RESEARCH ARTICLE

Exploring the smart-natural city interface; re-imagining and re-integrating urban planning and governance [version 1; peer review: awaiting peer review]

Michael Grace [1], Alister J. Scott[2], Jonathan P. Sadler[3], David G. Proverbs [1], Nick Grayson[4]

[1]Computing, Engineering & Built Environment, Birmingham City University, Birmingham, West Midlands, B4 7XG, UK
[2]Dept. of Geography, Northumbria University, Newcastle Upon Tyne, NE1 8ST, UK
[3]School of Geography, University of Birmingham, UK, Birmingham, B15 2TT, UK
[4]Climate Change & Sustainability, Birmingham City Council, 6 Margaret Street, Birmingham, B3 3BU, UK

v1 **First published:** 14 Feb 2020, **2**:7
https://doi.org/10.35241/emeraldopenres.13226.1
Latest published: 14 Feb 2020, **2**:7
https://doi.org/10.35241/emeraldopenres.13226.1

Abstract

Globally, urban planners and decision makers are pursuing place-based initiatives to develop and enhance urban infrastructure to optimise city performance, competitiveness and sustainability credentials. New discourses associated with big data, Building Information Modelling, SMART cities and green or biophilic thinking inform research, policy and practice agendas to varying extents. However, these discourses remain relatively isolated as much city planning is still pursued within traditional sectoral silos hindering integration. This research explores new conceptual ground at the Smart – Natural City interface within a safe new interdisciplinary opportunity space. Using the city of Birmingham UK as a case study, a methodology was developed championing co-design, integration and social learning to develop a conceptual framework to navigate the challenges and opportunities at the Smart-Natural city interface. An innovation workshop and supplementary interviews drew upon the insights and experiences of 25 experts leading to the identification of five key spaces for the conceptualisation and delivery at the Smart-Natural city interface. At the core is the space for connectivity; surrounded by spaces for visioning, place-making, citizen-led participatory learning and monitoring. The framework provides a starting point for improved discussions, understandings and negotiations to cover all components of this particular interface. Our results show the importance of using all spaces within shared narratives; moving towards 'silver-green' and living infrastructure and developing data in response to identified priorities. Whilst the need for vision has dominated traditional urban planning discourses we have identified the need for improved connectivity as a prerequisite. The use of all 5 characteristics collectively takes forward the literature on socio-ecological-technological relationships and heralds significant potential to inform and improve city governance frameworks, including the benefits of a transferable deliberative and co-design method that generates ownership with a real stake in the outcomes.

Open Peer Review

Reviewer Status *AWAITING PEER REVIEW*

Any reports and responses or comments on the article can be found at the end of the article.

Keywords
Biophilic, Co-design, Conceptual Framework, Natural City, SMART, Urban Planning, Transdisciplinary.

This article is included in the Sustainable Cities gateway.

Corresponding authors: Michael Grace (michael.grace@bcu.ac.uk), David G. Proverbs (david.proverbs@bcu.ac.uk)

Author roles: Grace M: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Scott AJ**: Conceptualization, Data Curation, Formal Analysis, Funding Acquisition, Investigation, Methodology, Supervision, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Sadler JP**: Conceptualization, Data Curation, Formal Analysis, Funding Acquisition, Investigation, Methodology, Supervision, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Proverbs DG**: Conceptualization, Formal Analysis, Funding Acquisition, Investigation, Methodology, Supervision, Validation, Writing – Review & Editing; **Grayson N**: Conceptualization, Formal Analysis, Investigation, Methodology, Validation, Visualization, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: This work was supported by the for the Urban Living Birmingham (ULB) project, the Research Councils UK (RCUK) and Innovate UK as part of the Urban Living Partnership [EP/P002021/1].
The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

How to cite this article: Grace M, Scott AJ, Sadler JP *et al.* **Exploring the smart-natural city interface; re-imagining and re-integrating urban planning and governance [version 1; peer review: awaiting peer review]** Emerald Open Research 2020, **2**:7 https://doi.org/10.35241/emeraldopenres.13226.1

First published: 14 Feb 2020, **2**:7 https://doi.org/10.35241/emeraldopenres.13226.1

Introduction - smart and natural; two separate city discourses?

In recent decades, metropolitan planners and decision makers have employed place-based initiatives to improve cities performance, infrastructure, competitiveness, liveability and sustainability (de Jong *et al*., 2015; Nesta, 2015; UN, 2016). However, there are significant strategic challenges in reconciling how cities plan effectively for the competing resourcing demands of public health, water, housing, economic growth, biodiversity and climate change (Ravetz, 2018). Typically, these challenges are often addressed within separate sectoral "silos" leading to policy disintegration (Lennon, 2015; Scott *et al*., 2013).

The Smart City paradigm represents one of these silos, fuelling a significant research and policy agenda focussed on data-led solutions to urbanisation challenges (Buck & While, 2017; Viitanen & Kingston, 2014). The Natural or Biophilic city paradigm represents another silo, based on nature-based solutions to urbanisation challenges (Newman, 2014:47 see also Beatley, 2016; Reeve *et al*., 2015). Crucially, there is limited research that looks at the interface between these two areas of research activity, particularly that which has focussed on the role of the citizen-led approaches which have pervaded much urban policy and decision-making literatures (UN Habitat, 2016).

Our principle research challenge was to identify the added value and benefits for the environment and citizens from integrating these natural and smart city discourses. More specifically, the research aimed to show whether we could identify and mainstream the opportunities that arise from integrating knowledge flows and exchange across the Smart-Natural interface. By finding a method to de-construct the characteristics of the interface between these two hitherto disparate areas, could better policy and decision making processes and outcomes ensue? The research is part of a wider research project 'Urban Living Birmingham' which formed our principal case study (Leach *et al*., 2018). Significantly, the City Council had developed separate strategies towards achieving Smart and Natural cities (BCC, 2013; BCC, 2014a) and thus provided an excellent test bed for our research goal.

We proceed with a discussion of the core ingredients and evolution of the Natural and Smart City paradigms before explaining the development of a conceptual framework based on a convergence and synthesis of existing literatures. This framework is then used as a prompt for an innovation workshop and 'deeper dive' discussions with participants and key stakeholders in the city of Birmingham. The results were used to develop a set of characterisations to facilitate improved integration into future research, policy and practice. We then discuss the implications of this for new impact pathways in dealing with contemporary urban challenges globally.

The Natural City

In 2050, 68% of the world's population is projected to be urban (UN, 2018). The process of urbanisation globally is a key driver of significant declines in biodiversity (IPBES, 2018; WWF, 2018). This has shaped new agendas for cities to work with 'people and nature' together within changing models of urbanization to better respond to the challenges of inequality, climate change, informality, insecurity, and the unsustainable forms of urban expansion (Mace, 2017; UN Habitat, 2016; United Nations, 2015).

Distinctive approaches towards natural or green cities from the late 19th and early 20th centuries to today can be identified from the academic and practice literatures (Hou, 2013; Locke & Grace, 1993; Singapore Government, 2016). 'Urban ecology' and its potential as a means for integrated urban planning (Hough, 2004; Lord *et al*., 2003; Stefanovic & Scharper, 2011) and the opportunities for nature in cities (see for example, Barranco-León de las Nieves *et al*., 2016) have led others to recognise the importance that cities can potentially play in the conservation of global biodiversity (Aronson *et al*., 2017).

The recent emergence of 'Biophilic' cities extends the natural city concept to "*cities of abundant nature in close proximity to large numbers of urbanites…..value residents' innate connection and access to nature through abundant opportunities to be outside and to enjoy the multisensory aspects of nature by protecting and promoting nature within the city*" (Biophilic Cities Project, 2017; see also Beatley, 2010). Biophilic environments entail multi-sensory frequent contact with nature, and value, for instance, nurturing natural soundscapes and smellscapes in cities (Beatley, 2016; Porteous, 1985).

A network of cities, including Birmingham, have identified with Biophilia, recognising that it is conducive to comprehensive, intentional and strategic urban greening. Biophilic urbanism can be applied at multiple scales in urban environments through a range of multi-functional features including green and blue infrastructure providing multiple benefits for people (Reeve *et al*., 2015). Indeed, nature in the city is now topically viewed as part of urban green and blue infrastructure (GI), set often within the language of environmental protection, natural capital and the ecosystem approach, designed to maximise their value to urban populations (NCC, 2017). Here GI as living infrastructure has been promulgated as the "glue" to help deliver multiple benefits in policy and practice (Alexandra *et al*., 2017; Metro Tunnel Living Infrastructure Plan, 2017) and is a rapidly growing area of research (e.g. Connop *et al*., 2016; Hansen & Pauliet, 2014; Lennon & Scott, 2014; Mell, 2014).

