some aspects of the appraisal tools. The existence of a feature as a binary yes/no descriptor at the most basic level is all that is needed to get large values from the appraisal tools where land prices and some health measures are used. The quantity of green infrastructure is a factor for some of the benefit areas (like biodiversity), but at no point is there a way of accounting for the quality or connectedness of the green infrastructure as part of an effective infrastructure system. Use of any of these appraisal tools without regard for these limitations and the wider delivery context is likely to incentivise poor quality green infrastructure development, and leaves developments open to 'greenwashing' – that is, using basic non-functional green features to gain reputational benefit, but that are not effective as (part of) a green infrastructure network.

4.3.4 Lessons learned for green infrastructure appraisal

Critiquing, shortlisting and testing some of the available green infrastructure appraisal tools against realistic simulated data highlighted some of the particular strengths and weaknesses of the current methods for capturing and quantifying green infrastructure value.

4.3.4.1 Non-linear relationships in value functions

Testing the scenarios allowed an exploration of the relationship between the scale of green infrastructure and the scale of the resultant benefits. The relationship was not straightforward. Some of the benefits had a broadly linear relationship between the inputs and outputs, whereas others were affected more by the size of the beneficiary population or the buildings and land use types involved. There is no apparent 'critical mass' of green infrastructure needed to generate benefits nor is there a maximum threshold at which marginal gains are negligible. However, common sense reflection of the practicalities of creating a green infrastructure network, supported by the literature on benefits and disbenefits, suggests that this is unlikely to be an accurate reflection of reality. An isolated tree in the middle of a regeneration project may contribute a lot to the appraisal value, if it is in a densely populated area where many beneficiaries will have sight of the tree and therefore gain wellbeing or amenity benefits from it. Yet this is not going to contribute much beyond the site and will have little impact on other benefit areas like biodiversity. Yet due to the underlying principles of economic valuation, and the priority given to human health and life over that of other species, the economic value of the wellbeing and amenity will be much greater than any benefit created for biodiversity by a wider network.

4.3.4.2 Issues of scale: peak value, disbenefits, and minimum/maximum thresholds

When the sensitivity tests included an unrealistically high coverage of green infrastructure, there was no scope within the appraisal tools to reflect any increase in disbenefits. The quantity of around 4,930 trees used for the extreme increase test, test 2, would be unlikely to fit within the site bounds, and the basic function of the site as a mixed residential and commercial site would be lost if it instead became a dense forest. A truly effective appraisal tool would ideally include some element of threshold limits, but such input data are hard to find. The quantity of green infrastructure that would fit on one site compared to another is often contextual and would vary depending on the type of green infrastructure assets used and the other functions of the site. This makes it virtually impossible to include this variable in a tool that has been simplified sufficiently to be useful for general appraisal, and so is a limitation of this type of quantitative evaluation generally, rather than of any of these tools specifically.

4.3.4.3 Usability and practicability

Care must therefore be taken to ensure that appraisal tools are used as a support for development and a source of opportunities but are not solely relied on to illustrate the need for, or benefit of, a comprehensive system of green infrastructure. The challenge in evaluation and appraisal is always trying to balance the need for usable inputs and outputs, while still capturing the essential information to accurately represent the thing that is being evaluated. Finding a tool to simplify reality into a meaningful conversation that still allows the capture of nuance and subtlety is difficult – perhaps even impossible. Thus, creating an effective evaluation of green infrastructure is inevitably an ongoing process and will be supported by ongoing improvements in understanding benefits and how these can be quantified.

The use of metrics in the case of green infrastructure appraisal is inconsistent, depending on the metrics and modelling available as inputs. Previous work has developed extensive modelling for some values, meaning the tools can calculate benefit from very simple inputs (for example, translating the number of trees into air quality), whereas others require specialist expertise and expensive computational load to create the inputs (for example, detailed flood modelling to calculate average annual damages for the site). This differing level of complexity and expertise in generating the necessary inputs is a particular barrier. In this project, illustrative flood modelling was done to show flood depths of the site under different scenarios, but this has not been developed further into a full damages assessment. This demonstrates both this barrier to use, and the fact that there is a range in how accessible the tools can be for different value types.

4.3.4.4 Connectivity and interactions beyond the site

Another limitation of the tools, especially the quantitative ones, was the inability to appreciate the value of the green infrastructure development of one site in relation to the wider area. The connectivity of green infrastructure is one of its key defining features (see Chapter 2, section 2.1), yet there is little ability to understand how the simulated green infrastructure at *The Helix* might contribute to the wider green infrastructure network for the city as a whole. As with the consideration of flooding in the context of the wider catchment, so the green infrastructure is only effective if it connects with the wider city area. The *multiple benefits toolbox* allowed for some understanding of its setting with the surrounding area, but even this could not effectively illustrate any required distances between assets in order to ensure they are linked. The role of the network as a system in and of itself is unknown and unexplored by any of the current appraisal tools, yet it is in this that green infrastructure is defined and where it is likely to have most potential benefit.

For building green infrastructure, it is easier to create individual assets than to make a strategic network. Likewise it is easier to measure individual assets than a network.

Yet in order to function as a form of infrastructure, it does need to be a connected network.

4.3.4.5 Opportunities for value capture

Despite these limitations – problems common to many evaluations, not just those of green infrastructure – there are many opportunities to identify value using these tools, and ways in which the tools can provide information of relevance to different stakeholders, and to inspire and inform innovative business models for green infrastructure delivery.

4.4 Chapter conclusion

This chapter addressed Objective 2 and its research questions, to understand the value of green infrastructure.

4.4.1 What is the value of green infrastructure?

The value of a green infrastructure system relies on its use to human society, and the way different stakeholders use and appreciate various potential benefits will vary according to their own interests and ideology. It is from these potential benefits and values that new finance and funding options and innovative business models can be identified.

4.4.2 How is value captured, quantified, and used?

In this chapter, existing approaches of identifying and quantifying potential green infrastructure benefits were explored, with a particular focus on how these can be monetised so as to easily compare with development costs, or alternative infrastructure or development proposals. Tools specifically designed to evaluate or appraise green infrastructure systems were of most interest, and a number of these were critiqued.

While many relevant tools were identified, there is not yet a single standard approach, or one able to capture the full set of values reviewed in Chapter 2. Each of the existing tools or approaches had its own strengths and weaknesses.

Three tools were identified as the most useful for exploring the benefits and values of green infrastructure with a view to exploring finance and funding opportunities. Of these, two were primarily quantitative in approach, and one was built around spatial data analysis. There is not yet a dominant tool or approach in the industry, and so *B£ST*, *GI-Val* and the *multiple benefits toolbox* were tested with a view of identifying strengths and weaknesses in their design and use, as well as opportunities and challenges for green infrastructure delivery from their outputs. Quantitative approaches are most relevant for project planning and finance and funding information, while spatial analysis added a strategic overview and seemed more relevant from a design planning perspective.

In order to test these evaluation tools with realistic data, the case study introduced in Chapter 3 was developed into two detailed scenarios with simulated data. These two scenarios developed realistic options for the final green infrastructure network at *The Helix*, a regeneration site with mixed commercial and residential use. The two scenarios were designed to reflect high and low levels of green infrastructure in the final site, and to explore how the quantity and quality of green infrastructure assets might affect the system as a whole. Each of these scenarios was then evaluated using the three shortlisted appraisal tools. This testing was to explore both the tools themselves, but also to compare how different scenarios of green infrastructure on one site might differ in terms of their impact and benefits, including spatially.

Based on their ease of use, and the functionality of the inputs and outputs, *B£ST* proved to be the most fit for purpose. *GI-Val* was effective, but its lack of industry backing means it is less likely to become established going forward. Despite being chosen for the transparency of its coding, as well as to fulfil the need to use a spatial approach, the *multiple benefits toolbox* was not a particularly effective appraisal tool in this context. Its design as a proof of concept, and not a fully developed, supported tool was a known limitation. In addition, inconsistencies within its internal coding were found, and had to be edited to accommodate the input data and thus it was not as user friendly as it ideally would have been. In order to be useful for green infrastructure delivery in practice, the burden of evaluation needs to not be onerous. Thus, running just one evaluation tool is essential. Although they all give slightly different results based on their differing methodologies, it is realistic to choose simply one that is “good enough” for practical delivery.

Results from both quantitative approaches showed that although the overall green space in Scenario 1 was approximately twice as much as in Scenario 2, the effect of the benefits was not always an obvious linear effect. For some benefit areas, there was indeed a corresponding change in benefit that followed the same approximate scale. However, some benefit areas were not affected so directly by the quantity of green infrastructure assets. The outputs were influenced by factors like the size of the beneficiary population more so than the quantity and quality of green infrastructure assets in many cases.

4.4.3 How can value capture be improved?

Despite the limitations of evaluation generally, and of some of these tools specifically, important information was learned about the role and reach of green infrastructure assets for different benefits and types of value within the area it is implemented, and beyond. The spatial analysis provides a geographic starting point to identify interested stakeholders, as well as all three appraisal tools offering thematic links between potential benefits and stakeholders.

In particular, the challenges around calculating and using flooding data inputs are notable. The inputs for quantifying value from reduced flooding in *B£ST* require a much greater input burden than most of the other value types. Yet flood management is often a key priority for green infrastructure schemes. Additionally, flooding offers one of the main opportunities for understanding how value can reach beyond the immediate site of green infrastructure development, due to its impact on the wider catchment. This exploration of flood management as a value, and how it illustrates the need for a systems approach to green infrastructure delivery, is a key opportunity for improving value capture methodology.

4.4.4 Summary

Objective 2 of this research project was to understand the value of green infrastructure, how it is currently captured, and how this could be improved. The key findings are:

- The value of green infrastructure is derived from its benefits
- Tools exist for capturing and quantifying the value, but no single tool can currently do so comprehensively and accurately

- Quantification is difficult, especially of intangible or indirect benefits, and there is no good way of comparing very different value types
- The functionality and benefits of the whole system, beyond individual assets is unknown

The value of green infrastructure is a key ‘building block’ to develop innovative business models for its delivery. If value capture can be improved to widen the range of value types, it can therefore have relevance to a wider range of stakeholders, The role of value in the formation of business models is discussed in Chapter 7.

Chapter 5: The policy and governance context for green infrastructure delivery in Newcastle upon Tyne, UK

5.0 Chapter introduction

In order to set the effective delivery of green infrastructure within a relevant context it is important to understand the policy context. The reasons for this are twofold: firstly, to identify the shape and structure of governance that may provide opportunities and barriers for delivery, and secondly because the actors emergent from this policy context may be key stakeholders essential in a business model. Objective 3 identifies the need to assess the policy context for green infrastructure delivery and this chapter addresses these research questions. The role of these actors as stakeholders is developed further in Chapter 6.

Objective 3: Assess the relevance and effectiveness of policies shaping green infrastructure delivery

- What are the key policy levers to support an effective business model for green infrastructure?
- How can the policy context shape delivery, identify stakeholders, and create opportunities and barriers for green infrastructure investment?

This policy review for Newcastle was conducted to better understand the policy opportunities and limitations for green infrastructure delivery and expansion. The process of policy review goes beyond a simple literature search for policies, and into a methodical analysis of their likely impact. Policy making and stakeholder interaction are increasingly important for the effective delivery of projects (Van Der Meer and Edelenbos, 2006) – those that deliver contextually relevant outcomes, within the timeframes and budgets required – so understanding the policy context and the stakeholders involved are inherently interlinked.

This chapter details how and why a policy review was undertaken, with a detailed methodology. It then lists the relevant policies, highlighting particularly interesting details, before going on to assess their impact through a scoring process. Finally, the role of the policy context for green infrastructure delivery is visualised though the use of a novel matrix, and the opportunities and threats therein are summarised.

5.1 Methodology

5.1.1 Rationale

It has become standard practice in business and government to conduct regular research on the current and foreseeable future of the policy agenda, social trends, and market predictors (Williams and Lewis, 2008; Amanatidou *et al.*, 2012; Ferretti, 2016; Government Office for Science, 2017). Sometimes called ‘horizon scanning’, ‘environmental scanning’ or ‘futures mapping’, this process is either done in general, or with a particular event or occasion in mind. It helps businesses and other actors to assess and prepare for changes in their upcoming future and enables them to be proactive rather than reactive if their business is affected. The literature on stakeholder review and management also recommends environmental scanning of the wider context, to understand the key actors involved in delivery and their influence and power (See also Chapter 2, section 2.4.2 and Chapter 6 for further discussion of stakeholder analysis). This process of environmental scanning is useful for understanding the delivery context and can be done as a one-off or continuously (Mendelow, 1981).

Additionally, policy review with a specific focus is a common practice in assessing the wider governance structure for the development or delivery of a new project. In this case it is useful to illustrate the context in which green infrastructure may be delivered (Susskind *et al.*, 2001). When looking at a new product or service, or new markets, standard business practice includes stakeholder mapping: reviewing the actors involved in the situation and rating how influential they may be in the upcoming situations, and therefore informing how they are managed and communicated with. Despite the variety of names to suit to specific contexts, in this research the term ‘policy review’ will be used, as it is focused on governance bodies and their policies, strategies and plans that affect green infrastructure delivery.

These practices, along with various others, are supported by a range of decision support frameworks. Currently, none exists specifically for green infrastructure investment (though some evaluation frameworks are framed in this way – see Chapter 2, section 2.3 on evaluation frameworks). It was with these decision support frameworks in mind that the process of policy scanning for green infrastructure delivery was conducted.

This policy review provides a starting point to understand the context in comparable delivery settings, across the UK and into other Western, developed nations with similar capitalist systems. While some of the specific policies will vary by place, the context and the process of conducting such a review will be broadly the same.

5.1.2 Policy selection

A policy review forms a structured qualitative analysis of relevant policy documents, to understand the governance and operational context that shapes green infrastructure delivery (Flowerdew and Martin, 2005). Following the methodologies of stakeholder management, horizon scanning, environmental scanning and futures mapping (see Chapter 2, section 2.4.4), these systems of approach underpinned the methods for conducting this policy review.

This policy review was conducted in several distinct stages. Firstly, collecting and collating potentially relevant documents. Secondly, these documents were reviewed for relevance, and it became obvious that a method for objectively analysing these was needed. Finally, a way of synthesising and presenting the results of the review was needed, which led to the development of a novel matrix, to demonstrate the relative power and influence of various documents based on complex, multi-level criteria.

An initial search for relevant policies was structured around existing knowledge of the UK planning and policy hierarchy – with national, regional and local governance structures being used to frame the search. The websites for these governance bodies were searched for policies relevant to green infrastructure delivery, including search terms for specific ecosystem services, for example biodiversity or flood management.

The policy search was conducted with the case study focus of the whole city area of Newcastle, accepting that multiple geographies would shape this, from international right down to hyper-local level. All may have some power in shaping the delivery context for green infrastructure at city-scale, and many are structured around the geographies of governance.

In addition, a wider search was conducted using the search engine *Google*. Key terms used in the web searches, both individually and in combination, are shown in Table 34.

Table 34: Search terms used to find policies relating to green infrastructure

Green infrastructure	UK	Air quality
Policy	Newcastle upon Tyne	Environment
Strategy	Biodiversity	Flood management

Policies referenced by some of these initial search results were also sought out to include in the review as well. In this initial stage, policies that were explicitly concerning green infrastructure were of most interest, but those that were tangentially relevant were included at this stage as well. Flood management is particularly important, as it was identified in previous chapters that flood impact is of particular interest in terms of understanding the systemic role of green infrastructure across a whole city. It is also relevant for shaping the level of detail needed for effective analysis and evaluation of impact, therefore it was included specifically in the policy search.

5.1.3 Identifying key drivers and factors

Environmental and climate change targets have been set in the UK, and globally, yet there is a risk that they will not be met due to inadequate follow-through from stated intentions to actual change being delivered (Committee on Climate Change, 2019). Therefore it is unclear whether or not the policies reviewed have the strength behind them to create real change, and whether or not they are focused on impacts and delivering actual results.

Environmental scanning based on the stakeholder concept (Mendelow, 1981) acknowledges the inequality in stakeholder power, and recognises the need to assess the relative power and influence in order to assess and group stakeholders, or in this case policies. The key factors that influence whether a policy is effective are thus that it must be both relevant, and have the power and structure and focus needed to achieve its purpose. The focus will be influenced by, for example, the presence of specific objectives, measurable outcomes, and targets (Armstrong and Taylor, 2000). Having goals or targets and a delivery plan is more likely to achieve a real impact than a high-level visionary statement on where an organisation wants to go.

Thus, a policy can be assessed according to two main factors:

1. Strength – power structures that give weight and delivery power to a policy, and relevance to green infrastructure specifically.
2. Impact – whether it is a focused plan for delivery, and if it has goals or targets included within it. How effective it might be at delivering change.

The strength and impact were assessed through a structured qualitative analysis of the text. To do this, a system of scoring the documents according to fixed criteria was developed. These detailed criteria and scoring are explained in section 5.1.5.

5.1.4 Creating a novel matrix

It is common in the literature on horizon scanning or environmental scanning to place numerical scores against the relative importance of various information (Mendelow, 1981; Armstrong and Taylor, 2000; Government Office for Science, 2017; Hines *et al.*, 2018). Likewise, a matrix format is common in corporate policy reviews of this kind (Susskind *et al.*, 2001; Urban Foresight, 2018). Thus, a matrix system of multi-criteria analysis seemed the most relevant, in accordance with these examples in the literature. This is a novel approach within green infrastructure delivery planning. Policy reviews specifically for green infrastructure are not widely used, and applying the concept of matrix-based multi-criteria analysis of green infrastructure policy is unique to this research project. It will allow the identification of stakeholders, but also an understanding of the delivery context used to shape green infrastructure business models, discussed in Chapter 7.

The matrix concept was derived from the literature, but it was uniquely populated according to the needs of this review. In order to ensure the novel matrix reflected the key factors involved, it needed to identify and present the most important variables likely to dictate the effectiveness (or otherwise) of a policy in shaping green infrastructure delivery at city or sub-city scale. It was therefore populated according to the *strength* and *impact* criteria identified as key factors.

To demonstrate and visualise how the relationship between the two categories and how the policies perform in each they have been plotted into a two-by-two matrix. The four categories in the matrix have been named to give a typology of the objective scoring emerging from the matrix.

The four typologies, created specifically for this research, can be described as,

- 'Opinion piece' – low strength and low impact. This may have no delivery plan and is not from a governing body. NGO position statements on environmental issues are likely to fall into this category.
- 'Visionary plan' – low strength, high impact. They may have a strong delivery plan, but have little formal power or are not focused on green infrastructure
- 'Strategic ambition' – high strength, low impact. This group is typical of a high level strategy at government or international level. The power potential is high, but it is not realised with any specific targets or budgets for delivery.
- 'Delivery enabler' – high strength and high impact. This group have the greatest influence on green infrastructure delivery. They combine detailed delivery plans with the power and influence of a governing body and use them to target green infrastructure specifically.

It becomes self-evident that a policy with both high strength and high impact is more likely to achieve successful green infrastructure delivery than a policy which lacks both strength and impact. Policies which perform well in one or other of the two categories will have varying levels of success.

A scoring system was then deemed to be appropriate for this situation, for assessing the different documents in order to place them within a matrix.

5.1.5 Devising a scoring system

Initial metadata on the policies were collected as part of the policy search, in order to start to categorise the different types of policy documents. These criteria were identified *a priori*, listed in Table 35, though further detailed questions were devised from the content and format of the documents themselves, and used to shape a more in-depth review.

Table 35: Data collected for documents in policy review – set before reading policies

Key data collected:
• Policy name • Date written/updated • Author/organisation that owns the policy • Document type (Law, treaty, policy, strategy, delivery plan…) • Does it focus on green infrastructure?

The basic criteria of strength and impact are not sufficient alone – they each need defined criteria to assess relative performance of policy documents within these categories. In order to allow for an objective, repeatable process detailed questions and answers with set scores were used. This type of qualitative textual analysis will always be subjective to some degree, but using stated criteria and fixed scores reduces the variability and mitigates this risk (Flowerdew and Martin, 2000).

The strength criteria define the political or law-making power behind the policies, along with how directly focused on green infrastructure it is. As the geography of focus is city-scale green infrastructure delivery, the geographic scale of the document will have an inverse impact on the power score. International documents score lowest and local ones score highest. That said, an official governance body will score more than a NGO or non-departmental body, as they have more legal power in planning decisions at city-scale. At the hyper-local level, a specific landowning organisation or individual would have most power, but for the purposes of the policy review the city-scale is more important. Alongside the political power of a policy document and the organisation behind it, the relevance of the policy to green infrastructure specifically was also deemed to be essential to assessing its strength.

The other main group of scoring criteria relate to the impact. These criteria aim to assess how effective the actual delivery or scope of the document is. For example, a specific delivery plan will score higher than a strategy document with no actions. The policy documents were therefore scored according to the document type: that is, whether they were designed to be a position statement, a strategy or a delivery plan.

They were then also scored according to how detailed and effective any specific goals were, including whether timescales or budget were included in the policy documents.

The scoring was devised from the number of sub-categories each criteria might have, and therefore scored 1-*n*, where n is the number of total criteria options, with 1 being the poorest score and *n* being the best score in each set. There was no specific number of criteria designed for each beforehand, and they were derived from a combination of factors in the literature (as discussed in section 5.1.3) and that were emergent from initial scanning of the policy documents themselves.

The full criteria questions, scoring criteria and numerical scores are shown in Table 36 and Table 37. A table showing a summary of the policies and scores is included in section 5.3, and the full list of the policies, the scores they were given, and justifications for the scores is included in Appendix C.

Table 36: Scoring criteria for policy review: strength scoring

	Criteria	Notes	Score
STRENGTH (power and relevance)	**Geographic scale**		
	International	The scope of the policy, or the remit/scale of the organisation that owns it, if the policy does not specify a scale.	1
	National		2
	Regional		3
	City-scale		4
	Political power		
	Non-Governmental Organisation or professional body	Have reputational weight and power, but not decision making remit for public investment	1
	International governance/ committee	May have organisational power, but not to implement local-level decision making	2
	Non-departmental public body	Official NDPB, may have a specific remit for decision making.	3
	Government/local authority	National or local governance organisation with decision making power.	4
	Is it green infrastructure focused		
	Policy is relevant to the wider issues	Includes environmental or climate issues, but it quite vague/generic	1
	Policy is about a directly related issue	Has a focus on something that is directly related, but doesn't use 'green infrastructure' terminology (e.g. natural capital accounting)	2
	Policy includes a section focused on green infrastructure	Specific, explicitly mention of the role of green infrastructure is made, but it is not the main focus of the policy	3
	Policy is wholly and specifically about green infrastructure	This is specifically a policy or strategy about green infrastructure	4
Maximum score:			**12**

Table 37: Scoring criteria for policy review: - impact scoring

	Criteria	Notes	Score
IMPACT (delivery focus)	**Document type**		
	Position statement	Information about green infrastructure or related topics, but no specific delivery focus	1
	High level target	States an intention or plan, but there is no delivery plan or specific goals	2
	Strategy	A strategy, but no delivery plan	3
	Plan	A delivery plan, ideally with specific detail	4
	Does it have specific goals?		
	None stated	No attempt is made to specify goals or targets	1
	No, but it states some vague aims	Policy mentions aims for the future, but they're not focused	2
	Yes, but it's unclear how they're measured	Specific goals are included, but doesn't have measurements	3
	Yes, SMART goals are included	Goals are included, and are Specific, Measurable, Attainable, Relevant and Timely.	4
	Is there a delivery plan?		
	No apparent plan stated	Policy does not include a delivery plan	1
	Yes: with a timeline, but no funding	Some attempt at a plan, but it is missing either a timeline, or mention of funding sources	2
	Yes: with funding mentioned, but no timeline		2
	Yes: timeline, and non-specific funding mentioned (no £)	A plan with a timeline exists, and funding sources are mentioned but with no specific amounts	3
	Yes: timeline, and funding explicitly stated (£)	The plan has a timeline, funding sources, and specific figures attached to the funding.	4
Maximum score:			**12**

5.2 Policies for green infrastructure delivery

This section of the chapter discusses the policies that most influence the context for green infrastructure in Newcastle at the time of the research. Each policy highlighted includes a summary of its content, and the opportunities and threats it poses to local green infrastructure development.

Section 5.3 then goes on to develop this subjective discussion of strengths and weaknesses into a objective score and thus summarise the impact and strength of the policies.

Newcastle City Council holds a number of policy documents relevant to spatial planning, environmental provision, and the planning and development of its green infrastructure network. In addition, there are a range of regional, national, and international policies that shape the green infrastructure delivery context. Table 38 shows a summary of the key policies identified in this review, grouped according to their geographical hierarchy.

Table 38: Hierarchy of policies informing the strategic GI landscape in Newcastle upon Tyne

Geographical scale	**Policies**
International	United Nations (UN) Sustainable Development Goals (United Nations, 2015a); UN Paris Agreement (United Nations, 2015a); European Commission biodiversity strategy (European Commission, 2016a) and green infrastructure strategy (European Commission, 2016b); Intergovernmental Panel on Climate Change (IPCC) advice (Fischlin *et al.*, 2007).
National	National Planning Policy Framework (MHCLG, 2018); Defra 25 year environment plan (HM Government, 2018); Environment Agency guidance (Environment Agency *et al.*, 2015); Natural England guidance (Environment Agency *et al.*, 2015); Town and Country Planning Association (TCPA) Green Infrastructure Partnership (GIP) (Town and Country Planning Association (Great Britain), 2017); Landscape Institute (Landscape Institute,

	2013); National Trust (National Trust, unknown); Historic England (Historic England, 2015).
Regional	North East Local Enterprise Partnership (LEP) strategic economic plan (North East Local Enterprise Partnership, 2017a); North East Combined Authority transport strategy (North East Combined Authority, 2016).
City- or local-scale	Urban core plan for Newcastle and Gateshead (Newcastle City Council and Gateshead Council, 2015); air quality management plan (Newcastle City Council, 2006); biodiversity action plan (Hilton-Brown and Hunter, 2014); climate change strategy (Newcastle Partnership, 2010); flood risk, surface water and river management plans (Tyne Rivers Trust, 2012; Newcastle City Council, 2015; Newcastle City Council, 2016).

5.2.1 United Nations Sustainable Development Goals

The United Nations sustainable development goals (United Nations, 2015b) aim to create a common global shift towards identified development challenges and sustainability. The UK is committed to these goals, and while there is no specific agenda relating to green infrastructure, several of the individual goals have contextual relevance.

In particular, goals *11: sustainable cities and communities* and *13: climate action* have direct relevance for green infrastructure delivery, as summarised in Table 39.

Additionally, the principles of some of the other goals, namely *2: zero hunger*, *6: clean water and sanitation* and *15: life on land*, have further influence on the green infrastructure delivery context.

These goals are comprehensive, including some specific targets and timeframes for achievement, but their high-level nature makes them of limited influence. While there is an opportunity to lean on the momentum from interest in the SDGs, they are unlikely to be a primary driver for green infrastructure delivery at this scale.

Table 39: Relevance of SDGs for green infrastructure delivery

Sustainable Development Goal target	Relevance and opportunities for green infrastructure delivery
2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.	More relevant in a rural than urban context, nonetheless GI functions are relevant for improving soil quality and ensuring good quality food production systems. In particular, improving biodiversity and maintaining ecosystems.
6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	While not necessarily relevant in Newcastle specifically, water scarcity issues are still an increasing challenge in the face of a changing climate. In the UK, and across the world, good water management practices involving trying to balance between times of excess and scarcity, and GI can offer systems that will help with this, thus improving resilience to water scarcity as well as flooding.
6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	Although only a small part of the Tyne-catchment ecosystem falls within the remit of the urban Newcastle area, it can contribute to overall management of the catchment, and especially can influence the ecosystems downstream.

Sustainable Development Goal target	Relevance and opportunities for green infrastructure delivery
11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage	GI has a role to protect natural heritage, particularly in face of urban development and pressures over land.
11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations	While GI has a limited impact on flooding from severe or extreme rainfall events, it still has a role to play in management of water within urban environments, and can be used to plan for large scale water storage in the event of extreme rainfall.
11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	While GI cannot prevent air pollution from its sources, it can be used to limit air pollution in urban environments, or create areas with lower air pollution for urban populations.
11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities	High quality green public spaces are a key function of GI, and parks and open spaces are one central component in urban GI networks.

Sustainable Development Goal target	Relevance and opportunities for green infrastructure delivery
11.B By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels	A holistic, integrated approach to urban planning is a central tenet of GI ideology. Climate change mitigation and adaptation are key functions of a well-designed GI network.
13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	A key function of GI is its role in climate change adaptation, increasing urban resilience to the impacts of a changing climate.
13.2 Integrate climate change measures into national policies, strategies and planning	Climate change mitigation and adaptation are potential benefits of a GI network that is incorporated in strategic planning policy.
15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts	Integration of ecosystem and biodiversity values into local and national planning is a fundamental principle of GI strategy.

5.2.2 International climate change targets

The Paris Agreement (United Nations, 2015a) commits its signatories to reduce carbon emissions in a bid to limit the global rise in temperatures and limit the increase to 1.5 degrees Celsius above pre-industrial levels.

However, the Paris Agreement leaves individual countries to set their own policies and interim targets to achieve this overall goal. So while it shapes the national government commitments and policies to climate change mitigation, it has little direct relevance in and of itself.

Green infrastructure has a stronger role to play in terms of climate change adaptation and urban resilience than it does for mitigation and reducing carbon emissions. While it can be used in part for carbon storage and sequestration for example, this is unlikely to be at a significant scale, compared to reducing emissions at source.

The Intergovernmental Panel on Climate Change (IPCC) collects research and evidence for climate change mitigation and adaptation, and so also has a potential influence on dictating roles for green infrastructure strategy. However, the role of ecosystems in terms of climate change has only so far been recognised in terms of the impact of a warming climate on ecosystems and biodiversity, and does not reflect the potential for ecosystems and biodiversity to help a human population adapt to this changed climate in return (Fischlin *et al.*, 2007). The IPCC (2018b) special report on global warming included some strategic guidance on use of green infrastructure to manage climate change, but these were high level and not focused on delivery.

The high level, indirect, and non-binding nature of these targets and related documentation mean that they have little impact or influence on green infrastructure delivery at a city-scale. Where they do influence it, it is via the impact on national policies set by the UK government. However, these impacts are considered as a direct influence of those national policies, and not the international targets and aims that shape them.

Thus international climate change policy and targets for carbon emissions have very little direct influence on green infrastructure strategy in Newcastle.

5.2.3 European Commission directives

> "Developing green infrastructure is a key step towards the success of the EU 2020 Biodiversity Strategy."
>
> *(European Commission, 2016b)*

At the European level, the biggest driver of green infrastructure is the EU Biodiversity Strategy (European Commission, 2011), which *"aims to halt the loss of biodiversity and ecosystem services in the EU and help stop global biodiversity loss by 2020."* (European Commission, 2016a).

The development of green infrastructure is identified as contributing to the achievement of all six targets within this strategy. Additionally, the European Commission has promoted investment in green infrastructure since 2013 (European Commission, 2013b) and promotes the development of a Trans-European Network for Green Infrastructure in Europe (TEN-G).

These policies at this level offer a strong underpinning to the local development of green infrastructure. Explicit mention is made of the role of biodiversity for the wellbeing and economic growth of Europe and its citizens. However, the effectiveness of this type of trickle-down policy is not well known. In addition, the commitment to such directives may be undermined by the Brexit agenda.

5.2.4 UK Government policies

There are two key policies at national level in the UK that strongly influence green infrastructure delivery, the Department for Environment, Food and Rural Affairs (Defra) 25 year environment plan (HM Government, 2018) and the Ministry of Housing, Communities and Local Government (MHCLG) National Planning Policy Framework (MHCLG, 2018). These core policies are supported by additional guidance from other government and non-governmental sources.

The 25-year environment plan sets out a comprehensive strategy for a range of environmental challenges to 2043. Green infrastructure and its related concepts feature heavily within the report.

> "We want to encourage more investment, in part by doing a better job of explaining what 'good' green infrastructure actually looks like. We will do this by defining a set of standards in close consultation with stakeholders, including the Parks Action Group."
>
> *(HM Government, 2018, p. 76)*

The environment plan specifically cites the role of green infrastructure across several of its target areas, some of its specific actions are shown in Table 40. Many of these stated actions include time frames, and state that they are being funded.

Table 40: Actions for green infrastructure delivery from the 25-year environment plan

Chapter and section of report	Stated action
Chapter 1, section 1: Using and managing land sustainably – Embedding an 'environmental net gain' principle for development including housing and infrastructure	Supporting Community Forests so that they can play a leading role in urban tree planting, both as part of the Northern Forest and in wider partnerships to bring trees and green infrastructure to towns and cities across England.
Chapter 3, section 1: Connecting people with the environment to improve health and wellbeing. Helping people improve their health and wellbeing by using green spaces	Help people improve their health and wellbeing by using green spaces including through mental health services.
	Encourage children to be close to nature, in and out of school, with particular focus on disadvantaged areas.
	'Green' our towns and cities by creating green infrastructure and planting one million urban trees.
Chapter 3, section 3: Connecting people with the environment to improve health and wellbeing. Greening our towns and cities	Establishing a cross-government project, led by Natural England, that reviews and updates existing standards for green infrastructure by summer 2019.
	Supporting Local Authorities to assess green infrastructure provision against these new standards.
	Working with the Ministry of Housing, Communities and Local Government to see how our commitments on green infrastructure can be incorporated into national planning guidance and policy.

Overall, the policy is very strong. It offers a clear course of action for delivery of green infrastructure alongside its other environmental policies, including specific targets with time frames and funding to underpin the political will and intention. In addition, it cross references other key policies, including the National Planning Policy Framework (MHCLG, 2018), therefore showing that it forms part of a considered and coherent set of government plans to enable green infrastructure. This weight of national government policy provides a key opportunity for delivery at a city-scale.

In 2012, the existing framework of UK Planning Policy Guidelines and Planning Policy Statements was overhauled. One streamlined National Planning Policy

Framework (NPPF) was adopted as the overarching strategy for planning. This was later updated and replaced by the NPPF 2018.

Within the NPPF, green infrastructure is identified as a core component for strategic local plan making,

> 20. Strategic policies should set out an overall strategy for the pattern, scale and quality of development, and make sufficient provision for:
>
> […] d) conservation and enhancement of the natural, built and historic environment, including landscapes and green infrastructure, and planning measures to address climate change mitigation and adaptation.
>
> *(MHCLG, 2018, p. 9)*

In addition, it is identified as being particularly relevant within several sections of the report, namely for: promoting healthy and safe communities; meeting the challenge of climate change, flooding and coastal change; and, for conserving and enhancing the natural environment.

Regarding the strategic support for a green infrastructure network, this would favour development options with sustainable measures, especially where related to nature and biodiversity goals and climate change adaptation and flood management within local plans. It is influential in encouraging use of SuDS in new build housing estates, for example. However, it is not prescriptive therefore the case can be made for other options, or at last keeping schemes separate rather than promoting the coherent network that will maximise the effectiveness of green infrastructure.

Nonetheless, it remains a strong policy in terms of creating opportunities for delivery of local green infrastructure, particularly as it is supported by the 25-year environment plan.

Guidance from other national bodies also provides support for the NPPF. In particular, the Environment Agency (EA) and Natural England provide additional guidance on the detail of green infrastructure needed for planning consent, and for considering a development plan (Environment Agency *et al.*, 2015).

5.2.5 Regional government policies

Newcastle falls within the jurisdiction of the North East Combined Authority and the North East Local Enterprise Partnership (LEP), both of which provide a governance structure for local authorities to work together to deliver joined up strategies that benefit the whole region. Neither of these bodies have guidance specific to green infrastructure, but the plans and priorities of both shape the delivery context.

