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Engineering nature-based solutions: examining the barriers to effective intervention

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A growing body of research is examining how nature-based solutions (NBS) are offering planners, politicians and engineers options to promote responses to a wide range of biophysical and socio-economic problems. However, despite the increasing popularity of NBS, there is limited analysis available on how these 'solutions' align with urban problems, at what scale they are most effective and what costs are associated with investment in urban nature. This paper analyses current approaches to urban sustainability through an examination of the EU Horizon 2020-funded project Urban GreenUP, in Liverpool (UK), to deconstruct how rhetoric translates to practical applications of NBS interventions. It interrogates the interactions of projects, policies and political buy-in for NBS and argues that an integrated understanding of scale, function and location is needed to successfully address issues of urban climate change vulnerability. This is contextualised against the wider discussions of NBS associated with other EU-funded projects. It concludes that although investment in NBS offers a useful approach to development, they cannot overcome existing barriers to investment in environmental improvements without attention to the same barriers that have always existed. Moreover, the paper argues that the promotion of NBS as solutions to problems is effective only when the problems are transparently and collaboratively defined.

Keywords: Europe/nature/nature-based solutions/partnership/planning/urban

1. Introduction

Nature-based solutions (NBS) are positioned as an innovative and adaptable approach to 're-naturing' urban and environmental planning. Defined as 'living solutions underpinned by natural processes and structures that are designed to address various environmental challenges while simultaneously providing economic, social and environmental benefits' (Frantzeskaki *et al*., 2017: p. 67), the NBS concept has gained popularity since it was first used in the early 2000s, and subsequently by way of its use by the International Union for Conservation of Nature (IUCN) from the early 2010s onwards (Nesshöver *et al*., 2016). In this period, NBS were championed by the EU, through its Horizon 2020 (HO2020) programme, which tested the efficacy of NBS interventions. The debates supporting NBS have recently been synthesised by Kabisch *et al*. (2022), providing a more robust grounding for the concept to examine alignments between nature and people in urban planning.

Support for NBS has centred on the need to increase the quality, quantity and functionality of green space (in terms of the variety of elements in some circumstances named green or blue infrastructure) in urban areas, which helps address problems associated with density and the conversion of green space into built infrastructure. Embedded within this discussion is a dilemma for academics and practitioners who may be wedded to specific terms when examining ecological issues. Within the academic literature, there are differing schools of thought regarding the terminology used, including green infrastructure (GI), ecosystem services and NBS, which potentially undermines a societal understanding of the value of investing in street trees, parks, waterways and urban 'green space', exacerbated by the use of technical language in design, implementation and management debates (cf. Escobedo *et al*., 2019).

The following uses a conception of NBS that acknowledges the principles of GI within this broader discourse to support investment in a range of nature-based options. This is comparable with the typologies presented by Castellar *et al*. (2021) and Cohen-Shacham *et al*. (2016), who examined the role of new and retrofitted NBS in supporting more sustainable forms of urban planning, including reference to investment/enhancement in water, habitat/biodiversity creation, trees and more formal green spaces – that is, parks. The authors also recognise that in some contexts, NBS are still largely discussed as parks even though they encompass a wider range of ecologically focused interventions. Examples of this disparity include Whitten's reflections on the dominance of 'parks' as GI/NBS thinking in landscape professional perceptions in London and the

exploration of NBS by Almassy *et al*. (2018: p. 6) in 100 European cities, noting that in approximately 50% of cases, NBS are presented as parks or urban forests, 40% as traditional grey infrastructure and 30% as water/blue infrastructure.

Despite ongoing variation in terminology and application, NBS have mobilised innovative urban experimentations as an approach to greening that offers urban planners, developers and city governments a suite of options to address complex socio-economic and ecological problems (Cohen-Shacham *et al*., 2016). The provision of natural 'solutions' is predicated, though, on practitioners deciding which urban issues to target and orchestrating the most effective way to solve these problems. Moreover, there is a need to frame contemporary urban issues as multifaceted – that is, they are not solely economic or environmental in nature, and true solutions are rare. NBS interventions are therefore being framed as an approach targeting the nexus of interconnected political, social, environmental and economic factors that address unsustainable urbanism practices (Faivre *et al*., 2017). Consequently, the EU has positioned NBS as a set of tools and management approaches to aid cities as they attempt to break down siloed planning, delivery and management by finding synergies between

- biophysical environment issues – for example, climate change, biodiversity loss, flooding and air quality
- socio-economic variables – for example, green space use, crime, property price uplift and health and well-being
- political/local planning authority processes – for example, policies, projects and plans.

Alongside its multifaceted examination of interconnected urban challenges, the NBS concept has garnered interest due to its cost-effectiveness when compared with 'man-made' infrastructure (IIED, 2018). Interventions such as rain gardens, for example, are perceived as offering urban dwellers, businesses and urban infrastructure more effective protection from climate change in comparison with engineered approaches such as storm drains due to the ease of implementation, reduced costs of maintenance and increased ecological functionality. They also challenge existing dependencies on built infrastructure to control urban environments and shift government thinking towards a more holistic and ecological-system-based analysis of urban functionality (Markolf *et al*., 2018; McPhearson *et al*., 2016). It is largely because of these benefits that NBS have been endorsed by organisations including the World Bank and the European Commission (EC), who promote the concept as being capable of integrating an ecological framing within traditional planning practice (Lafortezza *et al*., 2018).