Much emphasis has also been on the economic valuation of GI (e.g. Foster *et al*., 2011; UK NEA, 2011). Sadler *et al*. (2018) argue that natural capital in urban GI, helps unlock the other four capitals: financial, human, social and manufactured, transforming hitherto negative associations with GI as a burden (Scott & Hislop, 2019) and places people at the centre of ecosystem service delivery (Gaston *et al*., 2013; Hansen & Pauliet, 2014). Despite this progress and calls to move towards more holistic assessment methods (Spash, 2008), GI has yet to achieve its full potential in mainstreaming endeavours (Scott, 2019).

The Smart or Digital City

The Smart city concept is underpinned by the extensive application of information and communications technology within an explosion of research but a single consensual definition

remains elusive (Carter, 2017; Stimmel, 2015). Albino *et al.* (2015) identify 24 definitions with a strong focus towards sustainability, focusing on people and community needs. From the rapidly growing literature on Smart cities, a number of definitional groupings can be unearthed (Centre for Cities, 2014). Some are data-driven (Falconer & Mitchell, 2012, for Cisco); whilst others revolve around citizen-focused approaches, which are defined by approaches to governance and yet others towards city efficiency and performance and finally as prestige for the city and its leaders (Nesta, 2015).

Marsal-Llacuna *et al.* (2015) describe the evolution of the Smart Cities initiative over a decade at the start of the 21st century; from creative cities, to digital cities, to knowledge cities, to Intelligent Cities to then Smart Cities. They argue that the development has grown from a concern with measuring environmentally friendly and liveable cities. The 'Smart City' can therefore be positioned as a distinct category of urban modernization ambitions and initiatives, albeit with concerns about whether this type of smart growth can adequately cater for social equity and environmental progress (De Jong *et al.*, 2015; Hernandez & Roberts, 2018).

Within the literature there is concern that SMART initiatives must move away from generating huge amounts of city-level data for its own sake and develop an improved understanding of cities as transboundary, multisectoral, multiscalar, social-ecological-infrastructural systems (Ramaswami *et al.*, 2016). It is here that improved urban diagnostics and natural or biophilic-style ideas can help filter the data needed to address particular challenges (Leach *et al.*, 2018).

Integrating smart and natural city discourses?

The approaches towards Smart(er) cities and Natural cities can be described as transition discourses; part of a range of alternatives with no single one providing all the answers for urban futures (Blaschke *et al.*, 2011; Ravetz, 2016). Individually, neither the Smart nor the Natural city approach are currently sufficient to deliver a sustainable city and weaknesses have been identified in how they might converge into hybridised notions of a sustainable city (Hassan & Lee, 2015). Others are clear that being green must be a facet of being a smart city (Cavada *et al.*, 2017: Colding & Barthel, 2017).

Our case study of Birmingham reinforced the view that no single discourse could fully address current urban challenges. A city-wide diagnosis was undertaken within the ULB project (Leach *et al.*, 2018) which assessed the key strategic issues facing Birmingham and identified four interlinked critical challenges – health & wellbeing, energy, connectivity and the economy - all located within an overarching governance challenge which collectively formed the Birmingham 'nexus' (Bryson, 2017). The diagnosis also found a significant 'disconnect' between citizens and their place.

A number of authors have described new or alternative categories of sustainable city development that capture partial components of SMART and/or natural city principles in the same approach (Buizer *et al.*, 2016; De Jong *et al.*, 2015; Dhawan, 2017; Hassan & Lee, 2015; Hulme, 2017). In practice, these multiple terms often appear to be used uncritically and interchangeably by academics, policy makers, planners and developers, reflecting their relatively weak theoretical underpinnings (Caprotti *et al.*, 2016). Indeed, De Jong *et al.* (2015) consider only six to be conceptually robust enough; 'sustainable city', 'smart city', 'eco city', 'low carbon city', 'resilient city' and 'knowledge city'.

Furthermore, it has been argued that the social, environmental and community aspects of the smart city have not been sufficiently integrated into the smart city research and policy agendas (Capdevila & Zarlenga, 2015: Colding & Barthel, 2017), which has underplayed the role of social and environmental capital and the resulting behaviours of its citizens (ERKC, 2014; Eurocities, 2018).

New digital techniques for informing better decisions are not yet systemic but are emerging and Arts *et al.* (2015) have identified a number of categories of data alongside risks and problems that accompany digital conservation. Others have identified specific applications for urban landscapes, remote and human sensing (see for example; Blaschke *et al.*, 2011; Hill, 2016; IWUN, 2017; Roberts *et al.*, 2018; Seresinhe *et al.*, 2017 and Tu *et al.*, 2018). Carton & Ache (2017) have specifically explored the rise of citizen-sensor-networks, combining civic engagement and ICT. The appropriation of digital technologies by citizens can also be an important integrating mechanism for the governance of a Smart and Natural city, though, crucially there is a significant lack of understanding as to how these benefits are transferred to, and received, by urban populations (Roberts, 2017).

Achieving integration in practice is, however, not so straightforward. There are a plethora of economic, political, institutional and financial barriers to overcome and working across disciplinary and professional boundaries is challenging and time consuming (see, for example, Tress *et al.*, 2005). This requires significant behaviour change, consideration of citizen-led perspectives and development of new tools for decision makers (Grace & Proverbs, 2017: Naylor *et al.*, 2018; Scott *et al.*, 2018).

This critique of the literature highlights the need for more holistic and robust theoretical frameworks that can better conceptualise and measure the contribution towards sustainability and SMART goals. It is here that social ecological thinking has started to dominate the discourse (Ahvenniemi *et al.*, 2017; Bruckmeier, 2016; Cumming & Allen, 2017 and Ramaswami *et al.*, 2016). Furthermore, Ramaswami *et al.* (2016) identify eight principles to help reconnect contemporary urban infrastructure within the social ecological system of the city. Here infrastructure is positioned as a key integrative tool allowing connections to be made across grey, green and blue infrastructure components (Lennon, 2015; Mell, 2014) with access for all across sectors and scales.

Both the Smart and Natural city paradigms argue for new investment, capacity building and delivery models concomitant with a change in culture and behaviours and there is clear

added value from exploring mechanisms that facilitate their integration (Cowell & Lennon, 2014). This also ties in with a need to move 'from industrial to network-age designs for institutions' as part of a shift toward smarter governance that recognises the importance of the citizen at the heart of this behavioural change (Noveck, 2015). The smartness in Smart cities is realized only when the system adapts itself to the user needs (Albino *et al.*, 2015) and, we suggest, this is a key element where the integration of people with nature and with digital technology can occur.

The main themes from the literature review are summarised in Table 1. These 4 propositions have directly informed our research questions and helped shape the conceptual approach that has evolved through this research.

Research methods

Our research method takes a deliberative approach set within a wider social learning agenda. Here, Roger's (2003) contribution on the diffusion of innovation provides a useful theoretical catalyst for conceptualising how new innovation or knowledge progresses through its various stages (see also Scott *et al.*, 2018). Our method can be described as having 4 significant steps and these are shown in Figure 1.

1. **The 4 key Smart-Natural Propositions:** The sophisticated diagnostic of the case study city, Birmingham UK (Leach *et al.*, 2018), considered a range of statistical and policy documents and, as we have noted, this identified key challenges facing the city. Our literature

Table 1. Summary of key themes and challenges arising from the Smart-Natural City literature (Source – authors).

Thematic propositions	Research challenges
Taking a 'whole city' approach	This steers us toward identifying a place-making and place-keeping approach. How do we bring together the capabilities needed to address a wide range of challenges from infrastructure and environment to smart cities and big urban data?
The value of green and the rise of smart	An influential and substantial body of evidence now exists that emphasises the important role of Green Infrastructure provision in cities in enhancing the health and wellbeing of citizens. How to merge this with the Smart City discourse that is for a more efficient city and services to its citizens; addressing the challenges of low economic performance, unemployment and skills gap; tackling health and wellbeing inequalities; the need for seamless and effective mobility and establishing a low carbon society?
People and their connection with the city	The diagnostic of our case study city, Birmingham, highlighted the disconnect between citizen and city. Approaches are required for the resolution of the tensions between both managing for different goods and services and the frequent differences between the needs or expectations of urban dwellers and the reality of urban landscapes. How to address governance issues to look at the bigger strategic picture including the large numbers of land managers?
Infrastructure and a systems perspective	Delivering a concept of Green Infrastructure that is part of a more holistic narrative for the city came to the fore. How to integrate with other critical systems that provide energy, water, food, houses, public health, employment, transportation, communication, waste management and recreational spaces for economic development and societal benefit? Understanding the city ecosystem so that green infrastructure, biodiversity and climate change agendas can be planned and managed to evolve as part of a smart city? This has to recognise a complex management environment.

