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Delivering sustainable, resilient and liveable cities via transformed governance

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In the context of steadily declining Natural Capital and universal recognition of the imperative to reverse this trend before we get to the point that nature is not able to restore itself, cities have a crucial role to play. The UK Government commissioned a comprehensive study into the value of biodiversity, and by extension nature, reinforcing "why we should change our ways"—yet what is missing is the "how?". This paper uniquely describes both the "how?" and a conclusive demonstration of the remarkable benefits of implementing it in a city. Critical to this process, it took a UK Parliamentary Inquiry to reveal that nature has become invisible within the economy, yet the ecological ecosystem services nature provides have enormous benefits to both people and the economy. Therefore integration—or seamless weaving—of urban greenspace and nature into people's lives and the places where they live, work, and spend their leisure time is vital. Moreover, what nature does not provide must be provided by engineered systems, and these have an economic cost; put another way, there are enormous cost savings to be made by taking advantage of what nature provides. In addressing these issues, this paper is the definitive paper from a 20-year portfolio of research on how to bring about transformative change in the complex system-of-systems that make up our cities, providing as it does the crucial in-depth research into the many diverse strands of governance—the last link in a chain of the creation, testing and proof of efficacy of methodologies underpinning a theory and practice of change for infrastructure and cities. The impact of this portfolio of research on Birmingham is two-fold: the Star Framework that placed natural environment considerations at the heart of all decision-making in the city, and the successful bid for the largest of the UK Future Parks Accelerator awards. While both are transformative in their different ways, yet mutually supportive, the latter enabled the design of a suite of system interventions from which the value of Birmingham's greenspaces is estimated to rise from £11.0 billion to £14.4 billion—a remarkable return on investment from the research's conceptualization of Birmingham's urban greenspace as a "business" (with its associated business models). In achieving this, the necessary enablers of thinking and practicing systemically, seamlessly working across disciplinary boundaries, an unusually strong focus on both the aspirations of all stakeholders and the context in question to define "the problem," and the testing of proposed system intervention(s) both now and in the future have been iteratively combined. However, it is the critical enabling steps of identifying the complete range of value-generating opportunities that

the interventions offer, formulating them into alternative business models to underpin the case for change and ensuring that they are synergistic with all the dimensions of governance that yielded the profound outcomes sought.

KEYWORDS

infrastructure, cities, governance, urban systems, transformation, framework, business models, business case

1 Introduction

Cities are places that accommodate communities of people and the multiple activities with which they engage. Originally, people came together in settlements according to relatively few essential criteria: a place where trade, especially in food, could take place, a place of safety and a place where shelter could be provided and clean water obtained. Nowadays, they are far more complex compilations of systems-of-systems in which very large numbers of people live, work and engage in leisure activities. Cityscapes are an amalgam of residential, commercial, retail, industry, leisure, transport, open spaces, green and blue spaces, and much more. They are places of business, busyness and peaceful solitude: places for dynamic 24-hour city living and places where one can escape from this dynamism. They must also be places in which biodiversity can flourish, not least because human interaction with nature is crucial for health and wellbeing (Shanahan et al., 2015; Cox et al., 2017).

> "*Part of the great pleasure of living in a city is discovering the many forms of nature in unexpected places. Some of this nature is designed, of course, but much of it is simply extant, and resiliently co-adapting to urban conditions… Over the course of a day there are typically numerous opportunities to be surprised (pleasantly) by the nature around us, as it appears and disappears from view (a bird, a mushroom, a flower), and appears again, depending on season, weather, and on the pathways and routes we choose to travel. Discovery and surprise, the possibility of epiphanous moments of delight, are part of what makes living in a biophilic city so much fun.*"
>
> Prof. Tim Beatley, 13 October 2014 (BC, 2023)

By accommodating such a breadth of form and purpose, cities are by their nature places that offer very many opportunities, and yet they present very many challenges as a result of the way that they operate. Every city is unique because of its geographical and historical context, the size of its population and its demography, and how it fits into its local, national and global context. In many ways, cities have to be all things to all those who use them. Put another way, communities and individuals seek many different things from – they have many different aspirations for – their cities, and, indeed, they seek different things at different times: different people in the same community, or even the same individual, will both welcome the excitement and dynamism of the 24-hour city and will seek places of peaceful solitude where they can immerse themselves in the culture of the place and commune with nature.

Cities must therefore deliver multiple functions, and they must create and/or accommodate infrastructure and urban systems that are operated, maintained and progressively updated to deliver these functions. In the UK, and in most developed nations, there is a deeply ingrained legacy of the past that has shaped the present cityscapes, which in turn provide the starting points for improvement. Most obviously they have been shaped by changing points of focus created by their transport systems: local roads to market for local trading were complemented by rivers that provided the first means of mass transport, and the ports would provide the eye of the local distribution networks. This pattern was followed by artificial rivers (the canals that followed the ground's contours) with wharves providing different points of focus, then trains forcing their way through the landscape on routes dictated by gradients, and then even more pervasive major road networks that were not so strongly limited by topography, and then airports providing further shifts. All these developments came with their own supporting infrastructures and systems of operation, and most can still be seen reflected in the cityscapes of today, and so continue to influence the operation of today's systems.

Cities are equally places of invention in which the entrepreneurial spirit can thrive. Cities provide the engines, or at least enthusiastically facilitate the engines, for economic activity and form hubs for the, not necessarily quite as well justified, continued pursuit for ever-greater economic growth. A thriving economy supports individuals and society, and forms one pillar of the universally-accepted performance criteria of sustainability (Brundtland, 1987) – a future-looking aspiration common to all cities and their urban systems. In the debate here about balancing cities and their systems across the three pillars of sustainability (economy, society, and environment) lies the distinction between economic growth and economic stability. Nevertheless, cities are places of business and fail to perform well unless they are economically successful.

Alongside sustainability as a primary criterion for successful cities lie two further well-established criteria (Rogers, 2018). The first is resilience: ensuring that our cities, and the infrastructure and urban systems that support them, continue to function effectively in the face of contextual change, no matter the nature of that change nor the rate at which that change occurs (Rogers et al., 2012a). While climate change often dominates the debate on resilience, there are several other important influences (e.g., population growth and migration, demographic change, the emergence of new technologies, resource scarcity and resource security). As for all cities, resilience naturally features in the policies and plans for Birmingham [BCC (2021a), describes its approach to transport resilience; e.g., its 12-point plan is outlined in BCC (2023)] and the wider West Midlands region (WMCA, 2023), and experiences from the region and the UK more widely have fed into EU

policies and strategies (Climate ADAPT, 2023a,b). Although not covered in detail herein, we point later to the work encapsulated in *Designing Resilient Cities* (Lombardi et al., 2012) to describe how we test a proposed action for likely vulnerability to contextual change. The second is liveability. Arguably this is already covered by the societal pillar of sustainability, and yet people often get overlooked; liveability explicitly puts people and communities at the centre of a city's thinking, embracing health and wellbeing, for which there is an allied need to look after planetary health and wellbeing (Leach et al., 2016, 2017). Indeed, there are multiple interdependencies between all three broad criteria, yet this is not an impediment to analysis since siloed thinking gets in the way of understanding. Systems are no respecters of silos, and it is systemic thinking and practices that are needed when addressing such complex problems as cities pose (Hall et al., 2016a; Janssen et al., 2022).