The combined authority has a remit to,

> "work closely with the North East Local Enterprise Partnership, to create the conditions for economic growth and new investment."
>
> *(North East Combined Authority, 2014)*

The North East Local Enterprise Partnership (North East LEP) likewise,

> "Is a public, private and education sector partnership. […] responsible for promoting and developing economic growth in the local authority areas of County Durham, Gateshead, Newcastle, North Tyneside, Northumberland, South Tyneside and Sunderland."
>
> "We produce our area's Strategic Economic Plan, which acts as a blueprint for the activities that need to take place to improve our economy."
>
> *(North East Local Enterprise Partnership, 2017a).*

The LEP is responsible for the area's Strategic Economic Plan (SEP), which outlines the intended economic growth activity across the region (North East Local Enterprise Partnership, 2017b). The Combined Authority works closely with the LEP to try and ensure that this economic growth happens as planned.

The SEP does not include any mention of the region's natural capital nor its need to manage and regulate the natural environment within its urban areas. The rural economy is barely featured. Despite the opportunities and threats to economic growth from green infrastructure, it is not included in the plan.

Where green infrastructure delivery is in line with the economic growth plans for the region, the SEP provides a strong underpinning for investment. However, the impetus needs to be on innovation of business models to promote themselves as relevant to the growth overall, rather than it being a requirement of the plan for growth to promote and enhance green infrastructure.

As well as economic growth, the North East Combined Authority oversees the strategic transport network for the region, having taken over responsibility from the former transport authority. One joined up transport strategy has been written for the whole area (North East Combined Authority, 2016). This strategy makes no direct mention of green infrastructure, but it includes several areas of overlapping interest, which may form opportunities for green infrastructure delivery.

The transport strategy includes an aim to improve conditions for walking and cycling, and thus increase their modal share. In addition, it states the need to improve sustainable transport, including decreasing greenhouse gas emissions. All of these things provide opportunities where a strategic green infrastructure network could be beneficial in helping to achieve these aims.

However, this transport plan does not include specific targets, nor does it state a delivery plan for any of these intentions. Thus as a policy document it is unlikely to have a significant impact on green infrastructure delivery.

Governance at a regional level is becoming increasingly important. The national government is increasing regionalisation of most sources of funding, which is forcing local authorities to fund essential services out of a limited revenue stream. This is increasing pressure on budgets and new or innovative development options can be difficult to create, as priority must be given to protecting basic frontline services. The consequences of this can be seen in the closure of many leisure and library facilities. This gap in funding has not yet been a problem for new development, which is frequently able to find funding streams, for example from the European Regional Development Fund. However, maintenance and running costs of any green infrastructure network developed through these would still have to be met from the revenue stream.

Further uncertainty is being introduced by the UK government decision to leave the European Union, and the lack of any clear information on how this will affect funding streams in the UK is a threat, as it makes forward planning difficult, and reduces the willingness of investors to commit to long-term plans. There is also a consideration to be made of a potential rising wage bill as a shortage of workers caused by leaving the EU and severely restricting immigration may create supply side control of wages.

5.2.6 City-level plans

In addition to the regional plans, Newcastle is influenced by its own local plans. The main document forming this structure is the urban core plan, which is supported by additional specific policies pertaining to individual issues. The urban core plan, *Planning for the Future: Core Strategy and Urban Core Plan for Gateshead and Newcastle upon Tyne 2010-2030* (Newcastle City Council and Gateshead Council, 2015) is the overarching strategic development plan for the area – and has been developed in alignment with partners from adjacent local authority areas. It recognises that Newcastle is economically dominant within the region, but that it is intrinsically linked with its adjacent areas, and indeed is often reliant on surrounding places for workers.

As well as the economic development, this plan outlines all other urban plans for the short to medium term. In line with national and regional development plans, these need to be directly supportive of economic growth. Social and environmental plans are largely structured in terms of their contribution to economic growth.

The urban core plan explicitly outlines a strategy for green infrastructure in several topic areas. It has a dedicated green infrastructure strategic plan and the existing (known) green infrastructure network is mapped. It also features as a key element of achieving goals in other related policy areas, including biodiversity.

As well as the urban core plan, Newcastle has a suite of related strategy documents at city- or local-scale, which also influence the green infrastructure delivery context. This are listed and briefly described in Table 41.

Table 41: City and local strategies for environmental issues in Newcastle upon Tyne

Strategy	Description
Air quality management strategy (2006)	Although old, the air quality management strategy has a strong intention with specific targets and funding options for necessary measures. It does not explicitly mention green infrastructure, possibly due to its age, but it is clearly in alignment with the priorities and ideology of green infrastructure delivery. (Newcastle City Council, 2006)
Biodiversity action plan (2014)	Biodiversity action plans have identified the strategy for protecting and enhancing biodiversity within the area. However, it is unclear how areas identified as important will be protected if they face challenge from an economically

Strategy	Description
	essential development plan. It does not explicitly cite green infrastructure, but its aims are in line with delivery of a good quality green infrastructure network. (Hilton-Brown and Hunter, 2014)
Climate change strategy (2010)	Many of the development issues within the city are focused on resilience. Climate change mitigation is one of the important ecosystem services provided by green infrastructure, and that is mandated by national government policies. What is probably more important, given that the world is extremely unlikely to be able to stop global temperature rises of 2C or more, is the ecosystem service function of GI for climate change adaptation. Newcastle is a voluntary signatory of the EU Covenant of Mayors for Climate and Energy (EU Covenant of Mayors, 2008). This means they have committed to trying to reduce carbon emissions beyond the minimum targets. As an international movement, the covenant of mayors is highly influential in shaping green infrastructure delivery at city-scale in participatory areas. However, its strength is reliant on commitment from participating areas, and there is no legal power or consequences for non-compliance by participating cities. (Newcastle Partnership, 2010)
Flood risk management plan (2016)	Pluvial flooding and surface water run-off have the biggest impact on the central urban area. Although surrounding areas are subject to fluvial flooding. Ground water is not a significant problem for the most part. Newcastle has a combined sewer system, and the requirement to develop 30,000 new homes by 2030 (Newcastle City Council and Gateshead Council, 2015). This increase in population will put the existing sewer network under further strain. Using green infrastructure options to reduce demand and increase capacity in the sewer system by

Strategy	Description
	dealing with some of the surface water will increase the useful life of the system and should reduce the economic burden of improving sewer networks, allowing slower developments to be made over time and thus spread the cost of development. The flood risk management plan is a coherent and comprehensive document that aligns well with the other strategic policies for the area. It sets clear goals with timeframes and funding considerations included. (Newcastle City Council, 2016)
Ouseburn Surface Water Management Plan (2015)	As the catchment covering a large part of the Newcastle area, the Ouseburn is key to the management of surface water in the city. Developed after the severe flooding events of June 2012, this plan is jointly created by several stakeholders responsible for different aspects of surface water management. It is explicitly aligned with the Urban Core Plan and the Tyne Catchment Plan and sets out options and plans for reducing the impact of surface water flooding over the whole catchment area, with particular focus on the urban core. It suggests a plan that works with other existing plans and activities in order to deliver surface water management up until 2030. The plan includes details, timescales, and budget considerations. It is coherent, focused and links well with other policies. (Newcastle City Council, 2015)
Tyne Catchment Plan (2012)	The Tyne catchment plan summarises the plans for the Tyne catchment as a whole, which includes Newcastle city but also the surrounding areas as well. It provides a list of suggested projects to improve the catchment as a whole and reduce risks, including flood risk. The plan includes goals, but these are not stated in measurable terms, though this may however be due to the document’s nature as a high level summary of

Strategy	Description
	other activities. The detail for proposed new projects includes specific timescales and budget considerations, even where specific measurable targets are not included. In summary, the plan is detailed and focused, albeit at an overview level. The plans therein have specific goals, and the document is joined up with other relevant policies. (Tyne Rivers Trust, 2012)

5.2.7 Non-Governmental Organisations (NGOs) and professional bodies

Other organisations as well as private individuals are key stakeholders. Some, especially larger landowners and national organisations, have their own policies that will influence the situation for Newcastle. Such groups include:

- Town and Country Planning Association (TCPA) Green Infrastructure Partnership (GIP) – the TCPA introduced the GIP to support good quality green infrastructure in the UK (Town and Country Planning Association (Great Britain), 2017).
- Landscape Institute – as the chartered body for the landscape profession, the LI can be an influential driver for green infrastructure delivery. Their position statement supports the widespread use of high quality green infrastructure networks to support development (Landscape Institute, 2013).
- National Trust – a major landowner in England and Wales, as well as having statutory obligations to preserve its entrusted sites. The National Trust provides commentary on national planning policy, and identifies the need to protect green space from development (National Trust, unknown). However, it does not formally advocate for green infrastructure as a framework for environmentally sensitive development.
- Historic England – as the public body responsible for preserving the historic environment in England. In its advice on good practice for planning it recognises the role of green infrastructure, and the need to balance urban development against protection of historic buildings and spaces, especially in the face of climate change (Historic England, 2015).

Other stakeholders also have position statements on green infrastructure; however, these are not key policies shaping strategic green infrastructure delivery, and thus are considered only in their role as stakeholders (see Chapter 6), and not as policy drivers in this section.

5.3 Matrix analysis

As detailed in section 5.1, the scoring process for the policy review included six main criteria, three under each of the two key headings strength and impact. Each policy is therefore ranked according to its overall score out of 24. The scoring questions and categories are shown in section 5.1, and a summary of the scores, totalled as strength and impact scores in shown in Table 42. A table showing the full scoring process, including the justification for various scoring decisions, is included in Appendix C. Figure 34 shows all the policies mapped on the matrix. To improve the readability of this Figure 35, Figure 36 and Figure 37 highlight the policies at each geographical scale.

As already identified, the scoring process was used to classify policies by two dimensions: strength and impact. Strength represents the authority and influence of the organisation behind the policy to implement it or to influence other policy makers (based on statutory/legal power rather than on 'behind the scenes' power holders). Without a strong body publishing the policy it is less able to be implemented and less likely to achieve any outcomes.

Table 42: Strength and impact scores for review policies (scored out of 24)

Policy	Year	Organisation	Strength	Impact	Total
United Nations Sustainable Development Goals	2015	United Nations	4	6	10
Paris Agreement	2015	United Nations	4	6	10
IPCC special report on 1.5 degree warming	2007	IPCC	5	4	9
EU 2020 Biodiversity Strategy	2011	European Commission	5	9	14
Green Infrastructure - Enhancing Europe's Natural Capital	2013	European Commission	7	7	14
25-year environment plan	2018	UK Government\Defra	9	11	20
Green infrastructure - position statement	2013	Landscape Institute	7	4	11
National Planning Policy Framework	2018	UK Government\MHCLG	8	6	14
Historic Environment Good Practice Advice in Planning	2015	Historic England	4	4	8
TCPA Green Infrastructure Partnership	2017	TCPA	7	5	12
Land use planning - position statement	unknown	National Trust	4	3	7
Transport strategy	2016	North East combined authority	9	6	15
Local Enterprise Partnership Strategic Economic Plan	2017	North East Local Enterprise Partnership	7	6	13

Policy	Year	Organisation	Strength	Impact	Total
Flood risk management plan	2016	Newcastle city council	11	12	23
Ouseburn Surface Water Management Plan	2015	Newcastle city council	11	11	22
Air quality management strategy	2006	Newcastle city council	10	10	20
Tyne Catchment Plan	2012	Tyne Rivers Trust	7	11	18
Core Strategy and Urban Core Plan	2015	Newcastle city council and Gateshead council	10	9	19
Biodiversity action plan	2014	Newcastle city council; North Tyneside council	9	9	18
Climate change strategy	2010	Newcastle partnership	7	8	15

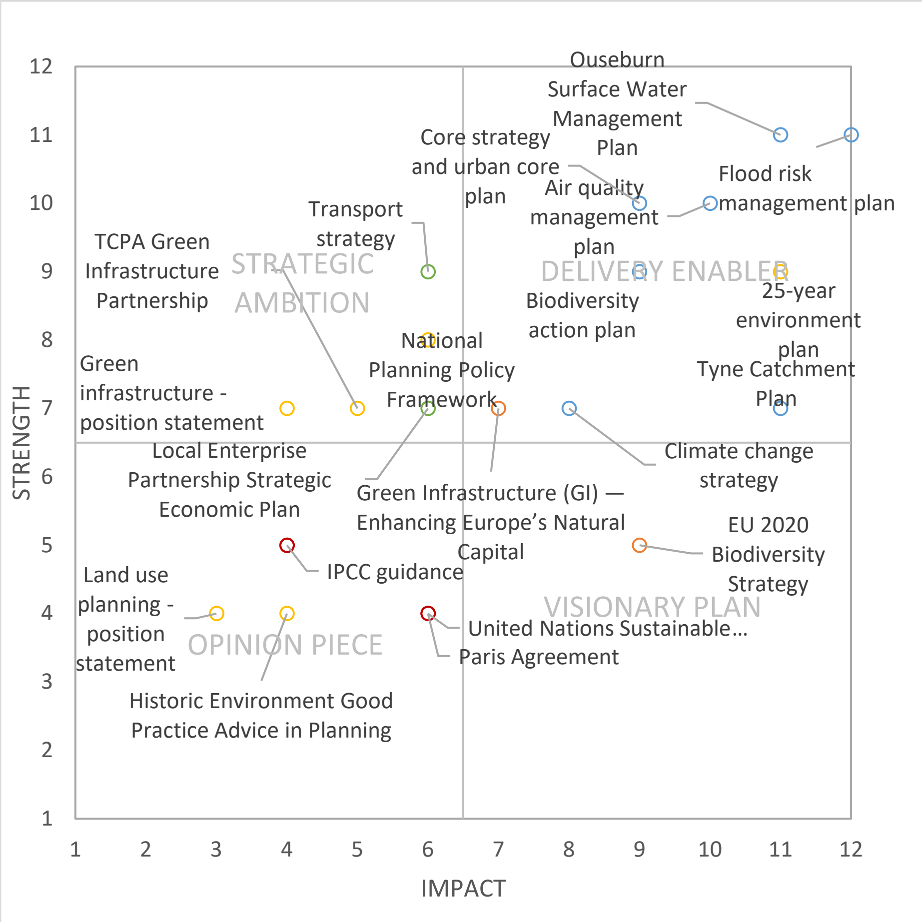


Figure 34: Policy matrix for green infrastructure in Newcastle upon Tyne: All policies (International policies shown in red; European policies in orange; National policies in yellow; regional policies in green; and city-scale or sub-city policies with blue markers)

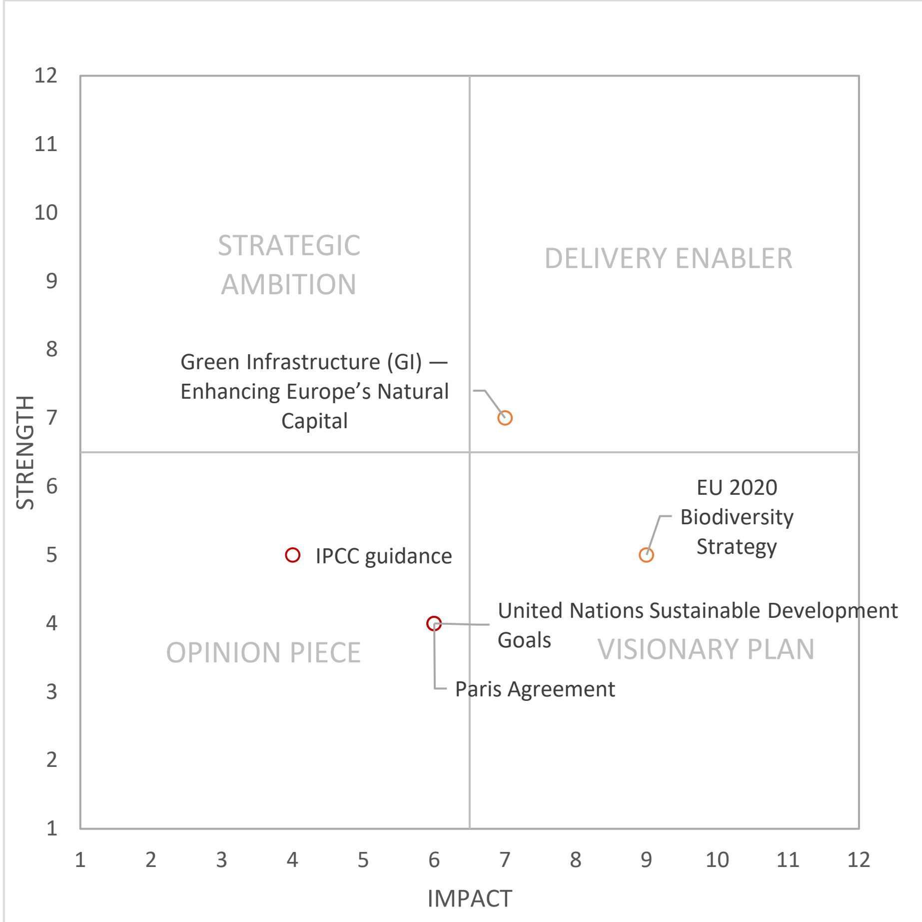


Figure 35: Policy matrix: International level policies (Wider international policies shown with red markers; European policies are shown in orange)

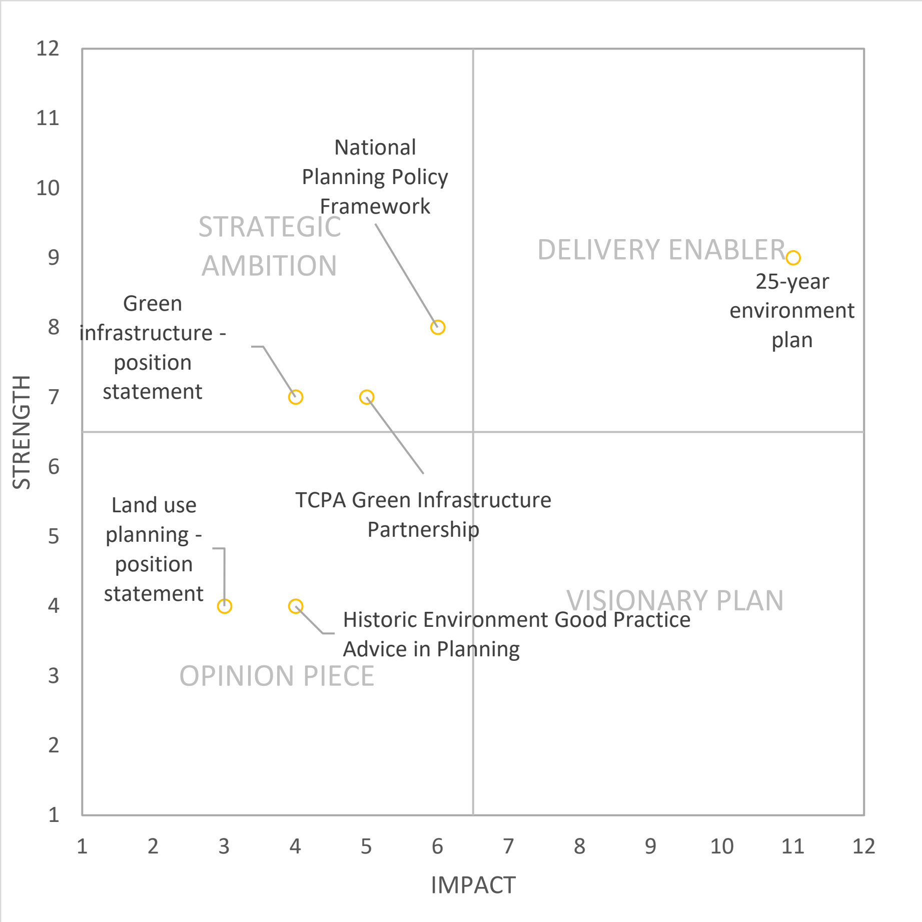


Figure 36: Policy matrix: National level policies (yellow markers indicate national level policies)

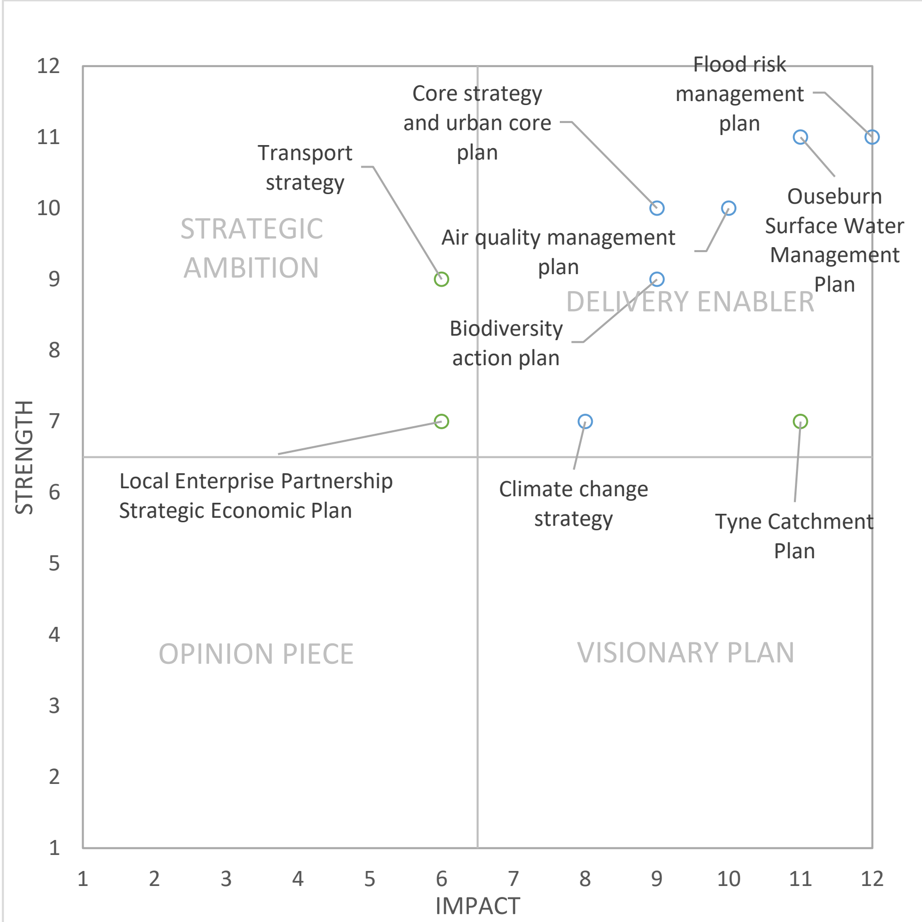


Figure 37: Policy matrix: Local level policies (green indicates regional policies, blue indicates city-level, or sub-city policies)

Looking at each of the geographical scales in turn, there is some alignment apparent between the geographical extent of the policies and their relative typologies emerging from the matrix, which reflects the fact that geographic scale was included in the scoring criteria.

Figure 37, which shows only the local (blue) and regional (green) policies has a clear trend of ‘Enabling action’. As can be expected from local policies, they focus extensively on achievable delivery plans at local scale. The two regional policies are both ‘Strategic ambition’, which is in alignment with their higher-level strategy.

Figure 36 shows only the national policies. These tend to score lower for impact than the local policies, as befits the role of national policy to show ‘strategic ambition’. Two policies fall into the ‘opinion piece’, which are the National Trust position statement on land use planning and Historic England’s good practice guidance for planning policy in historic environments. These are both contextually relevant but as they are from non-governmental organisations, they score lower on the strength scale. One notable exception in the trend is the Defra 25-year environment plan, which has maximum scores for both strength and impact, and thus falls into the ‘enabling action’ category. This is unusual for a national policy as it goes into detail on delivery plans, specific targets and funding sources.

Looking solely at the international policies, Figure 35, there is a less strong grouping within the matrix. Here both of the European level policies (orange) score more highly than the wider international ones (red), reflecting the greater focus of the European Commission directives compared to the higher level, less targeted strategic aims of the United Nations and the IPCC.

The policy context is important for the delivery of any infrastructure, but in the inherently cross-disciplinary context of green infrastructure it is even more so. This policy review sets the delivery context in which UK green infrastructure projects sit, from the international right down to the local scale in terms of opportunities and threats for green infrastructure delivery.

These policies, particularly the city-level ones, have the ability to influence delivery of green infrastructure. It is clear, however, that national and international policies are still relevant to the delivery context, even if they do not have direct impacts. The international and national scale policies can still be key drivers for local policy and for local delivery. For example, seeking funding to deliver a green infrastructure project in a local area, a funding bid may highlight its contribution to wider carbon reduction targets or sustainable development goals, thus a policy may support bottom-up delivery, even while it fails to enforce green infrastructure delivery from a top-down approach.

These opportunities and threats must be considered alonside the existing and potential green infrastructure networks within Newcastle upon Tyne throughout this thesis, or indeed when translating the experience to other city-scale green infrastructure delivery for practical delivery.

5.4 Chapter conclusion

This chapter has outlined the process of conducting a policy review focused on green infrastructure delivery for Newcastle upon Tyne, though with relevance for any green infrastructure delivery at city-scale in a UK or other western city with a comparable governance structure. The purpose of the policy review was to better understand the policy opportunities and limitations for green infrastructure delivery, as well as starting to identify stakeholders in a green infrastructure system, which will be taken forward in Chapter 6.

The policy review methodology took the concept of horizon scanning or futures mapping from business practice, and then developed a novel approach to policy review for green infrastructure delivery, with a multi-criteria matrix devised specifically for this purpose. Documents were identified and then scored according to criteria that assessed the relative strength and impact of the policies. It is anticipated that this methodology would be applicable to other cities across the UK and beyond, even where the specific policies will differ.

The relevant policies were briefly described, with key details highlighted, before the scoring process was applied (full details of scoring in Appendix C). The scores of the policies were then visualised though the use of a novel matrix.

The process of conducting a policy review has highlighted that while international policies can be useful for creating a framework for high level goals and targets, it falls to local policies predominantly to enable action when it comes to green infrastructure delivery. The key opportunities delivery of strategic green infrastructure networks is to draw on these local policies and their specific plans and build on this foundation. While a green infrastructure network should have an overarching strategic structure, the policy review suggests that it can nonetheless be created from a bottom up approach more effectively than from a top down one.

The key findings from this chapter are:

- Local-level policies (particularly those at city-scale) have the biggest potential to shape green infrastructure delivery
- Higher level policies have less relevance, albeit with some influence in shaping the focus of local level policies
- A systems level approach for green infrastructure delivery at city scale would be appropriate to align with the policy and governance context
- Some policy actors and governance organisations have power at the local and regional scale, and therefore are stakeholders within a city-scale green infrastructure system
- The policy focus of different stakeholders shows some of the value types they are interested in, and can be a key source of information for developing business models

Chapter 6: Who benefits and who pays? Identifying stakeholders in a green infrastructure system

6.0 Chapter introduction

The key elements of an infrastructure business model include various different stakeholders, whether they are project partners, users or potential users of the system, or involved in finance, funding, governance or regulation (see Chapter 2, section 2.4, Chapter 3, section 3.2, and Chapter 5). It is important therefore to understand who these stakeholders are, and what role or roles they may play in the business model at different stages of the infrastructure lifecycle. In addressing these questions of stakeholders and their priorities, this chapter includes elements of both Objective 3 and Objective 4.

Objective 3: Assess the relevance and effectiveness of policies shaping green infrastructure delivery

- How can the policy context shape delivery, **identify stakeholders**, and create opportunities and barriers for green infrastructure investment?

Objective 4: Identify stakeholders with potential interest in a green infrastructure network, and consider how to align their priorities and needs

- How are stakeholders identified?
- What are their priorities and needs, and how can these be aligned with green infrastructure value?

Understanding the context of stakeholder analysis in the specific delivery setting should be an essential part of the project management of any green infrastructure system, and it is from the project management literature that a lot of stakeholder analysis and management practice is drawn. Using the policy review from Chapter 5 as a starting point, this chapter develops these results further and begins to identify stakeholders in the context of business models for green infrastructure delivery.

Although the exact definition of a stakeholder cannot be agreed upon in the literature (see Chapter 2, section 2.4.3), it can broadly be described as any individual or group who may be impacted by a project. This is a broad definition, and further work must be undertaken to ascertain the extent that stakeholders may be impacted or interested, and thus to what extent they need to be included in project decision making. When considering the opportunities and barriers for green infrastructure delivery, the stakeholders can be crucial in the success or failure of a project. Indeed, in any complex city-scale system, the interplay of stakeholders and their effective management is perhaps the most challenging element of green infrastructure delivery. How they are identified and the channels of communication with them are therefore crucial.

Stakeholders do not exist in isolation, but form relationships between the green infrastructure network, and other infrastructure and non-infrastructure urban systems, as well as with other stakeholders. In addition, they can play multiple roles. Most importantly, it is the relationship between stakeholders and potential values of green infrastructure that can offer innovative opportunities for finance and funding and help to structure non-traditional business models that are relevant for effective green infrastructure delivery.

This chapter of the thesis explores the identification of, and interaction with, stakeholders in a green infrastructure system. It considers both supply side and demand side stakeholders (that is, those that predominantly deliver green infrastructure and those that are not involved in delivery but do benefit from it) and is set within a policy context as identified in Chapter 5. The interactions between stakeholders and value are then considered, building on the work of identifying value from Chapter 4. The interests of the stakeholders then feed into the discussion of stakeholder-value overlaps in the following chapter, Chapter 7.

6.1 Rationale

One of the main threats to successful green infrastructure network delivery identified in the literature review was the knowledge and communication gap between academic research and delivery organisations (see Chapter 2, section 2.4). Identification of key stakeholders, and appropriate communication and management is essential, especially for knowledge transfer. Understanding the potential value of green infrastructure is only useful if this information can be shared with relevant stakeholders to increase the value proposition of the system, and target this to relevant stakeholders (Ugolini *et al.*, 2015).

Therefore, identification and analysis of stakeholders, their interests, influence, and the roles that they may play in delivering an infrastructure system is essential to achieve success. This was done by first identifying the stakeholders, and secondly analysing them to establish the different opportunities and challenges they create, and the different roles they may play.

Stakeholders may have some thematic interest in the green infrastructure system, or be involved through geographic proximity. Communication with stakeholders can also create opportunities or barriers for the success of a business model (El-Gohary *et al.*, 2006). For example, in Chapter 2, section 2.4.3, it was identified that the academic and research fields of green infrastructure benefits and value are not well integrated with operation and delivery of green infrastructure projects – a barrier that could be addressed through improved stakeholder communication. It is essential to understand not only who the stakeholders are, but also how and when they can be included within the delivery of the green infrastructure system at different points in time. In order to address all of the potential opportunities and challenges created by stakeholders, a detailed identification and analysis was conducted.

6.2 Stakeholder identification

6.2.1 Methodology

The first stage in stakeholder analysis for a green infrastructure system is to identify the relevant stakeholders. This was done by combining several sources of information and developing a comprehensive list of stakeholders that might play a role in a green infrastructure system and its current and potential alternative business models.

A range of stakeholder identification approaches exist, from multiple academic disciplines, including business management practice, and also specifically designed in the context of natural resource management (Brugha and Varvasovszky, 2000; Reed *et al.*, 2009).

No single approach stands out as a definitive choice for green infrastructure business models, but concepts can be drawn from this broad range of literature. Both active and passive approaches exist, and while active approaches can offer a more comprehensive collection of stakeholders, more passive approaches have been used in this research, as a useful first step into this process.

A method has been developed that combines three approaches to ensure coverage of current and potential relevant stakeholders:

1. Policy review and governance
2. Interest-based analysis
3. Value flow analysis

While more active stakeholder analysis could have been undertaken (for example, participatory approaches involving stakeholders identifying other as a means of creating a comprehensive audit), these were not chosen for the research at this stage. The methods used here are a 'first step' in the stakeholder analysis process. A second step, which would be needed to apply this process to a live project, would be to then use active methods to improve the robustness of the stakeholder analysis.

6.2.1.1 Policy review and governance

Identifying stakeholders was done initially by building on the policy review for Newcastle, detailed in Chapter 5, to identify those stakeholders involved through governance, regulation and other policy contexts. This created a list of stakeholders relevant to this case study city, which was also refocused into a more generic list, to ensure wider applicability beyond the case study area. While different settings and contexts will vary, this list should be broadly applicable across a range of contexts around the world.

Content analysis was used to identify the role and function of each of the authoring organisations of the policies (in Chapter 5). Each of the organisations' role and remit, as it related to green infrastructure, was noted, and they were grouped according to emergent patterns in their typologies. For example into official governance organisations, non-governmental public bodies, and others. The specific organisations from the Newcastle-focused policy review were 'translated' into their broader roles based on these functions and organisation types. For example, Newcastle City Council is specific to Newcastle, but the Local Authority will usually be a relevant green infrastructure stakeholder in any context. The full results of the policy-driven stakeholder analysis are shown in section 6.2.2.

6.2.1.2 Interest-based analysis

Not all stakeholders will be represented through the policy review, as this forms a list based on formal governance, large organisations, and is a top-down approach to identifying stakeholders. In order to create a comprehensive list of stakeholders, more sources of information were needed. Two main approaches were used. Firstly, drawing on the literature and other secondary sources; and then by identifying other infrastructure systems, land use types, and key features.

The literature on the benefits of green infrastructure (see Chapter 2, section 2.2) identified that some of the values of green infrastructure are intrinsically linked to particular stakeholders, due to a shared interest in the types of benefit, whether through regulatory obligation, for example flooding, or other common interest, like land ownership, or reliance on a particular ecosystem service. Because of this inherent relationship between some values and stakeholders, one of the evaluation tools used in Chapter 5, *CIRIA B£ST*, also identifies potential project stakeholders for the delivery of a green infrastructure system, and is also used to identify potential stakeholders in this research. The results of this interest-based stakeholder identification are shown in section 6.2.2.

6.2.1.3 Value flow analysis

As an infrastructure system within a city-scale area, green infrastructure will inevitably interact with and affect individuals and groups through spatial proximity, even if they otherwise would not be involved as stakeholders through any other motivations. Likewise, cities exist and function via the interdependencies of critical infrastructure systems, with communications, transportation and utilities all relying on each other to continue functioning. An effective green infrastructure system will be subject to the same interdependencies, and therefore these systems, their operators and users may all be in some way involved.

In order to identify where these interactions and interdependencies might occur, spatial data were used. Using the case study of Newcastle as a starting point, mapping the potential interactions between the proposed green infrastructure additions and the other infrastructure systems and land use types identified these stakeholders. Mapping stakeholders was done by using the list of already identified stakeholders, and then digitising their key location in an ArcGIS shapefile, by cross referencing the list of stakeholders with the OS base map data for the city area and creating new shapefiles for the key stakeholders in the city.

This was then analysed according to the value types identified in Chapter 4, section 4.1, and grouped based on value flows throughout the city. With traditional infrastructures, value flows through a network in accordance with the service provided. For example, the value flow of the electricity grid is converting energy generation into power needed by consumers.

The value flow in a green infrastructure network therefore can be a range of value flows as there are a range of potential values. For example, it can include the value of reduced flooding that follows the path flood water could take through a catchment. Using this spatial data to identify stakeholders by proximity to the potential values created these more general, more broadly applicable value flows for the city. This value flow analysis is developed further in Chapter 7.

6.2.2 Results

6.2.2.1 Policy review and governance

The process of identifying stakeholders has been possible through the collection of data on the case study for Newcastle, especially for the policy review. This review, detailed in Chapter 5, has identified organisations, groups and individuals who may influence, or be affected by, the green infrastructure network.

The organisations that were included in the policy review for Newcastle are shown in Table 43, along with commentary on the more general application to wider contexts – translating the case study specific list of stakeholders into a more widely applicable one.