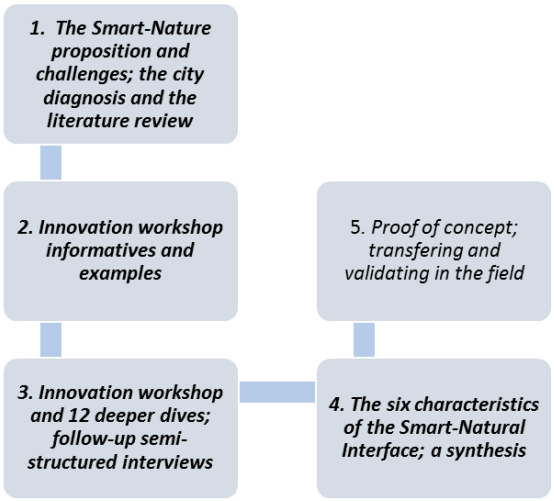

Figure 1. Research methodology.

review used a rapid evidence assessment (Collins *et al.*, 2014) to explore the interface between Smart and Natural City futures discourses and asked whether a Natural Capital could be a part of a Smart City. An initial search identified +40 items which were assessed for relevance and used to further refine the evidence assessment. We set out a number of sub-questions; what was meant by a smart city, how has nature been described within cities, how are technologies being applied to measure nature and what indicators of future policy are there? The key terms were, alone or in combination; smart city, natural or biophilic or green city, natural capital, future cities, technology and nature, digital conservation, co-design. This generated +80 references which were additionally reviewed for relevance by questions on whether there was systematic practice of joining smart and green, how smart data (remote and people sensing) is utilised to enhance green outcomes and people's interaction with green in cities and citizen-led approaches. The search principally used Google Scholar, as the most comprehensive academic search engine, Ethos (UK), Summon (Birmingham City University's discovery tool, a Google-style single-search-box for its databases and electronic resources). This was supplemented using Science Direct, the authors' substantial knowledge of the literature, a search of grey literature including conference papers, technical reports, discussion papers and working papers as well as suggestions from the experts within the ULB 'Touchstone Group'. 4 key propositions arose from the literature review and with the associated research challenges are summarised in Table 1. The feedback from the Innovation Workshop enabled us to extend the literature search further for this paper.

Our method then took on an iterative process which added substantially to the findings in the review. This process of adding value has its roots in good practice for urban place-making (see for example, AlWaer *et al.*, 2018) and the value added of each stage is indicated in Figure 2. The deliberative nature of the process is important in validating the outcomes within a heavily co-produced space.

2. **The Innovation Workshop:** 25 senior people with city, regional and national expertise were invited to an Innovation Workshop. The experts were primarily selected using the project teams' extensive networks and knowledge both of the region and its informed actors and organisations and others who could bring a non-local external view, Selection was based on capturing a range of highly relevant interests from private, public and NGO sectors concerned with the delivery of benefits and services across and within Smart city and Natural city approaches. This deliberately sought to bring in multiple and varied disciplines and included senior representatives from the fields of health, development and regeneration, green infrastructure and natural

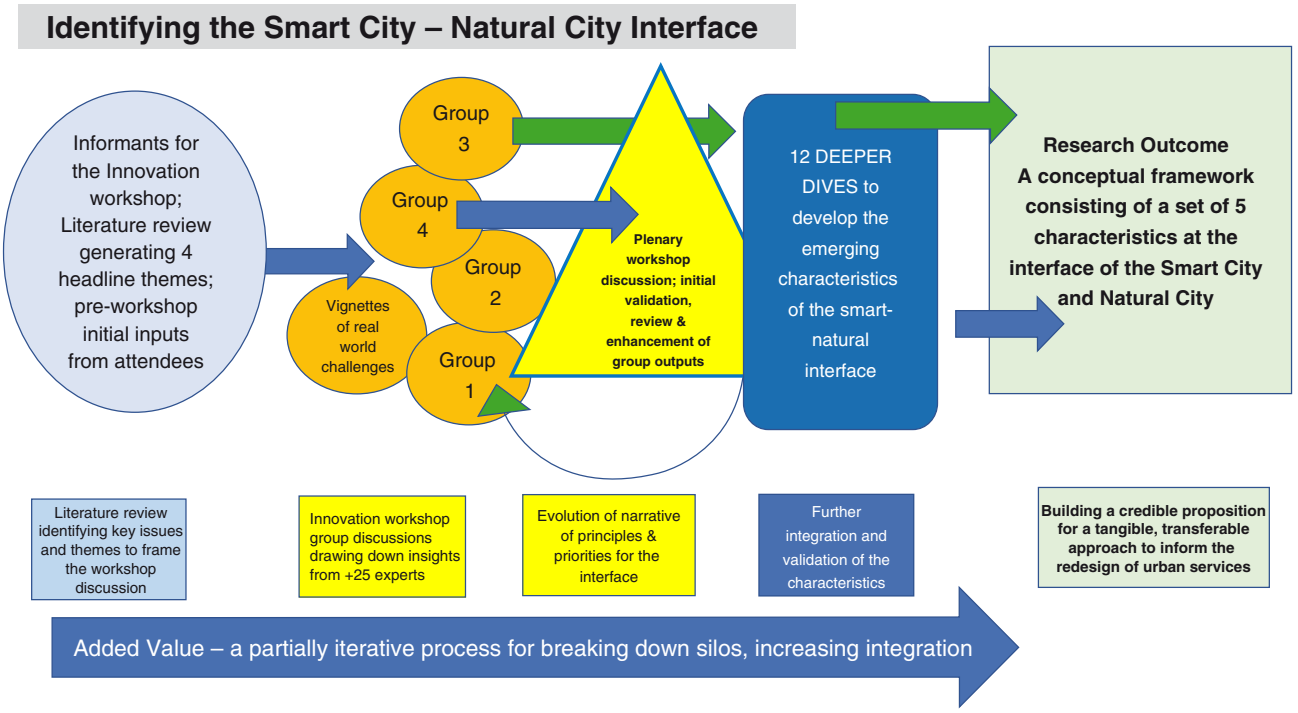

Figure 2. Process diagram for identifying the Smart City – Natural City Interface.

capital, smart and wider city policy and strategy development, business representative bodies, academics, individual business organisations, built environment consultancies, national and local government agencies. To avoid unintended pre-determination, selection deliberately invited individuals not otherwise engaged in the wider ULB project alongside those who already had some knowledge of this context.

The workshop was informed by a pre-circulated briefing document setting out the four themes (see extended data (Grace *et al.*, 2019)) and the day was introduced with several 'vignettes' from selected attendees that described current challenges and their specific ideas and approaches: establishing a city-wide environmental observatory; designing new garden village urban settlements with integrated digital and natural components; and seizing opportunity spaces within major redevelopment projects. Facilitated discussions in groups addressed one of the four themes per table. These discussions had been further primed and framed by comments and questions put forward by attendees in response to the briefing document; these included additional perspectives on 'green commercial' opportunities, governance and connecting citizens to the city. The workshop culminated in the group developing and justifying a set of recommendations and actions. Key to the design of the workshop was holding the discussions within a managed and "safe" confidential space within a neutral academic location.

Post-workshop, the intelligence and ideas gathered were then combined with the findings of the literature review and translated by the project team into a set of principles with associated characterisations. These were initially reviewed through a follow-up phone conference with some 14 members of the workshop participants.

3. **Validation through 'deeper dives':** These emerging characterisations were subsequently tested in a series of semi-structured interviews and discussions in some 12 follow-up 'deeper dives' involving workshop participants and a number of other appropriate audiences of academic and other experts. We asked our expert collaborators to address a relevant live example and a template was designed to facilitate consistent feedback from the 'deeper dive' participants. We used a variety of forms of engagement, involving presentations and semi-structured discussion, conference telephone calls, Skype calls and face to face meetings between September and November 2017 (Table 2).

Ethical Statement: The research described in this paper adhered to the UKRC-approved ethical framework for the Urban Living Birmingham Project and which was administered by the ULB

Table 2. Methods used to facilitate 'deeper dives' into the definition of the Smart-Natural City Interface.

	Expert Contributors and selected topic	Date and form of discussion
1	Birmingham City University Computing, Engineering and Built Environment Faculty staff and post-graduate students [15 attendees]; HS2 and city centre redevelopment	Seminar on 4th October 2017
2	Innovation workshop attendee - Independent Consultant; future commercial viability of city parks and green spaces.	By teleconference on 17th October 2017
3	Innovation workshop attendee - Senior Officer local authority – Growth; High Speed 2 and associated regeneration	Meeting on 17th October 2017
4	Senior Officer local authority – Development; City centre development and associated regeneration	Meeting on 17th October 2017
5	Innovation workshop attendee - Director – Health & Well-being; Green spaces and opportunity for innovation in community health service delivery	By teleconference on 17th October 2017
6	Ten experts – 8 attendees of the Innovation Workshop plus 2 others representing Local Authority/ Digital-Smart City and the Business/Environment sector (who could not attend the workshop); several examples were raised, including linear transport infrastructure and new development	By teleconference on 13th October 2017
7	Innovation workshop attendee - Development company, Director; new settlement development	Meeting 25th October 2017
8	Innovation workshop attendee - Consultancy Smart Cities, Director; new urban development	By email during October 2017
9	Innovation workshop attendee - Academic; the challenge of air quality especially around schools,	By email during October 2017
10	Academic; Housing issues	By email 16th October 2017
11	Academic and Project Manager; new housing development	Meeting 20th October 2017
12	Academic and Project Manager; the operation (individually and collectively) of UK (and international) cities to enable best practice	By email 8th November 2017

Project's Consortium Management Committee. The CMC was chaired by the

Principal Investigator of the ULB Project who was delegated responsibility for ethical matters. Oversight was provided through bi-monthly meetings throughout the period of this research in 2017. All of the participants in the research engaged in the Innovation Workshop and subsequent interviews on a voluntary basis, consenting through email acceptances.