Many cities have been bold in announcing their aspirations to be sustainable, resilient, liveable and smart, albeit using a variety of language in articulating these intentions. 'Urban transitions' with regard to governance have explored using innovation and experimentation to deal with the multiple uncertainties faced by cities, including resilience when confronted with a shock event (Ernstson et al., 2010). The ongoing crystallisation of the climate change crisis has given rise to a focus upon 'just urban transitions', "*the fusion of climate action and justice concerns at the urban scale*" (Hughes and Hoffmann, 2020). Much research time, effort and funding has been devoted to understanding and characterising cities that meet the criteria for sustainability, liveability, resilience and smartness (Climate ADAPT, 2023a,b), and to developing methods to transition from an imperfect present to deliver, now and in the future, better performance from urban systems and the infrastructure systems that support them (Hillier et al., 2019; Scott and Hislop, 2020; Grace et al., 2021; TABLES, 2023). It has become universally acknowledged that all stakeholders – especially the primary cohort of users for whom the systems provide support (either directly or indirectly) and those responsible for operating and governing the systems – should co-create these systems from their conception through to detailed design, operation and retirement (Ataman and Tuncer, 2022). This represents an important change from traditional practice whereby those who govern create policies and strategies that they believe will be good for the users, and infrastructure and urban system providers respond by designing, constructing and operating their systems *on the basis of perceived need* (predicting what people will need or want), and then offer them to users *in the hope and expectation* that they will be enthusiastically welcomed and used. Co-creation – of visions (aspirations), policies, designs of system interventions, and their implementation and operation – removes these uncertainties (Bartle et al., 2018). Extending this argument further, both those who govern and the ultimate end users should also be directly engaged in the research programmes that seek to create better systems of service delivery.

Moreover, cities have to take cognisance of, and respond to, a wide range of global, national and local priorities. The global priorities include the UN Sustainable Development Goals (SDGs; UN, 2015a), and the UN Habitat approaches that seek to put the UN SDGs into practice. Naturally, they take a whole-planet perspective in considering societal and planetary wellbeing, for example raising awareness of the health and wellbeing benefits of interaction with nature and spawning initiatives such as Building with Nature (2023). Integration of nature into people's daily lives results in the consumption of ecological ecosystem services (Sadler et al., 2016), and is perhaps achieved most easily via initiatives such as pervasive, connected green infrastructure corridors to facilitate active travel to enable people and wildlife to move through urban areas (Rogers and Hunt, 2019; Cavada et al., 2021). Such joined-up, holistic thinking would benefit towns and cities in almost any context.

There is little disagreement about the relevance of such global priorities, and they have stood the test of time. The only issue with their implementation is whether governments choose to proclaim their importance and reflect them in their own national and local priorities. National and local priorities, on the other hand, vary enormously depending upon the political views of those who govern. While some policies do persist – for example, the move towards Net Zero – the importance attached to them, and thus their rate of implementation, varies; however, there are many policies that simply emerge and then disappear. The one comfort in this is that national and local politicians are only in a position to govern if they are elected by the populace to do so (at least in democracies), and therefore policies are usually underpinned in some way by a consideration of the 'common good'.

This discussion lands with a variously implied and explicitly-stated need for both cities and society (individuals and their collective) to shape the ways that cities operate with good intentions in mind – a feature of cities, and indeed of all places, that combines under the umbrella term of "governance". Top-down governance refers to governing (e.g., by local and national government), which seeks to create and implement rules, whereas bottom-up governance refers to the informal ways in which society and organisations combine to make urban systems work.

The need for governance is perhaps most starkly emphasised by the 'tragedy of the commons' (Hardin, 1968). This thinking suggests that if consumption of common resources is unregulated (either top-down by imposed 'rules' or bottom-up by the collective actions of citizens to discourage such actions; see Ostrom, 1990), those in a position to do so will obtain and consume more than their fair share. Infrastructure and urban systems represent many of the common resources in cities, and their construction and operation should be governed by a sense of social justice (e.g., see Shrimpton et al., 2021). The means of control include both formal and informal forms of governance (Scott, 2019a,b). The formal forms of governance include legislation, regulation, codes and standards, taxation and incentives – the various levers that can be pulled from the top-down perspective. The informal forms of governance include individual and societal attitudes and behaviours (see Topal et al., 2021), social norms, practice norms and other bottom-up influences on how societies operate. The ultimate bottom-up influence is, of course, the election to power of local and national governments in the

expectation that elected members will enact the wishes of the people; this is where the bottom-up and top-down processes of governance meet.

While there is a need for those who govern to take into consideration all of the above arguments and put in place the policies and strategies that deliver successful and balanced outcomes, this paper argues that there is a further dimension that exists but is implicit rather than explicit: governance should be formulated in a manner that is receptive to changes that will enable the sustainability, resilience and liveability criteria to be met. It is not just policies and strategies that are important, but also a willingness to be sufficiently agile to adjust them as contexts change and new technologies emerge. It has been famously said that alongside the quote of Alberto Villoldo (2014) "*there are those who follow maps and those who make them*" – "for cities, there is no map." This aligns perfectly with the arguments put forward in this paper that cities are complex systems of systems, and the consequences of a systemic intervention – whether a policy, technological development, the construction of a piece of infrastructure, a change of operational system protocols, altered citizens behaviours or suchlike – cannot be predicted with certainty. We have to 'learn while advancing' and 'advance in response to learning', and this is just as true for governance as any other aspect of cities.

One crucial, and dominant, feature of cities is the natural environment in which they are embedded, which policies and strategies seek to enrich (Scott et al., 2013). Quite apart from the global perspective of planetary protection, nature in cities provides a plethora of ecological ecosystem services (ESS, see Sadler et al., 2016; Scott, 2019b; Grace et al., 2021) that benefit people in cities in myriad ways. However, this suite of natural benefits is under threat. The Natural Capital that provides Ecological Ecosystem Services (EESs) has been diminishing over recent years, with calls for its restoration (NCC, 2014) being refined to its protection and improvement (NCC, 2015), as shown in Figure 1. Natural Capital can be defined as the world's stock of natural assets which include geology, soil, air, water and all living things (NCC, 2013) and is described in context in the 'Five Capitals' model (Forum for the Future, 2022). It is from this Natural Capital that humans derive such a wide range of services (the EESs) and indeed it can justifiably be claimed to be the very source of all human activity, health, wealth and happiness (e.g., English Nature, 2006; Gibbons et al., 2013). It is for the restoration, protection and enhancement of this Natural Capital that governance regimes must strive, and the starting point for any city must be a comprehensive and detailed understanding of its Natural Capital – this is a critical element of the context that must influence holistic designs for systemic change.

