RESEARCH ARTICLE

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

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

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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, fueling a significant research and policy agenda focussed on data-led solutions to urbanisation challenges (Buck & White, 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 ecol’ 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 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 usedcritically 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 & Zarlanga, 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>
<thead>
<tr>
<th>Thematic propositions</th>
<th>Research challenges</th>
</tr>
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<tbody>
<tr>
<td><strong>Taking a ‘whole city’ approach</strong></td>
<td>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?</td>
</tr>
<tr>
<td><strong>The value of green and the rise of smart</strong></td>
<td>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?</td>
</tr>
<tr>
<td><strong>People and their connection with the city</strong></td>
<td>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?</td>
</tr>
<tr>
<td><strong>Infrastructure and a systems perspective</strong></td>
<td>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.</td>
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![Figure 1. Research methodology.](image-url)
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
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>
<thead>
<tr>
<th>Expert Contributors and selected topic</th>
<th>Date and form of discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Birmingham City University Computing, Engineering and Built Environment Faculty staff and post-graduate students [15 attendees]; HS2 and city centre redevelopment</td>
<td>Seminar on 4th October 2017</td>
</tr>
<tr>
<td>2 Innovation workshop attendee - Independent Consultant; future commercial viability of city parks and green spaces.</td>
<td>By teleconference on 17th October 2017</td>
</tr>
<tr>
<td>3 Innovation workshop attendee - Senior Officer local authority – Growth; High Speed 2 and associated regeneration</td>
<td>Meeting on 17th October 2017</td>
</tr>
<tr>
<td>4 Senior Officer local authority – Development; City centre development and associated regeneration</td>
<td>Meeting on 17th October 2017</td>
</tr>
<tr>
<td>5 Innovation workshop attendee - Director – Health &amp; Well-being; Green spaces and opportunity for innovation in community health service delivery</td>
<td>By teleconference on 17th October 2017</td>
</tr>
<tr>
<td>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</td>
<td>By teleconference on 13th October 2017</td>
</tr>
<tr>
<td>7 Innovation workshop attendee - Development company, Director; new settlement development</td>
<td>Meeting 25th October 2017</td>
</tr>
<tr>
<td>8 Innovation workshop attendee - Consultancy Smart Cities, Director; new urban development</td>
<td>By email during October 2017</td>
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<tr>
<td>9 Innovation workshop attendee - Academic; the challenge of air quality especially around schools,</td>
<td>By email during October 2017</td>
</tr>
<tr>
<td>10 Academic; Housing issues</td>
<td>By email 16th October 2017</td>
</tr>
<tr>
<td>11 Academic and Project Manager; new housing development</td>
<td>Meeting 20th October 2017</td>
</tr>
<tr>
<td>12 Academic and Project Manager; the operation (individually and collectively) of UK (and international) cities to enable best practice</td>
<td>By email 8th November 2017</td>
</tr>
</tbody>
</table>
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.

**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

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**Figure 3. The characteristics of the Smart – Natural Interface: connectivity at the hub.**
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 characterisation 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 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 & Paulet, 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 ‘scenicsness’ 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 & Zarlanga (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 disfunctionality 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-Group2draftnarrative-Anonymised2A.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 (Metadata 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-NERCDatasetSupportingInformation.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.

This data is available under the terms of the the Open Government Licence v3 (OGL).

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