4. **Defining the Smart City – Natural City Interface:** the authors used the outcomes of the deeper dives to further construct the 5 characteristics that we suggest identify the opportunity and challenges in this new conceptual space. The set of 5 is described in the results and discussion sections below. A full summary of the key informant points arising from the process of engagement is provided in a meta-table in Appendix A (included as extended data (Grace *et al.*, 2019)).

The meta-table allows the reader to follow the threads from the literature review-driven inputs to the innovation workshop to the final 5 characterisations of the smart-natural interface. The 5 characteristics are described in column F. Columns A to E show the 4 thematic inputs and research challenges (column A) alongside the results of the workshop group discussions, narratives that emerged from individual groups and summary comments (columns B to D) with the collective summary of the 12 deeper dives (column E) that helped to validate that particular one of the set of [the 5] characteristics. It illustrates the association of the comments and the evolution of the characterisations.

We can note that some expert insights can be assigned to shaping more than one of the characterisations whilst a single theme from the review also inspired different expert advice. It is the richness in combination of the results from each stage of the research project that enabled the synthesis of the final descriptions of the 5 characterisations.

Results - Characterising and constructing the Smart – Natural Interface

The outputs from the research process were 5 interconnected principles or characterisations of the interface between the Smart City and the Natural City. We have described these as conceptual 'spaces' and are captured in Figure 3 (see underlying data (Grace *et al.*, 2019)).

Drawing on the material from the innovation workshop and deeper dives, we can describe each of the 5 characteristics of the Smart-Natural Interface as follows.

A connectivity space

This space is where people, digital technology and nature connect across each other and places to improve performance. In academic terms it is the space between smart urban strategies and social-ecological systems thinking for the 'whole-city'; where grey and green infrastructure evolves into 'silver green' through the combination of smart and natural (or biophilic) city solutions to generate multiple benefits.

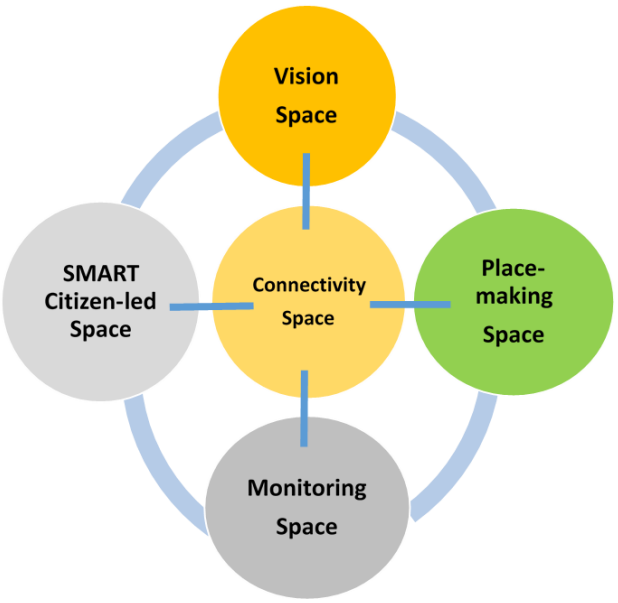

Figure 3. The characteristics of the Smart – Natural Interface: connectivity at the hub.

A vision space

This space reflects the idea to have a clear and bold vision for the kind of liveable city we need. Here we need to move away from economic, social or environmental silos to re-imagining city spaces within exciting new co-produced visions. Using interactive technology is key here to engage and excite people and communities in making choices and decisions for their city.

A place-making and place-keeping Space

This space reflects where living, learning, working and recreating functions are combined as part of integrated smarter natural solutions. It responds to political and environmental challenges by championing silver green infrastructure and driven by the increasing body of evidence that supports the value of natural capital for people, business and the economy of the city. Crucially it does not pit green and grey infrastructure against each other.

A SMART citizen-led space

This space is where citizens are able to access and resource the necessary data to help them make decisions about how they live their lives and where they can themselves influence change through using and interacting with said data in real time. Thus this becomes a participatory social learning space where the flow of information is two-way; between people and city managers and planners. Communities will be empowered through new evidence about their place being made available in different, smarter and more accessible ways. Through a better understanding of technical processes citizens can directly

engage with service providers and suggest innovations, helping to integrate policy and delivery and potentially leading to better service re-design.

A monitoring space

This space is where ICT and smart applications are used to measure, track and monitor progress of the vision and other characterisation metrics. There is a need to establish baselines and identify the indicators for the Smart-Natural interface e.g. the health and economic benefits that accrue from co-designed and community managed spaces. This is essential if the interface is to have traction and help identify accountabilities for the delivery of more integrated and better services and benefits for people and that, in turn, can help justify investment.

To demonstrate the evolution of the 5 characteristics, we have provided a detailed narrative of the way the Connectivity space was formulated. For the other characteristics, as described above, Appendix A allows the reader to follow the threads from the literature review-driven inputs to the innovation workshop and 'deeper dive' conversations to the final 5 characterisations of the smart-natural interface (see extended data (Grace *et al.*, 2019)).

Formulating the connectivity space. Informed by the literature review, the innovation workshop sought to address multiple challenges for the whole city at the same time. This evolved through an exploration by the workshop participants of how social connectivity and cohesion could be supported as part of connecting people back with their city and using smart technology to move toward a more natural city.

The expert group discussion suggested that there should be deliberately designed attempts to join up agendas, informed by targeted data collection; this would (a) evidence metrics that connect the local to city to regional outcomes and (b) would give an open data source for green and blue infrastructure linked to community aspirations and delivery programmes.

In the deeper dive conversations, our experts from local authority and other agencies thought that they would as a result "*be driven to change points of contact with people, engaging a broader variety of people and groups in different (better) ways"* (Senior Regeneration Officer; Birmingham City Council).

In turn this would inform changes in behaviours across decision making that could be more confident in taking informed risks for more benefits. To reinforce this steer, the deeper dive conversations in particular suggested that the whole set of the characterisations would ask people to present information in more accessible ways and to connect citizen-led science with big data to inform decision making.

A second theme contributing to the Connectivity characterisation, concerned the challenges and opportunities of the city as a system from a 'people' perspective. Given the societal challenges of inequalities across Birmingham, the workshop discussions considered how the Smart-Natural interface can help break down barriers to change across the city. The expert group quickly identified the issue of language and how terminology can define silo thinking, encouraging us to think in terms of 'us', that is to share issues and co-produce solutions, and not 'them' as the deliverer of solutions. Our business sector representative noted a weakness in limited references to the business sector but identified an opportunity to develop a new *"business value model"* whereby the private sector could innovate new solutions to the delivery of nature and so, in turn, suggested that *"accountability for the delivery of benefits can be shared across collaborating organisations"* (Senior Executive; Business).

Looking across both of these themes, a senior local authority manager from the City Council suggested that the characteristics could help *"create an engagement framework"* with the interface as a means of changing the connection between city authorities and citizens; allowing for new innovative and connected ideas to come through and helping the city council behave differently, as an enabler rather than a provider of services.

The third theme contributing to the Connectivity characteristic suggested the importance of taking an infrastructure and systems perspective to integrate delivery. The importance of having a city systems approach which could combine digital technology and nature emerged as a key element of connected thinking; the common aim of *'silver green'* solutions for infrastructure was identified.

Our health and well-being experts suggested that, for the evolution of city systems, *"the opening up of data and information can enable people to understand risks and choices and to push for better facilities, greenspace, air quality etc."* Nature was quickly identified as a core concern that should be embedded in infrastructure from the outset and debate began about what digital technology applications could assist blue and green infrastructure. The deeper dive conversations explored how better information provides a sounder base for effective engagement and investment decisions. Indeed, our health experts endorsed systems changes which are *"more complex but much more powerful than reverting to individual and largely technical innovation which are much easier to measure"* (Director; Health & Well-Being Consultant).

The drivers from the literature, the inputs from the expert group and the validation through the deeper dives have shaped the 5 characteristics collectively, through being informed by multiple strands of knowledge and advice, with overlapping interests. Indeed, we suggest, that the methodology has helped expose a web of connectivity underpinning the strength of this new conceptual thinking.