Bucking such a downward trend in Natural Capital provision is enormously challenging and a sudden transformation is impossible, as illustrated by the Natural Capital Committee (Figure 1). NCC's (2015) report in essence led to the UK Government's commitment to a 25-year environment plan (DEFRA, 2018). The Paris Climate Accord of 2015 (UN, 2015b) introduced the ratchet principle, which has been overlaid onto this graph to emphasise the point that it is through capacity building that this transformation will be achieved, not through the action of any single environment department or city service (NEA, 2011). If this ambition to reverse the decline in Natural Capital is to be achieved, a clear understanding and mapping of the factors and agencies responsible for it is required. The decline can in part be attributed to the way Natural Capital has always been treated as a regenerative commodity, and therefore by implication one that could be continuously exploited without the need to reinvest. Many of those who have benefitted from this 'nature-take' are often 'hidden beneficiaries', and it is these beneficiaries (identifiable from the system maps described later) who now need to form part of the reinvestment, restoration and improvement solution. Convening and engaging these stakeholders would form a vital element of a new capacity-building effort, which in turn needs to be built into any new governance model.

Figure 1 also depicts what is likely to happen if decision-makers choose to do nothing: a continuation of the red line illustrating continued decline of the natural environment. This could reach the point beyond which nature cannot restore itself and our attempts to effect restoration are too late to be effective. Taking this back to the first principles established in the Five Capitals model, such a position would simply be 'terminal' for either the human race or the place being governed.

This paper addresses the pressing contemporary research question of whether the availability of new types of environmental data and understanding can result in a transformational change to the ways in which cities are governed for sustainability, or whether economic and social concerns will dominate – *could environmental considerations ever truly be become pervasive in city governance?* In answering this question, the paper focuses on a research programme that created a generic framework to facilitate changes to the governance regime in towns or cities. This was both shaped and trialled with Birmingham City Council to support the growth of Natural Capital by putting natural environmental considerations at the heart of all its decision-making, recognising that in so doing it will beneficially impact on every aspect of city life. Birmingham City Council has a long tradition of links and joint projects with its city universities – The University of Birmingham, University of Aston and Birmingham City University – spanning two decades (Rogers, 2018; Cavada et al., 2021; Grace et al., 2021). While acknowledging that many of the City policy statements (e.g., Green Infrastructure policy) draw on this research, this paper describes its crystallisation in a collaboration between the City and academics at the University of Birmingham, and elsewhere, funded by the Engineering and Physical Sciences Research Council (EPSRC). This research programme, *Liveable Cities*, enabled a trajectory for city improvement to be defined, methodologies targeted at the delivery of multiple benefits from urban system interventions to be refined and adapted to the local context, and the creation of receptive governance by the City to be introduced so that the sustainability, resilience and liveability criteria can be more effectively embraced. In essence, the paper explores the nature and extent of the evidence base needed to design and implement programmes of transformational change in governance for any city. It challenges the notion that change is something that happens and needs to be responded to or that (beneficial) change is just something to be hoped for, but demonstrates that change is something that can be *planned* (Rogers et al., 2022) and that systems

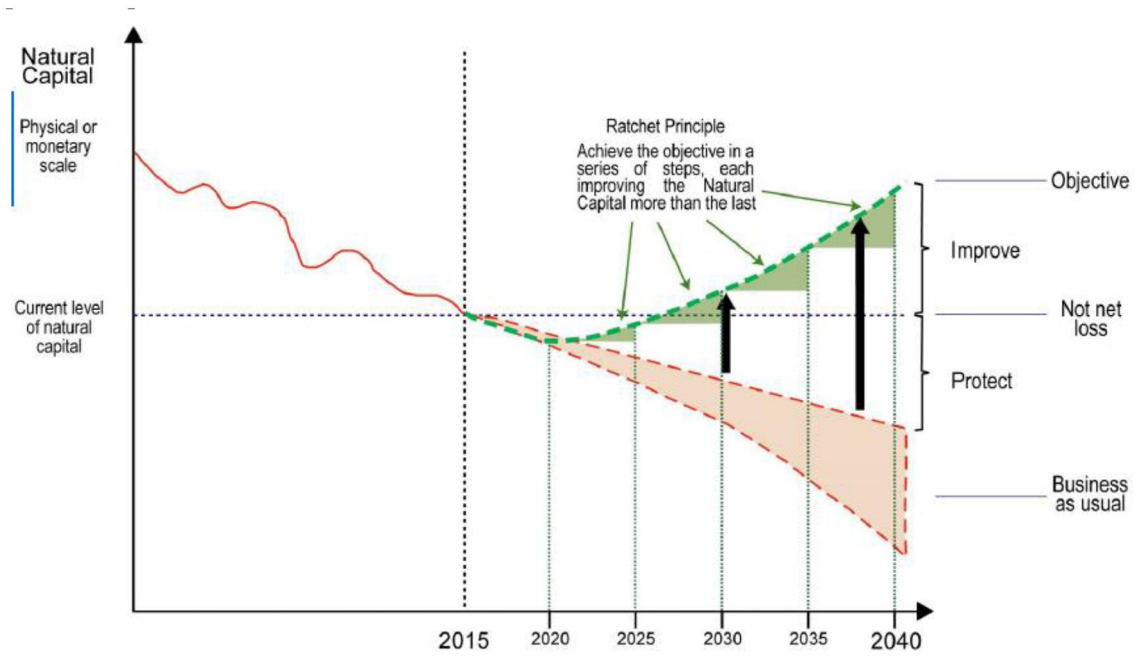

FIGURE 1
Protecting and improving natural capital over a generation – a stylised interpretation [adapted from NCC (2015)].

of governance to enable this change to happen effectively can be engineered in the same way as artefacts or operational protocols.

2 Methodologies for the design and operation of a city's system-of-systems

A complementary suite of methodologies to enable effective change to happen via interventions in a city's system-of-systems has been created over the past 20 years via highly multidisciplinary, cross-university research programmes (Rogers, 2018). This necessarily collaborative approach to researching and creating more sustainable, resilient and liveable cities, and the infrastructure systems that support them, is now being advanced by the UK Collaboratorium for Research on Infrastructure and Cities (Rogers et al., 2022; UKCRIC, 2022). The methodologies by necessity draw on the very considerable evidence base on urban sustainability, resilience, liveability, adaptability, and smartness, noting the current authors' contention that 'smartness' is only truly smart if 'smart interventions' lead to enhanced urban sustainability, resilience and/or liveability (Cavada and Rogers, 2019; Grace et al., 2021). Importantly, they have been devised not to dictate solutions, but to help those responsible for commissioning, designing, constructing, operating and refining our infrastructure and urban systems to make better informed decisions. In the context of this paper, the interventions could relate to policies, strategies, practices and/or technologies that are aimed at restoring, protecting or enhancing Natural Capital (and the EESs they provide), and in every case they would specifically include the role of governance as an enabler of achieving this efficiently and effectively in any city and context.