Although the literature assessing these issues is developing, there remains a limited examination in practice evaluating whether these solutions address urban problems, at what scale they are most effectively deployed and what the true costs of investing in urban nature are. The outcomes of the HO2020-funded Naturvation project go some way to address these gaps through their examination of the socio-economic and health benefits of NBS, as well as through assessments of alternative provisions of NBS across 100 European cities (Almassy *et al*., 2018; Cooper *et al*., 2018). These discussions highlight the variability of approaches being taken to support NBS conceptually and practically. Furthermore, their analysis has been used to inform more contemporary discussions of the feasibility of investing in NBS and their meanings to different stakeholders in both local and international debates (Kabisch *et al*., 2022). However, there remains reluctance within some sections of the built environment profession to transition from traditional engineered solutions to approaches based on ecological knowledge (Kabisch *et al*., 2016; Markolf *et al*., 2018).

To examine the influence of these issues in practice, this paper analyses evidence generated from the Liverpool component of the 5-year HO2020-funded Urban GreenUP (2017–2022). Urban GreenUP is a consortium of 25 EU and international partners drawn from local governments, the environment sector, small to medium-sized enterprises and academic institutions located in Australia, China, Colombia, Germany, Italy Spain, Turkey, the UK and Vietnam. As a frontrunner city, alongside Izmir (Turkey) and Valladolid (Spain), Liverpool has been at the forefront of the design and delivery of NBS. To assess the effectiveness of the project, this paper examines the structural (i.e. project team and governance) and localised implementation factors (i.e. what projects were delivered and where). This includes reflections on whether the approach taken was effective in addressing the variation in understanding climate change, socio-economic inequality, access to NBS, health and well-being benefits and public and political knowledge embedded within discussions of the viability of investing in NBS. To achieve this, the paper examines the interaction of project partners in Liverpool with local delivery through an embedded research approach to consider the effectiveness of NBS practice in Liverpool.

After introducing the HO2020 NBS programme, the authors outline the data collection and analysis process, which draws on an analysis of internal project developments and debates by the authors using an embedded research process of interaction with the project. The paper also discusses the complexity of NBS delivery undertaken in Liverpool, before moving on to analyse barriers to effective investment. It concludes with a series of recommendations for stakeholders considering investment in NBS. This paper should be viewed as a reflective analysis of the discussions associated with delivering NBS in 'real-world' scenarios and thus contributes case study evidence for academics and practitioners working within the natural and built environment.

2. HO2020 NBS research and innovation programme

In 2014, the EC launched an expert group exploring how NBS could be mobilised to bring nature back into European cities. Building on the recommendations that emerged, a survey was conducted in 2015

exploring citizens' views and perceptions of 'nature in cities' providing insights for future developments (Faivre *et al*., 2017). Evolving out of this process, the EU began funding NBS projects within their urban re-naturing plans through the HO2020 programme (Faivre *et al*., 2017). The funded demonstration projects, Urban GreenUP, Connecting Nature and Grow Green, were considered to be a continuation of the research undertaken for the Seventh Framework Programme Regional Funding programme that promoted scalar appreciation of ecological systems within urban planning. Each HO2020 project emphasised the role and knowledge of local partners to direct their planning for NBS in line with previous EU-funded work (Raymond *et al*., 2017). In practice, the EU aimed to test the effectiveness of NBS to deliver multiple socio-economic and ecological benefits in urban areas. Within each of the three projects named earlier, cities such as Liverpool were designated as 'frontrunner' locations acting as demonstration sites where partnerships of diverse urban advocates could trial innovatively designed NBS interventions and/or approaches to implementation. Lessons from this experimentation are to be used to guide 'follower cities', a second tier of smaller cities who would subsequently apply the learning from frontrunner locations to shape their design of NBS. The Naturvation project was also supported through the same funding stream but was structured around the development of a conceptual foundation of NBS that could subsequently be tested in practice. The evidence developed will also enable EU officials, as well as planning authorities, policymakers and political decision makers, environmental and development specialists and communities, to consider how best to apply this knowledge in their specific geographic, political and environmental contexts (Cohen-Shacham *et al*., 2016; Frantzeskaki *et al*., 2020).

3. Barriers to successful NBS provision

The successful implementation of NBS interventions is dependent on several governance, financial, programming and delivery factors. Each is well researched in the academic and practitioner literature – for example, O'Sullivan *et al*. (2020), Trinomics and IUCN, (2019), Raymond *et al*. (2017), Cohen-Shacham *et al*. (2016) and Nesshöver *et al*. (2016) who all examined the complexity of aligning institutional, political and delivery mandates in different locations. However, although best practice evidence exists (cf. Almassy *et al*., 2018), there is a need to reflect on whether this research can be translated effectively into implementation programmes. This is critical in terms of addressing tensions between the provision of evidence to local stakeholders supporting individual or a portfolio of NBS interventions, as well as their realistic ability to resolve specific urban problems. This requires an examination of the following points synthesised from the contemporary literature on NBS (EC DG RTD, 2021; Frantzeskaki, 2019; Kabisch *et al*., 2022; Trinomics and IUCN, 2019), to locate opportunities for, as well as barriers to, investment in NBS:

- support of innovation and its translations into practice
- reflection of the scalar aspects of NBS functionality and its benefits to a diverse range of stakeholders
- an appreciation of the complexities of interdisciplinary working and its limitations on implementation
- engagement with stakeholder aspirations and locating these within local needs assessments
- understanding of the pathways to effective knowledge exchange/transfer
- financial variability, timescales and political support.