Table 43: Stakeholders from policy review, generalised to broader applicability

Organisation	Generalised stakeholder
United Nations	International bodies that are likely to be relevant everywhere – in place of the European Commission, other global regions may have strategic bodies that will provide influence.
IPCC	
European Commission	
UK Government\Defra	Government departments at a national level will always have some influence as stakeholders. In addition to these two, in the UK context, the Department for Transport (DfT) and the Department for Business, Energy & Industrial Strategy (BEIS) are probable stakeholders, depending on the context of the specific project. Outside of the UK context, other national and regional governments will have similar departmental stakeholders.
UK Government\MHCLG	
Historic England	A non-departmental public body, Historic England have a role to play in the preservation of listed buildings, and with other issues of conservation. Whether or not this type of stakeholder is involved is context specific, but it is likely that some sort of NDPB with specialist knowledge may often be a stakeholder.
National Trust	The National Trust as a potential stakeholder may have two distinct roles. Firstly, as a major landowner they may be involved through land use. However, more commonly in an urban setting will be their role as an expert advisor on issues of conservation and land management. In particular, their emergent strand of work around Future Parks (Bradford-Keegan, 2019; National Trust, 2019) will increase their role as a source of knowledge and information for green infrastructure delivery and management.

Organisation	Generalised stakeholder
Landscape Institute Town and Country Planning Association	As industry bodies these organisations can offer guidance and best practice relevant to developing a green infrastructure system. The level of involvement that they have will depend on project-specific need. Other countries have similar organisations who would play a similar role in different international settings.
North East Combined Authority Newcastle Partnership North East Local Enterprise Partnership	In the UK context, there has been a recent shift in the past 10 years towards more regional levels of governance on some issues. For example, the North East region has a Combined Authority, a North of Tyne Mayor and a Local Enterprise Partnership (LEP). Each of these has their own specific remit and roles, but all can be key stakeholders in delivery a green infrastructure network. Not every region within the UK has these functions, but where they are their equivalents do exist they ought to be included in a stakeholder list.
Newcastle City Council Gateshead Council North Tyneside Council	Local authorities with a remit covering the area of interest for the green infrastructure network must be included as stakeholders. Additionally, as green infrastructure does not recognise the local authority boundaries imposed on regions, combinations of councils may need to be involved.
Tyne Rivers Trust	In some areas, specific organisations have been established to look after a particular asset or sub-area of interest. In the case of the Newcastle policy review, the Tyne Rivers Trust had published a strategy for catchment management for the River Tyne and its tributaries. Where such asset- or benefit-focused organisations exist they should be included as stakeholders as they may prove to be valuable delivery partners.

Based on the types of organisation emergent from the policy review, the generic stakeholders from this example are:

- International organisations (global or regional)
- National government departments
- Non-departmental public bodies
- National or local charities with relevant expertise
- Industry bodies
- Regional governance organisations
- Local governance bodies
- Delivery or strategy organisations with a specific remit.

This list of stakeholder types is a useful starting point, but it is limited by its basis in policy review. Other organisations whose presence was not noted in the policy sphere for the case study of Newcastle may still have roles as key stakeholders. The following two sections identify additional stakeholders, not already identified from this process.

6.2.2.2 Interest-based analysis

Some of the stakeholders identified from the policy review were included because they had a governance role in the specific area, whereas others had some issue-based interest in green infrastructure. Additional stakeholders with an interest due to some thematic link between their organisational aims and green infrastructure delivery are identified in this section.

One key resource for this has been the *B£ST* evaluation tool, introduced in Chapter 4. This tool includes a list of potential stakeholders identified by the project team behind the tool's development. Their list is shown in Table 44.

The potential stakeholders listed here form a comprehensive and detailed list, all with a focus on their potential roles as funding organisations. While one goal of this stakeholder identification exercise is to identify and inform potential value streams and funding opportunities, it is essential to consider not only those organisations and groups with a specific finance and funding role, but also to consider non-traditional combinations of stakeholders and values to identify novel and innovative approaches to structuring a business model. This identification of overlaps between stakeholders and value is explored further in Chapter 7, section 7.2. Nonetheless, even with this focus on funding streams, this list of stakeholders is a useful starting point to build from.

Table 45 shows the main benefit areas, first identified in Chapter 2, section 2.2.2, Table 3. Alongside these benefits are key stakeholders that might be involved based on these benefit types. There is some repetition with the types of stakeholders listed in Table 44, but this has a benefit focus rather than a funding source focus.

The potential stakeholders listed in Table 45 provide an illustrative starting point within the UK context. The delivery of any specific green infrastructure strategy or project would need a detailed and specific identification of the potential and relevant stakeholders itself. However, this list of generic stakeholders is designed to capture the range of potential stakeholders based on the relevance of different potential benefits, which could become value streams within the business model.

The concept of these stakeholder-value links is explored further in Chapter 7. While the government departments listed in this table are based on a UK perspective, they also provide a starting point for converting this to an international perspective, depending on the remit of departments in other settings.

Table 44: Illustrative examples of Potential GI stakeholder types and funding stream identified by B£ST

Organisation type	**Organisations or groups**
National, Regional & Local Authority	Flood & Coastal Risk Management Grant in Aid (FCRM GiA)
	Local Levy Funding
	Community Infrastructure Levy (CIL)
	Developer based contributions (S106)
	Council Tax (Add. Levies and Precepts)
	Public Works Loan Board (PWLB)
	Business Rate Supplement
	Regional Growth Fund
	Tax Increment Funding
	Business Rate Retention
	Local Economic Partnerships (LEPs)

Organisation type	Organisations or groups
	New Homes Bonus
	Business Improvement Districts
	Asset backed financing
	Public-Private Partnerships/Private Finance Initiative (PPP/PFI)
	Defra one-off grants & pilot projects
	Water framework directive funding
	Clinical Commissions Groups (NHS)
	Housing Association
EU	European Regional Development Fund
	LIFE+ programe
	European Social Fund
	European Investment Bank
Corporate	Volunteering
	Sponsorship and Corporate Social Responsibility
	Private Beneficiary Funding
Lottery	Heritage Lottery Fund
	Big Lottery
Others	Grant Making Trusts
	Landfill Community Fund
	Volunteering
	Public Appeal
	General Drainage Charge
	Walking / Cycling / Angling groups etc
	Not-for-profits & Charities
Services	Water
	Power
	Network Rail
	Highways Agency

(CIRIA, 2018)

Table 45: Potential stakeholders by benefit type

Benefit area	Benefit	Potential stakeholders
Environmental	Air quality	Public Health England (PHE); NHS; local authority (LA); individuals
	Urban cooling	LA; residents and businesses; PHE

Benefit area	Benefit	Potential stakeholders
	Stormwater management	Defra; LA; Environment Agency (EA); Lead Local Flood Authority; Water companies; residents and businesses; Transport executive and operators; Highways England
	Water quality	Defra; EA; LA; river users; tourism businesses; water companies; wildlife
	Noise abatement	Residents and businesses; PHE
	Biodiversity	Defra; Natural England; LA; wildlife; residents
	Carbon storage	LA; Climate Action Groups;Department for Business, Energy and Industrial Strategy (BEIS)
	CO_2 and other GHG emissions	LA; Climate Action Groups; BEIS
	Ground water recharge and water balance	Defra; EA; lead local flood authority; Water companies; landowners
Social	Social cohesion	LA; residents; community groups
	Mental health	PHE; NHS; residents; charities and support services; employers
	Wellbeing	PHE; NHS; residents; charities and support services; employers
	Physical health	PHE; NHS; residents; charities and support services; employers
	Physical activity	PHE; NHS; residents; charities and support services; employers; sports clubs; schools
	Education	LA; Department for Education; schools, colleges and universities; residents
	Reduced inequalities	Department for Work and Pensions (DWP); LA; residents; charities and support services
	Crime reduction	Police and crime commissioner; Department of Justice; regional police force; residents

Benefit area	Benefit	Potential stakeholders
Economic	Tourism	Businesses; tourists
	Business activity	Businesses; LA; BEIS, Business Improvement Distrcits (BID)
	Land and property values	Landowners; residents and businesses; LA
	Energy costs	Residents and businesses; energy suppliers; BEIS
	Amenity value	LA; residents and businesses, BID
	Employment	LA; residents and businesses; BEIS; DWP

6.2.2.3 Value flow analysis

The previous two sections, 6.2.1.1 and 6.2.1.2, have identified some key stakeholders in a green infrastructure system, based on their policy, governance, or thematic interest in the system. Some of the stakeholders listed include local groups like businesses, residents and community organisations. However, identifying specifically which businesses, residents and community organisations will rely heavily on their spatial proximity to the green infrastructure network, and the reach of its benefit which may be much further away. Similarly, while there will be interest from, for example, transport operators, which ones and their level of interest will be affected by their location relative to the proposed green infrastructure assets and network.

Therefore, having some concept of the spatial relationships between stakeholders in the area of interest is essential to properly identify all of the stakeholders and before moving on to conduct stakeholder analysis. Using Newcastle upon Tyne as a worked example again, Figure 38 shows the distribution of key stakeholder types, across the core urban area, and for each of the specific case study focus areas, *The Helix* and the CBD. Although some stakeholders are shown across the whole area (Figure 38a), these do not show every single resident, business or organisation. Instead this level of detailed stakeholder identification was done only for the two case study areas of focus, shown in Figure 38b and Figure 38c.

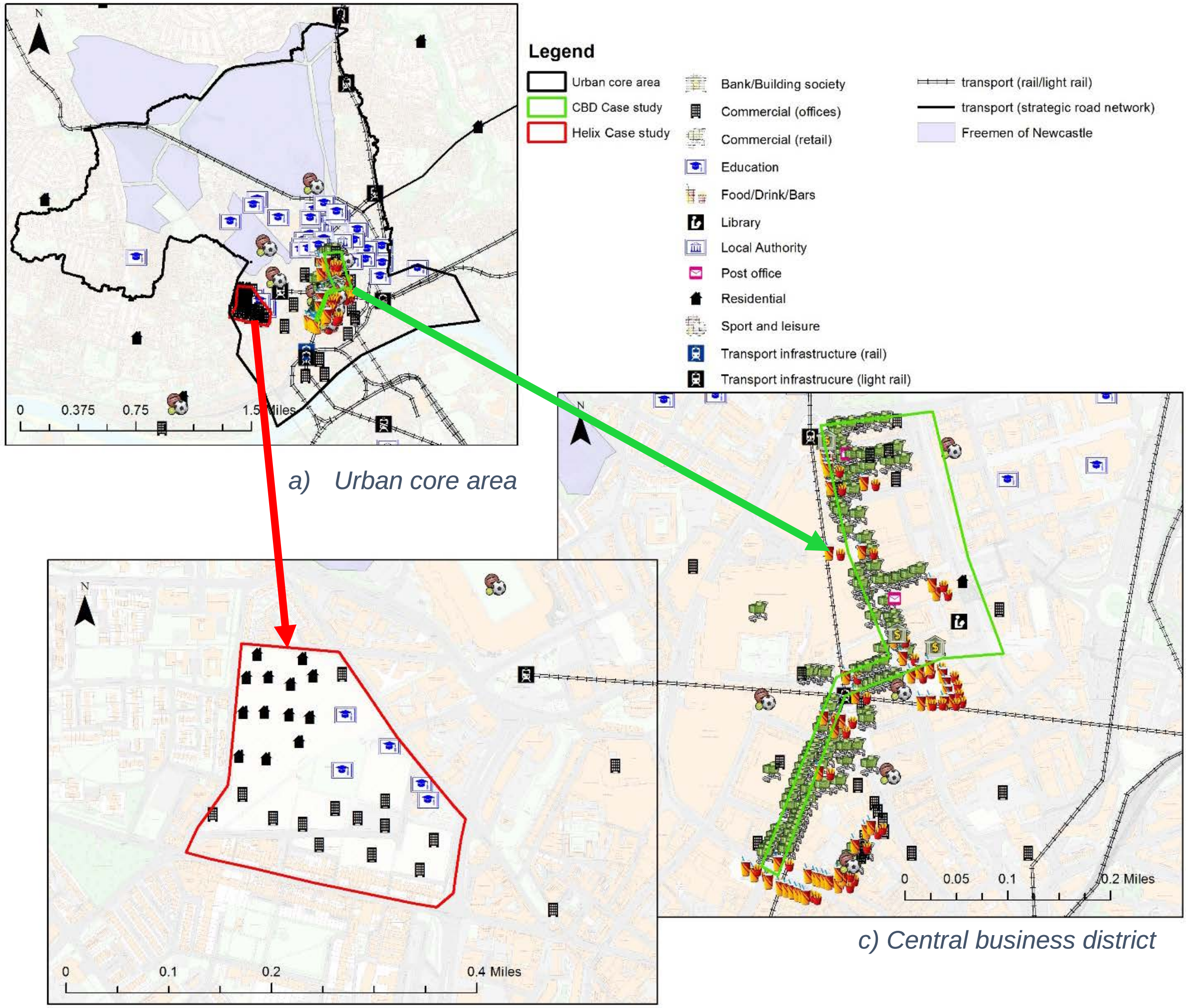
While not including the entire list of stakeholders, as some are grouped by categories rather than individual organisations, this nonetheless highlights the quantity and variety of potential stakeholders, especially across a whole city region. As identified in the literature review, working to coordinate green infrastructure delivery across such a scale is therefore potentially complex. This stakeholder identification exercises reinforces this complexity, in particular in terms of comparing stakeholders that benefit from a green infrastructure asset (beneficiary-side stakeholders) with those who commission, finance, or manage it (supply-side stakeholders). This complexity creates challenges for green infrastructure delivery, but also provides opportunities to draw interest and funding from additional groups that may not traditionally have a role in commissioning infrastructure networks.

When considering the strategic delivery of a comprehensive green infrastructure network across the whole city region, this will then need to become a much more involved process of not only identifying the stakeholder using spatial data, but also trying to understand the extent to which they might be impacted (positively or negatively) by the development of the network. More detail on this stage of stakeholder analysis, and its intrinsic link with value, is discussed in Chapter 7.

6.2.2.4 Results summary

Different stakeholders have been identified at different stages of this process, with each of the methods offering a new approach from which to highlight those stakeholders that may become involved in delivering a green infrastructure project. It is particularly important to identify stakeholders that may not be involved in a traditional business model for delivery, but that could be engaged within a new business model format. This highlights new opportunities for green infrastructure delivery.

Table 46 below shows a summary of which stakeholders have been identified at successive stages of the stakeholder identification process.



a) Urban core area

b) The Helix

c) Central business district

Figure 38: Stakeholder maps for Newcastle urban core (a), The Helix (b) and the central business district (c)

Table 46: Summary of stakeholders identified in section 6.2

Stakeholder	**policy review**	**interest-based**	**Value flow**
Industry bodies	X		
International organisations (global or regional)	X		
IPCC	X		
Landscape Institute	X		
Town and Country Planning Association	X		
United Nations	X		
Businesses		X	X
Employers		X	X
Tourism businesses		X	
Charities and support services		X	
Climate Action Groups		X	
Community groups		X	
National or local charities with relevant expertise	X		
National Trust	X		
Sports clubs		X	
Tyne Rivers Trust	X		
Schools, colleges and universities		X	X
European Commission	X		
Gateshead Council	X		
Lead Local Flood Authority		X	X
Local Authority (LA)		X	X
Local governance bodies	X		X
National government departments	X		
Newcastle City Council	X		X
North East Combined Authority	X		
North Tyneside Council	X		
Regional governance organisations	X		
UK Government\BEIS		X	
UK Government\Defra	X	X	
UK Government\Department for Education		X	

Stakeholder	policy review	interest-based	Value flow
UK Government\Department of Justice		X	
UK Government\DWP		X	
UK Government\MHCLG	X		
Energy suppliers		X	
Transport executive and operators		X	
Water companies		X	X
Delivery or strategy organisations with a specific remit.	X		
NE1 (Business Investment District)			X
The Helix group			X
INTU (retail operator)		X	X
Environment Agency (EA)		X	
Highways England		X	X
Historic England	X		
Natural England		X	
Newcastle Partnership	X		
Non-departmental public bodies	X		
North East Local Enterprise Partnership	X		
Police and Crime Commissioner		X	
Regional police force		X	
NHS		X	
Public Health England (PHE)		X	
Individuals		X	X
Landowners		X	X
Residents		X	X
River users		X	
Tourists		X	
Wildlife		X	

6.3 Stakeholder analysis

6.3.1 Methodology

Once these stakeholders were identified, in section 6.2, it was necessary to conduct stakeholder analysis. The list of stakeholders alone is insufficient to inform their role within a green infrastructure network or in the business model underpinning this. A more detailed understanding of the roles, priorities, drivers and influence is needed to understand how they fit into a business model for successful green infrastructure delivery.

There are many and varied ways of conducting stakeholder analyses that can be drawn from project management literature and best practice. For the purposes of this research, the aim is to understand how the different stakeholders may influence or be influenced by a green infrastructure system with a view to identifying overlaps between these stakeholders and the values that are of relevance to them. Ultimately this will be used to identify novel and innovative opportunities for value streams, finance and funding, and help shape business models for green infrastructure delivery. Therefore, several stakeholder analysis tools have been chosen to help identify areas of interest for the stakeholders in terms of value, and also to understand the relevant power and roles that these stakeholders may have. While the potential for grouping and interpreting stakeholder relationships offers a wealth of analysis options, only those used in this research are described and justified in this section. One key limitation of the approaches chosen here are that they do not include active stakeholder participation in the analysis process. It is recommended that in order to apply a robust stakeholder analysis process to a live project then more active engagement should be undertaken, however it has not been done at this point in the research process in order to limit the scale and scope of the project.

6.3.1.1 Stakeholder classification

An emergent theme when identifying every potential stakeholder is the type of role that each may play within their interaction with a green infrastructure system. Although the relative power, roles, and priorities of the stakeholders is explored further throughout the stakeholder analysis, it became apparent through the process of identification that some initial classification of stakeholders was needed before this detailed analysis could be applied. Therefore, based on the natural groupings emerging from the identification stage, two key stakeholder types have been identified. For the purposes of this research these have been labelled as ‘Active’ and ‘Passive’ stakeholders, see Figure 39. Further discussion of the stakeholders within this classification is shown throughout the results.

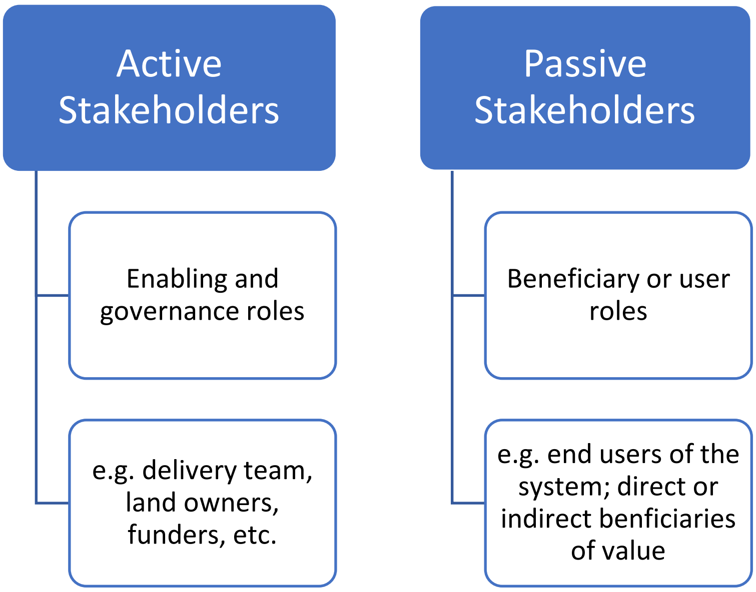


Figure 39: Basic stakeholder classification

6.3.1.2 Power-interest matrix

Chapter 5 of this thesis details how a novel matrix was developed to categorise the level of power and influence that different policies have on the delivery of green infrastructure at a city scale within the case study city of Newcastle. These policies have helped to identify some of the stakeholders (see section 6.2.1), but the matrix itself was also derived from stakeholder mapping and project management literature. The power-interest matrix in its original form is used in this chapter, as it is directly applicable to stakeholders (whereas it was adapted specifically for policy analysis in Chapter 5).

The process of horizon or environmental scanning, introduced in Chapter 2, section 2.4, is used in business practice as a tool for identifying opportunities and challenges for businesses as a whole, or for the delivery of a specific project. This can therefore be used to rate the relative power and interest that stakeholders in a green infrastructure system might have for a particular development within that system, which can then be plotted in matrix form, as shown in Figure 40.

Using this tool, it is difficult to rank and score every potential green infrastructure stakeholder for an entire system as a whole. The role of different stakeholders will vary according to the specific asset or network development happening, and throughout the lifecycle of the system. Therefore, in order to fit with the practical limitations of the methodology, a proof of concept was used to test this methodology for rating stakeholders based on a smaller project delivery. In this case, reviewing how the stakeholders within the retrofit of green infrastructure assets to the central business district of Newcastle might perform and engage.

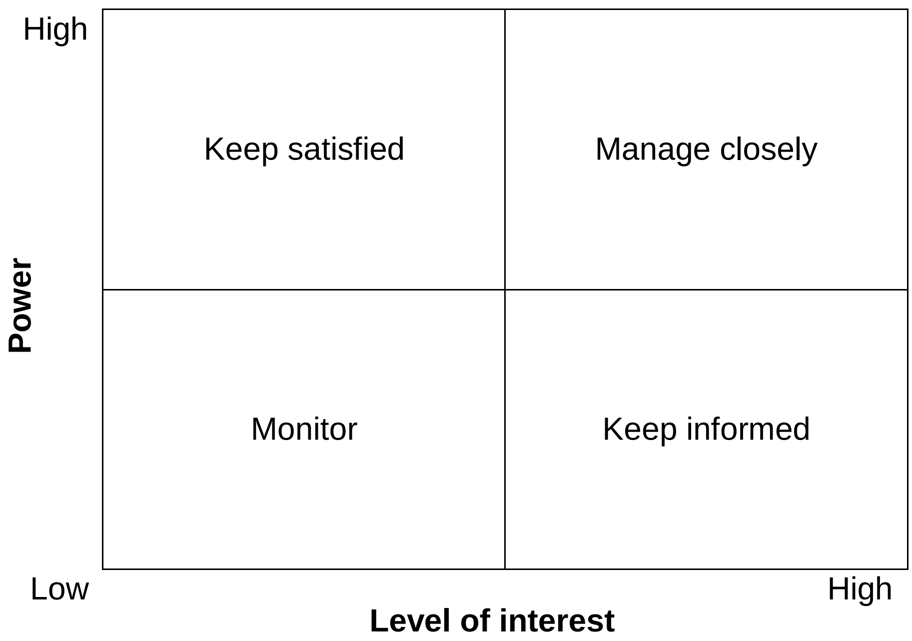


Figure 40: Stakeholder Power/Interest matrix

(adapted from Johnson et al. (2005) and Mendelow (1981) – see also the adapted form of this in Chapter 5)

One of the key strengths of this approach to stakeholder analysis is that it allows a detailed and nuanced review of the key decision makers, influencers, and potential delivery partners for a specific project activity. The power-interest matrix is, however, limited in some ways. As it is shaped by existing power structures, it inherently privileges some stakeholders over others, based on pre-existing hierarchies. It can therefore reflect existing power relationships and ignore marginalised stakeholders within the process (Olander and Landin, 2008; Horton and Pilkington, 2016). The matrix also cannot express the nuance of changing stakeholder roles and priorities over the lifecycle of a project, and so can only realistically provide a ‘snapshot’ of stakeholder interests for a single stage of a project lifecycle. These limitations form part of the rationale for using multiple types of stakeholder analysis approaches in this project.

This proof of concept is intended as a worked example – and it is recommended that any specific delivery activity for green infrastructure have a detailed matrix devised through expert input.

The decisions were made on which stakeholders may be involved and to what extent their power and interest may be scored differently by context. To get an accurate understanding of the different roles, this process would ideally be a collaborative output created by a whole project delivery team. For the purpose of making an illustrative example to identify potential roles in this research, the matrix has been completed without such expert input. As such, it is intended to be indicative of potential roles and power, but not a definitive statement of stakeholder roles for the case study.

It is possible that a high-level, indicative, matrix may be devised using generic examples. However, while this has been done in section 6.3.2, it can only be a starting point for context-specific stakeholder analysis, as the specific project detail will influence it greatly, so a true generic power-interest matrix is not possible.

6.3.1.3 Stakeholder roles: creating a DP(C)F chart

Understanding the roles and responsibilities of different stakeholders within a project or even a business model is essential to understand how they may be engaged. A RASCI chart is a stakeholder management tool designed to give an overview of the key roles and responsibilities for different stakeholders within the delivery of a specific project (Project Management Institute, 2013). This is typically used at the scale of a specific project delivery, where the team involved may consist of a handful of individuals. However, the concept can be scaled up or down to projects of different sizes and be applied for city-wide strategic green infrastructure.

For each of the strategic project activities, the stakeholders will be assigned as: Responsible (R), Accountable (A), Supportive (S), Consulted (C) or Informed (I). More detail of these roles is shown in Table 47. (Some versions used in project management do not use the ‘supportive’ category). RASCI charts are used to remove ambiguity in defining roles within a project, and each stakeholder should really only have one role for each project activity – although they may hold several over the breadth of a complex programme of activities. It is possible for one stakeholder to hold both R and A roles, but it is not recommended.

While a RASCI chart is typically used for a 'live' project, perhaps being completed as part of a project inception process to understand roles and responsibilities, this underlying methodology was adapted to form a theoretical basis for stakeholder analysis for this research. While a RASCI chart is designed to include the stakeholders who are currently included in a project, this new format is designed to consider all stakeholders who could be included. This draws on the concept of co-production, therefore trying to include all potential stakeholders, and can be done at the stage of project planning, rather than waiting until inception.

These stakeholder roles can be assigned as delivery (D), project partners (P), contractors (C) and future prospects (F). Table 48 describes the roles of this DP(C)F chart in more detail. This adapted role classification allows for the suggestion of potential stakeholders that don't traditionally feature in existing business models for green infrastructure delivery, but who could be involved in a new business model.

Additionally, it allows the flexibility to be used across multiple stages of the project lifecycle and can adapt and change as the green infrastructure project does. At project planning stage, it is not possible to definitively decide who will be project partners, but this is nonetheless an invaluable planning tool that can be used to identify potential links, and start to develop value-stakeholder relationships into potential funding streams and business models.

Table 47: RASCI chart roles - who does what?

Role	Detail
Responsible	The individual who does the work to achieve the particular project activity. This is a 'doing' role, focused on project delivery. They are accountable to the A stakeholder. This could be a group or team of people, though ideally there should be an identified person within that group who is responsible overall for delivery.
Accountable	The stakeholder with ultimate accountability for the delivery of the project activity. They should have decision-making power and ability to direct the necessary resources to help achieve the project. They sign off on the work delivered by the R role. A project should only have one A stakeholder.
Supportive	These stakeholders provide resources or support the execution of a project activity. Often there are several S stakeholders involved in project delivery. They may have specialist skills needed to complete a specific project activity.
Consulted	Stakeholders who possess the information, knowledge or capability that is needed to complete a project activity. The particular knowledge or expertise can guide and shape the delivery of the project activity. Often essential for providing information or decisions needed to complete a project activity. There should be two-way communication with these stakeholders.
Informed	These stakeholders need to be informed of key project activities and decisions – usually after the fact. They are affected by the project delivery but do not actively participate to shape it. Communications with this group are usually one-way.

(Adapted from Resch, 2011, p 76-78)

Table 48: DP(C)F chart roles - who does what?

Role	Detail
Delivery	This stakeholder has the lead responsibility for delivering the project, and it will be initially driven by the values they are most focused on. It is likely that the potential roles of other stakeholders will be identified by the Delivery stakeholder as they are usually the driver of the project.
Partners	Stakeholders whose values align with the values of the green infrastructure project, but that are not the key drivers of it. This draws on the multiple benefits of green infrastructure, creating opportunities for partners to be engaged who will benefit from the green infrastructure, even where these values are not the primary drivers for the project taking place.
Contractors	These stakeholders are needed to deliver some aspect of the green infrastructure project but cannot be engaged as project partners. This role is not always used, and the preferred option would be to engage these stakeholders as Partners.
Followers	These stakeholders could be project partners in future stages of the green infrastructure lifecycle. They may be end users of the green infrastructure network after the current project is finished. They may be able to be actively engaged in the project as they will become beneficiaries of the project, even if they are not engaged at the creation stage of the infrastructure. It may be possible to engage future beneficiaries as Partners, but where they are not directly connected enough, they can be assigned Follower status, and may become Partners at a later stage.

6.3.2 Results

In addition to the stakeholder identification, it is also essential to understand the different roles that stakeholders play within green infrastructure delivery, especially as they can have several roles within a business model framework and may change roles throughout the life cycle of the green infrastructure. This was done by taking the stakeholders identified and conducting further analysis.

6.3.2.1 Stakeholder classification

Defined in section 6.0 above, at the most basic level, stakeholders can be grouped into two broad categories: active and passive. Active stakeholders usually fulfil enabling and governance roles, and may deliver green infrastructure projects, or be integral to the decision-making process that allows them to be delivered. Passive stakeholders on the other hand may be indifferent to the green infrastructure network in their area. As end users of the system, whether directly or indirectly they may be unaware of it and its role in providing ecosystem services in their area. Nonetheless, as a group impacted by the green infrastructure network, they are stakeholders as they are a source of potential value streams.

Based on the stakeholder identification activities, a list of the potential stakeholder groups is shown in Table 49, along with an example of the types of stakeholders, and a classification of whether they are more likely to be active or passive stakeholders. The comprehensive list of all the stakeholders identified in section 6.2 is shown in Appendix D. The role of active or passive stakeholder will always be context dependent and may change during the lifecycle of the green infrastructure system, but some stakeholders are more likely to be one type than the other.

Table 49: List of stakeholders classified as active or passive

Stakeholder type	Examples	Active/ Passive	Commentary
Community and charities	Climate Action Groups, Housing Associations, Schools	Either	Community level groups and charities will vary in their level of engagement depending on proximity to the green infrastructure project and any special interests that those groups have. A local campaign group with a relevant focus may become Actively involved, but proximity alone is unlikely to make a residents group interested beyond a Passive level
Funder	Big Lottery, ERDF, European Investment Bank	Either	Funders are all potentially active stakeholders if their usual funding remit covers an area or issue that is relevant to green infrastructure delivery. If they become a formal part of a project through its business model then they will be an Active stakeholder.
Government department	Defra, BEIS, DfT	Passive	The remit of several government departments in the UK have overlaps with themes relevant to green infrastructure delivery. However, as can be seen in the power and influence scores for government policies in the policy review (see Chapter 4 and Appendix B), their interests are high level and often too removed from delivery focus to be more than passive stakeholders in a GI system.
International bodies	United Nations	Passive	While this level of stakeholder might shape the delivery in a strategic sense, they are too far removed from the project to be actively involved.
Local and regional governance/ strategy	LEP, Local authority, combined authority, devolved Mayor	Active	These organisations could all be active stakeholders, with a lot of strategic and decision-making power at the delivery level of a green infrastructure network. Not all of them are involved in existing green infrastructure systems, but they all represent key opportunities for involvement.

Non-Departmental Public Bodies (NDPB)	Environment Agency, Highways England, Network Rail, NHS, Public Health England	Either	NDPB have the capacity to be active stakeholders where the project being delivered is relevant to their specific remit. For example, Highways England would be involved if a project included or directly impacted part of the strategic national road network. The groups identified as Passive here are focused more on operational than strategic level, and so are less likely to become involved in this type of project. The EA is likely to always be an Active stakeholder due to the direct relationship between GI, flood strategies and water quality. This will depend on the scale, however.
Private concerns	Residents, businesses, visitors, landowners	Either	Individuals, residents, businesses and site users may all be in some way impacted by a green infrastructure system, but unless that is a direct and tangible impact, they are unlikely to be active stakeholders. Landowners are likely to be active stakeholders as they have decision making power for a GI system reliant on their land.
Special interest group	Industry bodies, lead local flood authority, walking groups	Either	Other groups and organisations beyond community/voluntary level will be actively or passively involved depending on what their focus and remit is, and the extent to which this interacts with a particular green infrastructure project's context.
Utilities/public service	Water companies, transport operators	Passive	Utilities and public services may be directly or indirectly impacted. Where they are directly affected, they are likely to be active stakeholders. However, those with an operational rather than strategic focus may still remain passive stakeholders (for example, transport operators).

6.3.2.2 Power-Interest matrix

The power-interest matrix for stakeholder management was introduced and adapted for the policy review in Chapter 5. In this chapter it is being used in its original form to categorise the types of stakeholder in order to understand the power and interest they might have in a green infrastructure network, and therefore what level of communication and input they might need to have.

High

Power

Keep satisfied	**Manage closely**
These stakeholders will be those that have a governance or regulation function, but that have been classified as Passive stakeholders.	Active stakeholders who are involved in the delivery or guidance of a green infrastructure system or project. They are core to the project and it is probably reliant on their contribution for its success.
Monitor	**Keep informed**
These stakeholders are likely to be Passive, who are not from a position of power or regulation. This could include community groups like residents' associations, who don't have a special interest in the project but are ultimately impacted in some way by it.	They are likely to be Active stakeholders, but with an advisory or non-essential role in the project delivery. They could be useful for project success but are not essential to it.

Low High

Level of interest

Figure 41: Power-Interest Matrix for a generic green infrastructure system

As has already been discussed through the process of identifying and then classifying stakeholders, the specific stakeholders for any given delivery context will vary according to the parameters for that delivery. Therefore, it is difficult to make a comprehensive power-interest matrix for a generic example. Figure 41 shows a potential example of an indicative power-interest matrix for the stakeholder types already identified and used earlier in this chapter. While the stakeholder classification activity in the previous sub-section is reflected on the 'interest' axis of the matrix, here the 'power' axis starts to divide those by the regulatory or governance powers that stakeholders might have. Having decision-making power in the realm of public space, for new or retrofit development, or in assigning finance and funding will give stakeholders more power compared to those who do not have this.

6.3.2.3 Stakeholder roles: creating a DP(C)F chart

Building on the previous two sections of understanding and identifying whether stakeholders are active or passive, and the levels of power and interest they might have, this section starts to present more detailed classifications of stakeholders' roles using a DP(C)F chart. This reflects the roles and responsibilities that different stakeholders might have in the delivery of a green infrastructure system. Again, it is difficult to make an accurate, specific chart for a generic example, but a worked example based on the delivery of a hypothetical green infrastructure system for Newcastle is presented in Table 50. The project activities used in this example are a high-level conceptual example, representing the core components and delivery activities of green infrastructure assets.

This indicative framework outlines potential project roles and responsibilities within a green infrastructure network. As Table 50 is a hypothetical example it does not present a definitive or fixed attribution of roles – therefore only the main stakeholders (those most likely to be involved in the example project activities) are included in this table. (The table is populated with some key activities that might be used in delivery of a green infrastructure system, informed by the types of asset identified in Chapter 2, section 2.2). This type of table should be created at the onset of each green infrastructure project, populating it with the specific green infrastructure interventions and the full list of stakeholders relevant to that location. Once completed with each stakeholder assigned their DP(C)F status, the framework should be used to identify how each stakeholder can or should be engaged to create a business model for green infrastructure delivery, which is explored further in Chapter 7.

Table 50: Example DP(C)F for potential green infrastructure network activities in Newcastle upon Tyne

	Key stakeholders								
Green infrastructure intervention	Newcastle City Council	Newcastle Parks and Allotments Trust	Allotment site managers	Allotment plot holders	Building owners	Building residents	Development company	Expert advisors	Subcontractors (awarded delivery contracts)
Review of allotment sites (fit for purpose, need to expand, etc)	P	D	P	P			F	C	C
Establish project to assess city centre roofs for green roof suitability	D	F			P	F	P	C	
Annual park maintenance	C	D		P		P	F		C
Building SuDS at a new development	P				F	F	D	P	C
Adding new trees in city centre (retrofit)	P	P			P	D	F	P	P

6.4 Discussion: who benefits and who pays?

In order to address the barriers to green infrastructure delivery, this thesis has proposed that new forms of value need to be identified and capitalised upon in order to increase the business model archetypes that can be used. Traditional delivery and values are insufficient. In Chapter 4, a wide variety of potential values were identified. However, these potential values can only be realised if they are of interest to some stakeholder. The value proposition must be translated into actual value (whether monetary or otherwise) by being relevant to someone within the business model.