The guidance takes the form of a series of steps that draw on the evidence base to enable significant systemic interventions to be properly developed. A vital component is to identify the complete range of potential benefits that could be delivered by adopting alternative policies, strategies, practices or technologies, while taking into account a deep understanding of the context in which the intervention is to be made. Only then can an adequate case for change be made. However, effective change will only happen if the alternative business models are created and supported by compelling business cases. Business models are narratives of value generation and capture (Magretta, 2002) and therefore, in essence, can be seen as balancing all positive consequences (economic, social, environmental, cultural, political) of a systemic intervention with all negative consequences (which include the financial investment required), both now and in the future. It is by drawing on the comprehensive, transparent, evidence-based business models, created (like the design options) in response to policies (in BCC's case, shaped by the research from Birmingham's universities reported herein), that compelling business cases can be drafted and financial resources secured. Finally, the formal and informal rules of governance need to be identified and analysed, and, where necessary, changes to these systems of governance must be made, or recommended, to ensure that the business models deliver their desired outcomes. The reason for outlining these important elements of the process here is that awareness of each of them, and indeed awareness of every stage, is necessary before starting to consider how our current infrastructure and urban systems could be improved. Furthermore, iteration is necessary throughout the process since such circularity in thinking will result

in far more effective outcomes than a linear process (one which adopts linear thinking) would provide.

Consideration of clearly defined, multi-stranded indicators is essential here (Carhart et al., 2016), as is the ability to track change, not only of an organisation or of a place, but across the stakeholder group. Such tracking will ensure all parties are effectively playing their part in the solution (this is a key facet of co-conception and co-design) and not just benefitting without contributing. This reflects another crucial point about the need for thinking and working seamlessly across the siloed structures that we have created (academic disciplines, government departments, industrial and business sectors, regulatory bodies, the voluntary/third sector, residents and community groups, etc.) if the complete range of potential benefits are to be identified and delivered, and hence interventions are to be truly effective. Siloed thinking all too often follows from linear approaches.

The steps in the process and the associated methodologies (see Rogers et al., 2022) are summarised hereafter, together with an indication of how a City Council, or equally Town Council, should be involved.

1. Stakeholder Identification. To address a specific problem or bring about an improvement in a city, it is essential to identify and assemble all relevant stakeholders. This will almost certainly result in the convening of a broad, multi-disciplinary, multi-sectoral group of potentially interested parties who are able to represent the views of all stakeholders influenced by, or who influence, the problem and its potential solutions. It is equally important to provide each member of the group with the same opportunity to contribute. This requires all involved to be open to collaboration and be willing to move towards transdisciplinarity. What this essentially means is a willingness to become sufficiently well versed in all others' spheres of operation to be able to challenge each other with confidence – a trait needed for systemic change (Leach and Rogers, 2020). Techniques have been developed to make public engagement effective (e.g., Wilson et al., 2019). The City Council is evidently a key stakeholder, no matter what the intervention.
2. Establish Stakeholder Aspirations. It is essential to understand the aspirations of all the stakeholder communities involved (Rogers and Hunt, 2019). At its most basic level this means establishing the aspirations of the city governors and leaders (a top-down perspective) and of those people who live, work, spend leisure time and otherwise engage with the city (a bottom-up perspective). The aspirations of the other stakeholders will fit somewhere on this spectrum. Once again, the City Council is at the core of this process, noting that its aspirations will commonly be centred on what is considered good for its citizens.
3. Understand the Context. As alluded to earlier, it is necessary to understand the context in which the city exists, both its current context and its historical development. This provides the foundation for a city narrative into which proposed interventions would fit. This narrative will be important in communicating the reasons for change and gaining public support, and the City Council would be well placed to contribute. An illustration of this point can be found through an analysis of the evidence collected through the Parliamentary Inquiry 2016–17 "Future of Public Parks" (HC, 2017). The Inquiry posed 3 simple questions, the first of which was: what are the challenges facing parks? The most common answer was a lack of revenue funding. When digging deeper into that position, what emerges is not a lack of funding but (more importantly) a lack of identity. This links back directly to Figure 1, insofar as 'nature' has become invisible within the economy and within cities, and yet the EESs it provides has enormous economic consequences. The historical context and identity of parks in cities, as defined by the Victorians, was that they were to serve as *'destinations'*. Once you map all the twenty-first century challenges cities face, the role and identity of parks (and city green space more generally) then has to evolve into one of *'integration'* – both integrated into the fabric of the city as a pervasive thread of nature woven into the cityscape (termed by some authors 'green infrastructure') and integrated into the governance model for the place.
4. Establish Baseline Performance. It is clearly necessary also to establish the baseline performance of the city in terms of its sustainability, resilience and liveability, using one of the many frameworks (e.g., Boyko et al., 2012; Pearce et al., 2012; Hall et al., 2016b; Leach et al., 2016, 2017). The City Council will necessarily have had a large influence on the outcomes of this assessment due to the way in which it has governed to this point; its efficacy in doing so will *de facto* be judged by this independent analysis (Hislop et al., 2019).
5. Problem Diagnostics. A detailed diagnosis of the problems raised by the stakeholders should be conducted, both as defined in the literature (including the grey literature) and revealed by the above performance analysis (Leach et al., 2019). The City Council will be exceptionally well placed to advise and contribute since it will have engaged in this activity intensively.
6. Application of Professional Expertise and Ingenuity. Only now should ingenuity be applied to create solutions to the problems, yielding a number of alternatives from which to choose the most appropriate (see below). This is typically the role of the urban professionals, albeit informed by the views of the stakeholders, including the City Council, who will have an intimate knowledge of the way the systems currently operate; they will be well-placed to advise on potential issues that those coming to the context from the outside might miss.
7. Determine Immediate Impact. The impact of the solutions on the city's urban and infrastructure systems should be assessed using one of the many sustainability assessment frameworks (Arcadis, 2022; EC, 2023), resilience frameworks (Lombardi et al., 2012; Rockerfeller Foundation, 2023, though see also the next step) and liveability frameworks (Leach et al., 2020; EIU, 2023), with their particular focus on the environmental aspects of liveability (Convention on Biological Diversity, 2013; BC, 2023). A more global touchstone for assessing cities is provided by the UN Sustainable Development Goals, and in particular Goal 11: Make cities inclusive, safe, resilient and sustainable (UN, 2015a). This process is aided by an understanding of how the system of interest – that of the proposed solutions, or system interventions – interact with the other infrastructure and urban systems. System mapping provides graphical evidence of the system interdependencies (see Cavada et al., 2021; Rogers et al.,

2022), which can then be explored for the likely impacts of implementing the solution. The City Council here will adopt the role of a stakeholder commentator and share experiences with others in local government (e.g., via networks such as ICLEI, 2022).