Understanding the interplay between these factors is critical to embedding knowledge into delivery, as each influences the ability of practitioners to work effectively. Moreover, within the governance literature, the formation of supportive delivery frameworks, where all members of a project are aware of their roles and responsibilities within local power structures – that is, to understand who has the authority to shape policy/practice and to what extent this shapes delivery – is key (Carlisle and Gruby, 2019). Thus, by reflecting on the malleability of funding, political support and public engagement, it is possible for a project team to manage effectively expectations, project deliverables and the relationships between public–private community stakeholders (EPA, 2015; Lueckenhoff and Brown, 2015).

Achieving this goal is complicated by local political, socio-economic and ecological contexts, which must be taken into consideration during project planning. Moreover, the NBS literature raises concerns over the delivery focus of investment – that is, what kind of urban nature should be implemented and how the multiple benefits associated with NBS can be presented by and to partners. For example, Sekulova and Anguelovski (2017) also illustrated the risks of overselling the capacity of NBS interventions to 'solve' sustainability issues. It is imperative that stakeholders therefore possess an accurate understanding of the added value that NBS can deliver and how issues of scale, innovation and access to land can impact on intervention. Caution is also needed to curate the agendas of partners in projects governed through multi-partner arrangements (O'Sullivan *et al*., 2020).

4. Methodology

The paper takes a reflective approach to understanding the complexity of delivering NBS. Unlike other papers, the discussions presented are populated by peer-to-peer experience of the authors with the development, delivery and evaluation of NBS within the case study context (Wamsler *et al*., 2020). Although not considered as an ethnographic approach, the analysis undertaken analyses the expertise of planning, delivery and evaluation of NBS (and GI and environmental governance more broadly) of the research team, and the authors, within the development of the Urban GreenUP project. The authors thus situate the following analysis within an embedded research process that acknowledges authors as '… part of a team that generates and uses research results … [and that embedded research is] … an example of a joined-up approach to knowledge production and use, which takes account of context and stakeholder interests' (Cheetham *et al*., 2018: p. i64). Embedded

research has been used in health and educational research to facilitate nuanced analysis of working practices that may be withheld in other formal evaluation practices (Vindrola-Padros *et al*., 2017). Moreover, the use of an embedded research approach facilitates additional access to decision making and provides evidence of institutional thinking, conflict and resolutions normally absent from evaluative research.

The use of an embedded research technique is a purposeful methodological choice, as it allows the nuances of interdisciplinary public and environmental sector working to be examined (Chang *et al*., 2013). The data collected take the form of in situ observations of project delivery, providing insights of the effectiveness of institutional partnerships in generating design and implementation frameworks for the delivery of Urban GreenUP (Frantzeskaki, 2019). As the paper reflects on a specific project delivered over an extended period (2017–2022), it affords opportunities to examine project management and intra- and inter-partner collaboration. This approach was used to highlight decision making and knowledge exchange between partners that are unavailable in more traditional research methodologies – that is, in stakeholder interviews (Kabisch *et al*., 2016; Kooijman *et al*., 2021).

The authors are acutely aware of the ethical implications associated with such access and acknowledge the potential biases that this may integrate into the following analysis (McGinty and Salokangas, 2014). However, the authors propose that this reflective approach to discussion from 'within' offers important real-world insights that other built and natural environment specialists can learn from (Fook, 2011). To situate the analysis, the authors draw on extensive experience working for – and with – partners in local government, academia, the environment sector and local communities in the UK, and internationally, over an extended time period.

The analysis generated by the embedded research process is supported by a presentation of the initial outcomes of the surveys undertaken with business and residential communities in Liverpool focusing on awareness, perceptions and use of NBS in the Urban GreenUP project. The project received 228 responses in total (128 for the Otterspool/Jericho Lane area and 120 for the Sefton Park area). The survey work undertaken provides a detailed analysis of local perceptions, which offer useful insights to support this discussion but are not relevant to all of the following sections (an overview of the survey responses can be seen in Tables 2 and 3).

5. Case study: Urban GreenUP in Liverpool

Liverpool is a city of approximately 400 000 residents in the north-west of England located east of the River Mersey (Sykes *et al*., 2013). The city has a strong maritime and mercantile heritage and has been subject to post-industrial decline, the negative implications of which include physical change to environmental, housing, commercial and transport infrastructure (Mell, 2020). It also has a visible network of green spaces, predominately focused on its parks; however, the quality, quantity and functionality of the city's ecological resource base is geographically variable (LCC, 2016). The Liverpool component of the Urban GreenUP project brought together stakeholders from local government (Liverpool City Council), the environment sector (The Mersey Forest) and academia (University of Liverpool and University of Manchester) to examine the need for, design of and implementation of NBS within the city. The location of each investment area is shown in Figure 1. The three main areas of investment were the city centre (a largely commercial district), the Baltic Triangle (an area of mixed residential, commercial and light industrial use) and Sefton Park/Jericho Lane (a largely residential area of south Liverpool). All three locations are considered 'strategic opportunity areas' within Liverpool City Council and are core elements of the city's socio-economic and ecological investment plans (Figure 2). The selection of each location was related to previous analysis undertaken for the Liverpool Green Infrastructure Strategy (Mersey Forest, 2010) and the Liverpool Green and Open Space Review (LCC, 2016), which identified each as an area of significant opportunity to invest in ecologically focused interventions. The development of a portfolio of NBS interventions was supported by the