It is also essential to understand at what stage during the infrastructure lifecycle particular stakeholders may be drawn in, and what their roles within the business model might be. The results in this chapter go some way to addressing these concerns though stakeholder identification and analysis.

Identification using three different approaches ensured that a comprehensive list of the potential stakeholders in a green infrastructure system was possible. However, it also highlighted the fact that the list is very long, and that it is difficult to identify specific stakeholders without having the context of a specific green infrastructure network delivery to work with. The quantity and complexity of stakeholders means that a generic list can be made at a high level, but that a detailed list is really only practical when using a specific project or network. For example, in section 6.3.2.3, Table 50 only some of the stakeholders were identified as the most obviously relevant for particular green infrastructure delivery activity. Nonetheless, this list of potential stakeholders is a useful starting point, especially for providing examples to use when analysing their relevance. Stakeholders will have different interactions across the spatial distribution of a green infrastructure network, and also may play different roles at different times within the lifecycle of a particular infrastructure asset. It is therefore essential to combine stakeholder analysis with the work on value (see Chapter 4) in order to understand their priorities and drivers through the value mapping process. Developing these stakeholder-value overlaps with more comprehensive detail starts to create business models, and this is explored further in Chapter 7.

The spatial analysis in particular introduced some nuanced detail that would need to be explored further in order to design an effective green infrastructure system for the city as a whole. It used the case study of Newcastle again, and even with only some of the stakeholders plotted as an indicative starting point, some key relationships became obvious. For example, the green infrastructure new development at *The Helix* in Newcastle is further up the Tyne catchment than some of the city centre area, therefore water flow downstream of the site towards the river may be impacted. This location houses some critical infrastructures, including the national railway station. In order to explore this sort of nuanced relationship in more depth, stakeholder analysis of various types was conducted.

Simply identifying stakeholders was not sufficient to be able to understand their potential roles within a business model. More detailed analysis was used to explore more detail of the interests, power dynamics, and roles of different stakeholders for delivery of green infrastructure. Classifying stakeholders as passive or active provides a simplified starting point for gauging their level of interest. This can then feed into the process of developing a power-interest matrix for the stakeholders. The most potential for detailed analysis, however, comes from the process of creating a DP(C)F chart for green infrastructure delivery. A DP(C)F chart can be used at the activity-specific level, as it is in the worked example in Table 50 (building on the conceptual original of a RASCI chart). However, it is designed to be translated into a strategic level for the delivery of a whole green infrastructure system at city-scale. This concept, creating a strategic and specifically delivering individual projects in alignment with it, would involve sub-levels of management and delivery plans, where specific components are delivered based on the assets and links within the green infrastructure network. However, as noted in Chapter 2, green infrastructure is currently not identified as a critical infrastructure for an urban area; no single organisation, group, or individual can be identified as accountable for the delivery of the strategic network of green infrastructure overall.

This is a key barrier to the translation of green infrastructure assets into an interconnected network, which is discussed further in Chapter 7, section 7.3. No one is accountable for the provision of green infrastructure and therefore its delivery as a system does not happen. As noted in Chapter 2, the ecosystem services provided are just as essential as power, communication or mobility services provided by other infrastructure systems. Drivers for green infrastructure creation must therefore be found elsewhere than stakeholders, for example through policy mechanisms. These drivers, and how they motivate stakeholders and identify or create value propositions, are essential for translating the value-stakeholder overlaps into actual business models.

If green infrastructure's potential for supporting and creating resilient cities is to be realised, then accountability needs to be introduced for its provision. The changes towards devolved regional governance may provide an opportunity for this to happen.

The ways in which such connections can be made and utilised is developed further in the following chapter, and it is there that the essential relationships between the stakeholders identified here, and the potential values of a green infrastructure network are explored. This chapter used the Newcastle case studies to identify a list of who benefits and who might therefore pay for a green infrastructure system, but knowledge of how those values are understood and connected is essential in order to realise the full potential for green infrastructure business models.

6.5 Chapter conclusion

Understanding stakeholders within a green infrastructure system is essential to identifying opportunities and barriers for the delivery of green infrastructure networks, and for finding novel and innovative ways to finance and fund them. Stakeholder identification and analysis are needed to translate potential value into an actual value proposition for a business model. Drawing on tools and techniques from project management literature and best practice makes it possible to start to identify and analyse who these stakeholders are and what their interests and roles might be within the network.

Identification of potential stakeholders used multiple approaches to create a comprehensive and detailed list that reflects how different values intersect with different urban organisation. However, not all stakeholders will be relevant at every stage and type of green infrastructure project. Therefore, a more detailed understanding was needed. Knowing what is interesting to different stakeholders enables the engagement of non-traditional ones, and increases the potential options for business model creation.

No single approach for stakeholder identification and analysis was fit for purpose, to provide a comprehensive understanding of them and their priorities. Therefore, several techniques were used to explore the stakeholder dynamics, using a mix of both generic and specific examples of stakeholders and delivery activities.

Key findings were that:

- Multiple approaches are needed to conduct a robust stakeholder analysis (including active stakeholder engagement for ‘live’ projects)
- Spatial proximity to green infrastructure assets is associated with stakeholder interest
- Stakeholder relationships to individual green infrastructure assets is easier to define than the relationship to a system-wide network
- The ‘power’ of a stakeholder influences how effective they might be at enabling green infrastructure development
- Stakeholders can be categorised as providing green infrastructure or benefiting from it, however in reality it is not a binary role: many stakeholders fall into both categories
- This circular relationship between providing the infrastructure and benefitting from it is an essential foundation for creating business model innovation for its delivery.

The relationships between stakeholders and benefits (value types) as building blocks for business models are taken forward in the following chapter, Chapter 7, as is the detail around spatial understanding of stakeholder relationships with the green infrastructure network, and the opportunities and barriers to having accountability for a comprehensive green infrastructure system at city-scale.

Chapter 7: Towards new business models for green infrastructure delivery

7.0 Chapter introduction

The core aim of this research project is to explore and define what an innovative business model for effective green infrastructure system delivery would look like. In this chapter, the work building the necessary elements to achieve this is brought together.

The concepts of business model structures were first identified from the literature in Chapter 2, section 2.4, and these have been adapted to create a series of business model archetypes that could be used for delivery of green infrastructure. These business models are informed and shaped by the research into values, stakeholders, and policy drivers, detailed in the preceding chapters. Using these elements and developing the evidence into suggested practice is fundamental to the underpinning methodological ideology of evidence-based project planning (see Chapter 3, section 3.1 for further discussion of this methodological approach).

Objective 1: Identify current opportunities and barriers to green infrastructure delivery • What opportunities could be developed further? Objective 4: Identify stakeholders with a potential interest in a green infrastructure network, and consider how to align their priorities and needs • What are their priorities and needs, and how can these be aligned with green infrastructure value? Objective 5: Develop an innovative business model archetype for effective green infrastructure delivery. • How are these various elements used to build and shape new and innovative business model archetypes for green infrastructure delivery? • Which opportunities can be capitalised on; and how are barriers overcome?

The overall synthesis and discussion of these results is presented in this chapter and used to create business model archetypes suitable for green infrastructure delivery, along with recommendations for improved delivery generally. This addresses several research questions, but particularly those under Objective 5.

This chapter brings together the key findings of this research project as a whole and considers how this can create innovation in business models for green infrastructure delivery, against the backdrop of changing political, economic and environmental landscapes for urban areas.

7.1 Improving value capture

In Chapter 4, the opportunities for and challenges of, capturing the value of green infrastructure benefits was critiqued. However, value capture could be improved and expanded in order to increase the potential value proposition for a business model, and increase the relevance to a broader range of stakeholders. This section proposes some improvements and discusses their implications with regard to business model development.

The current challenges for value capture – translating benefits of green infrastructure into values, whether monetary or not – include:

- Difficult to translate some values into quantifiable terms (especially intangible benefits, or those where attribution is hard to pinpoint)
- As with all evaluation, a balance needs to be made between using proxy values and averages and getting a robust and accurate appraisal for the asset or network. Most methodologies for economic appraisal are based on using proxy values or general values, rather than collecting detailed data specifically for the site or scheme in question. This overcomes the challenge of evaluation simply being too complicated due to the burden of data collection, and therefore making it impractical to do an evaluation, especially for a smaller scheme. However, this approach of using proxy values is not without its challenges. Some detail and nuance is inevitably lost, and the approach can imply a level of precision that is not an accurate representation of the uncertainty around a calculated value.

- Comparison between different value types often have different reference scales – e.g. land prices will always be very large for urban areas, even though the green infrastructure aspect of development may have little additional impact on the value over and above general regeneration. Whereas general regeneration will have little impact on the wellbeing of a nearby resident, but the inclusion of green infrastructure may. Pre- and post- value changes should focus on the impact of the green infrastructure aspect of a development separately to any other regeneration or development aspect of the scheme, but it is difficult to separate these out, and the methodology is not yet established for doing this.
- Green infrastructure is generally delivered in disparate schemes, but the overall function as an infrastructure system comes from it being connected – there is not yet an established way of identifying the specific value of the connectivity, nor an understanding of how to measure the value of the system over the individual assets. This can also lead to issues of double counting, and/or data sharing problems because of the number of different smaller schemes with little or no strategic oversight.

This research attempts to address some of these challenges: focusing on non-traditional stakeholders allows more connections to be made with hard-to-quantify values: where values are difficult to monetise or seem small compared to some of the big values like health, targeting the value towards a particular special interest group or because of a current issue will help to generate a value proposition from a benefit. The different ways of connecting value and stakeholders are discussed further in section 7.2.

7.1.1 Limitations of current evaluation tools

Using the currently available evaluation tools offers opportunities for quantifying value and therefore can inform the development of business models. However, most of the frameworks for this type of evaluation rely on use of proxy values, averages, and generalised data to create robust evaluations. This is standard practice within economic appraisals but is not without its critics. It is sometimes necessary to work with proxy values in order to simplify the burden of data needed to create a working evaluation. Non-experts on the areas of input data can still work with this kind of appraisal tool and get a working project evaluation out of it.

For example, the use of the *B£ST* evaluation tool in Chapter 4 (see section 4.2) included input data on the flood alleviation ability of a SuDS scheme being delivered. The input options included the detailed results from a separate flood modelling exercise, or input of data about the features of the site and relying on proxy values to estimate what the flood alleviation impact might be. Naturally using these two different types of inputs leads to two different outcomes. This means that comparing schemes using the same evaluation tool may show outcomes that are different, with one scheme performing better than the other, but without any way of showing in the result that they are based on inputs of different levels of accuracy/robustness. This is a challenge in all scheme appraisals of this type, and why it is folly to rely on headline figures alone without a discussion of the evaluation methodology every time. Schemes being directly compared ought to have the same underlying input types, or if this is not possible, they need to be accompanied with the relative uncertainty as part of their presentation and use.

While the pitfalls and caveats of this type of economic appraisal approach are well understood among the evaluation community, the underlying approximations, estimates, and confidence levels are often unknown outside of it. Particularly when discussing project impacts with a non-specialist audience, the nuance of the evaluation can be lost in favour of a headline figure. Also, such tools are not foolproof, and even an experienced evaluation specialist can choose the wrong inputs. For a non-specialist, understanding the types of inputs and outputs sufficiently to recognise potential errors is not a given. Where evaluations are conducted or reported inaccurately, this can destroy wider trust in the evaluation concept and potentially render all attempts to assess a project or scheme worthless. It is therefore the duty of the practitioner to accurately and objectively assess and report on any findings. Where research techniques exist to inform an appraisal, they should be used. Proxy values should really only be relied on when there is no other choice for input data. While this causes problems of accessibility and can make smaller schemes and community schemes harder to evaluate due to lack of expertise or limited funds to pay for expertise, it can improve the quality and reliability of the discipline as a whole.

7.1.2 Attribution of impact

Likewise, while one of the challenges of any evaluation is linked to attribution of the impact to the delivery of a specific scheme, clearer distinctions should be made in reporting between direct and indirect benefits. Only the direct benefits are usually of interest from a finance and funding perspective, and although the attribution and extent of them may only ever be an estimation, acknowledgement of the uncertainty and using potential value ranges should become more common. Insisting on this type of identification and discussion, and rejection of the single figure valuation is not impossible in collaborative working between delivery partners and other stakeholders. Understanding the likely and potential ranges of value that can be realised from a green infrastructure scheme, and the confidence level behind these, creates dialogue and builds trust between delivery partners and beneficiaries. Being upfront about uncertainty can help funders and finance partners to make informed decisions about risk levels and understand the potential return on investment. This collaborative, trust-based finance style is arguably better than promising high value returns, and then risking being unable to deliver. By communicating the uncertainty, the risk of a low return is shared between delivery and finance stakeholders, and the culture of collaboration is developed. This may also allow for the incorporation of more non-quantifiable benefits, as the main driver of a scheme is not purely and strongly motivated by profit, but by a shared goal for improvement, with less focus on the return on investment as the sole benefit.

7.1.3 Towards better value capture

In order to reduce the negative impact of these challenges, good practice among evaluation in green infrastructure needs to include:

- Specialist input data, where available
- Some way of scoring an evaluation on its robustness, depending on the input types, and confidence behind proxy values
- Only comparing schemes where the same data types have been used for the calculations – therefore comparing like with like as far as possible
- Routinely showing potential benefits as a value range than a single figure. Allowing better understanding of the confidence behind the figures, and the ideal, average, and conservative benefit levels.

- More collaboration and dialogue between delivery partners, financiers, and beneficiaries to understand the uncertainty in benefits calculation and work on the most robust calculations possible, and to share the risk.

Understanding who benefits and who pays is also essential to properly appreciate the potential costs and value of such a scheme, and this is discussed further in section 7.2. A key element of a business model is understanding the value proposition, and this requires knowing not only what the potential values are, but to whom they might be valuable.

7.2 Matching stakeholders and values – the value proposition

This section of the chapter explores the overlaps between the stakeholders and the values and therefore how this can create opportunities for realising the potential values. Benefits cannot be realised as values if they are not of interest to any stakeholder within the business model.

Following the previous stages of the research, it was possible to identify both the potential values of a green infrastructure network, and the key stakeholders within a city-scale level of green infrastructure delivery. These can therefore be explored in terms of spatial overlaps, to produce a stakeholder-value map. The stakeholders involved across an entire network may be many and varied. Likewise, the potential benefits that may be realised from an effective green infrastructure network are plentiful, cross-cutting, and can create opportunities in both direct and indirect routes. Thus, linking these to capitalise on the opportunities is paramount to the effective delivery of a suite of business model tools for enabling effective green infrastructure.

However, the value can only be realised within the business model if it is being targeted to the most relevant stakeholders. Chapter 6, matching stakeholder interests to potential values, becomes essential for building the innovative business model needed for stakeholder delivery. In this section of the thesis, the ways of mapping the stakeholders according to their overlapping interests, their spatial proximity, and through their roles in time and space are all explored.

7.2.1 Stakeholder and value overlaps: interest-based overlaps

As stated above, two of the key components in developing a business model for green infrastructure delivery are the values and the stakeholders of the system. In order to develop these two discrete elements, this research developed the potential connections between stakeholders and benefits through several types of value map, demonstrating how connections could be made between the benefits and beneficiaries of green infrastructure.

This is done in the first instance through matching the stakeholders and values thematically – that is, by area of interest based on the types of different value, and identifying which stakeholders have interests in that type of potential value.

Matching the stakeholders to their values-of-interest is to some degree circular logic, as the value types were also used to identify the stakeholders.

Nonetheless, this allows a comprehensive understanding from both a top down and bottom up approach to ensure that all potential stakeholders are considered, and prioritised according to their level of interest, relevance, and role. Table 51 shows some of the links between grouped types of stakeholders (based on stakeholder identification in Chapter 6, section 6.2), and some of the main benefit areas, which inform the potential values, based on the benefits of green infrastructure identified in the literature (see Chapter 2, section 2.3) and from the evaluation tools used in Chapter 4.

Table 51: Green infrastructure benefits and interested stakeholders

		International bodies	Local authorities	National government departments	Non-departmental public bodies	Professional bodies	NGOs	Regional governance	Utility infrastructure managers	Transport infrastructure managers	Housing developers	Educational institutions	Business interest groups (e.g. BID, etc)	Businesses	Employees	Resident associations	Residents	Local environment groups	Land owners
Environmental	Biodiversity and habitats	x	x	x	x	x	x					x					x	x	x
	Water regulation	x	x	x	x	x	x		x		x	x				x	x	x	x
	Thermo-regulation	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x	x
	Reducing air pollution	x	x	x	x	x	x	x		x		x				x	x	x	x
	Increasing or relocating flood risk	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Social	Amenity value		x			x		x			x	x	x	x	x	x	x	x	
	Reduction of crime		x	x	x	x		x		x	x	x	x	x	x	x	x	x	x
	Educational resource	x	x			x	x	x				x					x	x	
	Health and wellbeing	x	x	x				x				x			x	x	x	x	
	Social cohesion and sense of place	x	x			x		x		x	x	x	x	x	x	x	x	x	x
	Increase in crime/fear of crime	x	x	x		x		x		x	x	x		x	x	x	x	x	x
	Gentrification-related population displacement	x	x			x	x	x			x	x		x	x	x	x		
Economic	Land value		x	x		x		x			x	x	x	x					x
	House prices		x	x							x	x				x	x		
	Avoidance of cost (e.g. via lowered flood risk)	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
	Job creation		x	x				x				x	x	x	x		x		
	Increase in socioeconomic inequalities	x	x	x		x		x			x	x	x	x	x	x	x		
	Change from capital- to operational- expenditure		x					x	x	x	x	x							x

(adapted from CIRIA, 2018)

7.2.2 Value maps for green infrastructure benefits: spatial proximity

As identified in the literature review (see section 2.2), the benefits of green infrastructure can vary according to the context of the location in which the network is being implemented. Understanding the spatial distribution and extent of green infrastructure values enables the further identification of interested stakeholders based on proximity. Although the spatial evaluation of green infrastructure is largely under-developed (outside of proprietary approaches), the existing tools can be used to develop this identification process. At the most basic level, simply reviewing the locations of green infrastructure assets within an existing or proposed network can be cross referenced with location data of key potential stakeholders. Detailed street maps of urban areas, or business listings for example, can offer data on the stakeholders that may be potential beneficiaries of green infrastructure system development.

Building on the maps created in Chapter 4, showing some of the spatial extent of benefits (therefore potential value), the maps of some key stakeholders have been digitised into a shapefile in ArcGIS and overlaid on the value maps produced for *The Helix*. This shows the locations of stakeholders relative to areas of particular benefit impacts. As a simplistic starting point, this already shows areas for potential value and stakeholder overlaps and can provide a starting point to open dialogue around finance, funding, and business model development. No single methodology for a more sophisticated approach yet exists for this, and at this neighbourhood scale of analysis, the basic process of reviewing benefits relative to stakeholders is sufficient for the purpose.

This may only work for the benefits that are easy to visualise spatially, and it may be difficult to combine this with spatially distributed value, yet it identifies relevant connections nonetheless. While the case study testing with the spatial analysis tools of the *multiple benefits toolbox* (see chapter 4, section 4.2.3) reviewed in detail at the potential extent of green infrastructure assets in one small area, a wider view can be mapped as well.

Using the stakeholders and potential benefits together, it is possible to start to look at areas of shared interest, to work out who benefits from a green infrastructure network and to explore opportunities to engage new stakeholders directly.

Figure 42: Stakeholders overlaid on Access to Greenspace output map

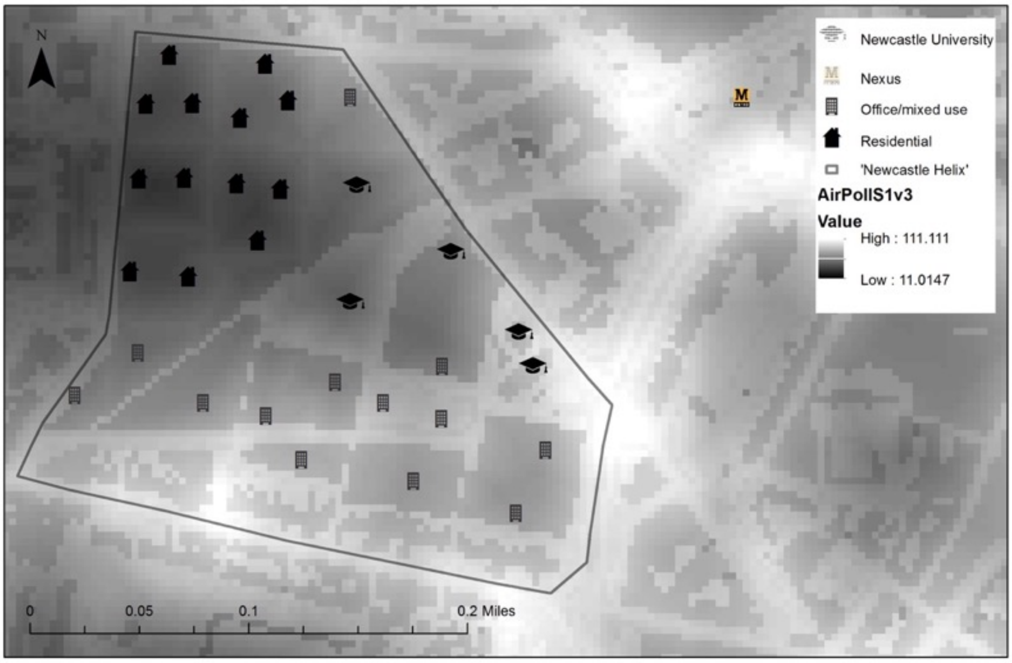
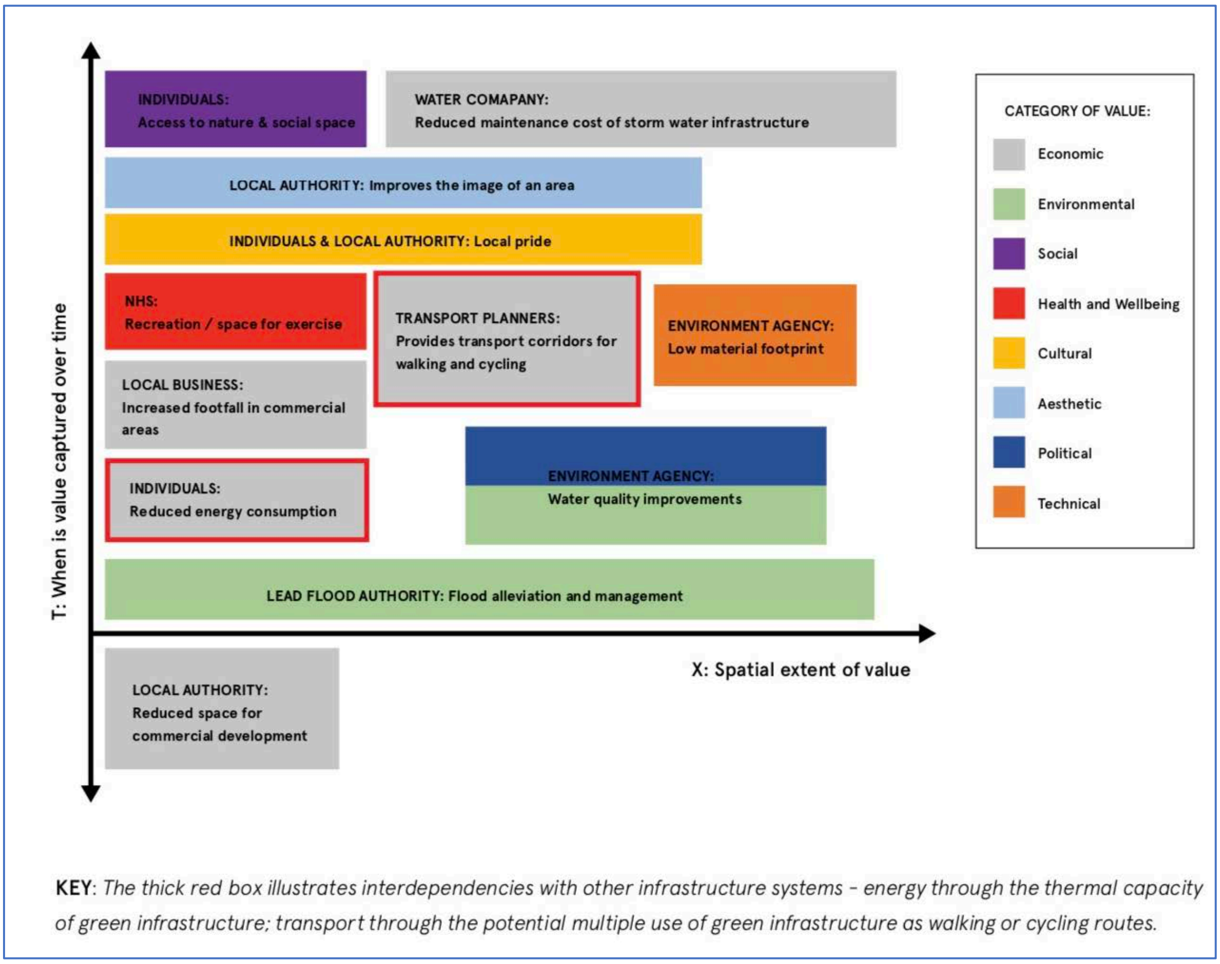


Figure 43: Stakeholders overlaid on Air Pollution output map

Figure 42 and Figure 43 show maps where some of the stakeholders overlap with two of the benefits that were mapped for *The Helix.* In an additional layer of complexity, there is also the fact that some green infrastructure assets can offer benefit at multiple spatial scales – for example shade and cooling from urban trees has a highly localised impact, while the biodiversity benefits of an urban tree network are more dispersed. They can also have different levels of benefits at different time scales. Some benefits may have impacts immediately, while others take time to have an effect. For considering this type of spatial and temporal relationship, a different method of drawing value maps is needed.

7.2.3 Spatial and temporal extent of value



Note: the negative plot on the y-axis indicates a negative impact, and not negative time

Figure 44: A generic value map for green infrastructure, created by the iBUILD project, iBUILD (2018)

A second layer of complexity can be seen in the differing timescales of benefits. Some parts of a green infrastructure network may provide instantaneous benefits, while others are delayed. The exploration of benefits across time (T) and spatial (X) scales can be done using a T-X diagram, to create a value map for green infrastructure shown in Figure 44. This process was used as part of the iBUILD programme, with the stakeholders and the values they might experience shown within the spatial and time scales that these values might be realised. This process was enhanced by defining the stakeholders, benefits, and the likely time and spatial scales through workshop activities, therefore creating a widely agreed on description of the system. This process creates a broad understanding of the relationship that stakeholders and values have in space and time, through a generic example, and can be a useful starting point for building the inputs needed for a business model. How this value map can provide inputs is discussed in section 7.4.

7.3 From assets to network

In Chapter 2, section 2.3.3, the concept that green infrastructure is a system, and therefore needs to be considered as such in the process of evaluation was introduced. Throughout this thesis so far, green infrastructure assets have largely been considered on an individual basis or in small groupings by proximity. However, the way they work together as an interconnected network is essential to be able to deliver them as a true infrastructure system, akin to any other infrastructure system that an urban area relies on. In section 7.3 this is discussed, with the opportunities and barriers for doing so highlighted, alongside some suggestions for using the systems approach to bring together isolated areas of green infrastructure assets within the case study of Newcastle.

A fundamental flaw in the current value and evaluation approaches is that they are all designed to treat assets in isolation, rather than as an interconnected network. Although several assets can be included to evaluate a whole scheme or area, this is still underpinned by treating them as separate assets, rather than reviewing the network or system as a whole. Yet the literature strongly suggests that being a true infrastructure system requires the delivery and acknowledgement of green infrastructure as a network as a whole (see Chapter 2, section 2.1). Therefore, to support the delivery of green infrastructure as a legitimate infrastructure system and maximise the ecosystem services it can offer, practitioners should be using a whole system approach. This creates a challenge for understanding value, as this systems analysis is less established in evaluation theory. In this section, the discussion reviews some of the challenges and opportunities for exploring a systems approach, and for taking the understanding and valuation of green infrastructure from separate assets, to an interconnected network.

One particularly useful example of the potential reach of green infrastructure benefits across a large area is that of its flood management value. As can be seen in Chapter 3, Figure 21, the city of Newcastle upon Tyne is located in the lower portion of the Tyne catchment as a whole. Thus, the surface water management and flood performance is affected not only by the permeability, vegetation and pluvial and fluvial conditions within the city itself, but also by the conditions in the upper catchment. This is a good argument for the holistic approach to green infrastructure network planning, and working across regional and governance boundaries to coordinate these networks at a greater level.

Even within the city, the case study focus sites of *The Helix* and the CBD are both further up the catchment than some of areas of the city, with water from more northern and western parts of the city centre draining down towards the River Tyne at the southern boundary of Newcastle city area. Within this area are many stakeholders, including businesses and individuals, but also key national infrastructure connections at Newcastle Central Station.

To properly understand the impact of any green infrastructure network development across the whole of the city area, flood modelling (of the kind shown in Chapter 3 section 3.3.5) should be conducted to assist with project planning. It can identify current or potential problem areas within the city, and by simulating different options for green infrastructure development, offer additional information on the impact that design options and location options can have within the city. Understanding how the green infrastructure network will perform in different conditions will help to maximise the value realisation of the network as a whole. It can also be used to identify and engage additional beneficiaries, whose location relevant to the green infrastructure value can be shown even when they are not close neighbours to the assets being developed.

Likewise, other types of green infrastructure value, like air quality, can be modelled in similar ways. Using as many sources of data as possible for the different potential values of any green infrastructure network development will enable trade-offs to be made between costs and benefits, and between locations, and for understanding whether the design of green infrastructure for one value type could have a negative impact on another. (The literature review identified, for example, that some planting types near roads could poorly affect air pollution – if this type of planting was designed for flood management, the potential flood management value and negative air quality value could be balanced according to their relative scale).

Additional research could be conducted to understand how these relationships work in a series of case studies, and to discover whether general guidelines can be derived in order to shape green infrastructure planning across as many contexts as possible, even where there is not the resource available to conduct detailed modelling of various development options. The additional research is discussed further in chapter 8, section 8.3.

7.3.1 The green infrastructure-benefit relationship

The evaluation tools tested in this research allow for inclusion of many assets, at any scale. It is underpinned by the assumption of a linear relationship between quantity of green infrastructure and benefit, with no minimum threshold nor plateau of effect. Yet the relationship between scale of the network and the resulting benefit is not understood. It seems logical that there must be an optimum range, below which is not useful (as assets won't form a network) and extra-optimal (where the marginal gains are not valuable, or even start to create disbenefits). The sensitivity testing of the tools in Chapter 4 (section 4.3.2) indicates that the linear relationship will continue even where it is not logical that the benefits will continue.

If we consider the literature on disbenefits of green infrastructure (Chapter 2, section 2.3), there is discussion of the need to choose practical and appropriate solutions based on the delivery context. For example, avoiding planting that prevents the dispersal of particulate pollution along roads, and avoiding the creation of too much tree shade in areas where cold and damp may cause problems. The evaluation tools do not allow for this type of detailed nuance in benefits and disbenefits. Largely because doing so is always so context specific. Economic appraisal alone cannot inform or dictate the decision-making process for establishing a green infrastructure network, and instead decision making needs to be based on practical considerations for the context. The evaluation tools can only provide an estimate of value and indicate the value types that may be prevalent. They cannot, and should never, be used to simply inform the available benefits.

The relationship between green infrastructure assets and potential benefits is not understood sufficiently to build in a very detailed relationship model within the evaluation tools. However, better understanding of the relationship between assets/network and benefit would improve the knowledge in this area and could be a key focus for future work.

Figure 45 and Figure 46 show proposed relationship models between the extent of the green infrastructure network and the extent of the benefit. Figure 45 suggests a linear relationship within threshold limits. It is suggested that above some minimum quantity of assets, and below a maximum limit, the relationship between benefit and asset is broadly linear. This builds on the existing relationships that underpin evaluation work, but sets a minimum amount under which there is insufficient quantity of green infrastructure to achieve any benefit, and a cap above which the marginal gains become negligible.

Figure 46 however, shows a more complex relationship, that there is no minimum level – any asset starts to create benefit, but there is an optimum amount, after which the marginal gains cease, and then ultimately, disbenefits occur due to impractical choices and the burden of maintenance, for example the overgrowth of planting starts to decrease the benefit.

It is arguable that either of these basic relationships could be possible, with the true relationship possibly including some mix of both. While there is not currently the underlying knowledge available to feed into this relationship exploration, the lack of this forms a barrier to understanding the connectivity or system, over and above the assets as individual elements. Both of these suggested relationship models are oversimplified already. Especially as within the existing evaluation tools, the relationship is sometimes a binary yes/no for the existence of green infrastructure, and then the proportion of benefit is dictated not by amount of green infrastructure but amount of other indicator, for example number of people.

Until these relationships are better understood, the evaluation tools are of limited use at the extremes of scale, as they are simply not designed to be accurate over very large assets. This is a key limitation in being able to understand the overall network or systems benefit of green infrastructure, as the connectivity and scale are two key elements that differ the system from its component assets.

While there is no established way of understanding this network relationship between the assets involved, future research does need to focus on this to fill the research gap, see Chapter 8, section 8.3 for more detail. In the meantime, other ways of exploring and understanding the relationships of the system as a whole can be used. First and foremost, by looking at the flows of value through the system.