Discussion – the value and opportunity of the Smart City – Natural City interface

Towards a hybrid governance model at the Smart - Natural interface

To date there has been only limited and sporadic progress in the convergence of theory, policy and practice of Smart and Natural concepts in city planning and governance (UN Habitat, 2016). The literature does not address urban ecology perspectives of the

smart city (Colding & Barthel, 2017) whilst Sagl *et al*. (2015) make the stark conclusion that it seems doubtful that any improvement in quality of life can be demonstrated to have resulted (to date) from most of the developments related to the establishment of smart cities. A comparison of the list of the world's top 20 smart cities with those within the Biophilic City network reveals only one common member, Singapore (Eden Institute, 2018). The research we are describing here is a contribution to filling these conceptual, policy and delivery gaps.

Where convergence is evident, it is the sustainable cities paradigm and its' spawning multiple hybrids that dominate (Hassan & Lee, 2015). However, the often called for holistic approach is all too easily disintegrated into silos due to hard-nosed financial, economic and political barriers reinforced by current institutional myopia (FCC, 2016: Scott *et al*., 2004). For example, in the recent Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) assessment it was recognised that nature as expressed through ecosystem services is in fundamental decline globally and where still economic growth is not decoupled from environmental degradation. Even in biophilic cities, approaches to biophilic solutions have often been found to be mostly random (el-Baghdadi & Desha, 2017).

Our conceptual framework offers a different pathway to move out of silos through navigating five spaces to build sustainable and resilient cities city that are now desired (Ravetz, 2016; United Nations, 2015). Crucial to our conceptualisation is that the framework revolves around a connectivity space rather than a vision. In this way this helps ensure that visions are grounded across key participants, stakeholders and evidence thereby challenging current mainstream urban planning approaches and strategies (Scott *et al*., 2013). By addressing the dis- functionality between different urban futures discourses, the five principles and their associated characterisations can help bridge the often encountered policy and delivery gap (Matthews, 2010). This was most evident in the deep dives when narratives were framed by the participants across each space helping them reflect upon their own initiative. This in many ways reveals the power of the process itself (Glass *et al*., 2013) where re-thinking past/current or future activities in reflective mode can be helpful in getting people to connect outside their usual comfort zones. In such respects the co-production of the conceptual framework helps build bridges for multiple audiences to engage with a move away from elitist vocabularies, so supporting the contention of Scott *et al*. (2018). This becomes a starting point for more fertile conversations and shared dialogue about city systems and governance where social learning and knowledge exchange (see Scott *et al*., 2013) help to understand existing (mis-)connections and interdependencies (Lockwood, 2010). Moreover, there is potential to strengthen and form new alliances and partnerships for the benefit of nature and people through the connectivity space itself. Below we signpost some of the key outcomes that enable move from hypothetical benefits and use the Smart- Natural City interface to add value to existing urban planning and governance.

The ULB project found improved governance to be at the heart of addressing the challenges facing Birmingham (Leach *et al*., 2018). Success will depend on effective governance frameworks that have clear, accountable and transparent decision making processes, with effective monitoring of interventions and strong evidence-led leadership (Ahvenniemi *et al*. 2017: Lockwood, 2010; Scott *et al*., 2018). This suggests that we should view the city as an evolving ecosystem to start to close the current conceptual and policy gap between smart city and natural city frameworks. This would overcome some of the risks identified by Gulsrud *et al*. (2018) that the coupling of ecology and technology could heavily reduce human involvement in decision making.

By using the shared 'Visionary Space' we have available a crucial but currently neglected step in rethinking and reimagining the kind of natural and smart city "we" collectively need. That is, if 'SMART' can be more multifunctional, inclusive and participatory it can cater for social equity and environmental progress. Constructing a digital environment that systemically embeds the natural environment through a 'network of networks' that link, say, sensor networks co-designed by citizens with networks of other remote sensors at the local as well as the city scale will be one of the challenges in governing this evolving ecosystem. This will help deliver on the importance of the value of natural capital and subsequent ecosystem goods and services to citizens (see Connop *et al*., 2016; Forest Research, 2011; Newman, 2014; UK NEA, 2011 and UK NEA, 2014). It can also be a filter of data required to address specific natural environment challenges, such as the loss of biodiversity and trend toward a homogenization of terrestrial ecological assemblages associated with human land use identified by Newbold *et al*. (2018).

By their simultaneous use, together the 5 characteristics of the Smart-Natural city interface have the potential to help start dialogues to resolve concerns (Arts *et al*., 2015; Roberts, 2017) over how these benefits are transferred to and received by urban populations and the circumstances under which this can happen most effectively. The use of this new approach can guard against widening the digital divide and amplifying poverty gaps as described by Hernandez & Roberts (2018), allows us to 'see the expertise of citizens' (Noveck, 2015) and so address the disconnect challenge identified by Colding & Barthel (2017). This has the potential for high impact in cities such as Birmingham which exhibit this problem but has an age structure with relatively high proportions of young people (BCC, 2014b) who will be familiar with the technology.

The research outcomes identified within the Smart-Natural City interface two particularly strong opportunities.

Infrastructure and systems perspective: embracing a 'silver-green' model. The exploitation of the Smart-Nature Interface can fill the gap identified by Gaston *et al*. (2013) for the development of new kinds of ecosystem process models to help manage conflicts and inform city design and management. In particular the interface can be exploited to focus attention away from the polarisation of grey and green infrastructure towards an urban ecosystem that stresses and optimises the more positive 'silver-green' infrastructure; this necessarily combines smart and

natural attributes as a default solution for infrastructure and can produce better outcomes for people and the environment. Critical here is the realisation that people are an integral part of natural systems. Here the development of improved design standards such as BREEAM and Building with Nature (Callway *et al*., 2019; Jerome *et al*., 2019)

This would be a key integrative tool, using smart, digital technology to allow connections to be made across silver, green and blue components. Through this integration, exploiting the interface can help the wider mainstreaming of nature in decision making, avoiding the binary positioning that sees green pitted against grey and help nature based solutions to be integrated within existing built infrastructure (Hansen & Pauliet, 2014).

Towards Smarter Green pathways using SMART citizens. Secondly, as well as integrating physical infrastructure, the rise of the Smart Citizen offers exciting new potential at the smart-natural interface. This sees the integration of enabling technology with people and environment in terms of their expectations of high quality living environments with accessible green infrastructure. This provides decision makers and communities a means of achieving co-creation pathways (Mahmoud & Morello, 2018) and the ability to exploit fully the opportunities being presented by urban computing and key dimensions on data (Arts *et al*., 2015; Zheng *et al*., 2014), both of which can have a substantial impact on ecology and nature conservation. In particular, the combination of multiple sources of data on people, on nature, communication and especially participatory sensing to inform governance models. It also endorses work such as that by Sereshine *et al*. (2017) on 'scenicness' which combine public perceptions and ratings of landscape with new data handling capabilities. This would work for enhancing new developments and retrofitting the existing city spaces that link them, provided the data is generated from identified challenges and problems (Gaffney & Robertson, 2018). It would help address the gap identified by Capdevila & Zarlenga (2015) that the social/community/human aspect of the smart city has not been sufficiently integrated in the smart city policies. It does, however, require the application of more interactive better decision-support tools so that they can better visualise data.

Good Smart City governance recognises the importance of co-creation with citizens and digital inclusion (Eden Institute, 2018 p8). The use of the smart-natural hybrid space encourages us to create citizen-led dialogues that can connect with established techno-centric dialogues that currently dominate much city planning (Adams *et al*., 2014). This intersection is related to the learning capacity of citizens, communities and institutions in dealing with common problems and so can enhance the performance of the smart and natural city. The interface can assist with identifying the appropriate ICT and environmental measurements as an important integrating and connectivity mechanism, such as that described by Zheng *et al*. (2014) and Carton & Ache (2017) for citizen-sensor-networks. Furthermore, the space explicitly allows for exploiting the value of social media and Big Data arising from our use of technology. Social mapping applications (such as 'schmapped'; IWUN, 2017; McEwan *et al*., 2019) and social networks (such as Twitter; #greeninfrastructure and #naturebasedsolutions) for understanding the use of local green space (Roberts, 2017) can create a human powered participatory sensing network that can be combined with remote sensing into SMART city systems and applied in the context of optimising the multiple benefits from ecosystem services.

Conclusions and recommendations

This research has designed a transferable method from the Birmingham experience to other cities to start new dialogue that bring the hitherto separate dialogues and policy interventions together. Crucial to our progress in this transdisciplinary endeavour has been the innovation workshop and its management within a safe learning space. By identifying key players across the Smart-Natural City interface we have started new dialogues on common themes thereby securing significant additional value from the participant's insight and experience. The need to enable interdisciplinary and transdisciplinary thinking here becomes key as does the need for enablers and catalysts who can enable this to happen (Newcastle City Futures, 2017; Tewdwr-Jones *et al*., 2015; Tress *et al*., 2005).