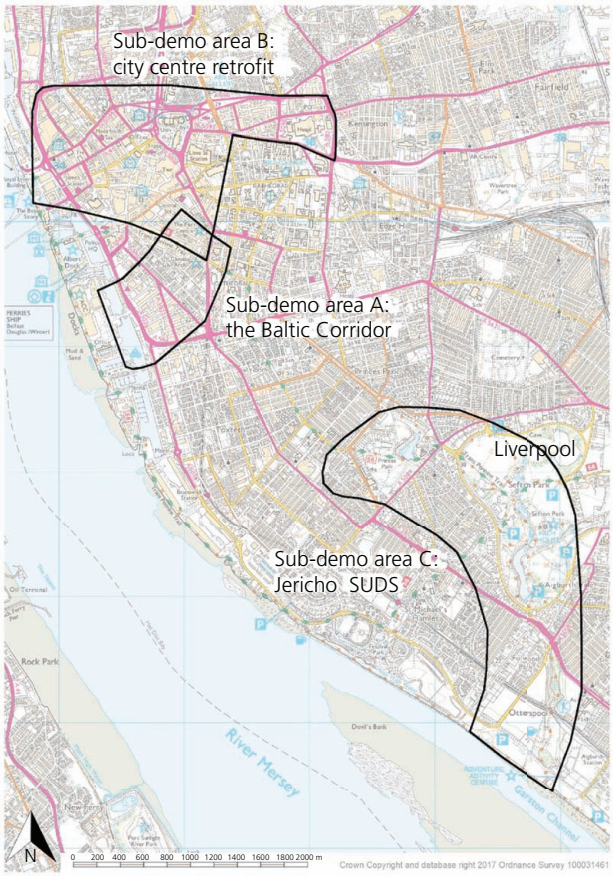

Figure 1. Location of NBS interventions in Liverpool associated with the Urban GreenUP project. SUDS, sustainable drainage. ©Crown copyright 2022 Ordnance Survey. Media 100025252

Figure 2. Urban GreenUP NBS interventions in Liverpool: (a) St John's Centre living wall; (b) lamppost pollinator, Baltic Triangle; (c) Parr Street living wall

establishment of a set of key performance indicators (KPIs) by the Urban GreenUP consortium (see Table 1). The project team worked extensively with public, private and community stakeholders in Liverpool to find solutions to issues of site access/ownership, current landscape functionality and the needs of each location for NBS (Table 2).

6. Analysis: project mechanics, implementation and evaluation

To appreciate the complexity of delivering a programme of NBS interventions, the following presents a series of issues observed in practice requiring attention from stakeholders. Each is grounded in the embedded research process and utilises in situ observations of project team discussions and discussions made within the Urban GreenUP project. Where appropriate, it also draws on the outcomes of the postal survey to support and/or substantiate the evidence.

6.1 KPIs and rationale for decision making

Three strategic areas – the city centre, the Baltic Triangle and the Sefton Park/Jericho Lane Corridor – were identified as investment locations and were supported by 42 KPIs evaluating the benefits of climatic, biophysical and socio-economic interventions in NBS (Table 1). The establishment of baseline KPIs was problematic due to variation in climatic context and urban form between the project's three frontrunner cities. For example, experiences of heat stress days – that is, daytime temperature of over 35 and 20°C overnight for three consecutive days – are common in Valladolid and Izmir but rare in Liverpool. Consequently, a process of internal negotiation was required to ensure (*a*) continuity between cities to produce comparable data for evaluation and (*b*) that a level of flexibility was retained allowing city partners to set KPIs relevant to their local context. Throughout the delivery of Urban GreenUP, KPIs were periodically evaluated by the Liverpool project team to ensure that they could generate data for evaluation.

6.2 Intervention location

The decision-making process used to locate interventions illustrates how urban greening projects must navigate interconnected socio-economic and environmental complexity. The broader aim of the project was to render urban areas more climate resilient while stimulating socio-economic benefits. Delivering on this argument would locate NBS interventions in north Liverpool, an area with greater socio-economic deprivation, possessing fewer green spaces of high quality and being more prone to high levels of pollution and surface water flooding compared with the south of the city. Combined, these factors suggest that communities in northern Liverpool are more vulnerable to environmental hazards. However, for a variety of practical, strategic and political factors (Clement, 2021), interventions were located in central/south Liverpool. While the city centre lacks green space, it is not subject to the same socio-economic and ecological issues as seen in north Liverpool, and south Liverpool is characterised by high-quality, extensive green space. Thus, a more strategic decision was taken within the Urban GreenUP project team to use urban greening as a tool to stimulate economic growth in a city centre. This emphasis on the city centre raises questions regarding the extent to which Urban GreenUP can effectively (and strategically) address the social and environmental,