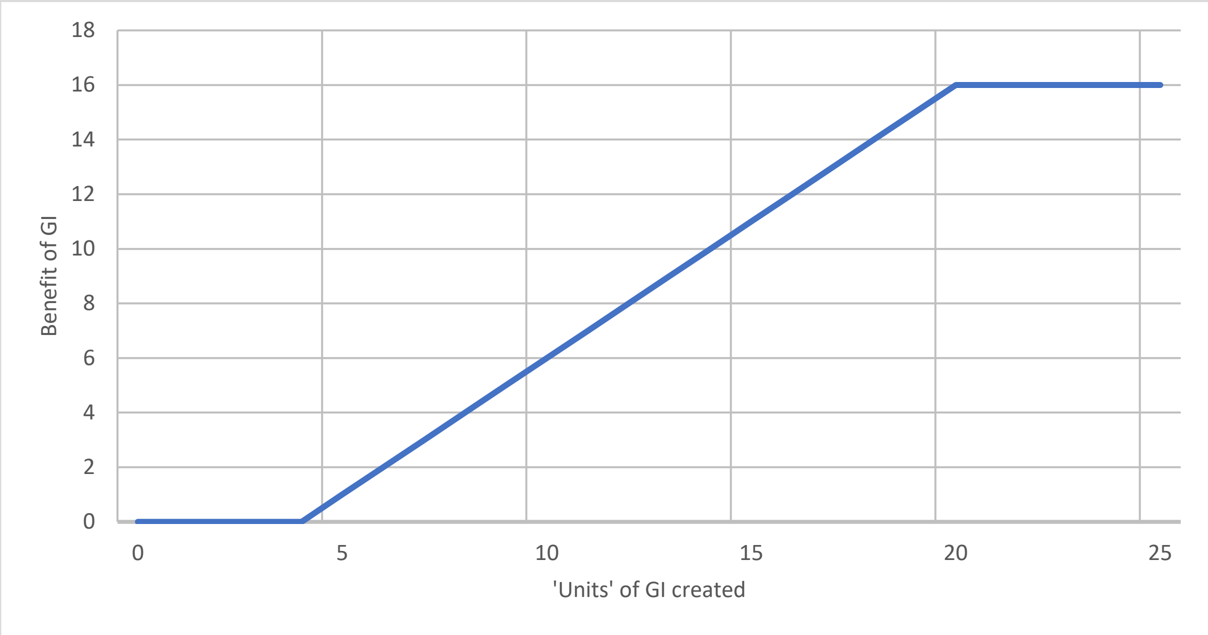


Figure 45: Suggested GI-benefit relationship: linear, with threshold limits

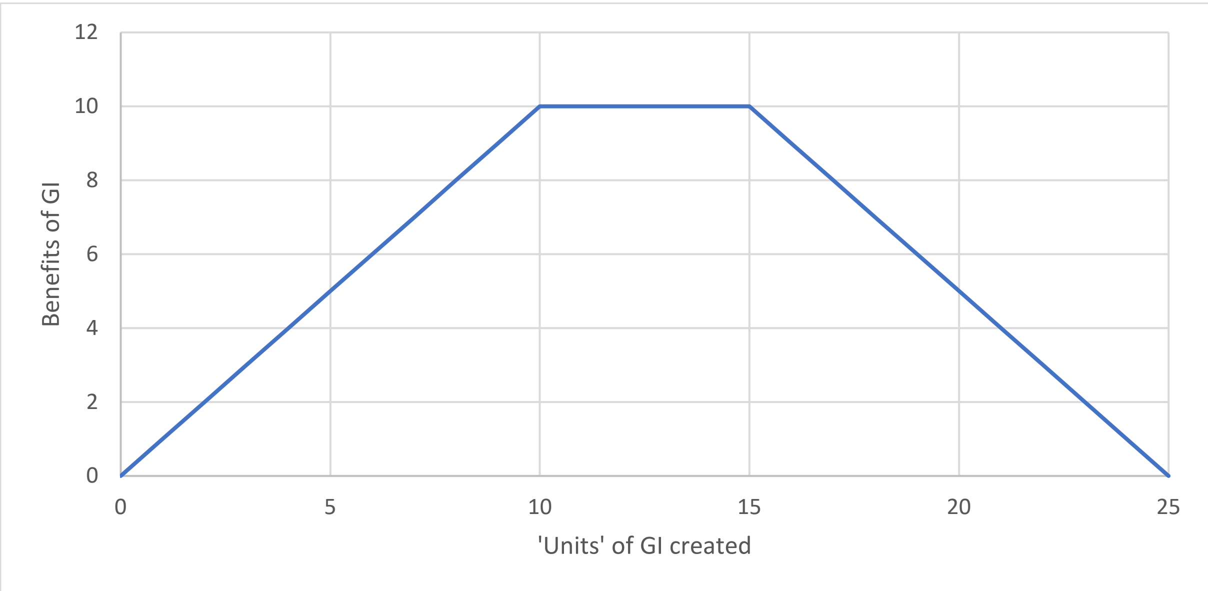


Figure 46: Suggested GI-benefit relationship: optimum amount, with decrease after

7.3.2 Flows of value

One way of reviewing the system as a whole, is to look at the flows of value through it. As shown in Chapter 3, section 3.2.1, flows of value through a system are a key tool to understand the benefits of infrastructure and how its business model might work. Figure 47 shows how the basic flow of value through development of an infrastructure asset might look, from the initial investment that allows the building of the asset. Note that the return arrow marks the role of some stakeholders as the providers of the investment. This is discussed further in section 7.3.3. The figure then shows how this process delivers benefits of various types, which are of value to different stakeholders (and there can be some overlap between which stakeholders are interested in which benefits), and ultimately there is an overall resultant value.

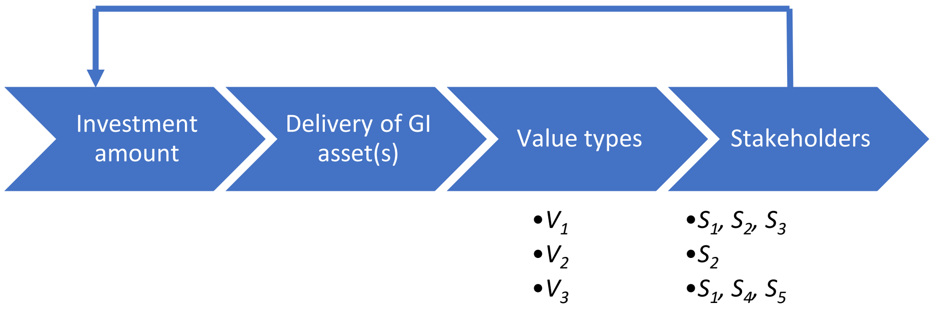


Figure 47: Basic value flow through a GI system

A worked example of this using a potential green infrastructure expansion for Newcastle is shown in Figure 48.

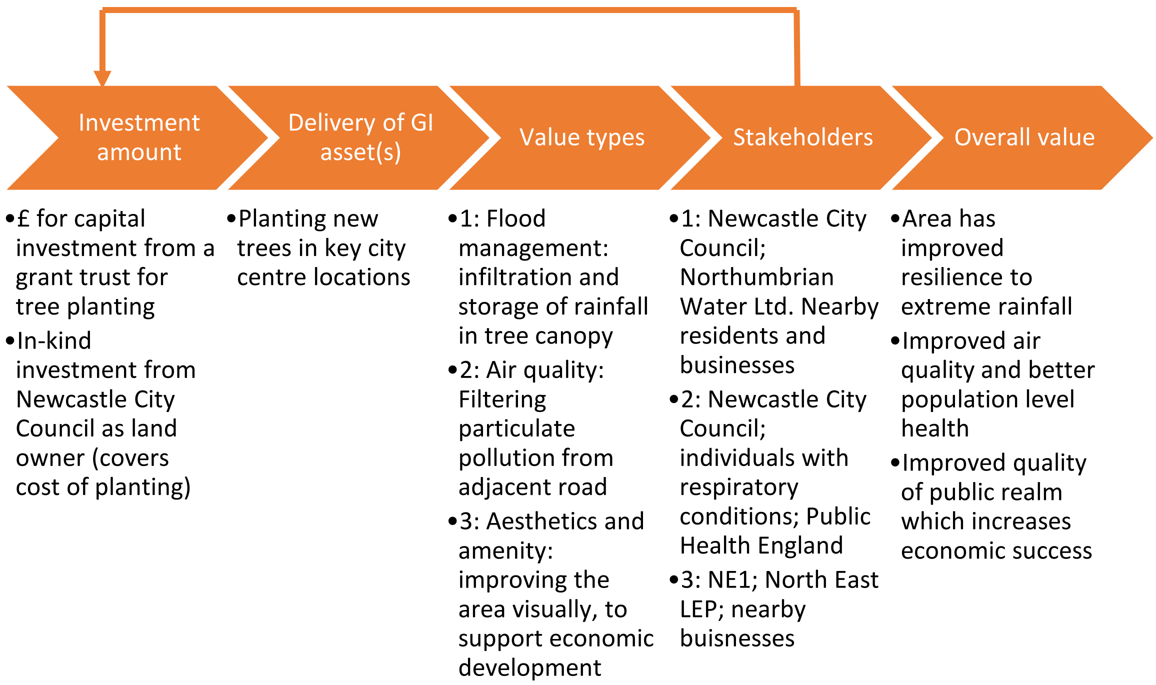


Figure 48: Flow of value, illustrative example using tree planting in Newcastle

The development of this type of value flow based on individual assets or asset types, into an overall network, involves more complexity. In practice it also requires a good understanding of how to avoid double counting of value, and ideally also ways of capturing scale of the network and the scale of the value. However, for the purposes of outlining the concept, the development of this simple value flow diagram into a city-wide flow of value is shown in Figure 49. This diagram shows value being introduced into the system through investment, and being used to deliver a green infrastructure system. This system is composed of interconnected assets, which deliver different types of value (V_n). The value types then flow to the relevant stakeholders (S_n). These stakeholders might enter the picture at different stages during the lifecycle of the asset, and can be involved in one or more types of value. Together, the values reaching all the different stakeholders form the city-wide value of green infrastructure as a whole, at a strategic level.

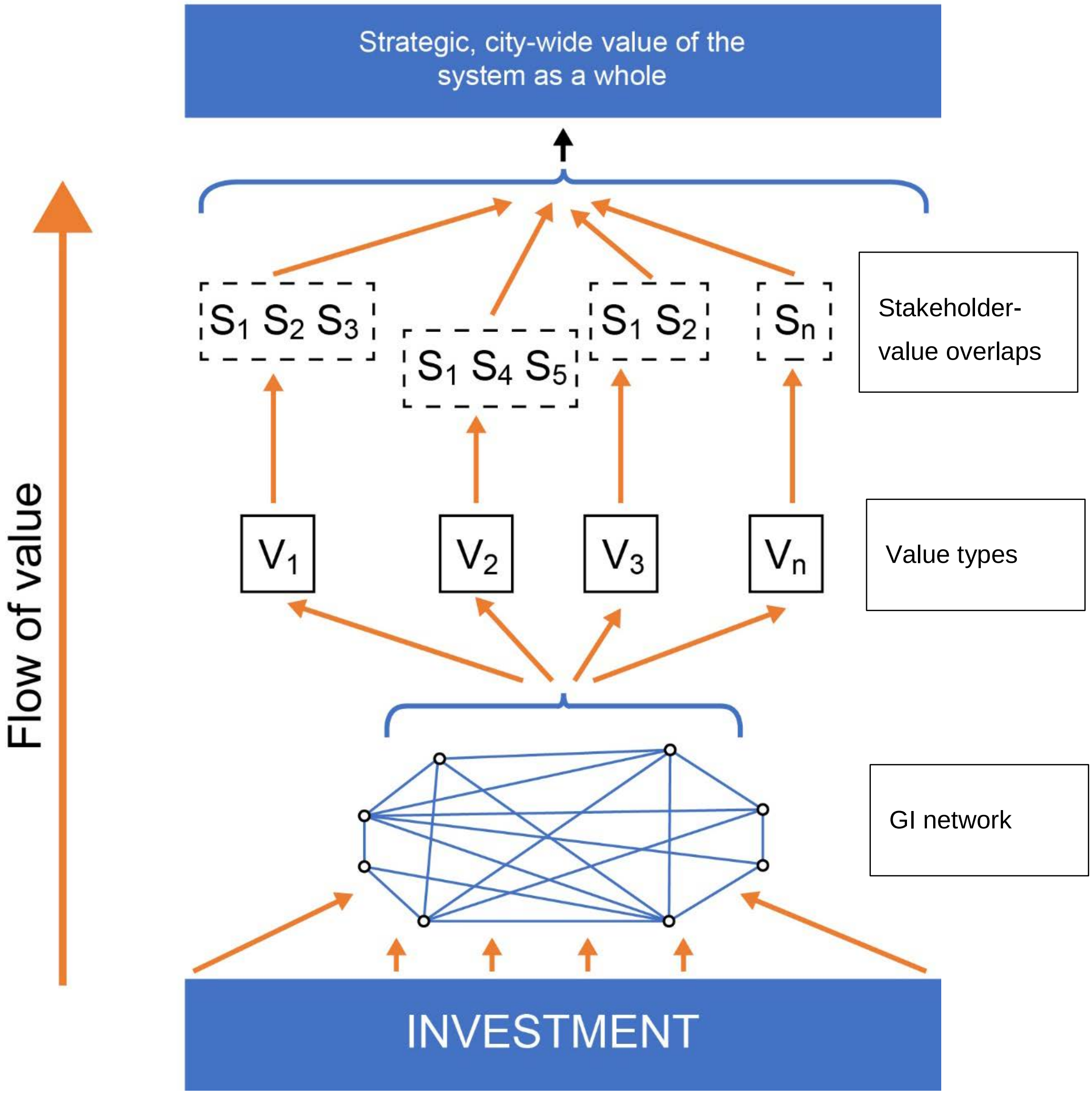


Figure 49: Flow of value through a city-wide green infrastructure system

7.3.3 Supplier – value – beneficiary relationships

A complexity of the flow of value is that stakeholders can be either supply-side, benefit-side, or both. Depending on the type of investment and the scale of green infrastructure asset(s) being delivered, supply side stakeholders can be a single person or group, a small collection, or a broad range. Not all supply side stakeholders must invest equally, and typically the supply side stakeholders would expect to also be beneficiary stakeholders. That is, they are unlikely to invest in a green infrastructure asset or network unless they expect to benefit from it. Even those stakeholders with the most altruistic of motives would be driven by some benefit, for example perhaps reputational or public relations benefits – or to be compliant with planning regulations.

Beneficiary stakeholders, however, may not be involved in the investment and supply-side at all. In fact they may even be unaware completely that they are beneficiaries of a green infrastructure network. One of the key opportunities for increasing the provision of green infrastructure, however, is to actively engage more of the beneficiary-side stakeholders. If they can be engaged and become aware of the value of the green infrastructure network to them, they are more likely to become supply-side beneficiaries. This could be in monetary form, but also can be non-monetary, for example championing the green infrastructure network or patronage of specific assets like parks.

Stakeholders (supply side)	–	Values	–	Stakeholders (beneficiary side)
Few	–	Few	–	Few
Few	–	Few	–	Many
Few	–	Many	–	Many
Few	–	Many	–	Few
Many	–	Few	–	Few
Many	–	Many	–	Few
Many	–	Few	–	Many
Many	–	Many	–	Many

Figure 50: Supplier-value-beneficiary relationships possible within a GI business model

As well as the number of beneficiaries, business models can have different value types, and can focus on just a single value or deliver a wider range of value types. Therefore, a combination of few or many supply side stakeholders, few or many value types, and few or many beneficiary stakeholders is possible within various business models for delivery, as shown in Figure 50. This will influence the potential forms of the business models and how they are structured and is therefore worth being aware of. To maximise the multiple benefits of green infrastructure, and the opportunities for investment and value creation, a many-many-many relationship would be ideal. Although it is not without its challenges, as including more stakeholders will inevitably complicate engagement and relationship management, and may be more difficult to coordinate.

7.3.4 Connectivity between assets

One key barrier to the creation of a functional network of green infrastructure assets, needed to call it an effective infrastructure system, is the total lack of connectivity between the different assets. These gaps reduce the functionality of any individual green asset as it cannot form a network without proximity to other nodes. For example, in Newcastle, there are significant green infrastructure features in all directions surrounding the city centre (see Chapter 3, section 3.3), but without sufficient links these cannot have maximum benefit for the central area, despite this being a major source of stakeholders and need. Although the optimum distance between individual assets, and areas of bigger green infrastructure, is not known, is it possible to make practical assumptions by looking at the types of ecosystem service that are hoped for. Surface water management will need a minimum level of tree canopy cover for each estimated volume of water, and components of a SuDS system need to work together. For air quality management functions, the quantity of GHG and particulate pollution in a certain area will dictate the necessary vegetation type and quantity to alleviate some or all of that pollution. Other relationships of this type may have fewer known quantities, but expert advice combined with research from a green infrastructure design perspective will be able to give reasonable estimates of the likely design capabilities.

At a strategic level, finding such information sources and identifying key locations to begin expanding a green infrastructure network for greater connectivity is needed. This would identify the existing assets, and areas of connectivity, as well as areas where there is a lack of green infrastructure. At even the most simplistic level, starting to identify key opportunities to connect existing green infrastructure assets together can be done using spatial and other data. A map of the existing assets, and an understanding of where problem areas (such as heavily used roads, or flood prone streets) are, can be combined with knowledge of the use of the area by businesses, residents, workers, shoppers, and other key individual stakeholders.

An example of this type of opportunity identification, using the urban core of Newcastle, is shown in Figure 51. Using the map of existing green infrastructure network (Chapter 3, section 3.3.2, Figure 22 and Figure 23), the dashed red lines have been added suggesting easy connections that can be made to start linking the green infrastructure assets to create a network. In order to develop this further, to the point of making recommendations for delivery, would need to also test these for feasibility, and review the options for the type of green infrastructure assets that might be suitable. Nonetheless these form a starting point for discussion on the development of a network rather than simply isolated assets.

These connections, in terms of both practical delivery of green infrastructure and of the connections between values and stakeholders, all piece together and form the building blocks for the development of business models for green infrastructure delivery.

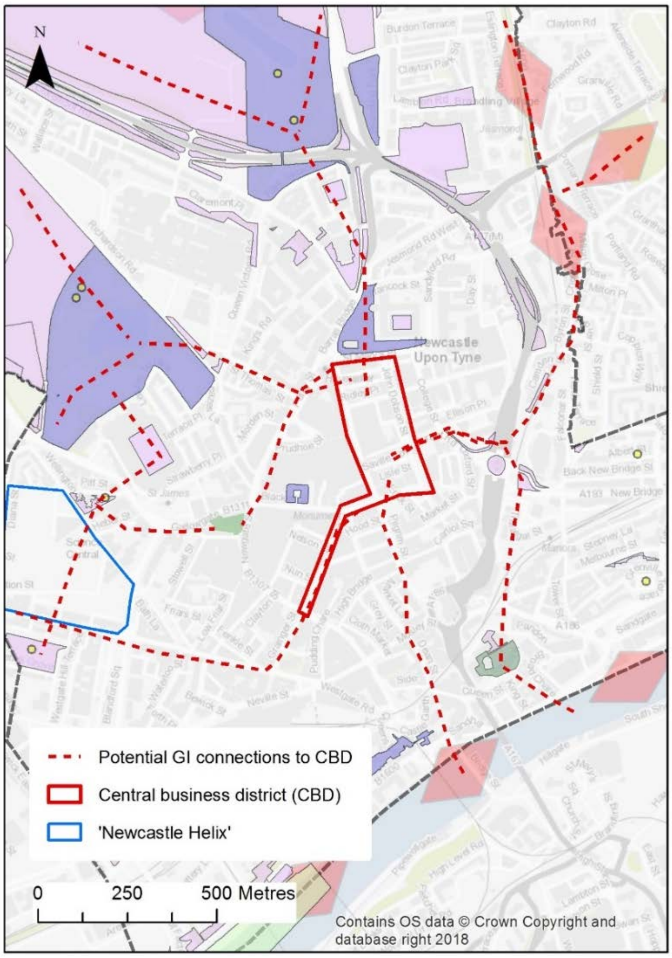


Figure 51: potential routes to connect existing green infrastructure to the central business district in Newcastle

Table 52: Examples of business model archetypes for infrastructure delivery

Archetype examples	Brief description	Opportunities and challenges for green infrastructure delivery
Energy supply – via licensed supplier	The business model used for electricity supply systems. Energy units bought from wholesale market, possibly supported by generators owned by the supplier. This is then sold on to consumers.	While theoretically there is no reason that this centralised supplier model couldn't work for green infrastructure systems, it is unlikely such a system would be developed. The values within the system include hard-to-quantify, non-monetary and long-term benefits. This does not lend itself to a traditional supply-demand business model, and those used in energy supply networks usually are.
Road networks – centralised delivery by local or national government	Centralised, top-down delivery of the road network is coordinated and funded centrally. Finance sources may include general taxation, investment funds, private finance initiative, or in rare cases (e.g. for bridges and tunnels) through user charging.	This type of coordinated, centralised approach with strategic oversight would offer key opportunities for green infrastructure delivery. Being able to access a range of finance mechanisms to deliver different assets, and having the overarching governance and control to ensure necessary prioritisation, connectivity, etc. Delivery of component assets could be subcontracted, but accountability is kept at this governance level. However, in the current climate of shrinking governance, harder to access finance, and the legacy of austerity, it is not realistic to assume local or national government could take on this type of project. That said, opportunities for this exist in increasingly regionalised decision making. A regional Combined Authority or devolved city-region Mayor could be the driver for such a top-down mechanism of green infrastructure delivery.

Bus networks – competitive marketplace of suppliers, operating under franchise agreements	For the delivery of bus and some tram/light rail/metro systems, the business model is run as an semi-open marketplace, with franchises offered to several transport operators, financed by user charging as well as subsidy from local governance (especially for unprofitable but essential routes), and add in revenue streams like advertising.	The idea of competition driven marketplace with some limited central oversight does suggest a certain level of suitability for green infrastructure delivery. The individual assets could be delivered by several delivery partners, with the strategic oversight used to ensure delivery is aligned with the overall needs of the area. However, a lot of the values can only be realised longer term and include a lot of non-market goods like social and environmental values, which can be difficult to quantify and to monetise. That said, assuming that finance and funding streams could be created, this model could work in terms of the governance and structure.
Newcastle Parks and Allotments Trust	Created to enable continued provision of parks and allotments in Newcastle upon Tyne. Capital investment from Newcastle City Council, which plans to create several revenue streams e.g. from user charges, event profit, trusts and grants, and a range of other sources.	This type of business model is intended as a not-for-profit organisation overseeing the ongoing care, maintenance and improvement of the public parks and allotments within the city. It is designed to have a broad portfolio of revenue streams in order to become self-financing. This centralised strategic delivery underpinned by a broad range of finance mechanisms would lend itself well to green infrastructure delivery more generally. Collaboration, risk sharing, and a portfolio of different value types are typical of any type of green infrastructure (of which parks and allotments form key assets).

(Hall and Roelich, 2015; Roelich 2015; Bradford-Keegan, 2019)

7.4 Towards new business models

The research that has been conducted, detailed in earlier chapters and with additional discussion above, is brought together in this section. It synthesises these findings into business model archetypes, looking at how these can work to create innovation, ultimately trying to answer the overall research aim: to explore and define what an innovative business model for effective green infrastructure system delivery would look like. This section of the chapter also considers some of the challenges and remaining unknown elements that are needed to create an effective business model but are outside the scope of this research.

7.4.1 Business model archetypes

This section of the chapter brings together the work on value capture, value-stakeholder links, and thinking about networks over assets. Considering how these elements work together to inform business models, to highlight opportunities for innovation in business models for successful green infrastructure delivery. As was discussed in Chapter 2, section 2.4, there are a range of business model archetypes in existence for infrastructure systems.

The key types of business model for some other main infrastructure types are shown in Table 52. Those that suggest opportunities for green infrastructure delivery, fitting with the understanding of stakeholders and values discussed earlier in this chapter, are the ones that allow for a broad range of value types, and smaller scale delivery managed by a high-level strategic oversight.

7.4.2 Realising actual value from potential value

Building on the flow of value in the previous section (see Figure 49), Figure 52 shows the completion of this value flow, whereby the business models form the mechanism by which value is transferred from the end to the beginning of this diagram.

The value types of interests to different stakeholders lend themselves to particular types of business model. These business models are the mechanism which allows the realisation of the potential values into actual values (shown with a dashed line to differentiate the mechanism from other types of component part). Starting with the anticipated future values and the stakeholders allows the investment in the green infrastructure network to be based on its anticipated outcomes, creating a circular flow of value. This also allows acknowledges both supply- and beneficiary-side stakeholders, and that engaging them as both types maximises the stakeholder engagement and value realisation opportunities.

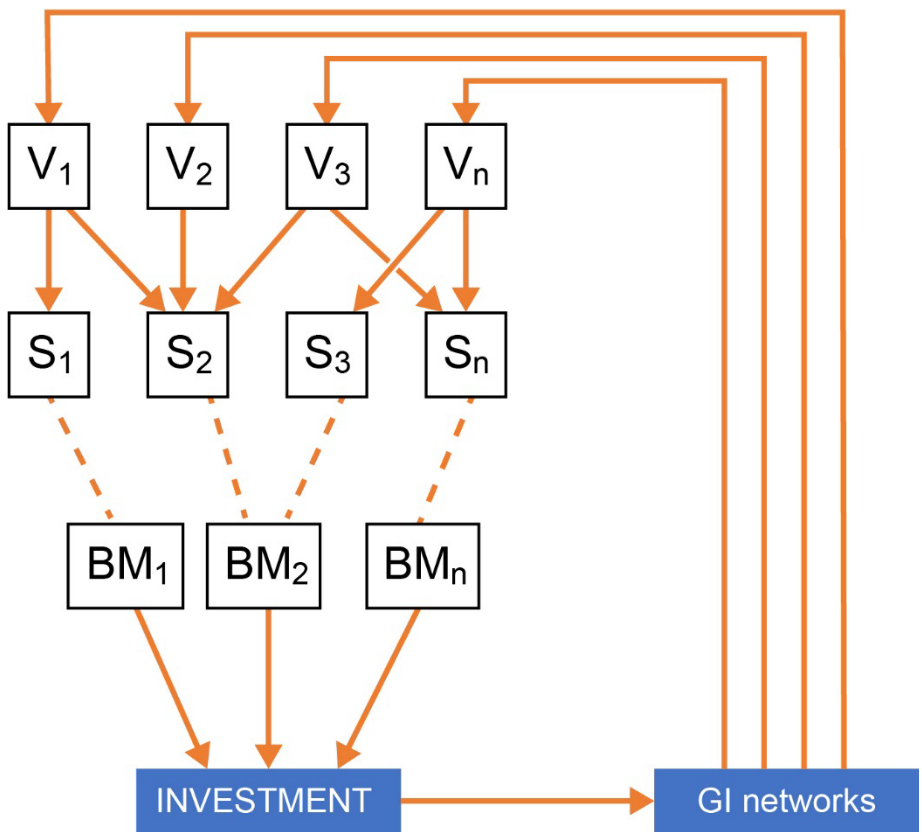


Figure 52: Value realisation through business models in a GI network

7.4.3 Creating shared value

An emergent type of business model, which is of particular relevance for delivery green infrastructure, is that of creating shared value.

> Shared value is the idea that by addressing society's needs and challenges, companies can create economic value in a way that also benefits society. Shared value seems promising, but many managers struggle to make it happen.
>
> *Massa, et al (2016) p.5*

Shared value therefore involves finding stakeholders to bring together into the network to pool resources and fund a network, through the focus on the wider social benefits: this type of approach is ideal for the delivery of green infrastructure. However, it does not represent just one type of business model, and several structures could be used to frame delivery and still fall into the archetype of shared value.

The theory allows for a disparate range of value types and flows, appealing to various different customer segments. Finance mechanisms can be de-centralised, though the overall accountability and strategic direction need to remain centralised.

The challenge therefore is finding the central strategic driver, allowing the provision of a green infrastructure network to be coordinated and the potential benefits maximised, and to minimise disbenefits and improve delivery efficiency. The lack of this central coordination is the main limitation to delivery of a coordinated green infrastructure system, though opportunities for it to happen do exist. In particular, the shift in recent years towards devolved governance, and strategic governance at a regional level – allowing local authorities to coordinate activity across boundaries for regional development.

7.4.4 Business models for green infrastructure delivery

Looking at this in conjunction with the section above, it suggests that the delivery of specific assets will have their own business models, including finance mechanisms relevant to the specific values. A business model for the overall network as a whole would have some governance or control at the strategic level, and these smaller units of delivery would feed in to create the overall network business model.

Using the business model canvas (see Chapter 2, section 2.4 for more detail on this as a business model tool), the development of a business model for the delivery of individual green infrastructure assets can be developed. An example of this using tree planting at a single location is shown in Figure 53, and while it is designed as a worked example for trees, a similar type of model could be created for any of the types of green infrastructure assets, informed by the value types likely for each type of asset, and the resultant stakeholders that would be involved due to the type of asset and types of value.

It would be counterintuitive to state that one type of business model archetype is the solution for green infrastructure delivery. The very purpose and underlying principle of this research is that innovation is needed, and that this sector needs to remain dynamic, to move with changing and improving value capture, and to constantly work to recognise and capitalise on new value propositions.

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
Newcastle City Council Learning Action Alliance Land owner (if not Council) Arboreal specialist Landscape architect subcontractors	Tree planting Initial maintenance Long term maintenance End of useful life – removal/replacement	Improved air quality, less particulate pollution, better health and wellbeing, lower spend on public health Management of stormwater, less flooding, less flood damages, avoided costs and lower insurance premiums Amenity value - people linger longer, enjoy the public realm, and visit more frequently. Happier people good for society. Pleasant space and longer time spent leads to increased spend in local shops and economic productivity.	Working with businesses and groups who can enable delivery. Inform other customers, like private individuals.	Direct beneficiaries Indirect beneficiaries Private individuals Community groups Businesses -SMEs Businesses – Large Note – direct beneficiaries may be hard to value (e.g. better air quality, better personal health), and value may instead be realised indirectly (healthier people reduces cost of healthcare and decreases incidences of short term sick days in businesses, with a financial benefit)
	Key Resources		**Channels**	
	Trees Land Money to buy trees and pay for installation		One-sided information flow often. Inform on benefits and partners. Agencies that are key stakeholders in the flow of value should be engaged more directly.	

Cost Structure	Revenue Streams
Cost of trees; cost of contractors; cost of maintenance; cost of replacement	Avoided costs of flood damages and healthcare; improved economic productivity. Little direct revenue.

Figure 53: Example business model (based on business model canvas) for delivery of a tree planting as a green infrastructure asset

Table 53: Suggested business model archetypes for green infrastructure delivery

Name	Description	Supply-value-beneficiary relationships	Strengths and weaknesses	Required conditions	Barriers to set up
Business as usual	A top down approach where individual assets, or small groups of GI assets as delivered as part of a development or improvement to an area, usually motivated by a single issue and single value type.	Few – few – many	Can have strong drivers for delivery, but the single value focus means benefits will not be maximised.	Policy and legislation is needed to require providers to deliver these GI assets. E.g. planning permission in favour of sustainable development.	Money available to invest – often GI development may be cut from plans to reduce costs if they're over budget.
Preventative planning	Investment in GI for future benefits – e.g. avoiding flooding / improving population level health. A top down approach, usually focused on just one or two value types.	Few – few-many	Improvements to the overall city area will have widespread benefit, but the time delay to this benefit makes attribution difficult.	Funding sources needed that acknowledge long-term benefit. Requires partnership working across a range of supply stakeholders.	Difficult to allocate funds for preventative work in austerity-style funding culture. Short term- is prioritised over long term benefit.

Name	Description	Supply-value-beneficiary relationships	Strengths and weaknesses	Required conditions	Barriers to set up
Green government	A government with a strong ‘green’ agenda actively encourages GI development in urban areas. Environmental targets are set, and GI is the recommended approach to achieving these. Supportive funding and policies are created.	Few – many – many	GI considered more of a priority in development plans. Risk of ‘greenwashing’ building GI for the sake of it, rather than planning ideal network.	Finance and funding sources would need to be created to support government policies. Targets and measurement need to be included to ensure specific delivery.	Radical change to mainstream government policy – current political climate unwilling to shift to this type of system in the short term. Requires change to LA budget silos.
User funded	Only direct users of a GI asset or network are involved. They are charged for the use, e.g. paying to get a SuDS scheme in their area, or to access a local park. No account is taken of indirect beneficiaries. It is focused on single value types and individual assets.	Few – few – few	Targets a specific need, and clear who the direct beneficiaries are. Strong local buy-in to the concept. Monetises green assets, ignoring other value types. Excludes poorer communities.	Sufficient local interest to yield influence and allow restricted access. Need private/restrictive ownership of GI assets.	Paying to access previously-free assets likely to be unpopular. Someone will need to administer access and user charging, with an incurred cost.

Name	Description	Supply-value-beneficiary relationships	Strengths and weaknesses	Required conditions	Barriers to set up
Local stewardship	A bottom-up approach, where local communities drive the need for GI investment. Mechanisms like community interest companies may be used to create and manage GI assets. The benefits of GI for the local area are recognised at a local level and there is a push to invest for the good of the area. The 'hook' for promotion and engagement may be a single value type (for example if the area has had issues with flooding), but there will be an active pursuit of multiple benefits.	Many – few/many (variable) – many	Local support for GI development. Clear structure for ownership and maintenance of assets. Requires community interest, and local people willing to take on the set up and running of a community interest company (CIC) (or similar organisation).	Sufficient interest, knowledge and skills to set up the business aspect, as well as to deliver the GI network. Assumes continued existence of policy- and legal framework for CIC and other similar organisation types.	Forming a CIC or similar company requires the knowledge and skills to set up and then run. Converting general interest and support in the local area into specific ownership and action to deliver and maintain a GI network may be difficult.

Name	Description	Supply-value-beneficiary relationships	Strengths and weaknesses	Required conditions	Barriers to set up
Collaborative co-production	Stakeholders from all levels are involved in supply and beneficiary side of GI network. A coordinated, strategic GI network is designed, actively seeking to maximise as broad a range of value types as possible.	Many – many – many (circular value flow)	A comprehensive network of GI is delivered. Engaged stakeholders have a vested interest in delivering an effective network. Complex stakeholder interactions and relationships may be challenging, and priorities may conflict.	Leadership to coordinate all partners and administer the planning and delivery. Policy drivers across several areas and levels to promote interest from stakeholders. Funding and finance mechanisms available to allow for centralised delivery.	Leadership, knowledge and skills all needed. Along with some appointed body or person with the remit to engage many stakeholders and coordinate large scale strategic planning and delivery.

A series of potential green infrastructure business model types are suggested in Table 53, along with identifying the value-stakeholder relationships, and some of the strengths, weaknesses, and necessary conditions for them to be used. This is not an exhaustive list, but aims to convey a range of suitable green infrastructure formats. Variations on these would of course be expected, and the context-specific nature of green infrastructure means that different archetypes would be suitable in different settings.

While Table 53 includes some indication of policy and other conditions needed for the type of business model, it is not a detailed analysis. To convert these archetypes into a specific business model, then a more detailed identification of the policy context should be done. Using the strength and impact scoring process that was devised in Chapter 5 will provide a better indication of whether the existing policy situation is supportive of the proposed business model. When designing a business model for delivery of green infrastructure in a specific context, where possible, aligning the business case to the highest scoring "delivery enabler" policies will maximise the opportunities for success.

A barrier common to all of the business model archetypes is the need for leadership and drivers to take them forward, having a lead stakeholder would be needed, even when there is collaboration and circular value flow.

7.4.5 Applying business model archetypes to Newcastle upon Tyne

The retrofit of green infrastructure in the CBD of Newcastle, and the development of green infrastructure as part of *The Helix*, could both be delivered by several business model types. An illustrative worked example of each, suggesting a method for identifying a suitable business model and then how this could be structured is shown below. In addition, a business model for creating a strategic, overarching green infrastructure network for the city region as a whole is also discussed.

7.4.5.1 Retrofit of green infrastructure in the central business district

Green infrastructure development in the CBD would involve the retrofit of various assets within a busy commercial area. There are some residential properties, but the vast majority of land use is commercial: mostly retail space with some office space. The key value types that would be relevant in this development would be around sense of place and amenity. Although in the central area of the city, one main road is pedestrianised, and another has restricted traffic flow and a segregated cycle lane. Compared to some other parts of the city centre, air pollution concerns are less of a priority. While there is surface run off, there have not been repeated incidents of high cost damages due to flooding, so water management is a value that can be realised as well, but is not a main driver for green infrastructure development.

Under current conditions, there is no particular push to consider other benefit types. The individual companies, retail operators, the BID, and the shopping centre management company INTU, form a very economic-focused main group of stakeholders. The main beneficiary-side stakeholders would also be these groups, but also the employees, visitors and shoppers in the area.

Policy drivers for this central area include the urban core plan (a ‘delivery enabler’ on the policy review matrix – see Chapter 5, section 5.3); the Local Enterprise Partnership (LEP) strategic economic plan (which was deemed to provide ‘strategic ambition’ in the policy review). This policy sphere also draws in the City Council and the LEP as key stakeholders.

From the business model archetypes listed in Table 52, two archetypes seem particularly relevant. Given the disparate nature of individual businesses and retail operators, it is less likely that a bottom-up approach would be relevant. Instead a top-down approach or collaborative system would be more likely. The BID (NE1) or the LEP would each be well-placed to push for investment in the green infrastructure of the area to gain economic improvement value in the medium to long term. If one or both of these stakeholders worked to deliver green infrastructure for the benefit of the area as a whole with little input from the beneficiary stakeholders, then a ‘preventative planning’ type of model would be suitable. However, they could each also take a leadership role, actively engage more of the stakeholders and involve them in delivering the green infrastructure network, and therefore work to a collaborative co-production model.