Emerging urban socio-ecological-technological relationships have been noted by Gulsrud *et al*. (2018) and Colding & Barthel (2017). The combination of steps in our research methodology has allowed us to describe the identity of the Smart-Natural City interface in the form of its 5 characteristics and exposed two distinct opportunities; the development of silver-green infrastructure and working with citizens to create smarter green pathways that can connect people with their place and nature.

These can prove to be a powerful means of addressing the dysfunctionality that exists between several policy silos in a city (Scott *et al*., 2013) where we champion the "power of the process" (Glass *et al*., 2013). The subsequent design, testing and exploitation of this hybrid space between the two separate urban discourses allows city planners and citizens to get 'smarter with nature' so that it generates more benefits to people and the city and helps shape conversations that can lead to a re-design of public services.

We recognise that there is an undoubted tension between the practice-led predilection towards short-term, reactive and incremental changes as opposed to the need for wider cultural and behaviour change in city governance (Buck & While, 2017; Low, 2002; UN Habitat, 2014) and which is exemplified in our case study of Birmingham (Kerslake, 2014). This heralds important questions as to the ability of our more strategic framework to provide the necessary tools and technology or outcomes (the key natural capital and services) that address specific and immediate practice problems.

A particular challenge will be the creation of a new business value model that can substitute for public funding of the nature that supplies ecosystem services to people. The use of the set of characterisations can provide improved urban diagnostics which engage with people, to better understand and 'read' (Leach *et al*., 2018) city systems over the long term. This in turn helps to unlock the governance barriers for more joined up working across traditional silos.

This research has revealed the opportunities that can emerge at the boundary or interface between any two or more policy areas. The importance of considering connectivity in both policy and spatial terms has especially emerged; this may be unsurprising but our framework provides a starting point and a route map for ensuring that the challenge of exploiting digital technology for connected urban futures, futures which can benefit both people and nature. It is an approach which merits further testing across other cities that aspire to be biophilic and smart, as well as within Birmingham itself.

Data availability

Underlying data

Environmental Information Data Centre: Record of expert inputs shaping future city discourses for Urban Living Birmingham. https://doi.org/10.5285/474e090d-4502-432c-b8de-ce9f33571f8e (Grace *et al.*, 2019)

This project contains the following underlying data:

- ULB-GettingSmarter-datasetMatrixfeedbackfromExperts-Anonymised2A.rtf (Matrix of Feedback from Expert Collaborators)
- ULB-SmartNaturalCityWorkshop12thSept2017-writeup-ofnotescomments-Anonymised2A.rtf (Comments and key points captured on the day from the plenary and group discussions)
- ULB-Smart-Natureworkshop-Group1draftnarrative-Anonymised2A.rtf (Record of Group 1 outputs from the Innovation Workshop)
- ULB-Smart-Natureworkshop-Group2draftnarrativeAnonymised2A.rtf (Record of Group 2 outputs from the Innovation Workshop)
- ULB-Smart-Natureworkshop-Group3draftnarrative-Anonymised2A.rtf (Record of Group 3 outputs from the Innovation Workshop)
- ULB-Smart-Natureworkshop-Group4draftnarrative-Anonymised2A.rtf (Record of Group 4 outputs from the Innovation Workshop)

Extended data

Environmental Information Data Centre: Record of expert inputs shaping future city discourses for Urban Living Birmingham. https://doi.org/10.5285/474e090d-4502-432c-b8de-ce9f33571f8e (Grace *et al.*, 2019)

This project contains the following extended data:

- ULB-Smart-Nature-AppendixA-anonymised.rtf (Meta-table which organises and summarises all of the outputs from the Innovation Workshop held in Birmingham, UK on 12th September 2017 and subsequent group discussions and individual or collective 'deeper dive' conversations that were held between September 2017 and November 2017)
- ULB-Smart-Nature-InformativenoteforSC-NCworkshop-final-anonymised.rtf (Briefing Note provided for expert attendees ahead of the Innovation Workshop)
- ULB-GettingSmarterpaper-NERCDataRepository-SupportingInformation.rtf (copies of photographs of the collective 'stickies' contributions at the workshop)

Please note an account must be made to be able to access and download the data.

Acknowledgements

The authors would especially like to thank Joanne Leach of the University of Birmingham, Manager of the ULB Project for her practical support and to our group of expert advisers who so willingly contributed their ideas and experience.

References

Adams D, Scott AJ, Hardman M: **Guerrilla Warfare in the Planning System: Revolutionary Progress towards Sustainability?** *Geogr Ann B Hum Geogr.* 2014; **95**(4): 375–387.
Publisher Full Text

Ahvenniemi H, Huovila A, Pinto-Seppä I, *et al.*: **What are the differences between sustainable and smart cities?** *Cities.* 2017: **60**(A): 234–245.
Publisher Full Text

Albino V, Berardi U, Dangelico R: **Smart Cities: Definitions, Dimensions, Performance, and Initiatives.** *J Urban Technol.* 2015; **22**(1): 3–21.
Publisher Full Text

Alexandra J, Norman B, Steffen W, *et al.*: **Planning and Implementing Living Infrastructure in the Australian Capital Territory – Final Report.** Canberra Urban and Regional Futures, University of Canberra, Canberra. 2017; [Accessed 29th January 2018].
Reference Source

AlWaer H, Wright F, MacPherson I, *et al.*: **Shaping better places together. Research into the facilitation of participatory placemaking.** The University of Dundee School of Social Sciences, Architecture + Urban Planning Matthew Building, 13 Perth Road, Dundee DD1 4HT, UK. 2018.
Reference Source

Aronson MFJ, Lepczyk CA, Evans KL, *et al.*: **Biodiversity in the city: key challenges for urban green space management.** *Front Ecol Environ.* 2017; **15**(4): 189–196.
Publisher Full Text

Arts K, van der Wal R, Adams WM: **Digital technology and the conservation of nature.** *Ambio.* 2015; **44**(Suppl 4): 661–73.
PubMed Abstract | Publisher Full Text | Free Full Text

Barranco-León de las Nieves M, Luna-Castellanos F, Vergara CH, *et al.*: **Butterfly Conservation within Cities: A Landscape Scale Approach Integrating Natural Habitats and Abandoned Fields in Central Mexico.** *Trop Conserv Sci.* 2016.
Publisher Full Text

Beatley T: **Biophilic Cities: Integrating Nature into Urban Design and Planning.** Timothy Beatley. Island Press, 21 Oct 2010. Washington, USA. 2010.
Publisher Full Text

Beatley T: **Planning for biophilic cities; from theory to practice.** In Mark Scott,

Mick Lennon, Dagmar Haase, Aleksandra Kazmierczak, Gerry Clabby & Tim Beatley (2016). Nature-based solutions for the contemporary city. *Planning Theory & Practice.* 2016; **17**(2): 267–300.

Biophilic Cities Project. Accessed 12th May 2017.
Reference Source

Birmingham City Council: **Green Living Space Plan.** Birmingham. 2013.
Reference Source

Birmingham City Council: **The Roadmap to a Smarter Birmingham; Digital Birmingham on behalf of the B'ham Smart City Commission.** 2014a.
Reference Source

Birmingham City Council: **Birmingham Demographic Brief - 2014 Population Projections.** Planning & Regeneration, Birmingham City Council. 2014b.
Reference Source

Blaschke T, Hay GJ, Weng Q, *et al.*: **Collective Sensing: Integrating Geospatial Technologies to Understand Urban Systems—An Overview.** *Remote Sensing.* 2011; **3**(8): 1743–1776.
Publisher Full Text

Bruckmeier K: **Social-Ecological Transformation: Reconnecting Society and Nature.** Palgrave Macmillan: London. 2016.
Publisher Full Text

Bryson J: **Urban Living Birmingham: From Citizen to Co-innovator, from City Council to Facilitator – Integrating Urban Systems to Provide Better Outcomes for People.** Six-month Report. 2017; [Accessed 23rd March 2018].
Reference Source

Buck N, While A: **Competitive urbanism and the limits to smart city innovation: The UK Future Cities initiative.** *Urban Studies.* 2017; **54**(2): 501–519.
Publisher Full Text

Buizer M, Elandsb B, Vierikko K: **Governing cities reflexively — The Biocultural diversity concept as an alternative to ecosystem services.** *Environ Sci Policy.* 2016; **62**: 7–13.
Publisher Full Text

Callway R, Dixon T, Nikolic D: **Lost in transition? Examining GI evaluation in neighbourhood master planning.** *Town & Country Planning.* 2019; 185–191.
Reference Source

Capdevila I, Zarlenga MI: **Smart city or smart citizens? The Barcelona case.** *Journal of Strategy and Management.* 2015; **8**(3): 266–282.
Publisher Full Text