Table 1. Urban GreenUP core KPIs

Challenge	KPI name
Climate mitigation and adaptation	Carbon dioxide stored
Climate mitigation and adaptation	Carbon dioxide sequestration
Climate mitigation and adaptation	Temperature decrease
Climate mitigation and adaptation	Temperature reduction (projection)
Climate mitigation and adaptation	Heatwave risk
Climate mitigation and adaptation	Species movement
Water management	Run-off coefficient
Water management	Water slowed down from the sewer system
Water management	Nutrient abatement (COD)
Water management	Nutrient abatement (BOD)
Water management	Nutrient abatement (SST)
Water management	Water removed from water treatment
Water management	Savings in treatment of storm water
Green space management	Green space accessibility
Green space management	GI connectivity
Green space management	Pollinator species increase
Green space management	Floral resource increase
Green space management	Plant species increase
Green space management	Insectivore increase
Air quality	Deaths related to pollution and contamination
Air quality	Annual mean levels of fine $PM_{2.5}$ particulates
Air quality	Annual mean levels of fine PM_{10} particulates
Air quality	Nitrogen oxide (NO_x) trends
Air quality	Sulfur oxide (SO_x) trends
Air quality	VOC trends
Air quality	Run-off mitigation
Air quality	Energy savings
Air quality	Increase in property value
Air quality	GI VAL to calculate the value of air quality improvements
Air quality	Value of air pollution reduction
Air quality	Total monetary value of urban forests, including air quality
Socio-cultural indicators	Benefits from interventions
Participatory planning and governance	Social learning
Participatory planning and governance	Citizen perception
Participatory planning and governance	Engagement with NBS
Social justice and social cohesion	Crime reduction
Public health and well-being	Walking area increase
Public health and well-being	Cycling area increase
Public health and well-being	Health quality perception
Potential of economic opportunities and green jobs	Job creation
Potential of economic opportunities and green jobs	Land and property price change
Potential of economic opportunities and green jobs	New businesses

BOD, biochemical oxygen demand; COD, chemical oxygen demand; SST, sea surface temperature; VOC, volatile organic compound

rather than economic, vulnerability in the city. A key question was raised by several stakeholders: if Urban GreenUP was mobilised to mitigate the limited access to quality green space, why did it focus interventions within areas of pre-existing and high-quality examples of accessible green space? One response is that as the most visible partner, the city council carries the burden of risk if interventions fail to deliver solutions. A fear of failure on this count created a climate of risk aversion in the project, which directed efforts towards interventions that were more likely to achieve 'success' across multiple metrics.

6.3 Stakeholder co-operation

The breadth of partners involved in Urban GreenUP led to tensions between the project team in Liverpool, the main project coordinators and the overarching project deliverables. Most noticeably the agreement on core KPIs proved difficult due to the differences between climatic, political thinking, professional expertise and land ownership arrangements in each project city. Consequently, negotiations were required at the local level to establish the parameters for KPI monitoring and adherence to EU guidance – that is, the use of the Eklipse framework (Raymond *et al*., 2017) – the outcome of which has been a level of uncertainty between partners regarding the implementation, delivery and evaluation of NBS, particularly for those areas that do not respect variation in local conditions – for example, temperature or environmental laws. Moreover, the delivery of NBS projects required mediation with public and private landowners – for example, for deculverting work in Otterspool – utility and

Table 2. Overarching themes/issues of Sefton Park and Otterspool/Jericho Lane postal survey