8. Determine Likely Future Impact. A futures analysis, using fully characterised extreme-yet-plausible future scenarios in which to trial the designs, is conducted to explore whether the system interventions are likely to be resilient to future contextual change (Lombardi et al., 2012; Rogers et al., 2012b), i.e., will they continue to deliver their benefits (and prove to be a good investment) into the long-term? Once again, the City Council will be a stakeholder contributor, albeit a well-informed stakeholder regarding the context.
9. Application of Modelling. Futures analyses are complemented by modelling to simulate present and future performance, both without and with the system intervention in place (e.g., Hall et al., 2014). The City Council will likewise be a stakeholder contributor.
10. Formulation of "Business Models". A suite of alternative 'business models' can then be created that capture the different forms of value that might be generated by the intervention(s), using the system maps to aid in the identification of all potential positive consequences and all potential negative consequences of the intervention(s). Different stakeholders will associate with different benefits, resulting in some of the alternative business models, while iteration of the solutions will likewise provide different sets of benefits and adverse consequences, and hence different business models (Bouch et al., 2018; Cavada et al., 2021). Apart from contributing via informed comments, the City Council will be one of the stakeholders for which business models will be formulated; the City Council has much to gain or lose as a result of systemic interventions.
11. Case for Change. The case for change can then be made – establishing a compelling 'business case' for the proposed intervention based on both the primary purpose and sustainability, resilience and liveability considerations, drawing on the stakeholders for comment and refinement (the City Council is one of many).
12. Alignment of Systems of Governance. The above processes should be complemented by identification and analysis of all the dimensions of governance relevant to the intervention and the context in which it is to be implemented, and where necessary, and possible, recommendations for change should be made so that the intervention can be implemented effectively and the business models operate successfully (Shrimpton et al., 2022). This is where the City Council will have very much to contribute. In support of this action in Birmingham, the Future Parks Accelerator (FPA) programme (see Section 3.3) provided the 'five themes' approach, having identified from live city trials the governance gaps that would require closing to ensure any change became embedded (FPA, 2018). These five themes also mimic the Five Capitals, which in turn prompts circular economy thinking.
13. Influencing Policy. Policy should be influenced by drawing on research findings to help shape local (i.e., the City Council) and national government policy, and make the case for the intervention(s) to policymakers. This is where the 'bridge' provided by the BCC secondment in *Liveable Cities* proved so effective, by introducing the research team directly to the elected Councillors to build trust, drawing them into free-thinking workshops, facilitating direct dissemination and introducing an unparalleled connexion to the evidence base. It is this latter point, in particular, that engenders confidence in decision making, and City Councils should consider (ideally local) academic collaboration to help the connection with the academic literature.
14. Influencing Practice. Practice should be influenced by providing guidance to urban professionals so that they make better informed decisions. The City Council will be a passive commentator here.
15. Public Engagement. Finally, the public must be informed about and engaged with the issues and the proposed system interventions, drawing on the narrative referred to above. The City Council will have a considerable interest in how these messages are formulated and delivered, though this task will have been made easier by the thread of co-creation with end users embedded throughout the process. Birmingham's FPA programme exemplifies this point: there was clear citizen feedback for the need for a citizen-led body to operate strategically across the City's themes, yet sufficiently at "arms-length" to allow for innovation and creativity. This led to the City of Nature Alliance (CNA, 2023), representing the core third sector groups in Birmingham and providing a citizen-led perspective and scrutiny function to the new city governance structure.

There are interesting parallels with the exhortation of UN Habitat, via the Urban October initiative (http://www.urbanoctober.unhabitant.org; UN Habitat, 2022), to make changes to move to Net Zero: '*The future of our planet depends on national, regional and local governments and organisations, communities, academic institutions, the private sector and all relevant stakeholders working together to create sustainable, carbon-neutral, inclusive cities and towns*'. Similar pronouncements have been made by the European Union and the UK Government, all recognising that collaboration forms the core enabler of moving towards these goals – the same thinking that provides the foundation for, and naming of, UKCRIC as a 'collaboratorium' – and this in turn leads to joined-up thinking and action via thinking and practicing systemically. In this case the City Council has the role of both contributor to the processes and necessarily a willing and well-prepared receptor of what emerges in terms of a portfolio of interventions. One crucial implication is the move from competition, which is often invoked to drive down costs, to collaboration that takes a more balanced view across the pillars of sustainability.

While the methodologies are designed to support the effective implementation of an intervention, or a combination of interventions, in the complex system-of-systems that make up our cities, for which sympathetic, responsible and responsive governance is required, this paper takes a higher-level perspective. If one considers the essential and urgent changes to the infrastructure and urban systems landscapes from the perspective of the change processes themselves, they would look to the processes of governance to act as an enabler of positive and

effective change in relation to each activity in its own context or contexts. Governance processes can then be analysed for their efficacy in enabling the delivery of the positive outcomes sought, and recommendations for beneficial changes to the formal and informal processes of governance can then be designed and implemented. These recommendations for change will be met with varying degrees of difficulty, and some might simply be impossible; this would in turn compromise the effectiveness with which the beneficial outcomes would be delivered.

The alternative approach and the focus of the research reported herein, is to make the governance systems and processes inherently receptive to the types of interventions that seek to advance the sustainability, resilience and liveability agendas. The only truly effective way to make this happen is to ensure that all governance processes are identified, articulated and considered at the start of any activity associated with the conception, design, development and operation of changes to our infrastructure and urban systems – put another way, governance processes should be included in the 'design brief' for the activity.

3 Transformation of Birmingham City Council's governance processes

The route to transforming governance follows a logical sequence of: (1) Carry out the enabling research to create the methodologies needed for an overarching theory and practice of change (here the change relates to recognising and evaluating the value of nature and the EESs it offers, and acting on it when making the City and its systems more sustainable, resilient, liveable and smart); (2) Work out how this thinking should influence the policies and strategy of the City; (3) Apply the thinking to a programme of work that seeks to bring about the intended change and deliver the intended outcomes (e.g., the Future Parks Accelerator); and 4. Trial the change in practice and observe what happens. This research – policy – practice – implementation and observe process is exemplified by the *Liveable Cities* programme and its successor and UKCRIC's Birmingham Urban Observatory, but it builds on the long history of research by Birmingham's universities that prepared the way for the City to be receptive to change.

3.1 The Liveable Cities programme

The *Liveable Cities* programme, or more properly *Transforming the Engineering of Cities to Deliver Societal and Planetary Wellbeing*, aimed to understand and assess the performance of cities from multiple perspectives. One of these dimensions was, of course, the natural environment: both how it was influenced by the transformative engineering processes (i.e., how they affected planetary wellbeing) and how it positively influenced people's health and wellbeing (i.e., societal wellbeing). However, the benefits of Natural Capital to cities extend far wider than societal health and wellbeing: the range of Ecological Ecosystem Services is extensive (Sadler et al., 2016). Moreover, if the natural environment is allowed to provide these services, then there is no need for engineered systems to do so.