Caprotti F, Cowley R, Flynn A, *et al.*: **Smart-Eco Cities in the UK: Trends and City Profiles 2016**. Exeter: University of Exeter (SMART-ECO Project). **2016; [Accessed** 3rd June 2017].
Reference Source

Carter D: **Smart cities: terrain for 'epic struggle' or new urban utopias?** *The TOWN PLANN REV.* 2017; **88**(1): 1–7.
Publisher Full Text

Carton L, Ache P: **Citizen-sensor-networks to confront government decision-makers: Two lessons from the Netherlands.** *J Environ Manage.* 2017; **196**(1): 234–251.
PubMed Abstract | **Publisher Full Text**

Cavada M, Hunt D, Rogers C: **The Little Book of SMART CITIES**. ISBN 978-0-70442-949-9. Editors of the Little Books series: Dr Christopher T. Boyko and Dr Claire Coulton, Imagination Lancaster, Lancaster University, 2017.
Reference Source

Centre for Cities: **Smart Cities**. May 2014. Centre for Cities Enterprise House 59 - 65 Upper Ground London SE1 9PQ. 2014.
Reference Source

Colding J, Barthel S: **An urban ecology critique on the "Smart City" model.** *J CLEAN PROD.* Letter to the editor. 2017; **164**: 95–101.
Publisher Full Text

Collins A, Miller J, Coughlin D, *et al.*: **The production of Quick Scoping Reviews and Rapid Evidence Assessments: A How to Guide.** Joint Water Evidence Group. Beta Version 2. 2014.
Reference Source

Connop S, Vandergert P, Eisenberg B, *et al.*: **Renaturing cities using a regionally-focused biodiversity-led multifunctional benefits approach to urban green infrastructure.** *ENVIRON SCI POLICY.* 2016; **62**: 99–111.
Publisher Full Text

Cowell R, Lennon M: **The utilisation of environmental knowledge in land use planning: drawing lessons for an ecosystem services approach.** *Environ Plann C: Gov Policy.* 2014; **32**(2): 263–282.
Publisher Full Text

Cumming G, Allen C: **Protected areas as social-ecological systems: perspectives from resilience and social-ecological systems theory.** *ECOL APPL.* 2017; **27**(6): 1709–1717.
Publisher Full Text

De Jong M, Joss S, Schraven D, *et al.*: **Sustainable - smart - resilient - low carbon - eco - knowledge cities; making sense of a multitude of concepts promoting sustainable urbanization.** *J CLEAN PROD.* 2015; **109**: 25–38.
Publisher Full Text

Dhawan P: **What is a Smart City**? 2017. Published on April 5, 2017; Accessed 12th May 2017.
Reference Source

Eden Institute: **Top 50 Smart City Governments**. 2018; Accessed 2nd December 2018.
Reference Source

el-Baghdadia O, Desha C: **Conceptualising a biophilic services model for urban areas.** *URBAN FOR URBAN GREE.* 2017; **27**: 399–408.
Publisher Full Text

Energy Research Knowledge Centre (ERKC): **Behavioural Aspects of Smart Cities Thematic Research Summary**. European Union, P.10. 2014; [Accessed 28th June 2017].
Reference Source

Eurocities: 2018; [Accessed on 28th February 2018].
Reference Source

Falconer G, Mitchell S: **Smart City Framework A Systematic Process for Enabling Smart+Connected Communities.** Cisco Internet Business Solutions Group. September 2012. 2012.
Reference Source

FCC: **FUTURE OF PLANNING: State of the Art Innovations in Digital Planning**. Future Cities Catapult. 2016.
Reference Source

Forest Research: **Green Networks and People; a review of research and practice in the analysis and planning of multi-functional green networks**. *Scottish Natural Heritage Commissioned report No. 490.* 2011; 19.
Reference Source

Foster J, Lowe A, Winkelman S: **The Value Of Green Infrastructure For Urban Climate Adaptation**. *The Center for Clean Air Policy.* Washington, DC USA. 2011.
Reference Source

Gaffney C, Robertson C: **Smarter than Smart: Rio de Janeiro's Flawed Emergence as a Smart City.** *J Urban Technol.* 2018; **25**(3): 47–64.
Publisher Full Text

Gaston KJ, Ávila-Jiménez ML, Edmondson JL, *et al.*: **REVIEW: Managing urban ecosystems for goods and services.** *J Appl Ecol.* 2013; **50**(4): 830–840.
Publisher Full Text

Glass JH, Scott AJ, Price MF: **The power of the process: Co-producing a sustainability assessment toolkit for upland estate management in Scotland.** *Land Use Policy.* 2013; **30**(1): 254–265.
Publisher Full Text

Grace M, Proverbs D: **Review of the Natural Environment Research Council Green Infrastructure Innovation Programme**. 2017; Accessed 5th January 2018.
Reference Source

Grace MH, Scott AJ, Sadler JP, *et al.*: **Record of expert inputs shaping future city discourses for Urban Living Birmingham**. *NERC Environmental Information Data Centre.* 2019.
Publisher Full Text

Gulsrud NM, Raymond CM, Rutt RL, *et al.*: **'Rage against the machine'? The opportunities and risks concerning the automation of urban green infrastructure.** *Landscape Urban Plan.* 2018; **180**: 85–92.
Publisher Full Text

Hansen R, Pauleit S: **From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas.** *Ambio.* 2014; **43**(4): 516–529.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Hassan AM, Lee H: **The paradox of the sustainable city: definitions and examples.** *Environ Dev Sustain.* 2015; **17**(6): 1267–1285.
Publisher Full Text

Hernandez K, Roberts T: **Leaving No One Behind in a Digital World**. *K4D Emerging Issues Report.* Brighton, UK: Institute of Development Studies. 2018.
Reference Source

Hill C: **Defra's Earth Observations Centre of Excellence: driving innovation and change**. Earth Observation Programme, Defra digital, Earth Observation, Open data. 2016; [Accessed 9th May 2016].
Reference Source

Hou S: **The City Natural: Garden and Forest Magazine and the Rise of American Environmentalism**. Pittsburgh: University of Pittsburgh Press. 256 pages. ISBN: 978-08229-4423-2. Reviewed by MacDonald, Eric (2015) Landscape journal; Volume 33, Issue 2, Page 195-197.
Publisher Full Text

Hough M: **Cities and Natural Process: A Basis for Sustainability**. Taylor & Francis. 2004.
Publisher Full Text

Hulme D: **Artificial Intelligence in our Environment**. 2017; [Accessed 25th May 2017].

IPBES: **Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), UNESCO**. 2018; Accessed 24th April 2018.
Reference Source

IWUN: **Improving Wellbeing through Urban Nature**. University of Sheffield. 2017.
Reference Source

Jerome G, Sinnett D, Burgess S, *et al.*: **A framework for assessing the quality of green infrastructure in the built environment in the UK.** *Urban For Urban Gree.* 2019; **40**: 174–182.
Publisher Full Text

Kerslake B: **The way forward: an independent review of the governance and organisational capabilities of Birmingham City Council**. Department for

Communities and Local Government. 2014.
Reference Source

Leach JM, Mulhall RA, Rogers CDF, *et al.*: **Reading cities: Developing an urban diagnostics approach for identifying integrated urban problems with application to the city of Birmingham, UK.** *Cities.* 2018; **86**: 136–144.
Publisher Full Text

Lennon M: **Green infrastructure and planning policy: a critical assessment**. *Local Environment.* 2015; **20**(8): 957–980.
Publisher Full Text

Lennon M, Scott M: **Delivering ecosystems services via spatial planning: reviewing the possibilities and implications of a green infrastructure approach.** *Town Planning Review.* 2014; **85**(5): 563–587.
Publisher Full Text

Locke A, Grace M: **Telford Forest City.** *Town Country Plann.* 1993; **62**(11).