	Sefton Park survey	Otterspool/Jericho Lane survey
Negative comments on GI/GS/NBS interventions	■ The NBS interventions are too small. ■ There has been no sufficient communication or engagement with communities. ■ There are problems with the scaling up and visibility and projects. ■ The NBS interventions do not necessarily address overarching issues of quality–quantity–access/traffic or amenity value of spaces in Liverpool. ■ The project is worsening the process of commercialisation of NBS/GS, NBS/GI is being used as branding to sell Liverpool (rather than to meet local needs). ■ There are ongoing conflicts between users. ■ The interventions do not address the disparity in distribution, scale and quality of Liverpool's green space provision.	■ Mixed distribution of NBS/GI and disparity in some areas in terms of size/quality and maintenance issues of NBS – perception of these spaces is poor ■ Awareness of conflict between users ■ Accessibility and design quality is variable ■ Ongoing issues of traffic and lack of access to some sites due to variability in user mobility ■ Preferences for specific landscapes and need for quality places that are safe and do not have litter or dog fouling
Positive comments on GI/NBS/GS interventions	■ The interventions improve the diversity of the city and soften hard landscapes. ■ Investments in more 'nature' and more NBS are good. ■ The innovation embedded within the project provides options to the city and other partners to do new things and not just the same as before. ■ The project promotes positive green/environmental messages. ■ Interventions are helping support physical and mental health improvements. ■ The project has positively improved the images of the city. ■ The interventions have created new habitats. ■ The project helped change mentality about the environment and promote greater engagement with it from businesses. ■ Interventions have promoted engagement with NBS for a wider range of people.	■ NBS viewed as being aesthetically pleasing and promote sense of place. ■ Links to property uplift. ■ NBS help raise awareness of environmental issues and climate change. ■ Sites can be used to support mental health and 'happiness'. ■ Calls to encourage additional/similar NBS projects in other parts of the city ■ NBS can be used to soften hard settings (greening the grey). ■ NBS help promote use and can be an attraction for visitors. ■ NBS support biodiversity and help create new habitats.
Positive comments regarding Urban GreenUP	■ The interventions have increased the level of biodiversity and proportion of nature in urban Liverpool. ■ The project has raised the visibility and awareness of environmental issues. ■ The interventions are positively greening the city (and specific areas of it). ■ The project has promoted greater engagement with NBS through increased visits and interactions with nature. ■ The project has increased the aesthetic quality of the city. ■ There is 'playfulness' in some of the NBS interventions. ■ The project highlights that 'little steps' can lead to bigger ones in terms of environmental improvements and that the project is a step in the right direction.	■ The project supports innovation and facilitates the ability of the city (and other stakeholders) to copy/do the same again. ■ The project helps offset carbon dioxide. ■ The project helps the city (and individuals/communities) raise their awareness of environmental issues and promote discussion of ecological quality/functions. ■ The city can use Urban GreenUP as a springboard to do other projects all over the city.
Negative comments regarding Urban GreenUP	■ The project interventions are too small and not distributed effectively. ■ The project does not address the existing spatial equity in provision. ■ The interventions are too small and do not do enough to make a meaningful contribution to managing the city's environment ■ Questions were raised about the wider contribution of NBS to the city, its residents, its environment and the economy.	■ The interventions are too small. ■ The project has not been communicated effectively to local people/communities. ■ Questions over the location of NBS interventions and impact on local homes/businesses ■ NBS interventions were considered to be of poor aesthetic quality –residents questioned whether the NBS work and make a positive difference. ■ Greater consideration of awareness raising and outreach is needed. ■ The project, and its NBS interventions, does not help address antisocial behaviour/poor user behaviour – that is, litter or dog fouling.

GS, green space

highways engineers – to plant street trees, implement sustainable drainage and other green interventions in built-up areas – that is, a major road located between the city centre and dockland areas – and local communities – for example, to generate support for the floating ecological islands by the project team to generate support for the investment programme.

One area where Urban GreenUP was critiqued by local public/business stakeholders in the survey results was due to a lack of community engagement with the NBS design process. As a consequence of the lack of public consultation, awareness of Urban GreenUP interventions was low, even for those living/working in areas where interventions were implemented (see Table 3). This sense of being 'experimented' on was reported in survey responses by local stakeholders as feeding an overarching view that the project was imposing its will on them, rendering local communities as passive bystanders (see Table 2). This curtailment of public participation, and the power imbalance it creates, is a common criticism of urban greening projects, as the technical specifications, locations and funding for implementation are often finalised as part of the bidding process (for further details, see the paper by O'Sullivan *et al*. (2020)). The roll-out of NBS without public engagement therefore threatens to create distrust between local communities and the city and as a result exacerbate low levels of community buy-in. It is therefore considered important to embed community engagement within the development process of NBS intervention design.

6.4 Establishment of data collection protocols

Establishing a protocol for data collection required an in-depth examination of project KPIs, project expertise and alignment with intervention objectives. Core KPIs were mapped onto investment opportunities to collect a range of ecological and socio-economic data. The data collection protocol was split into two sections (see Table 1), ecological and biophysical and socio-economic, to ensure that the potential added value provided by NBS could be assessed. Within this process, tensions were visible due to variation in the skills needed to collect data effectively to meet response to each KPI, which the project team did not always possess. As such, the recruitment of additional expertise was needed to monitor the breadth of indicators being investigated by Urban GreenUP. Besides, as a project based on innovation, there were discussions of what kind of data would be valuable in meetings its objectives. A process of negotiation was undertaken to ensure that technological data collection techniques – such as traffic/walking sensors – could be used alongside biophysical/ecological surveying practices – such as water flow sampling and bat monitoring. Due to the breadth of KPIs being investigated, the project devised a multifaceted data collection strategy that was delivered over an extended 24-month period. This enabled the project to collect data on seasonal biophysical changes – for example, reduction in aquatic pollutants, air particulates and insect pollinator numbers.

6.5 Barriers to effective data collection

A series of barriers were identified to effective data collection and addressed throughout the project. A significant issue was the restrictions placed on access, travel and interaction with people due to coronavirus disease 2019 (Covid-19) lockdown requirements. Throughout 2019–2021, the socio-economic surveying techniques used were redesigned to enable data collection through non-interactive methods – that is, online surveys, drop-and-collect surveys and telephone interviews – rather than face to face (see Tables 1 and 3 for indicative results). Moreover, access to specific locations to support biophysical sampling was reduced due to social distancing requirements. Subsequently, and where feasible, alternative methods of data collection were developed and deployed, highlighting the need for flexibility within a project team (and its experience in physical and social science methodologies) to ensure that high-quality data could be collected for examination. These barriers included access to specific locations to undertake biophysical sampling, developing and testing sensors, data collection platforms, the effective development of survey materials and the administration of public surveys with a range of residential and business communities. There were also challenges associated with monitoring a wide range of KPIs that were seeking to create uniform standards for NBS intervention. The Covid-enforced extended period of data collection was beneficial, as it facilitated ex ante and ex post surveys of NBS interventions focusing on the socio-economic benefits that they delivered – for example, crime reduction and property uplift. Collecting meaningful data across the project KPIs and ensuring that suitable conditions for uniform data collection were developed was challenging and meant that the timescales of data collection were often difficult to align.