Liveable Cities took a systemic approach to understanding the interrelationship between a system of interest and all the other urban systems, effectively establishing the basis of the methodology for formulating business models (Bouch et al., 2018; Cavada et al., 2021) referred to above. The system map for urban green space shown in Figure 2 demonstrates the extensive reach into so very many areas of cities and city living. While this might not be a surprise to those who live and work in cities, what it does do is make explicit how Natural Capital provides a more extensive and diverse range of EESs than is often claimed; it was this system map that caused Birmingham City Council to rethink how Birmingham could harness and exploit EESs. Aligning communities of practice that reflected the City's priorities and operations enabled an analysis of how these operations could be enhanced. Allied to the use of such a system map is the need to add professional understanding and experience: for example, the document analysis did not yield the fact that churchyards, cemeteries, brownfield sites, allotments (Scott et al., 2017) and road verges, along with blue spaces (canals and rivers), are habitats. Moreover, 'biodiversity' (in its category and its duplication) and 'urban fringe' (in its generality) do not align closely with the other more specific forms of habitat listed; nevertheless, their inclusion prompts consideration of the value proposition in relation to habitat and hence will have served its original purpose. In short, such a system map provides a basis for analysis and extension/refinement via the application of professional judgement.

Extending this argument to urban green space provision as a 'business', the system map can be analysed for all the anticipated benefits, or sources of value, that the business would realise. This is done by focusing on the points of interdependence and identifying, and where possible quantifying, the positive consequences of urban green space provision for each point of interdependence. Equally, adverse consequences of urban green space provision can be identified using the same approach. The urban green space provision 'business' would then develop its operations to enhance the positive consequences and reduce or remove the negative consequences, thereby iteratively improving its offering. Being the responsibility of the City Council acting on behalf of its people, this analysis would help to refine its policies and practices towards urban green space to deliver greater benefits to the economy and society, while protecting and enhancing the environment.

Any engineering research programme, and particularly engineering research that focuses on cities, requires the input of stakeholders to help shape and enrich the outcomes. It was recognised that such input covering both how the natural environment was protected and enhanced in practice and how governance regimes operated would be important to the success of the research. Accordingly, the academic team came to an arrangement with BCC to second Nick Grayson, its Climate Change and Sustainability Manager with a knowledge of and passion for research on sustainability, into the research team half-time. This enabled the research team to have a direct link to City governance to guide its various research strands, as well as providing a direct conduit to the City Council so that research

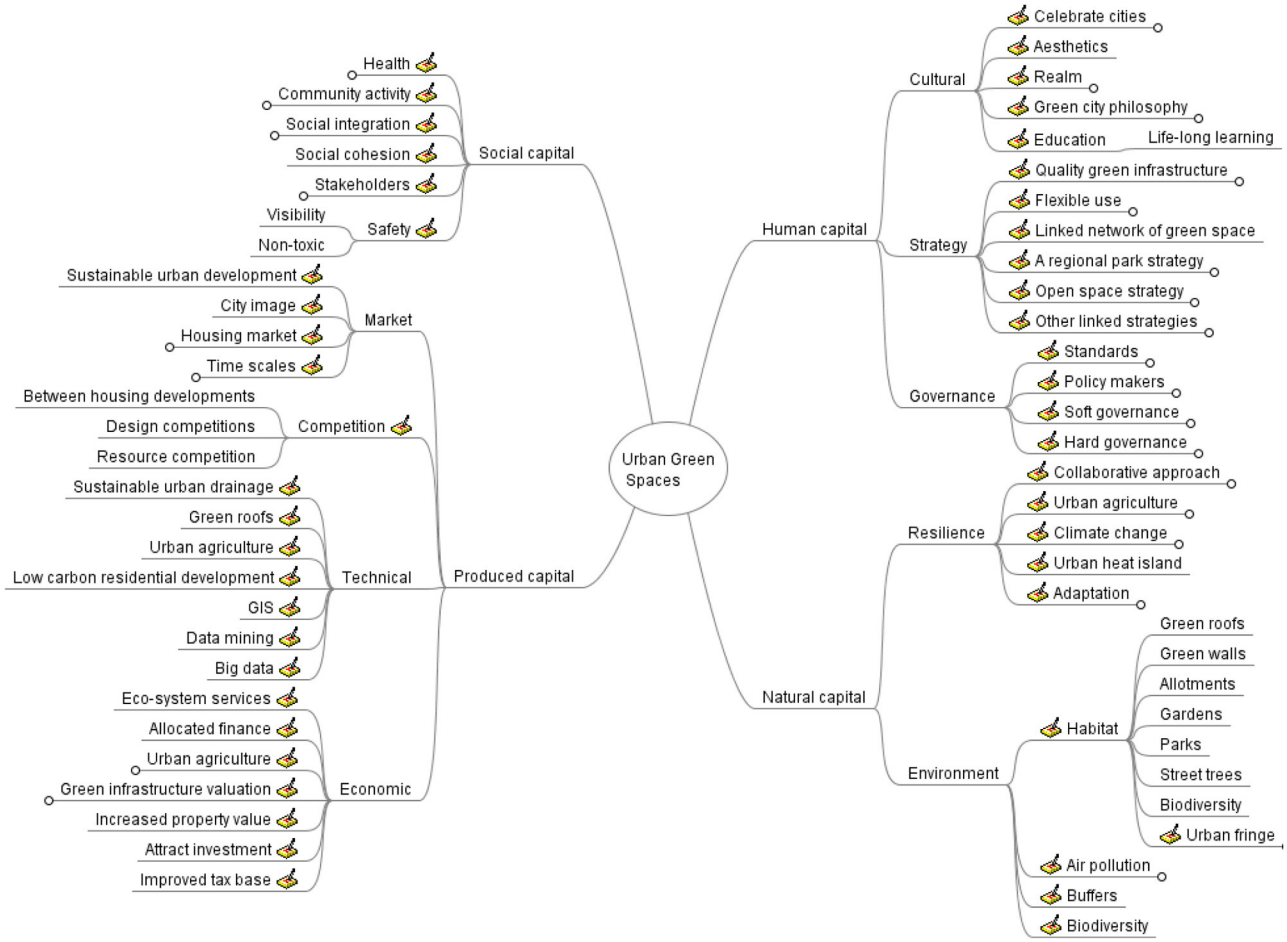

FIGURE 2
A system map to identify value-generating opportunities for urban green spaces [NB produced capital combines financial capital and manufactured capital (as defined by Forum for the Future, 2022)].

findings could influence the City's policies and practices as they emerge.

Engineering is essentially a discipline that is founded on problem-solving (the root of the word 'engineer' is ingenuity): it is the application of ingenuity to the solution of problems that defines the primary purpose of an engineer. It is widely appreciated that a complete definition of the problem provides a strong steer towards the solution. However, the *Liveable Cities* research programme consciously included a very wide range of disciplines so that problem definition was raised in importance and understood in all its dimensions. The alleged truism that '*engineers seek solutions to problems without spending enough time on problem definition, while social scientists focus on problem definition almost to the exclusion of seeking solutions*' undoubtedly proved to have some foundation amongst the highly multidisciplinary team. In terms of *Liveable Cities*' research, this deep collaboration enriched the disciplinary contributions and enabled the full team to move manifestly towards transdisciplinarity; this way of working, and the understanding that it generated (Leach and Rogers, 2020), underpinned the programme's remarkable success.