Lockwood M: **Good governance for terrestrial protected areas: A framework, principles and performance outcomes.** *J Environ Manage.* 2010; **91**(3): 754–766.
Publisher Full Text

Lord CP, Strauss E, Toffler A: **Natural Cities: Urban Ecology and the Restoration of Urban Ecosystems.** *Va Environ Law J.* 2003; **21**(3): 317–386.
Reference Source

Low N: **Ecosocialisation and environmental planning: A Polanyian approach.** *Environment and Planning A.* 2002; **34**(1): 43–60.
Publisher Full Text

Mace G: **Valuing Nature and the Sustainable Development Goals.** Keynote speech at the Valuing Nature Annual Conference, Edinburgh. 2017.
Reference Source

Mahmoud I, Morello E: **Co-Creation Pathway as a catalyst for implementing Nature-based Solution in Urban Regeneration Strategies; Learning from CLEVER Cities framework and Milan as test-bed.** *Urban Inf.* 2018; (Special issue No. 278).
Reference Source

Marsal-Llacuna M, Colomer-Llinàs J, Meléndez-Frigola J: **Lessons in urban monitoring taken from sustainable and livable cities to better address the Smart Cities initiative.** *Technol Forecast Soc.* 2015; **90**(Part B): 611–622.
Publisher Full Text

Matthews P: **Mind the Gap? The Persistence of Pathological Discourses in Urban Regeneration Policy.** *Housing, Theory and Society.* 2010; **27**(3): 221–240.
Publisher Full Text

McEwan K, Richardson M, Brindley P, *et al.*: **Shmapped: development of an app to record and promote the well-being benefits of noticing urban nature.** *Transl Behav Med.* 2019; pii: ibz027.
PubMed Abstract | **Publisher Full Text**

Metro Tunnel Living Infrastructure Plan: **Melbourne Metro Rail Authority**. PO Box 4509, Melbourne, VIC 3001. 2017.
Reference Source

Mell IC: **Aligning fragmented planning structures through a green infrastructure approach to urban development in the UK and USA.** *Urban For Urban Green.* 2014; **13**(4): 612–620.
Publisher Full Text

Natural Capital Committee: **Natural Capital Committee Advice to Government on the 25 Year Environment Plan**. 2017.
Reference Source

Naylor LA, Kippen H, Coombes MA, *et al.*: Greening the Grey: A Framework for Integrated Green Grey Infrastructure (IGGI). Technical Report. University of Glasgow, Glasgow. (In Press). Paper pending: **Developing a business case for greening hard coastal and estuarine infrastructure: preliminary results.** *Coasts, Marine Structures and Breakwaters.* 2017.
Reference Source

NESTA: **Rethinking Smart Cities from the Ground Up**. Saunders, T. & Baeck. P. for NESTA. 2015.
Reference Source

Newbold T, Hudson LN, Contu S, *et al.*: **Widespread winners and narrow-ranged losers: Land use homogenizes biodiversity in local assemblages worldwide.** *PLoS Biol.* 2018; **16**(12): e2006841.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Newcastle City Futures. 2017; Accessed 14th April 2018.
Reference Source

Newman P: **Biophilic urbanism: a case study on Singapore.** *Aust Planner.* 2014; **51**(1): 47–65.
Publisher Full Text

Noveck BS: **Smart Citizens, Smarter State: the technologies of expertise and the future of governing**. Harvard University Press, Cambridge, Massachusetts, and London, England. 2015; 261–264.
Publisher Full Text

Noveck BS: **Smart Citizens, Smarter State: the technologies of expertise and the future of governing**. Harvard University Press, Cambridge, Massachusetts, and London, England. 2015; 250.
Publisher Full Text

Porteous JD: **Smellscape.** *Prog Hum Geog.* 1985; **9**(3): 356–378.
Publisher Full Text

Ramaswami A, Russell AG, Culligan PJ, *et al.*: **Meta-principles for developing smart, sustainable, and healthy cities.** *Science.* 2016; **352**(6288): 940–943.
PubMed Abstract | **Publisher Full Text**

Ravetz J: **Chapter 6: Sustainable urban futures: contested transitions and creative pathways**. In: K. Archer and K. Bezdecny, *Handbook of Cities and the Environment*, 1st ed. Edward Elgar Publishing. 2016; 143.
Publisher Full Text

Ravetz J: **From 'smart' cities to 'wise': pathways for collective urban intelligence**. In: J. Bylund (ed.), *Connecting the dots by obstacles? Friction and traction ahead for the SRIA urban transitions pathways.* JPI Urban Europe, Vienna. 2018.
Reference Source

Reeve A, Desha C, Hargreaves D, *et al.*: **Biophilic urbanism: contributions to holistic urban greening for urban renewal.** *Smart and Sustainable Built Environment.* 2015; **4**(2): 215–233.
Publisher Full Text

Roberts HV: **Using Twitter data in urban green space research: A case study and critical evaluation.** *Appl Geogr.* 2017; **81**: 13–20.
Publisher Full Text

Roberts H, Resch B, Sadler J, *et al.*: **Investigating the Emotional Responses of Individuals to Urban Green Space Using Twitter Data: A Critical Comparison of Three Different Methods of Sentiment Analysis.** *Urban Plan.* 2018; **3**(1): 21–33.
Publisher Full Text

Rogers EM: **Diffusion of Innovations**. 5th edition. London: Simon & Schuster, 2003.
Reference Source

Sadler J, Grayson N, Hale J, *et al.*: **The Little Book of ECOSYSTEM SERVICES in the city**. Imagination Lancaster, Lancaster University, 2018; ISBN 978-0-70442-956-7.
Reference Source

Sagl G, Resch B, Blaschke T: **Contextual Sensing: Integrating Contextual Information with Human and Technical Geo-Sensor Information for Smart Cities**. *Sensors (Basel).* 2015; **15**(7): 17013–17035.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Scott AJ, Carter C, Hardman M, *et al.*: **Mainstreaming ecosystem science in spatial planning practice: exploiting a hybrid opportunity space.** *Land Use Policy.* 2018; **70**: 232–246.
Publisher Full Text

Scott AJ, Carter C, Reed MR, *et al.*: **Disintegrated Development at the Rural Urban Fringe: re-connecting spatial planning theory and practice.** *Prog Plann.* 2013; **83**: 1–52.
Publisher Full Text

Scott AJ, Christie M, Midmore P: **Impact of the 2001 foot-and-mouth disease outbreak in Britain: implications for rural studies.** *J Rural Stud.* 2004; **20**(1): 1–14.
Publisher Full Text

Scott AJ: **Mainstreaming the Environment in Planning Policy and Decision Making (in press)**. Chapter 38 for *Routledge Companion to Environmental Planning and Sustainability.* editors Davoudi, S. *et al.*, 2019.

Scott AJ, Hislop M: **What does good GI policy look like?** *Town and Country Planning.* 2019; **88**(5): 177–184.
Reference Source

Seresinhe CI, Preis T, Moat HS: **Using deep learning to quantify the beauty of outdoor places.** *R Soc Open Sci.* 2017; **4**(7): 170170.
PubMed Abstract | **Publisher Full Text** | **Free Full Text**

Singapore Government. 2016.
Reference Source

Spash CL: **How much is that ecosystem in the window? The one with the biodiverse trail.** *Environ Values.* 2008; **17**(2): 259–284.
Publisher Full Text

Stefanovic IL, Scharper SB: **The Natural City: Re-envisioning the Built Environment**. University of Toronto Press, 2011; 356.
Publisher Full Text

Stimmel CL: **Building Smart Cities P5**. CRC Press. [Accessed 5 March 2018]. 2015.
Reference Source

Tewdwr-Jones M, Goddard J, Cowie P: **Newcastle City Futures 2065: Anchoring universities in urban regions through city foresight.** Newcastle Institute for Social Renewal, Newcastle University, Newcastle. 2015.
Reference Source

The UK National Ecosystem Assessment (UK NEA 2011). Accessed 12th May 2017.
Reference Source

Tress G, Tress B, Fry G: **Clarifying integrative research concepts in landscape ecology.** *Landsc Ecol.* 2005; **20**(4): 479–493.
Publisher Full Text

Tu W, Zhongwen H, Lefei L, *et al.*: **Portraying Urban Functional Zones by Coupling Remote Sensing Imagery and Human Sensing Data.** *Remote Sensing.* 2018; **10**(1): 141.
Publisher Full Text

UK National Ecosystem Assessment: **The UK National Ecosystem Assessment: Synthesis of the Key Findings**. UNEP-WCMC, LWEC, UK. 2014.
Reference Source

UN-Habitat: **The Challenge of Local Government Financing in Developing**

Countries. United Nations Human Settlements Programme (UN-Habitat), the City of Barcelona and the Province of Barcelona. 2014; 19th August 2014.
Reference Source

UN Habitat: World Cities Report 2016: **Urbanization and Development–Emerging Futures**. Publisher: UN-Habitat; HS Number: HS/038/16E. 2016; 262. ISBN: 978-92-1-132708-3.
Reference Source

United Nations: **The 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development**. 2016; Adopted by world leaders in September 2015.
Reference Source

United Nations: **World Urbanization Prospects 2018: Key Facts.** DESA/ POPULATION DIVISION. 2018; Accessed 17th May 2018.
Reference Source

Viitanen J, Kingston R: **Smart cities and green growth: outsourcing democratic and environmental resilience to the global technology sector.** *ENVIRON PLANN A.* 2014; **46**: 803–819.
Publisher Full Text

WWF: **Living Planet Report - 2018: Aiming Higher**. Grooten, M. and Almond, R.E.A. (Eds). WWF, Gland, Switzerland. 2018.
Reference Source

Zheng YL, Wolfson O, Yang H: **Urban computing: Concepts, methodologies, and applications.** *ACM Trans Intell Syst Technol.* 2014; **5**: 55.
Publisher Full Text