6.6 Reacting to stakeholder needs

Throughout the Urban GreenUP project, consultations with business and residential communities were of paramount importance to gauge the added value that NBS interventions create. However, this process has been fraught with complexity due to the variation in communicating the benefits of NBS to myriad communities, each possessing different expectations of urban nature. Specifically, it was difficult to engage business communities effectively despite being supported by prominent stakeholders – for example, local business associations. In comparison, interaction with residents was more effective due to their being more accustomed to local government surveying. Where communities were engaged, data were collected and analysed illustrating the variety of opinions related to NBS and broader greening efforts, as well as their perceptions of pre-existing green spaces. Evidence from residential communities notes that NBS are not a panacea and that these must be integrated alongside other interventions and improvements – namely, better public/private transport links and parking access (see Tables 2 and 3). Those developing NBS should therefore reflect on the existing quality of NBS, as well as their interaction within the context of the area when communicating with businesses. Working with businesses to explore how NBS can provide support for staff – for example, mental/physical health benefits – was also deemed critical. A key lesson is that reliance on technical NBS specifications is not sufficient, and it is proposed that a multisectoral approach is taken to identify appropriate mechanisms for dissemination or the co-design of knowledge and investments.

Table 3. Participant ratings of NBS pre- and post-intervention of Urban GreenUP interventions

	Sefton Park (pre-NBS intervention)	Sefton Park (post-NBS intervention)	Overall change in positive perception	Otterspool (pre-NBS intervention)	Otterspool (post-NBS intervention)	Overall change in positive perception
How would you rate your neighbourhood G/BS in terms of quantity?	93.7% good/very good	92.1% good/very good	Decreased	100% good/very good	97.6% good/very good	Decreased
How would you rate your neighbourhood G/BS in terms of quality?	84.7% good/very good	82.5% good/very good	Decreased	90.5% good/very good/2.4% poor	89.3% good/very good/2.4% poor	Decreased
In your neighbourhood, how would you rate the green/blue areas in terms of accessibility?	90.7% good/very good	89.6% good/very good	Decreased	85.7% very good/good/2.4% poor	92.8% good/very good/1.2% very poor	Improved
Thinking about the city of Liverpool as a whole, how would you rate its green/blue areas in terms of quantity?	69.9% good/very good (+12.5% poor/very poor)	64.7% good/very good (+13% poor/very poor)	Decreased	76.2% good very/good	65.9% very good/good	Decreased
Thinking about the city of Liverpool as a whole, how would you rate its green/blue areas in terms of quality?	65.6% good/very good (+9.4% poor)	65.6% good/very good (+10.3% poor/very poor)	Decreased	54.7% very good/good (+11.9% poor)	75.3% very good/good (+5.9% poor)	Improved
Thinking about the city of Liverpool as a whole, how would you rate its green/blue areas in terms of accessibility?	61.3% good/very good/3.2% poor	59.2% good/very good/7.4% poor	Decreased	65.9% very good/good (+4.9% poor)	70% very good/good (+3.8% very poor/poor)	Improved
Before receiving this questionnaire, how aware were you of the Urban GreenUP project?		74.4% not aware			65.1% not aware	Moderate improvement in awareness of NBS interventions
Have you seen the green wall at St John's Shopping Centre?		65.1% no			82.4% no	Decreased awareness of intervention
Were you aware that it was an Urban GreenUP intervention?		84.9% no			96.3% no	Decreased awareness of intervention
Have you seen the green wall on Parr Street?		81% no			90.4% no	Decreased awareness of intervention
Were you aware that it was an Urban GreenUP intervention?		91.8% no			97.6% no	Decreased awareness of intervention
Have you seen the floating island in Wapping Dock?		79.1% no			91.8% no	Decreased awareness of intervention
Were you aware that it was an Urban GreenUP intervention?		81.9% no			97.6% no	Decreased awareness of intervention
Have you seen the floating island in Sefton Park?		69.8% yes			56.5% yes	Decreased awareness of intervention but overall positive awareness of it
Were you aware that it was an Urban GreenUP intervention?		74.4% no			81.5% no	Decreased awareness of intervention
Have you seen the bio-retention pond in Otterspool?		53.5% yes			71.8% yes	Increased awareness of intervention
Were you aware that it was an Urban GreenUP intervention?		90.7% no			89.3% no	Decreased awareness of intervention
Overall, what impact do you think Urban GreenUP has had on the natural environment of Liverpool?		68.2% significant positive impact			74.7% significant positive impact	Increased positive awareness of intervention

G/BS, green/blue space

6.7 Public response to interventions

Public responses to interventions were variable due to the diversity of locations, types and approaches to investment in NBS undertaken. Although the portfolio of options embedded within the Urban GreenUP delivery plan enabled the project team to target perceived NBS needs – that is, flood mitigation – it was difficult to align large-scale acknowledgements of the added value that they provide to society. Commentaries received from the Urban GreenUP public surveys highlighted a growing awareness and appreciation of NBS, but these are not necessarily directly related to project interventions (Table 2). While the most visible investments – for example, green walls and floating ecological islands – generated significant feedback, there has been a more limited reaction to investments that are less visibly 'green' or 'nature based' (e.g. street lights with pollinators). Reactions to investment thus appear to be linked, at least in part, to visibility as well the location, with less commentary focusing on the added ecological value that NBS provide for urban landscapes. Such preconceptions need to be considered if urban greening projects are to stimulate community buy-in towards NBS interventions and encourage a sense of environmental stewardship.