7.4.5.2 New development of green infrastructure at The Helix

As a new development, and the regeneration of a derelict site, green infrastructure inclusion has been a key part of the site plans. It was particularly driven by the site flood risk, emphasised by an extreme rainfall event in June 2012. The site is also adjacent to a busy road (St James Boulevard), so air pollution is a consideration for environmental values. The site is a mix of residential and commercial use, with a lot of office and university buildings, rather than retail space. This means that social benefits like health and wellbeing, and physical activity are also important. The economic performance of the site is obviously important, but as there isn't a retail focus, the sense of place is less important to its success.

The site is managed centrally by the Newcastle Helix organisation, so there is existing leadership and coordination of the key stakeholders and of the site users and residents. Some of the site occupants also have a strong interest in the development of green infrastructure, with the National Green Infrastructure Facility located there. Other interested stakeholders, based on the value types crossing environmental, social and economic spheres, would include the employees, residents, the surrounding residential suburbs, the road users, and the city council as well.

The large number of stakeholders and the broad range of value types lends itself to a more collaborative approach to the delivery of green infrastructure. It has the necessary stakeholder and value conditions in place to operate a collaborative coproduction style business model. Its policy drivers, focusing on the city- and regional-level strategic plans and environmental policies, have a strong emphasis on the 'delivery enabler' category from the policy review matrix, which will also facilitate this business model type.

7.4.5.3 Overarching strategic green infrastructure network

In addition to site-specific green infrastructure delivery, it is also possible to create a business model for the implementation of a strategic level green infrastructure plan across the whole city area. To create this type of overarching plan and actually translate it into delivery would need a business model underpinned by a strong voice. Community-level development, such as a 'local stewardship' or 'user-funded' model, is unlikely to work at this scale, due to the oversight needed. Likewise, the focus on single value types typical of the current business-as-usual green infrastructure investment, or a 'predictive planning' model rule those out. This leaves the most suitable archetypes for delivery as a 'green government' style approach, or one of 'collaborative co-production.'

Taking a ‘green government’ approach could require the local authority (or perhaps one of the regional governance or strategic organisations, like the North East Combined Authority) to deliver green infrastructure of prescribed quantity and quality. The motivation and drivers behind this at a high level seem unlikely in the current political climate, as they would require a huge shift towards recognising the need to prioritise environmental policies. Given the main political issues in the UK currently, this is unlikely to occur. However, it is not unrealistic that a shift to much higher prioritisation of ‘green’ issues would occur over the medium-term. The rising awareness of the climate crisis and the demands for governments across the world to take the issue seriously could shift the focus to much stricter environmental policies. There would need to be a radical shift in policy making to create the conditions needed for this delivery, but it is not completely unrealistic in future.

To deliver green infrastructure at a strategic level through a ‘collaborative co-production’ model could happen in the short term, using existing policy drivers. Unlike a green government approach, it would not need a high-level shift towards environment policies, and could work with the existing policy sphere. However, it would need strong leadership and probably also buy-in from local and regional level governance and administrative organisations. If a group or organisation was tasked with the remit to deliver a city-wide green infrastructure network, then within the existing policies and with the current stakeholders and value types, it may be possible to achieve. Working with the broad range of stakeholders would be the most challenging aspect, but it would be theoretically possible under current conditions.

7.5 Chapter conclusion

In this chapter, several key discussion points have been brought from the previous chapters and explored further. It has recognised that to work towards effective green infrastructure delivery, there is a need for change in current practice.

There are multiple options available for the approaches and business models that could be used. The key findings from this research suggest that in order to create effective, innovative business models then:

- Green infrastructure development should be underpinned by a shared vision and strategic masterplan for the city region.
- Expertise should be drawn from current knowledge and practice.
- Potential values should be matched to relevant stakeholders, to make relevant connections.
- This enables collaborative working and the creation of shared value
- A collaborative coproduction model would be a suitable business model archetype to shape this network delivery.

There are, however, remaining issues and outstanding questions, particularly around quantifying value. These details are explored further in the following chapter, Chapter 8, along with the overall conclusions that can be drawn from this work.

Chapter 8: Conclusion

8.0 Chapter introduction

The central aim of this research was to explore and define what an innovative business model for effective green infrastructure system delivery would look like, in order to understand how to move towards the vision of a strategic planned network of green infrastructure at city scale. The starting point was to tackle the problems of urbanisation rooted in the tradition of trying to separate and control nature – to keep it away from constructed human spaces. Green infrastructure is ideologically underpinned by the acceptance that as a species, humans rely on natural processes, and that by bringing nature into our urban environment we can utilise ecosystem services in order to address challenges like flood management, drought, pollution and urban heat islands.

Given that green infrastructure is relatively new as a concept (especially compared to other infrastructure, like roads!), methods to deliver it are not established. As with most types of infrastructure, it is traditionally outside the reach of standard market forces, and so the economic structures of modern capitalism are not obviously suited to the creation of something with such broad potential social and environmental benefit.

While humans will generally agree that nature has inherent worth, current systems struggle to define and capture that worth in a tangible way. Thus, in an economically driven age, with high levels of demand for urban space, green infrastructure is not prioritised. Its benefits are not immediate enough to gain funding through traditional economic processes.

This thesis aimed to explore the opportunities and barriers for the delivery of green infrastructure, using a city-scale case study of Newcastle-upon-Tyne, and to draw conclusions with wider applicability for different national and international contexts.

8.1 Key findings

The main research points throughout have been structured around five key objectives, each with associated research questions, which are shown in Table 54, and the research questions associated with these were explored throughout the main results and discussion chapters of this thesis.

Table 54: Objectives and research questions central to this thesis

Objective	Research questions
1. Identify current opportunities and barriers to green infrastructure delivery	What is preventing wide scale green infrastructure development?
	What are the barriers and challenges, and how can these be overcome?
	What opportunities could be developed further?
2. Understand the value of green infrastructure	What is the value of green infrastructure?
	How is this captured, quantified, and used?
	How can value capture be improved?
3. Assess the relevance and effectiveness of policies shaping green infrastructure delivery	What are the key policy levers to support an effective business model for green infrastructure?
	How can the policy context shape delivery, identify stakeholders, and create opportunities and barriers for green infrastructure investment?
4. Identify stakeholders in a green infrastructure network, and align their priorities and needs	How are stakeholders identified?
	What are their priorities and needs, and how can these be aligned with green infrastructure value?
5. Develop an innovative business model archetype for effective green infrastructure delivery.	How are these various elements used to build and shape new and innovative business model archetypes for green infrastructure delivery?
	Which opportunities can be capitalised on; and how are barriers overcome?

8.1.1 The value of green infrastructure

A main aim of this research project was to understand the value of green infrastructure, how it is currently captured, and how this could be improved. The key findings from Chapter 4 were:

- The value of green infrastructure is derived from its benefits
- Tools exist for capturing and quantifying the value, but no single tool can currently do so comprehensively and accurately
- Quantification is difficult, especially of intangible or indirect benefits, and there is no good way of comparing very different value types
- The functionality and benefits of the whole system, beyond individual assets is unknown.

A range of value types were identified, both monetary and non-monetary. These values were found across social, economic and environmental categories. They included flood management, air quality improvement, health and wellbeing improvements, and amenity value. The values were derived from the assumption that every benefit of green infrastructure has a potential value, provided that interested stakeholders can be identified.

The appraisal tools that were used with simulated data offered some useful outputs in terms of quantifying benefits, therefore enabling them to be used as values. No single tested appraisal tool was entirely fit for purpose however, with each having limitations either in its use or its mechanisms that meant they were not ideal. Nonetheless, the values derived from these approaches were useful as a starting point for building business models for green infrastructure delivery. Improvements can always be made to this type of approach, and there was no particular fundamental flaw in any of the approaches.

The key limitations of these tools, and of this style of appraisal generally, were that they often reflect the wider valuation system for the type of asset, rather than reflecting the relevance of values for the specific system. For example, improvements to the public realm increase land values and improve general population wellbeing. While both of these are key factors and should be included in a green infrastructure evaluation, they are still indirect and intangible. Yet the scale of value from these benefits vastly outweighed other more direct, tangible benefits like flood management or filtering particulate pollution. This reflects underlying inequalities in the way that economic project appraisal is conducted.

8.1.2 The policy sphere shaping green infrastructure delivery

The key findings from Chapter 5 were:

- Local-level policies (particularly those at city-scale) have the biggest potential to shape green infrastructure delivery
- Higher level policies have less relevance, albeit with some influence in shaping the focus of local level policies
- A systems-level approach for green infrastructure delivery at city scale would be appropriate to align with the policy and governance context
- Some policy actors and governance organisations have power at the local and regional scale, and therefore are stakeholders within a city-scale green infrastructure system
- The policy focus of different stakeholders shows some of the value types they are interested in, and can be a key source of information for developing business models.

Some of the high-level international and national policies and targets set the shape and focus for green infrastructure priorities. Some hyperlocal policies were useful to influence priorities for development. However, the policies with the most strength and potential impact, which formed the greatest drivers for green infrastructure delivery, were mostly the regional and city-scale local policies. Most of the “delivery enablers” in the analysis matrix were local or regional policies and these policies had a balance of the specific focus (that is, its relevance to creating green infrastructure), with the political or governance power and ability to direct resources. The policy review therefore identified opportunities to align and frame the green infrastructure values according to the relevant policy goals, to maximise stakeholder interest and to deliver green infrastructure.

In addition, the policy review was an essential information source to identify potential stakeholders, to identify their interests, and to engage them in the creation of green infrastructure. Some of the policies also aligned clearly with particular green infrastructure value types. This is particularly useful as it helps stakeholders (those involved or bound by certain policies) to understand the direct impact of green infrastructure towards achieving particular policy goals.

8.1.3 Stakeholders, and their priorities

They key findings from Chapter 6 were:

- Multiple approaches are needed to conduct a robust stakeholder analysis (including active stakeholder engagement for 'live' projects)
- Spatial proximity to green infrastructure assets is associated with stakeholder interest
- Stakeholder relationships to individual green infrastructure assets is easier to define than the relationship to a system-wide network
- The 'power' of a stakeholder influences how effective they might be at enabling green infrastructure development
- Stakeholders can be categorised as providing green infrastructure or benefiting from it, however in reality it is not a binary role: many stakeholders fall into both categories
- This circular relationship between providing the infrastructure and benefitting from it is an essential foundation for creating business model innovation for its delivery.

The stakeholder analysis that was conducted had the aim of understanding not just who benefits from and who pays for green infrastructure, but also to start to identify relationships between particular types of value and specific stakeholder groups. By identifying which values are relevant to which stakeholders, the potential routes for finance and funding (the value proposition), and ultimately the business model construction overall, could start to be created.

As well as the policy analysis, spatial analysis and value flow analysis were used to identify stakeholders. Combining these approaches gave the greatest chance of creating a comprehensive list of stakeholders to maximise their interest and engagement with green infrastructure. This could be improved for a 'live' project by also using active as well as these more passive methods for identification and engagement. The interests and needs of the stakeholders were wide ranging, but there was a lot of overlap between green infrastructure value types. Spatial proximity to the green infrastructure asset (or proposed asset) and whether an area had been negatively impacted by an event (for example, flooding) that could be addressed by green infrastructure were also key.

The list of stakeholders, including examples of specific groups and organisations for the case study of Newcastle, were matched with the values of particular interest or relevance. These relationships between stakeholders and values was then taken forward into Chapter 7, to start to put together business model structures that capitalised on these relationships.

8.1.4 Business model innovation

Chapter 7 considered the results overall and the way in which the elements of value, policy and stakeholders could be drawn together to form the building blocks for an innovative business model for green infrastructure. The key findings were:

- Green infrastructure development should be underpinned by a shared vision and strategic masterplan for the city region
- Expertise should be drawn from current knowledge and practice
- Potential values should be matched to relevant stakeholders, to make relevant connections (the value proposition)
- This enables collaborative working and the creation of shared value
- A collaborative coproduction model would be a suitable business model archetype to shape this network delivery.

Looking at the system as a whole, rather than just individual assets, and then the overall flow of value through that green infrastructure system, and how this can be realised through different business models was drawn out. A good business model should always be context specific for the infrastructure system being delivered, but this review of archetypes forms a starting point to create an actual business model for a real green infrastructure system.

The particular opportunities that could most enhance business models for green infrastructure delivery build on concepts of shared value and diversification to a broader range of value types. This is also reflective of the general shift in funding and finance structures across all types of markets that seems to be typical of late-stage capitalism, as was apparent in the literature on changing funding and finance structures.

8.2 Conclusion and recommendations

The overall aim of this research project was to explore and define what an innovative business model for effective green infrastructure system delivery would look like; and that this business model should form a ‘toolkit’ that allows a system-level green infrastructure plan to be implemented.

It is clear that there are several elements that can be drawn together to create and shape this business model, and that in doing so, can create opportunities for developing and delivering a high quality, functional green infrastructure system that works strategically at a city scale. These core elements are the value of green infrastructure (derived from its benefits), the stakeholders involved in, and the policy context that frames the delivery. The links between these building blocks is shown in Figure 54.

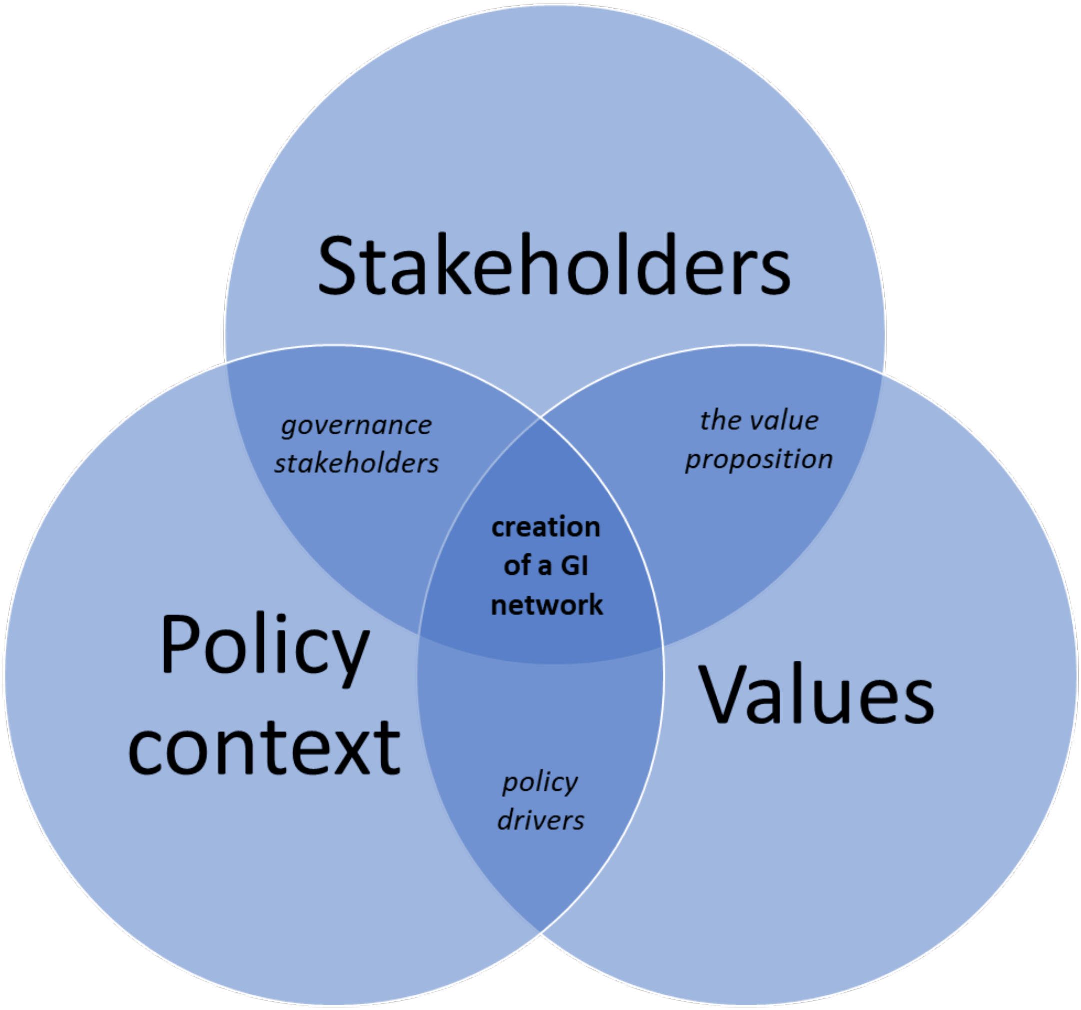


Figure 54: The key components of a green infrastructure business model

The overlaps between pairs of these elements further provide opportunities for green infrastructure delivery, but it is when all of them work together that they can be used to create a green infrastructure network. The intersection of value types and stakeholder interests creates the value proposition within the business model. The overlap of policy and stakeholders shows who those governance stakeholders are that can leverage power and resources for delivery. Where policy and values overlap then are the policy drivers which create the opportunities to generate interest and find resources to support delivery. By drawing on all three elements, to create shared interests, an innovative business model can be developed. This should draw on the concepts of co-production to strategically develop and deliver an effective, interconnected green infrastructure network that can deliver maximum benefits across the whole of a city region.

The recommendations that emerge from this research are that:

- Green infrastructure should be delivered to a strategic plan at city scale
- Values should be weighted according to their relevance to the delivery context, and should be considered across the whole city area
- The policy context should be used to identify opportunities and drivers for developing the green infrastructure network
- Policy actors may form some of the stakeholders in the network, but a range of active and passive methods should be used to identify and engage a broad range of stakeholders
- The shift from delivering green infrastructure assets as discrete elements and instead incorporating them into a wider network is a key opportunity to start to be able to coordinate green infrastructure as a true infrastructure system
- A collaborative, co-production business model archetype is a good option for drawing on value, policy and stakeholders to creative a strategic, interconnected, green infrastructure system.

8.3 Future work

There remain still gaps in knowledge, and in structures for green infrastructure business models, which need to be addressed by further research. Additional work can be done to further improve evaluation tools and approaches, therefore improving the value capture of green infrastructure benefits. Likewise, the ways of developing business models and understanding the role of green infrastructure spatially, and how stakeholders are engaged using these elements can also be improved.

Evaluation tools for green infrastructure need to be refined and improved with research to fill the gaps in green infrastructure benefit knowledge, and also to try and reconcile the different scales of value for some of the benefits. Some of the latter cannot be addressed in isolation but rather are a challenge to wider project appraisal principles. At a basic level, simply weighting value to give more importance to direct, tangible benefits might lead to more credible economic appraisals of infrastructure systems.

Understanding, analysing and sharing the spatial impacts of green infrastructure remains under-developed, yet it is essential to understand the spatial extent of a green infrastructure network in order to be able to appreciate its potential value and draw in appropriate stakeholders. Although the GIS software, tools, and expertise exist to make this possible, as yet an effective evaluation tool that uses a spatial approach does not exist for green infrastructure project appraisal. Having this would make it easier to conduct spatial review in a consistent way of existing or proposed green infrastructure networks.

Related to this, there is a need to better understand the spatial impact of green infrastructure, as it is connected into other systems and the impacts can be expected to be further reaching than the initial development of a new asset. The spatial performance is of particularly interest for values like flood reduction and air quality improvement, as the flow of air and water throughout an area is not bound by the focus of any project delivery area, or by administrative boundaries. One way to understand these larger spatial impacts is to use detailed flood modelling across the city in order to understand how different types and locations of green infrastructure development can affect the performance of the catchment as a whole.

Other future research could also focus on exploring the relationships between different types of green infrastructure asset and how they perform in an interconnected network. It would also be beneficial to model various scenarios against as many types of value as possible (for example air quality as well as flooding), and by looking at these understand the interrelationships between different value types, and also understand whether it’s possible to derive some general guidelines for shaping recommended delivery; to investigate if, for example, it is always better to plan for air quality rather than flood in certain road types, or what the ideal size and distribution of parks is for wellbeing (whether it is better to have fewer, larger parks or more smaller parks).

The shape of the relationship between asset and benefit also needs to be further explored. It was proposed in Chapter 7 that this could be a linear relationship with minimum and maximum extents, or a more of an optimum curve, with a peak level, after which marginal gains start to decrease. However, these relationships are currently only speculative, based on a logical and practical assessment of potential benefits. The nature of these relationships should be explored further to ensure the success of understanding system-wide benefits at larger scales.

Asset-benefit relationships could be explored, for example through flood modelling of a city based on existing green infrastructure network, re-running multiple times with various scenarios of more/less green infrastructure, and then quantifying the differences between them. However, this would rely on the flood model being appropriately calibrated to be realistic (for example, if it is programmed with a basic “more green space = more infiltration” then to a certain degree the relationship is going to be purely linear).

Another gap in knowledge is how the modelling and the interpretation account for variation in antecedent conditions, and whether it can be calibrated based on research of different types of green infrastructure asset and their effectiveness. For example, the different substrate depths of green roofs, the different flow capacities of swales, the vegetation types of hedgerows, and the different maturity and canopy cover of trees. These nuances are important for understanding the effectiveness of green infrastructure but the exact impacts of these design differences are not currently known or used in any evaluation tools.

An ideal future scenario for green infrastructure delivery would build on the existing connections between value and stakeholders and develop this into guidance for which finance mechanisms might be open to them. Centralised coordination of the strategic development of green infrastructure would enable the efficient delivery of the system and could create resources for this type of business model and finance mechanism guidance. The key opportunities for this type of coordination are perhaps through regional governance, such as devolved mayoral roles or combined authorities. More work is needed to explore whether these would be feasible options for the delivery of an effective green infrastructure system.

8.4 Chapter summary

While there remain some unknown factors, and further work is needed to develop the delivery of effective green infrastructure systems, key opportunities and methods do already exist as a starting point.

The key to creating high quality green infrastructure systems is to use the values, the stakeholders and the policy context to identify the opportunities and drivers, and create business models that will support and underpin the network.

Scaling delivery of green infrastructure from disconnected assets to overall network is not without its challenges, however, strategic oversight can focus on connectivity and targeting network creation as a whole, even the delivery of the assets continues to happen in a segmented way, as and when development opportunities arise.

By drawing on all of the 'building blocks' and working in a strategic way at city scale, the vision of high quality green infrastructure systems can be realised. This functional infrastructure system can, like any urban infrastructure, work to deliver the functions needed to for cities to face the challenges of the future.

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Appendix A: Green infrastructure audit pro-forma

FOR EXISTING GREEN INFRASTRUCTURE FEATURES

<table>
<tr><td>Survey date:</td><td colspan="2">__ __ / __ __ / 2016</td><td>Surveyor (initials):</td><td></td></tr>
<tr><td colspan="2">Weather:</td><td colspan="3"></td></tr>
<tr><td colspan="2">Site name:</td><td colspan="3"></td></tr>
<tr><td colspan="2">Location (address/lat. & long):</td><td colspan="3"></td></tr>
<tr><td colspan="2">Size (m^2):</td><td colspan="3"></td></tr>
<tr><td colspan="2">Photo/sketch plan:</td><td colspan="3"></td></tr>
</table>

Site category: *select one*

<table>
<tr><td>□ Pavement or other hard surface</td><td>□ Derelict building plot</td><td>□ Wetland/standing water</td></tr>
<tr><td>□ Planter/raised bed</td><td>□ Highway infrastructure e.g. traffic island</td><td>□ Shrub plantings</td></tr>
<tr><td>□ Street tree in pit</td><td>□ Grass verge</td><td>□ Community garden/allotment</td></tr>
<tr><td>□ Green wall</td><td>□ Hedge</td><td rowspan="2">□ Pocket park, garden or square (smaller or less formally designated than a local park. Not used for growing food.)</td></tr>
<tr><td>□ Green roof</td><td>□ Local park (formal space for community recreational use)</td></tr>
</table>

Condition:

□ Good Looks neat, well-managed, signs of active management and maintenance.	□ Moderate Some signs of active management, but not in ideal condition	□ Poor No signs of active management/derelict or seems neglected

Current management (if apparent/known): *select all that apply*

□ Grass cutting	□ Other plant or tree maintenance	□ Other:
□ Appears unmanaged/ overgrown	□ Productive use for food	

Land cover/habitat type(s) present: *select all that apply*

□ Amenity grassland	□ Pavement/paved area
□ Semi natural grassland	□ Highway
□ Woodland	□ Traffic island
□ Scrub/shrubs	□ Roof or wall
□ Building	
Other:	

Function(s): *select all that apply*

□ Public use: informal recreation	□ Food growing/productive use
□ Public use: formal recreation	□ Flood management/water storage
□ Visual/amenity	□ Not in active use/derelict
□ Wildlife	

Scope for enhancement(s) (if any?) *select all that apply*

□ Wildflower meadow/semi-natural grassland	□ Green wall or climbing plants	□ Green roof
□ Tree planting	□ Substantial window box	□ Street tree
□ Wetland features/rain gardens	□ Floristic annual planting	□ Shrub
□ Water storage feature	□ Food growing: fruit trees/vegetables	□ Planters
□ Other:		

Barriers to delivery: *select all that apply*

□ Isolated/poor visibility	□ Current use	□ Building constraints (e.g. listed buildings)
□ Utilities or wayleaves	□ Misuse/poor ambience (e.g. vandalism, feels unsafe, etc)	
□ Other:		

Any other considerations?

Ease of delivery (best guess if unknown):

□ Easy	□ Moderate	□ Challenging

Estimated cost of delivery (approximate):

£________________________________

FOR POTENTIAL GREEN INFRASTRUCTURE OPPORTUNITIES

Survey date:	__ __ / __ __ / 2016	Surveyor (initials):	
Weather:			

Site name:	
Location (address/lat. & long):	
Size (m^2):	
Photo/sketch plan:	

Type of site: *select one*

□ Pavement or other hard surface	□ Derelict building plot	□ Highway infrastructure e.g. traffic island/seating
□ Wall	□ Roof	□ Other:

Current land use/function: *select all that apply*

□ Building (commercial or residential)	□ Visual/amenity
□ Street/pavement	□ Not in active use/derelict
□ Highway/through-route	□ Other:
□ Flood management/water storage	

Potential GI type(s): *select all that apply*

□ Wildflower meadow/semi-natural grassland	□ Green wall or climbing plants	□ Green roof
□ Tree planting: woodland	□ Substantial window box	□ Street tree
□ Wetland features/rain gardens	□ Floristic annual planting	□ Shrub
□ Water storage feature	□ Food growing: fruit trees/vegetables	□ Planters

Ownership & owner interest in GI (if known):

Access restrictions (known or best guess, if any):

Height (if wall or roof):		□ Measured □ Estimate
Pitch (if roof):		□ Measured □ Estimate

Microclimate considerations:

Aspect: Sunlight/shading: Wind: Other:

Barriers to delivery (potential or known): *select all that apply*

□ Isolated/poor visibility	□ Current use	□ Building constraints (e.g. listed buildings)
□ Utilities or wayleaves	□ Misuse/poor ambience (e.g. vandalism, feels unsafe, etc)	
□ Other:		

Any other considerations?

Ease of delivery (best guess if unknown):

□ Easy	□ Moderate	□ Challenging

Estimated cost of delivery (approximate):

£________________________________

Appendix B: Appraisal tool inputs for each tool and scenario

B£ST

Scenario 1

Table 55: Evaluation time frame (year)

Start	End
2018	2028

Note: Evaluation of NPV, unless otherwise stated was always 10 years, 2018-2028.

Table 56: Project and tool data

Version:	3.020; February 2018
Appraisal conducted:	26 January 2019
Conducted for:	Scenario 1
Location name	The Helix
Development or Location size (nearest Ha)	10
Scheme Type	Redevelopment
Summarise baseline option	brownfield site, largely unused
Summarise proposed option	Mixed use site with green walls, suds, amenity planting & green space. Green walls and roofs, rain gardens, bioswales and strategic planting
Baseline option Present Value Cost (if applicable)	£0
Proposed option Present Value Cost	unknown
Scheme drivers / objectives	Redevelopment, Air quality, Amenity / Liveability, Carbon, Flood risk, Population growth / network capacity, Air temperature, Health, Water resource / rain water harvesting, Crime, Economic growth, PR – business / CSR
Scheme supporters	Developer, Local Authority, Water and Sewerage Company
Scheme funders	Developer, Local Authority, Newcastle university
Discount rate to apply	3.5%

Table 57: Appraisal inputs: GI features

		Infiltration			Conveyance			Storage	
Location reference / name	Location summary	Green Roof Extensive (size (m^2))	Rain garden (total size) (m^2)	Trees (number)	Vegetation - swale (length (m))	Vegetation - swale (typical width (m))	Detention (dry) basin size (m^2)	Retention (wet) basin size (m^2)	Retention (wet) basin (surrounding area size (m^2))
Whole site	trees			493					
Whole site	green roof	13392							
Snow Gardens a	rain garden		461						
Snow Gardens b	rain garden		430						
Swan Gardens	rain garden		406						
The Oakes	rain garden		481						
Oystershell Lane	swale				518	1			
Hedley Avenue	swale				169	1			
Science Square	detention basin						1110		
Knowledge Square	detention basin						739		
Buckingham Street	retention basin							108	546
Knowledge Square	retention basin							40	274
	TOTAL	**13392**	**1778**	**493**	**687**	**2**	**1849**	**148**	**820**

Air quality calculation sheet

Table 58: Vegetative SuDS excluding trees

SuDS type	(ha)
Green roof Intensive	0
Green roof extensive	1.3392
New basins (total incl. surrounding)	0.2817
Area of other vegetative SuDS e.g. raingardens, swales	0.2465
Total contributing vegetative SuDS area	1.8674

Table 59: Vegetation pollutant removal levels

Pollutant type	(tonnes/year/ha)
SO_2	0.019823
NO_2	0.02329
O_3	0.044919
PM_{10}	0.006494
CO	-

Table 60: New trees planted

Total number of trees	493		
Tree size	**Size of tree (species) when it has matured**		
	small	**medium**	**large**
Numbers	246	148	99

Table 61: Tree pollutant removal levels from ranges

Pollutant type	small	medium	large
		(tonnes/year/tree)	
SO_2	1.36E-05	3.18E-05	4.54E-05
NO_2	3.63E-05	7.71E-05	0.000127
O_3	6.35E-05	0.000122	0.000195
PM_{10}	6.8E-05	0.000132	0.000204
CO	-	-	-

Table 62: Benefit estimation

	Annual pollutant removal estimates (vegetation) tonnes	Annual pollutant removal estimates (trees) tonnes	Annual pollutant removal benefit (£)	Confidence of Quantity	Confidence of Valuation (£)	Present value before confidence applied	Present value after confidence applied
SO_2	0.037017	0.012538	£ 87	100%	100%	£ 684	£ 684
NO_2	0.043491	0.032913	£ 79	100%	100%	£ 617	£ 617
O_3	0.083882	0.053058	£ -	100%	100%		£ -
PM_{10}	0.012126	0.056414	£ 3,583	100%	100%	£ 28,110	£ 28,110
CO	0	0	0				£ -
					Difference	**£ 29,410**	**£ 29,410**

Amenity calculation sheet

Table 63: Permanent body of water

Option	Estimated no. of homes overlooking ponds	Monetary value description £/yr/resident household	Confidence in Quantity	Confidence in Valuation (£)	Present value before confidence applied	Present value after confidence applied
Baseline	0	71	100%	100%	£ -	£ -
Proposed	46	139	100%	100%	£ 50,044	£ 50,044
				Difference	**£ 50,044**	**£ 50,044**

Table 64: Average house price, £

Detached	Other houses	Flats
362,000.00	187,000.00	144,000.00

Table 65: Property price increase as a result of enhancements to parks

			Benefit, £ (one-off) before confidence	Confidence in Quantity	Confidence in Valuation (£)	Benefit, £ (one-off) after confidence
City public park enhancement	No. of detached houses <450m from park		£ -	100%	100%	£ -
	No. of other houses <450m from park					
	No. of flats <450m from park					
Local public park enhancement	No. of detached houses <450m from park		£ -	100%	100%	£ -
	No. of other houses <450m from park					
	No. of flats <450m from park					
Public open green space enhancement	No. of detached houses <450m from park		£ 885,760	100%	100%	£ 885,760
	No. of other houses <450m from park	73				
	No. of flats <450m from park	122				

Note: property price impact is only one year: 2020.

Table 66: Present value of benefit

Benefit, £ (one-off) before confidence	Confidence in Quantity	Confidence in Valuation (£)	Benefit, £ (one-off) after confidence
£ 696,200	100%	100%	£ 696,200

Building temperature sheet

Table 67: Input data for green roofs

Green Roof Size for all buildings (m^2)	13392
Green Roof Size for buildings using air conditioning (m^2)	10877
Annual number of heating degree days (Degrees Celsius)	2068
Annual number of cooling degree days (if air conditioning is used) (Degrees Celsius)	178

Table 68: Energy saving through heating (part a)

Energy saving to buildings through installing green roofs for heating (Kwh)	Confidence in Quantity	Confidence in Valuation (£)	Proportion (%) of properties heated through electricity	Proportion (%) of properties heated through gas
171530	100%	100%	50%	50%

Table 69: Energy saving through heating (part b)

Traded Carbon	Properties using electricity		Properties using gas	
	Energy Type	Energy Rate	Energy Type	Energy Rate
Central	Commercial/ Public sector	Central	Domestic	Central

Table 70: Energy saving through heating (part c)

	Estimated present value before confidence scores	Estimated present value after confidence scores
Energy savings through electricity	£ 90,905	£ 90,905
Energy savings through gas	£ 29,795	£ 29,795
Carbon Savings through not generating electricity over evaluation period	£ 3,963	£ 3,963
Carbon Savings through not generating gas over evaluation period	£ 3,753	£ 3,753

Table 71: Energy saving through cooling (part a)

Energy saving to buildings through installing green roofs for cooling (kwh)	Confidence in Quantity	Confidence in Valuation (£)
11992	100%	100%

Table 72: Energy saving through cooling (part b)

Traded Carbon	Energy Type	Energy Rate
Central	Commercial/ Public sector	Central

Table 73: Energy saving through cooling (part c)

	Estimated present value before confidence scores	Estimated present value after confidence scores
Energy savings	£ 12,710	£ 12,710
Carbon Savings through not generating energy over evaluation period	£ 554	£ 554

Carbon sequestration sheet

Table 74: Carbon sequestration from trees planted (part a)

Type of Trees	Number of trees planted	Start Year of the evaluation period	Finish Year of the evaluation period	Total Carbon Sequestered (tonnes)	Present Value of Carbon £	Confidence in Quantity
Deciduous - Small	246	2018	2028	5	£ 236	100%
Deciduous - Medium	148	2018	2028	57	£ 2,769	100%
Deciduous - Large	99	2018	2028	25	£ 1,206	100%
Conifer - Large	0	2018	2028	0	£ -	100%

Table 75: Carbon sequestration from trees planted (part b)

Non-traded Carbon	Estimated present value before confidence scores	Estimated present value after confidence scores
Central	£ 4,212	£ 4,212

Health sheet (emotional wellbeing)

Table 76: View over green space from homes

Option	Estimated no. of adults having a view over green space from house	Select appropriate monetary value description (or enter used defined) £/p/yr	Confidence in Quantity	Confidence in Valuation (£)	Present value before confidence applied	Present value after confidence applied
Baseline	0	145	100%	100%	£ -	£ -
Proposed	94	316	100%	100%	£ 233,211	£ 233,211
				Difference	**£ 233,211**	**£ 233,211**

Table 77: Access to freshwater/permanent water or wetlands

Option	Estimated no. of adults with freshwater or wetland within 1km of home	Select appropriate monetary value description (or enter used defined)	Confidence in Quantity	Confidence in Valuation (£)	Present value before confidence applied	Present value after confidence applied
Baseline	0	22	100%	100%	£ -	£ -
Proposed	365	73	100%	100%	£ 209,804	£ 209,804
				Difference	**£ 209,804**	**£ 209,804**

Table 78: Access to non-countryside green space

Option	Estimated no. of people using non-countryside green space monthly or more	Select appropriate monetary value description (or enter used defined)	Confidence in Quantity	Confidence in Valuation (£)	Present value before confidence applied	Present value after confidence applied
Baseline	0	121	100%	100%	£ -	£ -
Proposed	456	406	100%	100%	£ 1,453,178	£ 1,453,178
				Difference	**£ 1,453,178**	**£ 1,453,178**

Scenario 2

Table 79: Evaluation time frame (year)

Start	End
2018	2028

Note: Evaluation of NPV, unless otherwise stated was always 10 years, 2018-2028.