The City, of course, spends much time and effort defining the problems that it faces and the direct link to the City therefore manifestly helped the research team to understand the extent and distribution of the challenges that Birmingham faces (Figure 3, for example, shows where greenspace is needed and lacking). In the context of this paper, however, the acid test lay in the other direction: would the findings of the research fundamentally transform the strategy, policies and practices of BCC? For this to occur, the full spectrum of problem diagnosis through to practical implementation had to be accepted and 'owned' by BCC's leaders. From the very first engagement the Cabinet Member for Finance and Resources was highly complementary about *Liveable Cities*' systemic approach, and the approach of the Future Parks Accelerator programme that developed directly from it, since it identified both the problems that needed fixing in all their dimensions and offered fully-evidenced design options for solutions to address them. (In UK Local Government, elected Cabinet Members work with Council officers, such as the secondee into the *Liveable Cities* research team, and others to develop policy within their portfolio, work together on particular cross-cutting portfolio areas and produce the Council's budget.) In the Cabinet Member's view, so often consultants simply state what is wrong with a place, and then criticise the outcomes of actions, rather than providing any meaningful route-map to success. A subsequent

research programme, *Urban Living Birmingham*, advanced the thinking and practice of problem diagnosis (Leach et al., 2019), and this likewise features in the suite of methodologies referred to above.

3.2 The Star Framework

The City Council, via the contribution of its senior environmentalist, having contributed to the *Liveable Cities* research programme as well as prior foundational research at the city's universities, faced the subsequent challenge of how to place the principles and findings from the research centrally within the city's procedures. BCC's four priorities at the time of embarking on this challenge were Housing, Children, Health and Jobs and Skills, which nicely translated into Manufactured Capital, Social Capital, Human Capital and Financial Capital respectively (Figure 4). The missing capital in this picture is Natural Capital, and yet the logical implication from all the research is that Natural Capital considerations should lie at the heart of decisions on these other four priorities.

The process outlined at the start of Section 3 was applied to formulate the Star Framework by interpreting the evidence base in terms of the five Natural Capitals (points 1 and 2 of the logical sequence for transforming governance). Articulating the research findings, and notably the benefits deriving from them, in terms of the aspirations and policies being adopted by each of those responsible for leading on, and delivering the necessary outcomes from, the City's four priorities (Housing, Children, Health and Jobs & Skills) formed the essential transformative step. They, on behalf of the City, had to be persuaded to trial the thinking (point 3) and observe the benefits (point 4). This needed bold vision and leadership within the City Council, and this was readily forthcoming once the benefits of doing so were made clear.

3.3 Birmingham's Future Parks Accelerator

The Future Parks Accelerator programme, launched in 2018, is a collaboration between the Ministry of Housing, Communities and Local Government (MHCLG), the National Heritage Lottery Fund and the National Trust (FPA, 2018). The programme is designed to protect and develop natural resources in urban areas and ensure high-quality greenspace is accessible for everyone, now and into the future. It aims to enable local authorities and communities to take a longer-term strategic approach to funding and maintaining greenspace in cities so that people will be able to derive the many benefits it offers, and their urban systems will be supported by enhanced EESs.

> '*Parks are the lungs of our towns and cities. They provide space for us to escape, explore, rest, relax and play. They keep us healthy, soften hard urban landscapes, help to clean the air and provide crucial homes for wildlife*'. Future Parks Accelerator (FPA, 2018)

Of the 90 applications received, eight awards were made, with Birmingham receiving the largest of these awards because of the ambition of its programme, largely shaped by the thinking of the *Liveable Cities* research programme. '*Naturally Birmingham*' is testing new approaches to caring for the city's green spaces (Naturally Birmingham, 2022). Led by a consultant in Public Health from Birmingham City Council, the project is working with a range of partners that place the communities' views and values at the core of the endeavour. This aligns closely with the first step in the methodologies described above. The overarching visions are to transform the relationship between communities and parks at scale, and to move from the concept of maintenance to one of value creation. This latter point aligns specifically to the idea of taking a 'business models approach' to service delivery; in this case the 'business' is Birmingham's Parks and the service revolves around EESs provision.

It has been estimated that, based on the green estate in its current condition, the value of Birmingham's green spaces over a 25-year period is approximately £11 billion, with £4 billion of this linked to human wellbeing (Hölzinger and Grayson, 2019). With an overarching ambition to increase this value, '*Naturally Birmingham*' is focusing on four pilot themes – Health and Wellbeing, Housing, Children, and Employment Skills, as shown in Figure 5 – in different green spaces within the City, chosen on the basis of socio-economic factors, geographical spread and local context. The project's aims are to:

- Increase positive perception of and attitude towards green spaces in the community, within Birmingham City Council departments and across the senior leadership team.
- Promote skills and professional careers in green spaces and linked sectors, making sure they are locally accessible.
- Develop a clear approach to prioritising green spaces as part of future housing developments.
- Make green spaces a big part of children's education (e.g., FSA, 2023) and the provision of wider support for young people in care.
- Make sure green spaces are a key offering for communities and deliver clear health and wellbeing benefits to all, free of charge.
- Identify alternative funding sources to sustain parks.
- Develop a 25-year green spaces strategy.

When the full extent of the ambitions for Nature Recovery (embedded the project and outlined in Figure 5) are factored in, the value of Birmingham's green spaces over the subsequent 25 years was estimated to rise to £14.4 billion. Adopting the economic language inherent in traditional approaches to 'business models', this represents a remarkable return on investment. However, the most remarkable feature of '*Naturally Birmingham*' is the manner in which nature, and the natural environment, is woven into all policy and practice agendas. The underpinning ambition of the *Liveable Cities* programme was to deliver positive outcomes for society's and the planet's wellbeing by transforming the engineering of cities (or application of ingenuity to the design, construction and operation of urban systems); Figure 5 is a direct manifestation of this positive impact.