7. Conclusion

The development and delivery of the Urban GreenUP programme of NBS interventions in Liverpool offers insights into the complexities of multi-partner- and multi-outcome-orientated project work. While it could be argued that the Liverpool project team have navigated a range of political, financial and logistical issues associated with the programme of NBS interventions (including the impacts of Covid-19 on fieldwork), questions remain as to whether they have effectively balanced the objectives of the wider project with the climatic, socio-economic and community needs of the city.

Firstly, it appears that the focusing of interventions in strategic investment zones has downplayed the need for development in areas where vulnerability to climate change hazards or health inequality is greatest. Moreover, residents noted that the size and location of interventions have not led to a significant increase in awareness or engagement with NBS in the three trial areas. This is, in part, due to Urban GreenUP investing in locations that could be considered to have a higher proportion of existing green space/NBS, as well as being politically significant as strategic investment areas. In practice, this has potentially downplayed the NBS gaps identified in the city's own examination of need (cf. GINW and Mersey Forest, 2010; LCC, 2016). While the logic underpinning project decisions was pragmatic, the legacy of these decisions may be the deepening of the north/south green space divide and an entrenching of distrust towards the city council in some areas (see commentary in Tables 2 and 3; see also the paper by Mell (2020)). The mismatch between project objectives and community needs appears to have been exacerbated by a lack of community consultation, which ultimately may have weakened the benefits/outcomes of the project.

These two points illustrate that NBS are not the sole solution to failures in complex urban systems. They are, however, an important component of a wider discussion regarding the alignment of natural and built environment development/management in urban contexts. They also illustrate a need to consider location, NBS type, functionality and what benefits are to be delivered to a diverse range of stakeholders. The discussions presented by Almassy *et al*. (2018), Frantzeskaki (2019) and Kabisch *et al*. (2022) support this view, noting that the broader exploration of NBS interventions has called for more effective collaboration between stakeholders to deliver sustainable NBS. Therefore, engagement with communities and expert stakeholders is critical to ensure the inclusion of local knowledge, aspirations and needs in locating new or retrofitted investments in urban areas (Markolf *et al*., 2018; McPhearson *et al*., 2014).

Consequently, NBS should be considered alongside an understanding of existing barriers to effective urban management, as NBS may provide additional ecological pathways to more sustainable urbanism. Clarity with regard to what problems nature-based interventions are being used to target as solutions is also necessary to encourage the provision of appropriate NBS interventions in practice. The role of project (and city) stakeholders to support innovation is key here, as the knowledge embedded within expert and local communities should be used to shape policy and practice (Dushkova and Haase, 2020). This requires an ongoing dialogue between project, business and residential community partners. If a grounded set of problems can be identified and agreed on by all partners, then NBS can provide a suite of options for long-term enhancement.

Within such discussions, there is scope to understand the pathways to more effective knowledge exchange between partners. Urban Green UP has drawn on local government and environmental sector expertise to shape the location and design of interventions. This has been supported by academic knowledge of engagement and evaluative techniques to generate biophysical and socio-economic data for examination. The combination of public, environmental and academic expertise has facilitated a more directed approach to investment and monitoring than if one partner has been solely responsible for the project (Cohen-Shacham *et al*., 2019; Croeser *et al*., 2021). Best practice from Liverpool, and other EU-funded HO2020 NBS projects, represents an effective step towards this, but further evidence and piloting of NBS is needed to integrate urban nature fully in mainstream urban planning practice (Dumitru *et al*., 2020).

Moving forward, NBS offer scope for local government to engage with a more nuanced appreciation of the added-value investment in urban nature can provide. An ongoing examination of the complexities of interdisciplinary working and its limitations on implementation is crucial in this process. Moreover, an explicit appreciation of the variation in financial variability of alternative institutions and the fluctuating timescales associated with design, contract letting and implementation is needed, all of which are situated within an ongoing assessment of political support to ensure delivery (Nesshöver *et al*., 2016). Overall, politicians, planners, developers and communities need to be considerate of

the following factors drawn from the experiences identified in Liverpool when planning for NBS.

- An awareness of the various socio-economic and ecological roles that different types of NBS can deliver is key to selecting the most appropriate.
- Collaboration between central government funding bodies, local government as delivery agents and the built and environmental sectors helps produce a detailed contextual analysis of the natural and built environment to identify the 'problems' that NBS can address. Such an examination would potentially increase the legitimacy of objectives and enable existing spatial analysis to reflect better the current ecological and socio-economic issues facing a city/area.
- The local government should work with partners to deliver the most appropriate form of NBS in all locations. To do this requires an understanding of which forms of investment will work in which location, and plans should be developed to support a more nuanced approach to investment, as well as associated funding and management streams.

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