Table 80: Project and tool data

Version:	3.020; February 2018
Appraisal conducted:	26 January 2019
Conducted for:	Scenario 2
Location name	The Helix
Development or Location size (nearest Ha)	10
Scheme Type	Redevelopment
Summarise baseline option	brownfield site, largely unused
Summarise proposed option	Mixed use site with green walls, suds, amenity planting & green space. Green walls and roofs, rain gardens, bioswales and strategic planting
Baseline option Present Value Cost (if applicable)	£0
Proposed option Present Value Cost	unknown
Scheme drivers / objectives	Redevelopment, Air quality, Amenity / Liveability, Carbon, Flood risk, Population growth / network capacity, Air temperature, Health, Water resource / rain water harvesting, Crime, Economic growth, PR – business / CSR
Scheme supporters	Developer, Local Authority, Water and Sewerage Company
Scheme funders	Developer, Local Authority, newcastle university
Discount rate to apply	3.5%

Table 81: Appraisal inputs: GI features

		Infiltration			Conveyance		Storage		
Location reference / name	Location summary	Green Roof Extensive (size (m^2))	Rain garden (total size) (m^2)	Trees (number)	Vegetation - swale (length (m))	Vegetation - swale (typical width (m))	Detention (dry) basin size (m^2)	Retention (wet) basin size (m^2)	Retention (wet) basin (surrounding area size (m^2))
Whole site	trees			246					
Whole site	green roof	3001							
Snow Gardens a	rain garden		461						
Snow Gardens b	rain garden		430						
Swan Gardens	rain garden		406						
Oystershell Lane	swale				518	1			
Science Square	detention basin						1110		
Knowledge Square	detention basin						739		
	TOTAL	**3001**	**1297**	**246**	**518**	**1**	**1849**	**0**	**0**

Air quality calculation sheet

Table 82: Vegetative SuDS excluding trees

SuDS type	(ha)
Green roof Intensive	0
Green roof extensive	0.3001
New basins (total incl. surrounding)	0.1849
Area of other vegetative SuDS e.g. raingardens, swales	0.1815
Total contributing vegetative SuDS area	0.6665

Table 83: Vegetation pollutant removal levels

Pollutant type	(tonnes/year/ha)
SO_2	0.019823
NO_2	0.02329
O_3	0.044919
PM_{10}	0.006494
CO	-

Table 84: New trees planted

Total number of trees	246		
Tree size	**Size of tree (species) when it has matured**		
	small	**medium**	**large**
Numbers	197	37	12

Table 85: Tree pollutant removal levels from ranges

Pollutant type	small	medium	large
		(tonnes/year/tree)	
SO_2	1.36E-05	3.18E-05	4.54E-05
NO_2	3.63E-05	7.71E-05	0.000127
O_3	6.35E-05	0.000122	0.000195
PM_{10}	6.8E-05	0.000132	0.000204
CO	-	-	-

Table 86: Benefit estimation

	Annual pollutant removal estimates (vegetation) tonnes	Annual pollutant removal estimates (trees) tonnes	Annual pollutant removal benefit (£)	Confidence of Quantity	Confidence of Valuation (£)	Present value before confidence applied	Present value after confidence applied
SO_2	0.013212	0.0044	£ 31	100%	100%	£ 243	£ 243
NO_2	0.015522	0.011526	£ 28	100%	100%	£ 218	£ 218
O_3	0.029939	0.019382	£ -	100%	100%		£ -
PM_{10}	0.004328	0.02072	£ 1,310	100%	100%	£ 10,273	£ 10,273
CO	0	0	0				£ -
					Difference	**£ 10,734**	**£ 10,734**

Amenity calculation sheet

Table 87: Permanent body of water

Option	Estimated no. of homes overlooking ponds	Monetary value description £/yr/resident household	Confidence in Quantity	Confidence in Valuation (£)	Present value before confidence applied	Present value after confidence applied
Baseline	0	71	100%	100%	£ -	£ -
Proposed	35	139	100%	100%	£ 38,077	£ 38,077
				Difference	**£ 38,077**	**£ 38,077**

Table 88: Average house price, £

Detached	Other houses	Flats
362,000.00	187,000.00	144,000.00

Table 89: Property price increase as a result of enhancements to parks

			Benefit, £ (one-off) before confidence		Confidence in Quantity	Confidence in Valuation (£)	Benefit, £ (one-off) after confidence	
City public park enhancement	No. of detached houses <450m from park	-	£	-	100%	100%	£	-
	No. of other houses <450m from park	-						
	No. of flats <450m from park	-						
Local public park enhancement	No. of detached houses <450m from park	-	£	-	100%	100%	£	-
	No. of other houses <450m from park	-						
	No. of flats <450m from park	-						
Public open green space enhancement	No. of detached houses <450m from park	-	£	885,760	100%	100%	£	885,760
	No. of other houses <450m from park	73						
	No. of flats <450m from park	122						

Note: property price impact is only one year: 2020.

Table 90: Present value of benefit

Benefit, £ (one-off) before confidence		Confidence in Quantity	Confidence in Valuation (£)	Benefit, £ (one-off) after confidence
£	696,200	100%	100%	£696,200

Building temperature sheet

Table 91: Input data for green roofs

Green Roof Size for all buildings (m^2)	3001
Green Roof Size for buildings using air conditioning (m^2)	3001
Annual number of heating degree days (Degrees Celsius)	2068
Annual number of cooling degree days (if air conditioning is used) (Degrees Celsius)	178

Table 92: Energy saving through heating (part a)

Energy saving to buildings through installing green roofs for heating (Kwh)	Confidence in Quantity	Confidence in Valuation (£)	Proportion (%) of properties heated through electricity	Proportion (%) of properties heated through gas
38438	100%	100%	50%	50%

Table 93: Energy saving through heating (part b)

Traded Carbon	Properties using electricity		Properties using gas	
	Energy Type	Energy Rate	Energy Type	Energy Rate
Central	Commercial/ Public sector	Central	Domestic	Central

Table 94: Energy saving through heating (part c)

	Estimated present value before confidence scores	Estimated present value after confidence scores
Energy savings through electricity	£ 20,371	£ 20,371
Energy savings through gas	£ 6,677	£ 6,677
Carbon Savings through not generating electricity over evaluation period	£ 888	£ 888
Carbon Savings through not generating gas over evaluation period	£ 841	£ 841

Table 95: Energy saving through cooling (part a)

Energy saving to buildings through installing green roofs for cooling (kwh)	Confidence in Quantity	Confidence in Valuation (£)
3308	100%	100%

Table 96: Energy saving through cooling (part b)

Traded Carbon	Energy Type	Energy Rate
Central	Commercial/ Public sector	Central

Table 97: Energy saving through cooling (part c)

	Estimated present value before confidence scores	Estimated present value after confidence scores
Energy savings	£ 3,507	£ 3,507
Carbon Savings through not generating energy over evaluation period	£ 153	£ 153

Carbon sequestration sheet

Table 98: Carbon sequestration from trees planted (part a)

Type of Trees	Number of trees planted	Start Year of the evaluation period	Finish Year of the evaluation period	Total Carbon Sequestered (tonnes)	Present Value of Carbon £	Confidence in Quantity
Deciduous - Small	197	2018	2028	4	£ 189	100%
Deciduous - Medium	37	2018	2028	14	£ 692	100%
Deciduous - Large	12	2018	2028	3	£ 146	100%
Conifer - Large	0	2018	2028	0	£ -	100%

Table 99: Carbon sequestration from trees planted (part b)

Non-traded Carbon	Estimated present value before confidence scores	Estimated present value after confidence scores
Central	£ 1,028	£ 1,028

Health sheet (emotional wellbeing)

Table 100: View over green space from homes

Option	Estimated no. of adults having a view over green space from house	Select appropriate monetary value description (or enter used defined) £/p/yr	Confidence in Quantity	Confidence in Valuation (£)	Present value before confidence applied		Present value after confidence applied	
Baseline	0	145	100%	100%	£	-	£	-
Proposed	71	145	100%	100%	£	81,022	£	81,022
				Difference	**£**	**81,022**	**£**	**81,022**

Table 101: Access to freshwater/permanent water or wetlands

Option	Estimated no. of adults with freshwater or wetland within 1km of home	Select appropriate monetary value description (or enter used defined)	Confidence in Quantity	Confidence in Valuation (£)	Present value before confidence applied		Present value after confidence applied	
Baseline	0	22	100%	100%	£	-	£	-
Proposed	365	22	100%	100%	£	61,707	£	61,707
				Difference	**£**	**61,707**	**£**	**61,707**

Table 102: Access to non-countryside green space

Option	Estimated no. of people using non-countryside green space monthly or more	Select appropriate monetary value description (or enter used defined)	Confidence in Quantity	Confidence in Valuation (£)	Present value before confidence applied		Present value after confidence applied	
Baseline	0	121	100%	100%	£	-	£	-
Proposed	456	121	100%	100%	£	431,713	£	431,713
				Difference	**£**	**431,713**	**£**	**431,713**

GI-Val

Tool version used: 1.4.

Project data

Table 103: About the site

Current land use	unused/brownfield/regeneration
Project context eg inner city, urban or rural area (or a mix of all)?	inner city
Land ownership?	mixed
What is the level of deprivation in the area?	Site is in Westgate ward, within a LSOA that is in IMD Top 20% most deprived areas (and adjacent to several top 10% most deprived LSOAs, including in Wingrove).
"Is there currently a lack of green space in the area? How will this project help?"	Project specific Green Infrastructure audit has identified that the area of the city centre is extremely lacking in green space and particularly that the existing green space is very concentrated into one large block of land.
Does the site have heritage value?	Some elements of heritage value: a site of key industry forming Newcastle (coal mining history and site of S&N brewery)
Is the land publicly accessible?	yes - though the buildings are privately owned, the site is not gated
Is the site currently well connected or remote?	well connected, close to the city centre and to residential areas
Is the site liable to flooding? What is the level of flood risk?	low flood risk, though key surface water flow route
Is the area serviced by a combined sewer system?	Yes

Table 104: Green space created

	Scenario 1		Scenario 2	
	Before	After	Before	After
Project area (ha)	n.a.	10	n.a.	10
Total area of greenspace (ha)	0	4.66	0	2.04
New green space created by the project (ha)	n.a.	4.66	n.a.	2.04
Pre-existing area of greenspace enhanced by the project (ha)	n.a.	0	n.a.	0
Tree cover (ha)	0	0.35	0	0.08
Area of new woodland created (ha)	n.a.	0	n.a.	0
Total area of green roofs (sq.m)	0	13,392	0	3,001
including: area of intensive green roofs (sq.m)	0	0	0	0
area of semi-intensive green roofs (sq.m)	0	0	0	0
area of extensive green roofs (sq.m)	0	13392	0	3,001

Table 105: walking and cycling routes created

		Scenario 1		Scenario 2	
		Before	After	Before	After
Cycle routes	(km)	0	2.0786	0	2.0786
Current cycle routes upgraded	(km)	n.a.	0	n.a.	0
Footpaths	(km)	0	2.0786	0	2.0786
Footpaths upgraded	(km)	n.a.	0	n.a.	0

Table 106: Nearby homes and businesses

		Scenario 1			Scenario 2		
		<300m	**<1200m**		**<300m**	**<1200m**	
Before	Number of households within 300m and 1200m	2226	5200		2226	5200	
	Number of businesses within 300m and 1200m						
	Number of residents within 300m and 1200m	4360	10350		4360	10350	
		<300m	**<1200m**	**<450m**	**<300m**	**<1200m**	**<450m**
After	Number of households within 300m, 1200m and 450m	2421	5395	3269	2421	5395	3269
	Number of businesses within 300m and 1200m						
	Number of residents within 300m and 1200m	4816	10806		4816	10806	

Table 107: Potential site users

	Scenario 1		Scenario 2	
	Before	After	Before	After
Number of community groups involved	0	25	0	25
Total number of users per year	0	0	0	0
Of which number of visits from local visitors (recreation)	0	0	0	0
Of which number of visits from tourist visitors (tourism)	0	0	0	0
Estimate of working population	0	5000	0	5000

Table 108: Flood risk

		Scenario 1		Scenario 2	
		Before	After	Before	After
Number of residential properties at flood risk		0	0	0	0
Number of commercial, business, industrial premises at flood risk		0	0	0	0
Amount of SUDS storage	(m^3)	0	0	0	0
Length of watercourse	(km)	0	n.a.	0	n.a.
Length of watercourse improved/restored	(km)	n.a.	0	n.a.	0

Table 109: Economic value creation

	Scenario 1		Scenario 2	
	Before	After	Before	After
Number of construction jobs created as a result of scheme delivery	n.a.		n.a.	
Number of jobs created/safeguarded for management/maintenance of site	n.a.	0.26	n.a.	0.26
Average residential property price in the area (Before)	£190,000	n.a.	£190,000	n.a.

Climate Change Adaptation and Mitigation

Table 110: Reduced building energy consumption for heating

	Scenario 1	Scenario 2
Additional residential buildings with large trees < 10m	195	49
Energy saving for residential properties (kWh/yr (gas))	72540	18135
Commercial buildings	-	-
Energy saving for commercial properties	-	-
Output (£/yr)	3409	852

Table 111: Avoided carbon emissions from building energy savings for heating

	Scenario 1	Scenario 2
CO_2e saving ($kgCO_2e$/yr)	13380	3345
Output (£/yr)	80	20

Table 112: Reduced peak summer surface temperatures

	Scenario 1	Scenario 2
Evaporative fraction before project (=green area before/total site area)	0.00	0.00
Evaporative fraction after project	0.47	0.20
Peak temperature before (ºC)	43	43
Peak temperature after (ºC)	24	32
ºC Indicative peak temperature change	-18.7	-11.2

Table 113: Reduced building energy consumption for cooling

	Scenario 1	Scenario 2
Net additional area of green roof (m^2)	13,392	3,001
% building(s) air conditioned	75%	75%
Yearly air conditioning use (Hrs/yr)	500	500
Annual energy consumption reduction (kWh/yr)	248589	55707
Output (£/yr)	18,147.00	4,066.65

Table 114: Avoided carbon emissions from building energy savings for cooling

	Scenario 1	Scenario 2
CO_2e saving ($kgCO_2e$/yr)	124,382	27,873
Output (£/yr)	746.29	167.24

Water management and flood alleviation

Energy and carbon emissions savings from reduced stormwater volume entering combined sewers.

Annual rainfall: 600 mm/yr

Table 115: Land cover

	Scenario 1		Scenario 2	
	Before	After	Before	After
Buildings	0%	0%	0%	0%
Other impervious surfaces	100%	53%	100%	80%
Trees	0%	4%	0%	1%
Shrubs	0%	0%	0%	0%
Mown grass	0%	43%	0%	20%
Rough grass	0%	0%	0%	0%
Cultivated surfaces	0%	0%	0%	0%
Water	0%	0%	0%	0%
Bare soil or gravel surfaces	0%	0%	0%	0%

Table 116: Hydrological soil types

	Scenario 1	Scenario 2
A (high water infiltration rate; sandy soils)	0%	0%
B	0%	0%
C	100%	100%
D (low water infiltration rate; clay soils)	0%	0%

Table 117: Water diverted from sewers (part a)

			Scenario 1	Scenario 2
Before	Water currently diverted from sewers	l/yr	62,159	62,159
	Equivalent current energy saving	kWhr/yr	40	40
	Equivalent current carbon saving	tCO_2e/yr	0.02	0.02
	Value of current carbon saving	£/yr	0	0
	Value of current energy saving	£/yr	3	3
After	Water diverted from sewers under proposed design	l/yr	466,017	226,290
	Equivalent energy saving (proposed design)	kWhr/yr	301	146
	Equivalent carbon saving (proposed design)	tCO_2e/yr	0.15	0.07
	Value of carbon (proposed design)	£/yr	1	0
	Value of energy (proposed design)	£/yr	22	11

Table 118: Water diverted from sewers (part b)

		Scenario 1	Scenario 2
Water diverted from sewers	l/yr	403,857	164,130
Equivalent energy saving (water treatment)	kWhr/yr	260	106
Equivalent carbon saving	tCO_2e/yr	0.13	0.05
Outputs	£/yr value of carbon	1	0
	£/yr value of energy	19	8

Health

Reduced mortality from increased walking

Table 119: Potential beneficiaries

	Scenario 1		Scenario 2	
	Before	After	Before	After
Number of households <300m	2,226	2,421	2,226	2,421
Number of households <1200m	5,200	5,395	5,200	5,395
Number of local residents <300m	4,360	4,816	4,360	4,816
Number of local residents within 301-1200m	5,990	5,990	5,990	5,990
Number of local residents beyond 1200m	0	0	0	0

Table 120: Pedestrian routes

		Scenario 1		Scenario 2	
		Before	After	Before	After
Existing pedestrian routes	km	0	n/a	0	n/a
New pedestrian routes	km	n/a	2.0786	n/a	2.0786
Upgraded pedestrian routes	km	n/a	0	n/a	0

Table 121: Assumptions

	Before	After
Proportion of non-users within the local population	38%	25%
Proportion of green infrastructure asset users using the asset for walking	45%	45%

Table 122: Average No. of trips per year

	Scenario 1		Scenario 2	
	Before	After	Before	After
By residents within 300m	83	100	83	100
By residents 301m - 1200m	39	47	39	47
By residents beyond 1200m	0	0	0	0

Table 123: Walkers Usage: Total trips per year

	Scenario 1		Scenario 2	
	Before	After	Before	After
Residents < 300m	101,116	162,133	101,116	162,133
Residents within 301m - 1200m	65,177	94,612	65,177	94,612
Residents beyond 1200m	0	0	0	0

Table 124: Step 1: Calculate mean distance travelled per year

	Scenario 1		Scenario 2	
	Before	After	Before	After
Existing pedestrian routes (km)	0	0	0	0
Plus New and up-graded pedestrian routes added (km)	n/a	2.0786	n/a	2.0786
Average distance covered by walkers, say 40% of total pedestrian routes	0	1.66288	0	1.66288
Residents within 300m: Average trips per year	0	100	0	100
Residents 301m - 1200m: Average trips per year	0	47	0	47
Residents < 300m: Total distance travelled per year per by all pedestrians = Xkm (+ return journey from home) (km)	30,335	318,247	30,335	318,247
Residents within 301m -1200m: Total distance travelled per year by all pedestrians = X km (+ return journey from home) (km)	78,213	270,863	78,213	270,863
Residents > 1200m: Total distance travelled per year by all pedestrians = X km (km)	0	0	0	0
Mean distance travelled by resident pedestrian (within 1200m) per year (km)	38	162	38	162

Table 125: Step 2: Calculate relative risk for the green infrastructure scheme

	Scenario 1		Scenario 2	
	Before	After	Before	After
Mean distance travelled per year by cyclist in Copenhagen study (m)	1620	1620	1620	1620
Relative risk of death for cyclists found in Copenhagen study reduced to 72%, adjusted to 0.85 in Webtag 3.14 for walkers	0.85	0.85	0.85	0.85
Reduction in relative risk of death found in Copenhagen: 1 - 0.85	0.15	0.15	0.15	0.15
Estimated reduction in relative risk of death for green infrastructure scheme: C46 / 1620 x 0.15	0.003	0.0150	0.003	0.0150

Table 126: Step 3: Calculate reduced mortality benefit

	Scenario 1		Scenario 2	
	Before	After	Before	After
Mean % of England & Wales pop aged 15-64 who dies each year from all causes =	0.00235	0.00235	0.00235	0.00235
Number of green infrastructure users using asset for walking	2,888	3,647	2,888	3,647
Number of expected deaths in this population	6.8	8.6	6.8	8.6
Number of lives saved per year due to using green infrastructure for walking	0.02	0.13	0.02	0.13
Cost of life (source DFT, 2007) (£)	1,600,000	1,600,000	1,600,000	1,600,000
Value of annual reduced mortality (based on DFT 2007 cost of life) (£/yr)	£37,791	£205,097	£37,791	£205,097
Tool 4.2a output (£/yr)	n/a	£167,307	n/a	£167,307

Table 127: NPV of health value from walking

		Scenario 1	Scenario 2
NPV over 5 years	£	£458,350	£458,350
NPV over 10 years	£	£1,116,637	£1,116,637

Reduced mortality from increased cycling

Table 128: Potential beneficiaries

	Scenario 1		Scenario 2	
	Before	After	Before	After
Number of households (<300m)	2,226	2,421	2,226	2,421
Number of households (<1200m)	5,200	5,395	5,200	5,395
Number of local residents (<300m)	4,360	4,816	4,360	4,816
Number of local residents (<301-1200m)	5,990	5,990	5,990	5,990
Number of local residents (other - beyond 1200m)	0	0	0	0

Table 129: Cycle routes

		Scenario 1		Scenario 2	
		Before	After	Before	After
Existing cycle routes	km	0	n.a.	0	n.a.
New cycle routes	km	n.a.	2	n.a.	2.1
Upgraded cycle routes	km	n.a.	0	n.a.	0

Table 130: Assumption

	Before	After
Proportion of non-users within the local population	38%	38%
Proportion of green infrastructure users using the asset for cycling	10%	10%

Table 131: Average trips per year

	Scenario 1		Scenario 2	
	Before	After	Before	After
By residents within 300m:	83	100	83	100
By residents 301m - 1200m:	39	47	39	47
Residents beyond 1200m:	0	0	0	0

Table 132: Total number of trips per year

	Scenario 1		Scenario 2	
Cyclist Usage:	Before	After	Before	After
Residents within 300m:	22470	29784	22470	29784
Residents 301m - 1200m: Total trips per year	14483.82	17380.584	14483.82	17380.58
Residents beyond 1200m: Total trips per year	0	0	0	0

Table 133: Step 1: Calculate mean distance travelled per year

	Scenario 1		Scenario 2	
	Before	After	Before	After
Existing cycle routes (km)	0	n.a	0	n.a
New and up-graded cycling routes added (km)	0	2.0786	0	2.0786
Average distance covered by cyclists (including return trips), say 60% of total cycle routes (km)	0	2.49432	0	2.49432
Residents within 300m: average number of trips per year	0	100	0	100
Residents 301m - 1200m: average number of trips per year	0	47	0	47
Residents within 300m: total distance travelled per year per by all cyclists (incl. return journey from home) (km)	6,741	83,227	6,741	83,227
Residents 301m -1200m: total distance travelled per year by all cyclists (inc. return journey from home) (km)	17,381	64,209	17,381	64,209
Residents Other - beyond 1200m: Total distance travelled per year (km)	0	0	0	0
Mean distance travelled by resident cyclist (within 1200m) per year (km)	38	220	38	220

Table 134: Step 2: Calculate relative risk for the green infrastructure scheme

	Scenario 1		Scenario 2	
	Before	After	Before	After
Mean distance travelled per year by cyclist in Copenhagen study (km)	1620	1620	1620	1620
Relative risk of death for cyclists found in Copenhagen study reduced to 72%	0.72	0.72	0.72	0.72
Reduction in relative risk of death found in Copenhagen: 1 - 0.72	0.28	0.28	0.28	0.28
Estimated reduction in relative risk of death due to the green infrastructure scheme: C143 / 1620 x 0.28	0.006	0.0380	0.006	0.0380

Table 135: Step 3: Calculate reduced mortality benefit

	Scenario 1		Scenario 2	
	Before	After	Before	After
Mean % of England & Wales pop aged 15-64 who dies each year from all causes	0.00235	0.00235	0.00235	0.00235
Green infrastructure users using asset for cycling	642	670	642	670
Expected deaths in this population	1.5	1.6	1.5	1.6
Number of lives saved per year due to using the green infrastructure asset for cycling	0.01	0.06	0.01	0.06
Cost of life (source DFT, 2007)	1,600,000	1,600,000	1,600,000	1,600,000
Value of annual reduced mortality (based on DFT 2007 cost of life)	£15,676	£95,815	£15,676	£95,815
Tool 4.2b output		£80,139		£80,139

Avoided cost of air pollution control measures

Table 136: Project data

	Scenario 1	Scenario 2
What type of location is the project in?	Urban	Urban
What is the existing land use type?	Vacant	Vacant
Input existing area of tree cover (ha)	0	0
Proposed increased tree cover (ha)	0.35	0.08

Table 137: CURRENT LAND COVER - POLLUTANT REMOVAL (Scenario 1)

	Tonnes/ ha/yr	Tonnes/ tree/yr	Gross removal (tonnes/yr)	Cost savings
Carbon Monoxide removed	0.0003	3.635E-06	0	0
Sulphur Dioxide removed	0.0014	2.035E-05	0	0
Nitrogen Dioxide removed	0.0015	2.157E-05	0	0
PM_{10} particulates removed	0.0035	5.137E-05	0	0
Ozone removed	0.0031	4.628E-05	0	0

Table 138: CURRENT LAND COVER - POLLUTANT REMOVAL (Scenario 2)

	Tonnes/ ha/yr	Tonnes/ tree/yr	Gross removal (tonnes/yr)	Cost savings
Carbon Monoxide removed	0.0003	3.63E-06	0	0
Sulphur Dioxide removed	0.0014	2.04E-05	0	0
Nitrogen Dioxide removed	0.0015	2.16E-05	0	0
PM_{10} particulates removed	0.0035	5.14E-05	0	0
Ozone removed	0.0031	4.63E-05	0	0

Table 139: Net impact of scheme

	Scenario 1	Scenario 2
CO t/yr	0.000105	0.000024
SO_2 t/yr	0.00049	0.000112
NO_2 t/yr	0.000525	0.00012
PM_{10} t/yr	0.001225	0.00028
O_3 t/yr	0.001085	0.000248

Table 140: PROPOSED NEW ADDITIONAL LAND COVER - POLLUTANT REMOVAL (Scenario 1)

	Tonnes/ ha /yr	Tonnes/ tree/yr	Gross removal (tonnes/yr)	Cost savings
Carbon Monoxide removed	0.0003	3.635E-06	0.000105	0.133024
Sulphur Dioxide removed	0.0014	2.035E-05	0.00049	1.102585
Nitrogen Dioxide removed	0.0015	2.157E-05	0.000525	3.189819
PM_{10} particulates removed	0.0035	5.137E-05	0.001225	2.205477
Ozone removed	0.0031	4.628E-05	0.001085	0.732025

Table 141: PROPOSED NEW ADDITIONAL LAND COVER - POLLUTANT REMOVAL (Scenario 2)

	Tonnes/ ha /yr	Tonnes/ tree/yr	Gross removal (tonnes/yr)	Cost savings
Carbon Monoxide removed	0.0003	3.63E-06	0.000024	0.030405
Sulphur Dioxide removed	0.0014	2.04E-05	0.000112	0.252019
Nitrogen Dioxide removed	0.0015	2.16E-05	0.00012	0.729101
PM_{10} particulates removed	0.0035	5.14E-05	0.00028	0.504109
Ozone removed	0.0031	4.63E-05	0.000248	0.16732

Table 142: Total value of avoided cost of air pollution control measures

	Scenario 1	Scenario 2
NPV (£)	178.7466	40.856373

Property and land values

Table 143: Residential land and property value uplift (<450m from green space)

		Scenario 1	Scenario 2
Potential number of properties benefiting		3,269	3,269
New green space created	Ha	4.66	2.04
Of which high quality 'city park'	Ha	0	0
Of which quality 'local park'	Ha	0	0
Green space enhanced	Ha	0	0
Of which high quality 'city park'	Ha	0	0
Of which quality 'local park'	Ha	0	0
Average property price	£	190,000	190,000

Table 144: Households

	Scenario 1	Scenario 2
% of properties with green space <450m currently and benefiting	0%	0%
Estimated number of households benefiting	3,269	3,269

Table 145: Property value uplift

Property value uplift, apportioned between:	Scenario 1	Scenario 2
New green space created	£17,295,925	£17,295,925
Green space enhanced	£0	£0
Total output (£)	£17,295,925	£17,295,925

Labour productivity

Table 146: Savings from reduced short-term absenteeism from work

		Scenario 1	Scenario 2
Number of workers encouraged to walk or cycle to work by green infrastructure scheme	(n)	500	500
	(%)	10%	10%
Gross days lost avoided (low) = 6%*95%*6.8*extra walkers / cyclists		194	194
Gross days lost avoided (high) = 32%*95%*6.8* extra walkers / cyclists		1,034	1,034
Average hours worked per day (Census average)	Hrs	7.5	7.5
Average gross daily wage of walker / cyclist	£	200.00	200.00
Average gross employer savings (low) =extra walkers / cyclists X average gross daily wage.	£	38,760	38,760
Average gross employer savings (high) =extra walkers / cyclists X average gross daily wage.	£	206,720	206,720
Benefit discount. WHO research used is based on 30 min exercise 5 days per week. The assumption being made here is that people walk 4 out of 5 days/week.		77%	77%
Discounted gross employer savings (LOW CASE)	£/yr	£29,815	£29,815
Discounted gross employer savings (HIGH CASE)	£/yr	£159,015	£159,015

Biodiversity

Table 147: Willingness to pay for protection/enhancement of biodiversity

		Scenario 1		**Scenario 2**	
		Current	Proposed	Current	Proposed
Total area of green space	Ha	0	4.66	0	2.04
Area designated for nature and wildlife conservation: local designation or similar	Ha	0	0	0	0
Area designated for nature and wildlife conservation: national designation or similar	Ha	0	0	0	0
Area of woodland w/biodiversity value not captured above (ie: not protected through local or national designation)	Ha	0	0	0	0
Area of wetland w/biodiversity value not captured above (ie: not protected through local or national designation)	Ha	0	0	0	0
Net amount of land w/ biodiversity value created	Ha	n.a.	0	n.a.	0
Beneficiaries: number of households <1.2km		5395		5395	
Estimated value of biodiversity in site area (based on WTP)	£/yr	£0	£0.088	£0	£0
Tool 10.1 output	£/yr		0		0

Land management

Table 148: Employment supported by land management

	S1	**S2**
jobs	0.26	0.26
£/yr	6,500	6,500

Multiple benefits toolbox: outputs

Scenario 1

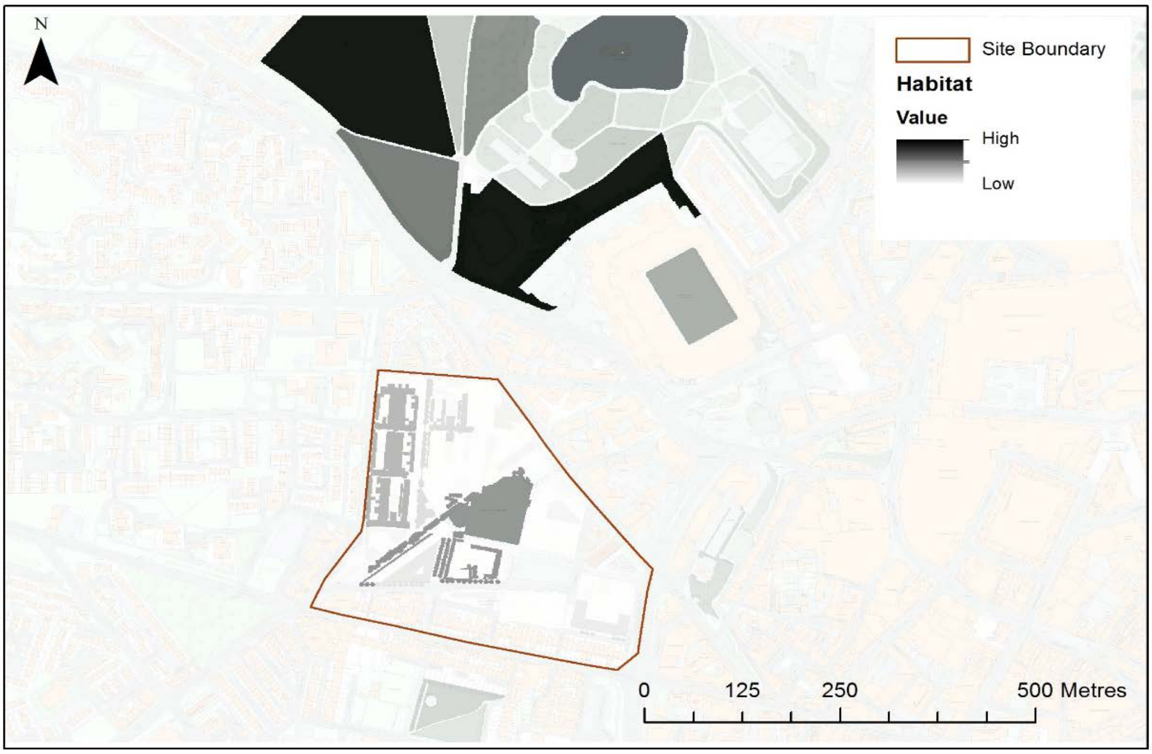

Figure 55: Habitat size, scenario 1

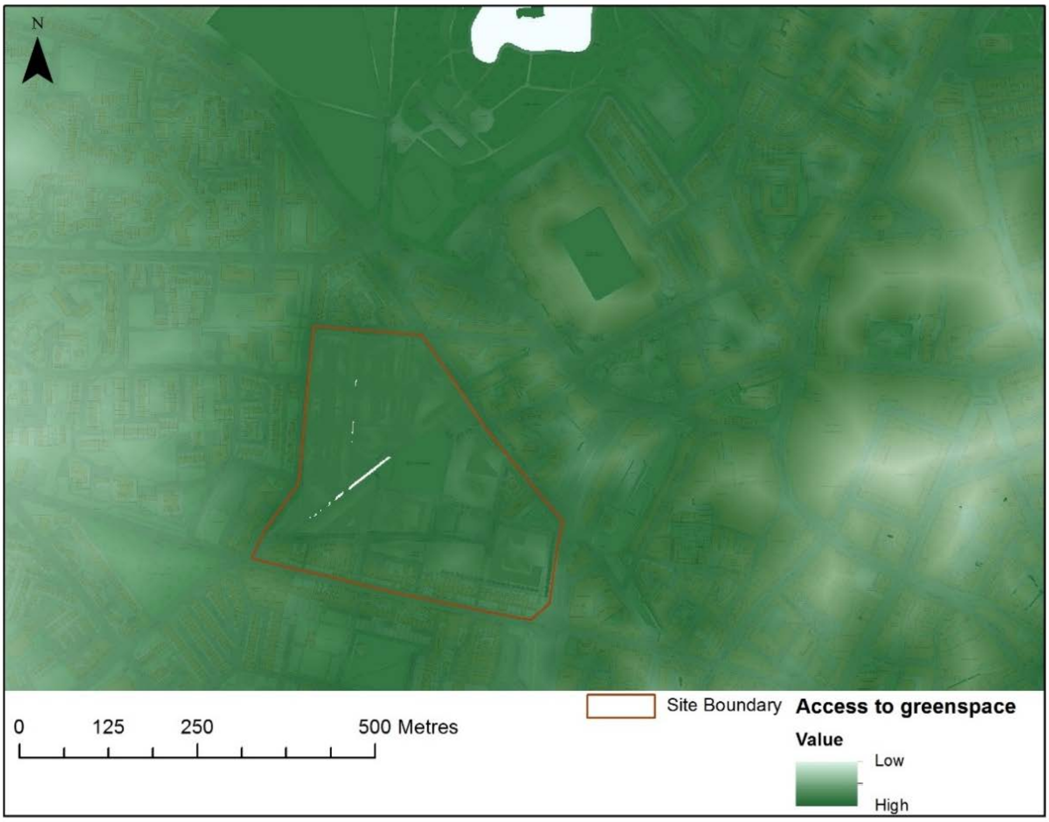

Figure 56: Access to greenspace, scenario 1

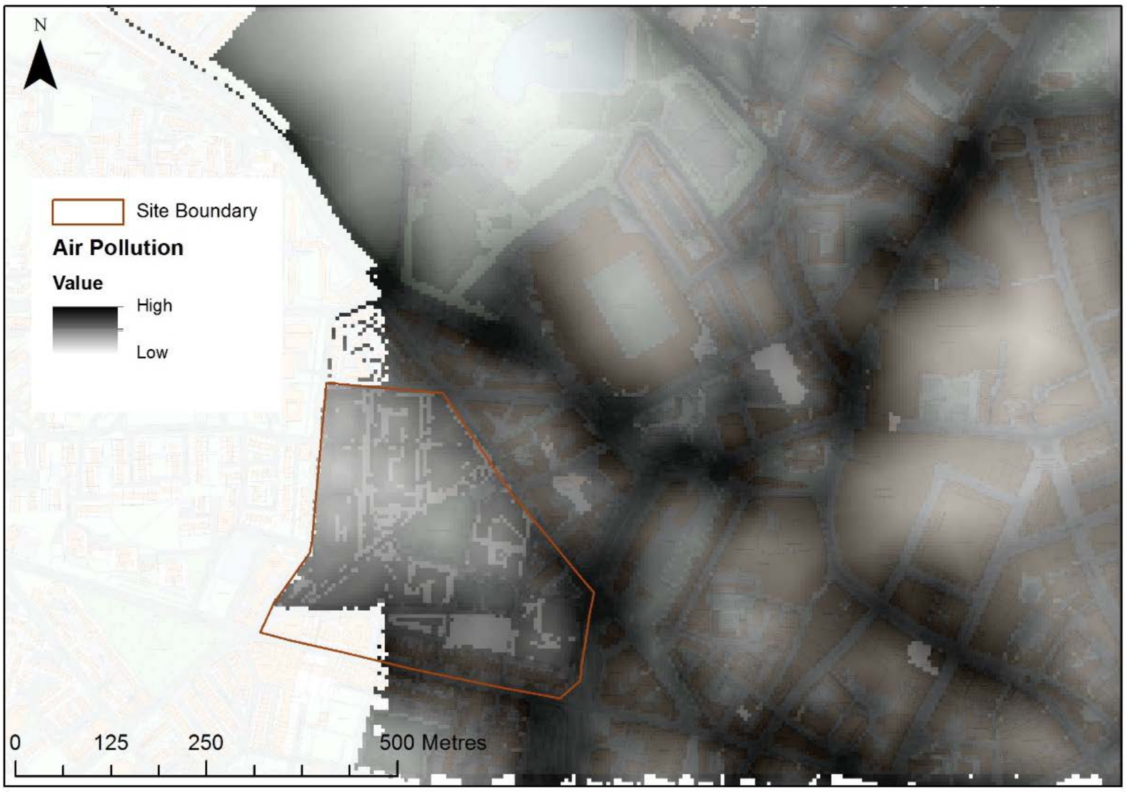

Figure 57: Air pollution (PM10), scenario 1

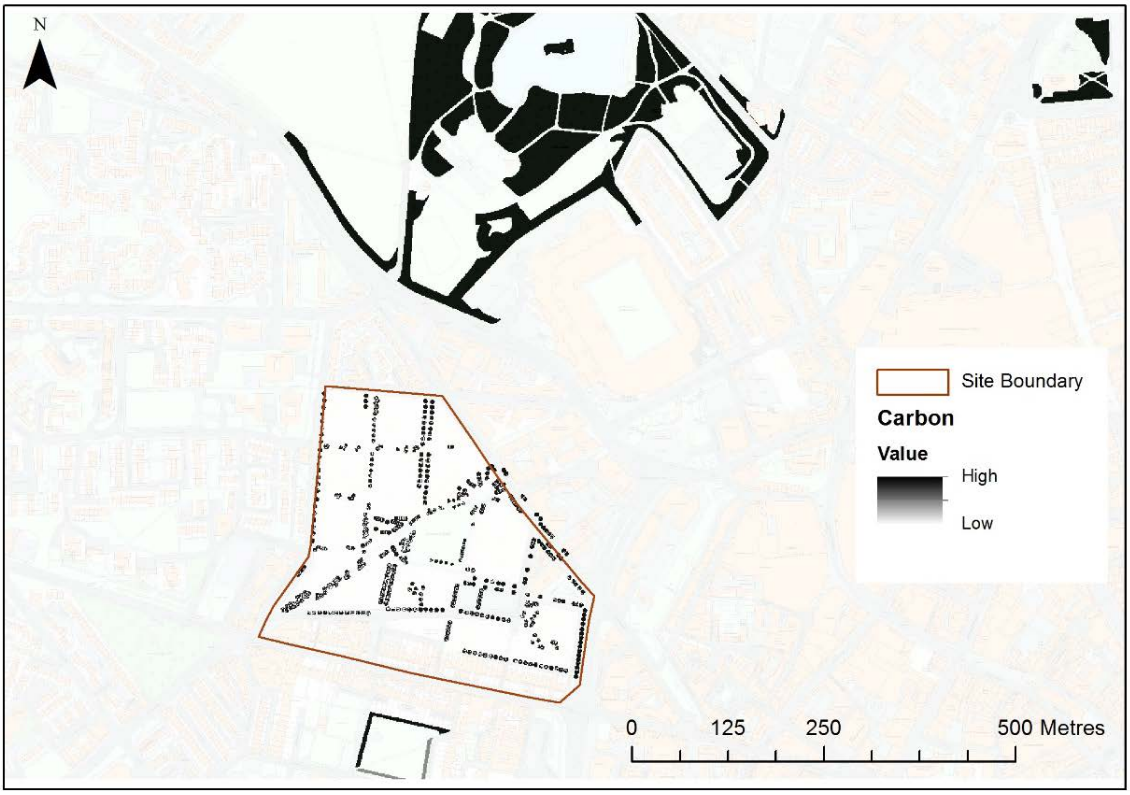

Figure 58: Carbon sequestration, scenario 1

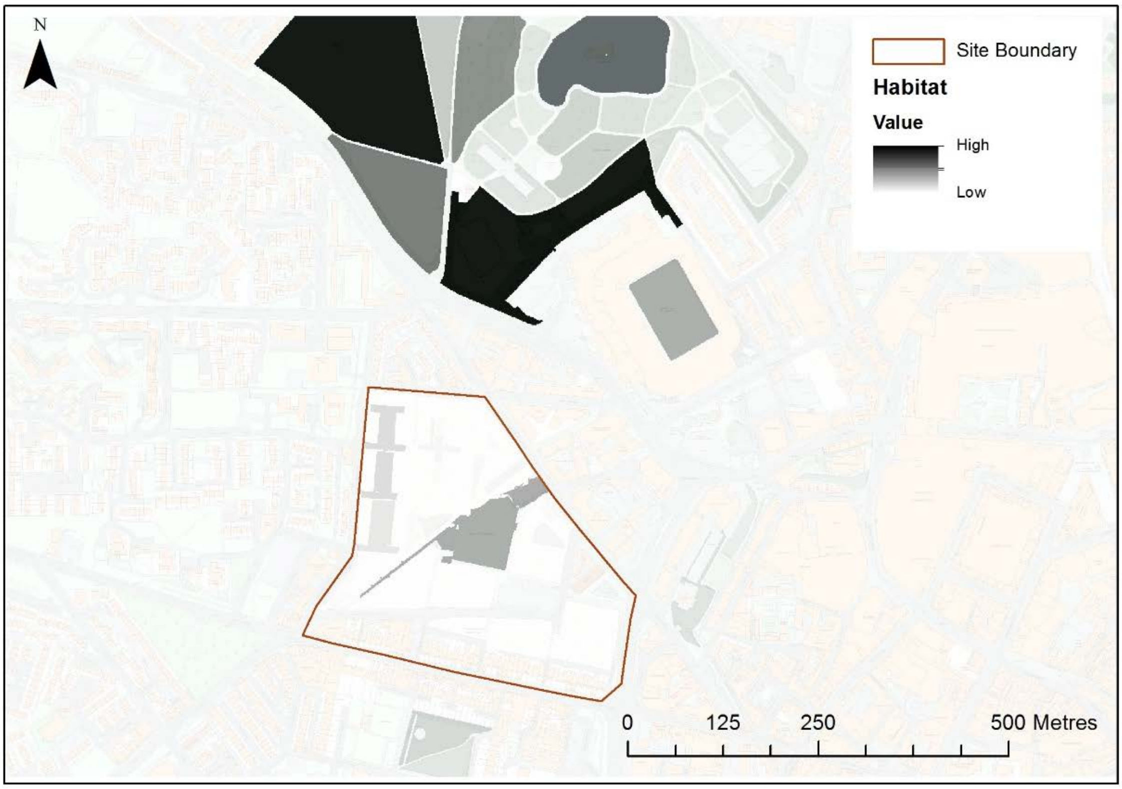

Figure 59: Habitat size, scenario 2

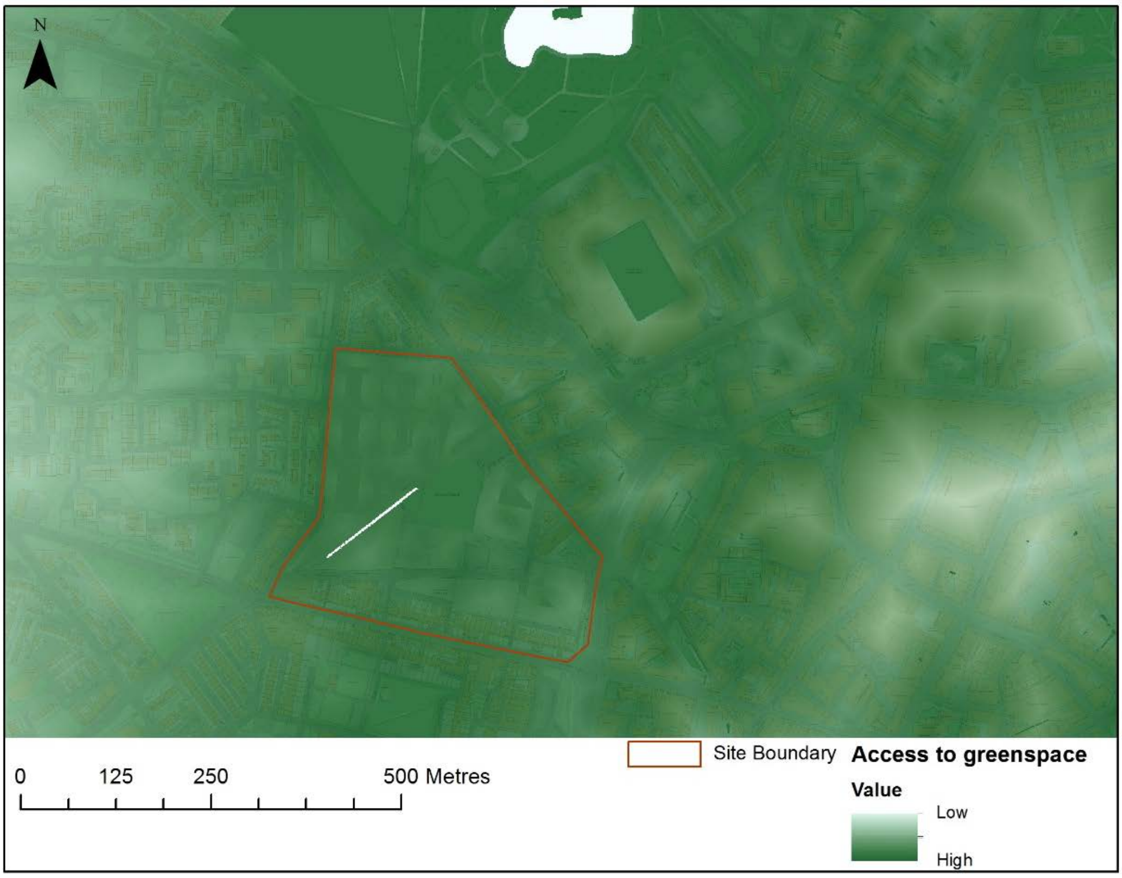

Figure 60: Access to greenspace, scenario 2

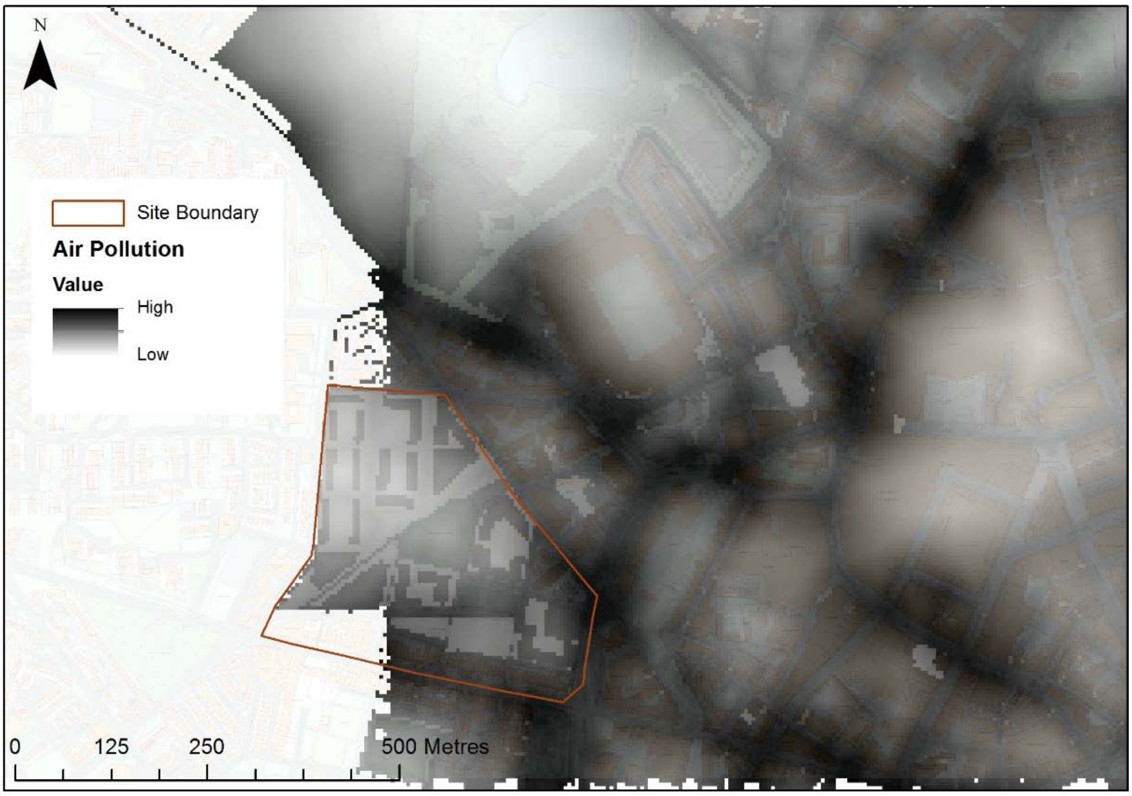

Figure 61: Air pollution (PM10), scenario 2

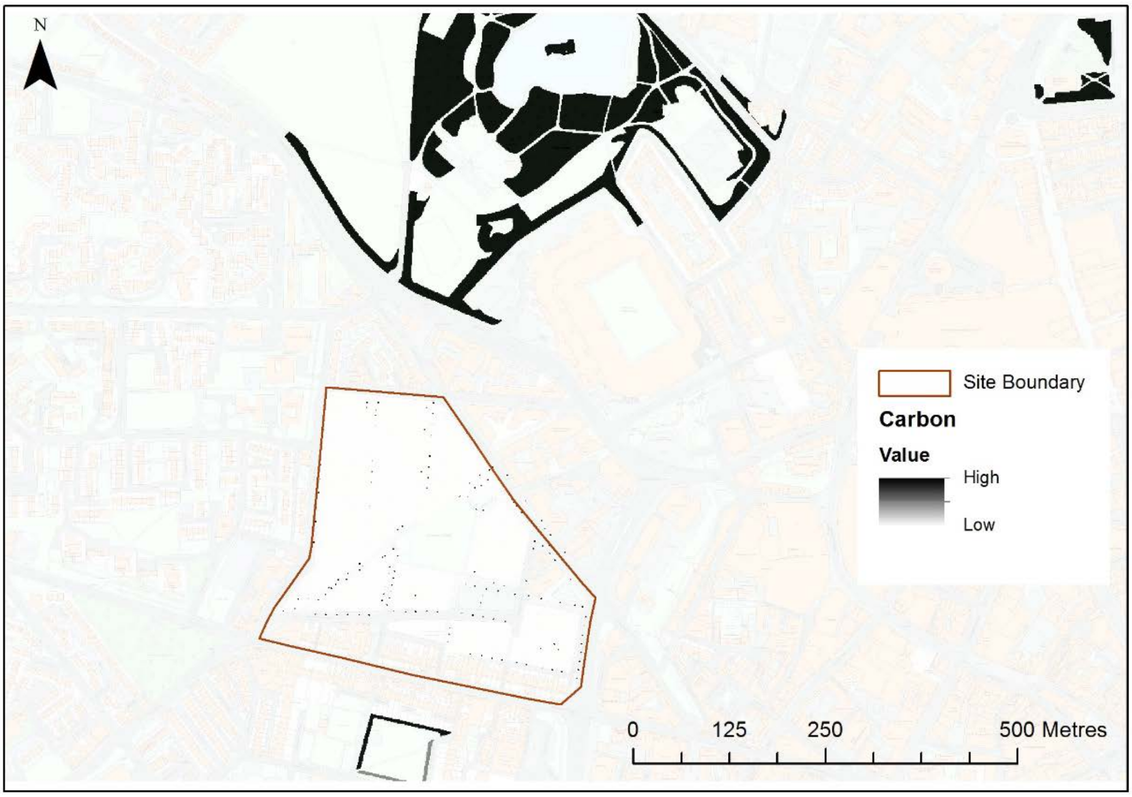

Figure 62: Carbon sequestration, scenario 2

Appendix C: Scoring the policy review and matrix

Policy name:	**United Nations Sustainable Development Goals**		
Date written	2015		
Organisation/owner:	United Nations		
		score	**notes**
Geog scale	International	1	
Political power	International governance/committee	2	
Is it green infrastructure focused	Policy is relevant to the wider issues	1	conceptually relevant, but not really about green infrastructure
Document type	High level goal	2	internationally relevant goals, but not specific enough to have impact at local level
Does it have specific goals	yes, but it's unclear how they're measured	3	
is there a delivery plan of some kind?	No apparent plan stated	1	
STRENGTH (relevance and power)	4		
IMPACT (goals and delivery plan)	6		
total score	10		

Policy name:	**Paris Agreement**		
Date written	2015		
Organisation/owner:	United Nations		
		score	**notes**
Geog scale	International	1	
Political power	International governance/committee	2	
Is it green infrastructure focused	Policy is relevant to the wider issues	1	conceptually relevant, but not really about green infrastructure
Document type	High level goal	2	internationally relevant target, with specific legal limits that are ratified, but not specific enough to have impact at local level - could be a driver for buy in at a large scale
Does it have specific goals	no, but it states some aims	2	
is there a delivery plan of some kind?	Yes: with a timeline, but no funding	2	
STRENGTH (relevance and power)	4		
IMPACT (goals and delivery plan)	6		
total score	10		

Policy name:	**IPCC special report on 1.5 degree warming**		
Date written	2007		
Organisation/owner:	IPCC		
		score	**notes**
Geog scale	International	1	
Political power	International governance/committee	2	
Is it green infrastructure focused	Policy is about a directly related issue	2	conceptually relevant, and acknowledges that green infrastructure has a role to play in achieving goal
Document type	High level goal	2	mentions green infrastructure as having a role, but is mainly an information document for the general context of global warming
Does it have specific goals	None stated	1	
is there a delivery plan of some kind?	No apparent plan stated	1	
STRENGTH (relevance and power)	5		
IMPACT (goals and delivery plan)	4		
total score	9		

Policy name:	**EU 2020 Biodiversity Strategy**		
Date written	2011		
Organisation/owner:	European Commission		
		score	**notes**
Geog scale	International	1	
Political power	International governance/committee	2	
Is it green infrastructure focused	Policy is about a directly related issue	2	european documents focus on ecosystem services and use of green infrastructure to deliver them
Document type	Strategy	3	outlines strategy for biodivesity
Does it have specific goals	yes, SMART goals are included	4	
is there a delivery plan of some kind?	Yes: with a timeline, but no funding	2	
STRENGTH (relevance and power)	5		
IMPACT (goals and delivery plan)	9		
total score	14		

Policy name:	**Green Infrastructure (GI) — Enhancing Europe's Natural Capital**		
Date written	2013		
Organisation/owner:	European Commission		
		score	**notes**
Geog scale	International	1	
Political power	International governance/committee	2	
Is it green infrastructure focused	Policy is wholly and specifically about green infrastructure	4	this is a green infrastructure document
Document type	Strategy	3	talks about how green infrastructure can be used to achieve strategic aims
Does it have specific goals	no, but it states some aims	2	
is there a delivery plan of some kind?	Yes: with a timeline, but no funding	2	
STRENGTH (relevance and power)	7		
IMPACT (goals and delivery plan)	7		
total score	14		

Policy name:	**25-year environment plan**		
Date written	2018		
Organisation/owner:	UK Government\Defra		
		score	**notes**
Geog scale	National	2	
Political power	Government/local authority	4	
Is it green infrastructure focused	Policy includes a section focused on green infrastructure	3	this policy includes a strong focus on the role of green infrastructure
Document type	Plan	4	specifically a plan
Does it have specific goals	yes, SMART goals are included	4	
is there a delivery plan of some kind?	Yes: timeline, and non-specific funding	3	
STRENGTH (relevance and power)	9		
IMPACT (goals and delivery plan)	11		
total score	20		

Policy name:	**Green infrastructure - position statement**		
Date written	2013		
Organisation/owner:	Landscape Institute		
		score	**notes**
Geog scale	National	2	
Political power	NGO or professional body	1	
Is it green infrastructure focused	Policy is wholly and specifically about green infrastructure	4	this is a green infrastructure document
Document type	Position statement	1	
Does it have specific goals	no, but it states some aims	2	
is there a delivery plan of some kind?	No apparent plan stated	1	
STRENGTH (relevance and power)	7		
IMPACT (goals and delivery plan)	4		
total score	11		

Policy name:	**National Planning Policy Framework**		
Date written	2018		
Organisation/owner:	UK Government\MHCLG		
		score	**notes**
Geog scale	National	2	
Political power	Government/local authority	4	
Is it green infrastructure focused	Policy is about a directly related issue	2	NPPF doesn't have a heading for green infrastructure, but specifically mentions its role. This isn't a strong prescriptive focus though, so I'm only scoring it a 2
Document type	Strategy	3	nppf is the guidance for planning decisions to be made, but it is not specific enough about delivery to call it a plan, but it is very influential so I am calling it a strategy
Does it have specific goals	no, but it states some aims	2	
is there a delivery plan of some kind?	No apparent plan stated	1	
STRENGTH (relevance and power)	8		
IMPACT (goals and delivery plan)	6		
total score	14		

Policy name:	**Historic Environment Good Practice Advice in Planning**		
Date written	2015		
Organisation/owner:	Historic England		
		score	**notes**
Geog scale	National	2	
Political power	NGO or professional body	1	
Is it green infrastructure focused	Policy is relevant to the wider issues	1	It does mention green infrastructure by name a couple of times (p7 and p8), but doesn't engage in detail with it as a concept for achieving the aims of the policy, so I think it is only worth a 1.
Document type	Position statement	1	good practice advice, but not specific enough to call it a strategy or plan. Does not set goals either.
Does it have specific goals	no, but it states some aims	2	
is there a delivery plan of some kind?	No apparent plan stated	1	
STRENGTH (relevance and power)	4		
IMPACT (goals and delivery plan)	4		
total score	8		

Policy name:	**TCPA Green Infrastructure Partnership**		
Date written	2017		
Organisation/owner:	TCPA		
		score	**notes**
Geog scale	National	2	
Political power	NGO or professional body	1	
Is it green infrastructure focused	Policy is wholly and specifically about green infrastructure	4	the TCPA set up this working group specifically to focus on green infrastructure.
Document type	Strategy	3	includes detail on delivery of green infrastructure, but is not a plan for delivery specifically
Does it have specific goals	None stated	1	
is there a delivery plan of some kind?	No apparent plan stated	1	
STRENGTH (relevance and power)	7		
IMPACT (goals and delivery plan)	5		
total score	12		

Policy name:	**Land use planning - position statement**		
Date written	unknown		
Organisation/owner:	National Trust		
		score	**notes**
Geog scale	National	2	
Political power	NGO or professional body	1	
Is it green infrastructure focused	Policy is relevant to the wider issues	1	talks about key issues in land use planning, which can include green infrastructure, but it isn't a focus. Scoring a 1 for the same reason that HE get a 1.
Document type	Position statement	1	
Does it have specific goals	None stated	1	
is there a delivery plan of some kind?	No apparent plan stated	1	
STRENGTH (relevance and power)	4		
IMPACT (goals and delivery plan)	3		
total score	7		

Policy name:	**Transport strategy**		
Date written	2016		
Organisation/owner:	North East combined authority		
		score	**notes**
Geog scale	Regional	3	
Political power	Government/local authority	4	
Is it green infrastructure focused	Policy is about a directly related issue	2	not about green infrastructure per se, but green infrastructure can help to deliver some of its aims, and it recognising this.
Document type	Strategy	3	
Does it have specific goals	no, but it states some aims	2	
is there a delivery plan of some kind?	No apparent plan stated	1	
STRENGTH (relevance and power)	9		
IMPACT (goals and delivery plan)	6		
total score	15		

Policy name:	**Local Enterprise Partnership Strategic Economic Plan**		
Date written	2017		
Organisation/owner:	North East Local Enterprise Partnership		
		score	**notes**
Geog scale	Regional	3	
Political power	Non-departmental public body	3	
Is it green infrastructure focused	Policy is relevant to the wider issues	1	shapes investment strategy for the region, which makes it relevant for decision making and green infrastructure can feed into it. But it doesn't acknowledge green infrastructure at all.
Document type	Strategy	3	
Does it have specific goals	no, but it states some aims	2	
is there a delivery plan of some kind?	No apparent plan stated	1	
STRENGTH (relevance and power)	7		
IMPACT (goals and delivery plan)	6		
total score	13		

Policy name:	**Flood risk management plan**		
Date written	2016		
Organisation/owner:	Newcastle city council		
		score	**notes**
Geog scale	City	4	
Political power	Government/local authority	4	
Is it green infrastructure focused	Policy includes a section focused on green infrastructure	3	explicitly acknowledges the role of green infrastructure in delivering the goals of the plan
Document type	Plan	4	
Does it have specific goals	yes, SMART goals are included	4	
is there a delivery plan of some kind?	Yes: timeline, and funding explicity stated	4	
STRENGTH (relevance and power)	11		
IMPACT (goals and delivery plan)	12		
total score	23		

Policy name:	**Ouseburn Surface Water Management Plan**		
Date written	2015		
Organisation/owner:	Newcastle city council		
		score	**notes**
Geog scale	City	4	
Political power	Government/local authority	4	
Is it green infrastructure focused	Policy includes a section focused on green infrastructure	3	explicitly acknowledges the role of green infrastructure in delivering the goals of the plan
Document type	Plan	4	
Does it have specific goals	yes, but it's unclear how they're measured	3	
is there a delivery plan of some kind?	Yes: timeline, and funding explicitly stated	4	
STRENGTH (relevance and power)	11		
IMPACT (goals and delivery plan)	11		
total score	22		

Policy name:	**Air quality management strategy**		
Date written	2006		
Organisation/owner:	Newcastle city council		
		score	**notes**
Geog scale	City	4	
Political power	Government/local authority	4	
Is it green infrastructure focused	Policy is about a directly related issue	2	No mention of green infrastructure specifically, but green infrastructure strategy could be key for delivery of clean air!
Document type	Strategy	3	
Does it have specific goals	yes, but it's unclear how they're measured	3	
is there a delivery plan of some kind?	Yes: timeline, and funding explicitly stated	4	
STRENGTH (relevance and power)	10		
IMPACT (goals and delivery plan)	10		
total score	20		

Policy name:	**Tyne Catchment Plan**		
Date written	2012		
Organisation/owner:	Tyne Rivers Trust		
		score	**notes**
Geog scale	Regional	3	
Political power	NGO or professional body	1	
Is it green infrastructure focused	Policy includes a section focused on green infrastructure	3	Specifically identifies role of green infrastructure in delivering the aims of the plan.
Document type	Plan	4	
Does it have specific goals	yes, but it's unclear how they're measured	3	
is there a delivery plan of some kind?	Yes: timeline, and funding explicitly stated	4	
STRENGTH (relevance and power)	7		
IMPACT (goals and delivery plan)	11		
total score	18		

Policy name:	**Core Strategy and Urban Core Plan**		
Date written	2015		
Organisation/owner:	Newcastle city council and Gateshead council		
		score	**notes**
Geog scale	Regional	3	
Political power	Government/local authority	4	
Is it green infrastructure focused	Policy includes a section focused on green infrastructure	3	explicit mention of green infrastructure and its role in achieving the goals of the plan, even though it's not a specific section
Document type	Plan	4	
Does it have specific goals	yes, but it's unclear how they're measured	3	
is there a delivery plan of some kind?	Yes: with a timeline, but no funding	2	
STRENGTH (relevance and power)	10		
IMPACT (goals and delivery plan)	9		
total score	19		

Policy name:	**Biodiversity action plan**		
Date written	2014		
Organisation/owner:	Newcastle city council; North Tyneside council		
		score	**notes**
Geog scale	Regional	3	
Political power	Government/local authority	4	
Is it green infrastructure focused	Policy is about a directly related issue	2	No mention of green infrastructure specifically, but green infrastructure strategy could be key for delivery of biodiversity!
Document type	Plan	4	
Does it have specific goals	yes, but it's unclear how they're measured	3	
is there a delivery plan of some kind?	Yes: with a timeline, but no funding	2	
STRENGTH (relevance and power)	9		
IMPACT (goals and delivery plan)	9		
total score	18		

Policy name:	**Climate change strategy**		
Date written	2010		
Organisation/owner:	Newcastle partnership		
		score	**notes**
Geog scale	City	4	
Political power	Non-departmental public body	3	not strictly a NDPB, but a partnership combining local authorities and NGOs. A score of 3 reflects the power of local authority contribution, reduced by it being a partnership organisation with non-statutory powers. But more powerful than an NGO because of the LA involvement.
Is it green infrastructure focused	Policy is about a directly related issue	2	
Document type	Strategy	3	
Does it have specific goals	yes, but it's unclear how they're measured	3	
is there a delivery plan of some kind?	Yes: with a timeline, but no funding	2	
STRENGTH (relevance and power)	9		
IMPACT (goals and delivery plan)	8		
total score	17		

Appendix D: Detailed stakeholder list

Stakeholders identified in section 6.2 (grouped by role)		Active/ Passive	Commentary
Community and charities	Charities and support services	Either	Community level groups and charities will vary in their level of engagement depending on proximity to the green infrastructure project and any special interests that those groups have. A local campaign group with a relevant focus may become Actively involved, but proximity alone is unlikely to make a residents group interested beyond a Passive level
	Climate Action Groups	Either	
	Community groups (location based)	Passive	
	Community groups (interest based)	Active	
	Housing Association	Passive	
	Not-for-profits & Charities	Either	
	Schools, colleges and universities	Either	
	Volunteering	Active	
Funder	Big Lottery	Either	Funders are all potentially active stakeholders if their usual funding remit covers and area or issue that is relevant to green infrastructure delivery. If they become a formal part of a project through its business model then they will be an Active stakeholder.
	European Regional Development Fund (ERDF)	Either	
	European Social Fund (ESF)	Either	
	European Investment Bank	Either	
	Grant Making Trusts	Either	

Stakeholders identified in section 6.2 (grouped by role)		Active/ Passive	Commentary
	Heritage Lottery Fund	Either	
	Landfill Community Fund	Either	
	Public Works Loan Board (PWLB)	Either	
	Regional Growth Fund	Either	
Government department	Department for Business, Energy and Industrial Strategy (BEIS)	Passive	The remit of several government departments in the UK have overlaps with themes relevant to green infrastructure delivery. However, as can be seen in the power and influence scores for government policies in the policy review (see Chapter 5 and Appendix C), their interests are high level and often too removed from delivery focus to be more than passive stakeholders in a GI system.
	Department for Environment, Food and Rural Affairs (Defra)	Passive	
	Department for Education (DfE)	Passive	
	Department of Justice (DoJ)	Passive	
	Department for Work and Pensions (DWP)	Passive	
	Other national government departments	Passive	
International bodies	International organisations (global or regional), e.g. United Nations; European Commission	Passive	While this level of stakeholder might shape the delivery in a strategic sense, they are too far removed from the project to be actively involved.

Stakeholders identified in section 6.2 (grouped by role)		Active/ Passive	Commentary
Local and regional governance/ strategy	Devolved Mayor	Active	These organisations could all be active stakeholders, with a lot of strategic and decision-making power at the delivery level of a green infrastructure network. Not all of them are involved in existing green infrastructure systems, but they all represent key opportunities for involvement.
	Local Enterprise Partnership	Active	
	Local Authority (LA)	Active	
	Local governance bodies	Active	
	Regional governance organisations	Active	
NDPB	Environment Agency (EA)	Active	NDPB have the capacity to be active stakeholders where the project being delivered is relevant to their specific remit. For example, Highways England would be involved if a project included or directly impacted part of the strategic national road network. The groups identified as Passive here are focused more on operational than strategic level, and so are less likely to become involved in this type of project. The EA is likely to always be an Active stakeholder due to the direct relationship between GI, flood strategies and water quality. This will depend on the scale, however.
	Highways England	Either	
	Natural England	Either	
	Network Rail	Either	
	NHS	Passive	
	Police and crime commissioner	Either	
	Public Health England (PHE)	Either	
	Regional police force	Passive	
	Transport executive	Either	

Stakeholders identified in section 6.2 (grouped by role)		Active/ Passive	Commentary
Private concerns	Businesses	Either	Individuals, residents, businesses and site users will all be in some way impacted by a green infrastructure system, but unless that is a direct and tangible impact, they are unlikely to be active stakeholders. Landowners are likely to be active stakeholders as they have decision making power for a GI system reliant on their land.
	Employers	Either	
	Individuals	Passive	
	Landowners	Active	
	Residents	Either	
	Tourism businesses	Either	
	Tourists	Passive	
Special interest group	Business Improvement Districts	Active	Other groups and organisations beyond community/voluntary level will be actively or passively involved depending on what their focus and remit is, and the extent to which this interacts with a particular green infrastructure project's context.
	Clinical Commissions Groups (NHS)	Either	
	Delivery or strategy organisations with a specific remit.	Active	
	Industry bodies	Either	
	Lead Local Flood Authority	Active	
	National or local charities with specific expertise	Active	
	Sports clubs	Either	

Stakeholders identified in section 6.2 (grouped by role)		Active/ Passive	Commentary
	Walking / Cycling / Angling groups etc	Either	
Utilities/ public service	Energy suppliers	Either	Utilities and public services may be directly or indirectly impacted. Where they are directly affected, they are likely to be active stakeholders. However, those with an operational rather than strategic focus may still remain passive stakeholders (for example, transport operators).
	Power	Either	
	Transport operators	Passive	
	Water companies	Active	