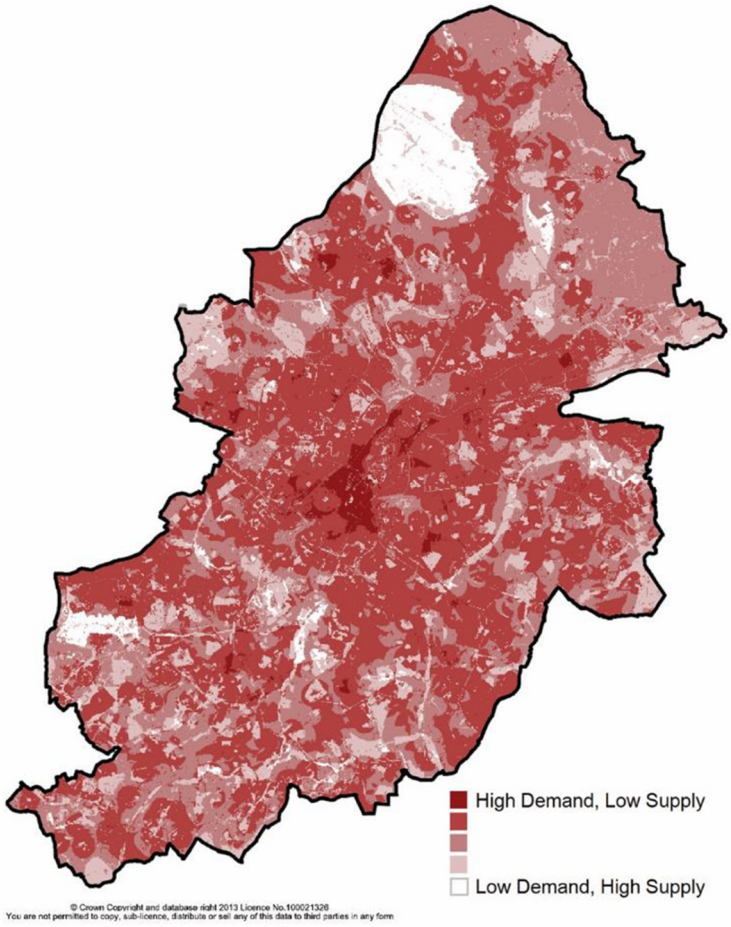

FIGURE 3
A greenspace challenge map for Birmingham (Hölzinger et al., 2013).

Echoing the five cities model advocated by the *Liveable Cities* programme – an 'ideal city' would constitute a synthesis of a courteous city, an evolving city, a healthy city, the city as a public space, and an active and inclusive city (Ortegon-Sanchez and Tyler, 2016; Leach et al., 2020) – '*Naturally Birmingham*' has likewise identified five components that need to be synthesised in its overarching vision for Birmingham as a City of Nature. These are:

- A Healthy City
- A Fair City
- An Involved City
- A Valued City
- A Green City.

'*Naturally Birmingham*' has adopted a three-scale approach, described as Micro (integrating across BCC and its partners – a no cost option), Capacity Building (providing equitable access to community green space – a low-cost option), and Macro (delivering on the ambitious visions of the Net Zero City, the Biophilic City and the West Midlands National Park – a high-cost option), starting locally and working upwards to become national and international in scope. The three stages are captured in a Sustainable Finance Ecosystem Model. Here again the language of business models permeates the discourse on Birmingham's green spaces, thereby avoiding their marginalisation in the intense competition for local funding.

3.4 UKCRIC Birmingham Urban Observatory

Smart city initiatives are now commonplace across the world (e.g., Cavada and Rogers, 2019), but it is important to emphasise the proposition advanced above that 'smart' is only 'truly smart' if delivering true benefits with respect to local agendas – in this case study of Birmingham, liveability. All too often, smart cities fail to deliver on their promises due to a lack of joined-up thinking and the limitations of small-scale projects that never really move beyond the demonstration phase. Here, the importance of governance is clear and can be considered as a key component of responsible innovation more generally (Owen et al., 2013). Fundamentally, incorporating the views of broad and multi-disciplinary stakeholders at the onset is the only way

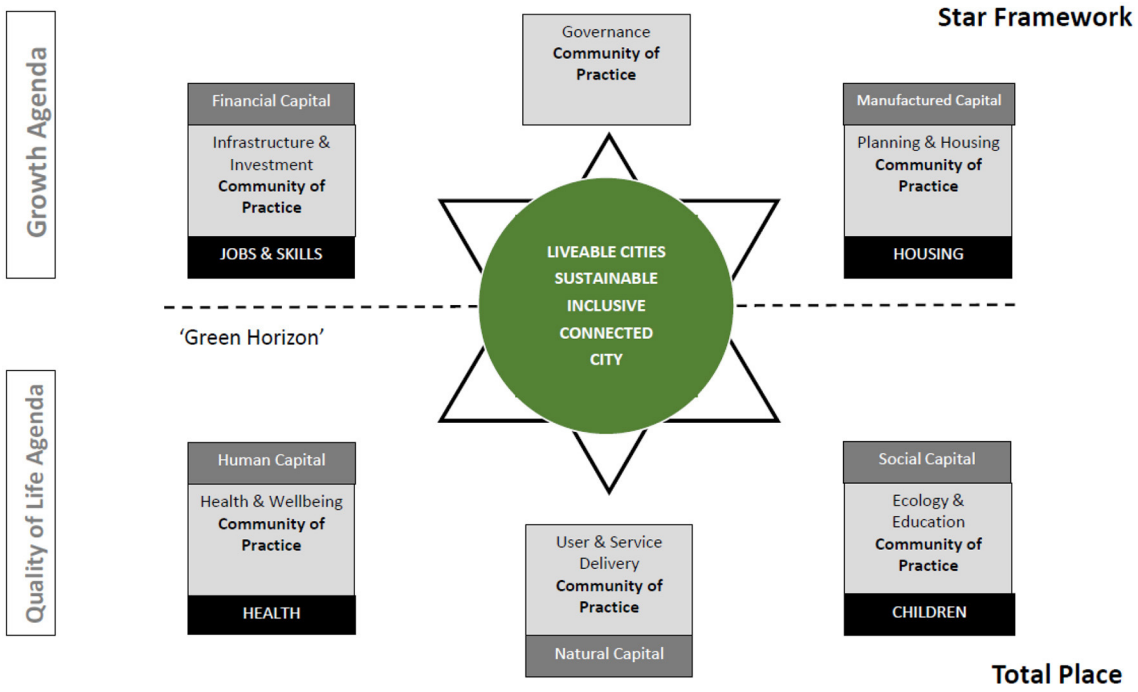

FIGURE 4
Birmingham City Council's Star Framework, in which Liveable Cities' principles were introduced into the heart of the city's decision-making.

to maximise returns on smart investments whilst maintaining the crucial oversight to scale benefits across projects and agendas (Grace et al., 2021).

The UKCRIC observatories were borne out of a desire to underline the importance of governance in the smart city agenda and ultimately move beyond the current smart city paradigm. Six urban observatories were funded across the UK to take a more holistic viewpoint of the collection of urban data and, in doing so, move beyond the silos of demonstrator projects that are all too often focussed on tackling a single problem. The UKCRIC funding effectively turned the pilot cities into living labs, bringing together a range of existing heterogenous data sources whilst deploying state-of-the-art sensing infrastructure to complement existing capability.

UKCRIC's Birmingham Urban Observatory was built upon over a decade of discussions with BCC and related stakeholders. During this period, the University of Birmingham worked with BCC to tackle a range of issues including climate change, air quality, winter road maintenance and preservation of Natural Capital. For the first time, the observatory brought the data for these challenges together in one place and provided an open-source platform which could be scaled and expanded to absorb more data to meet the changing priorities of stakeholders (Figure 6). The open-source nature of the platform allowed anyone to interrogate the data, whether they be a stakeholder or City citizen. Indeed, the approach goes further than merely informing the public on issues, it serves as an opportunity for the public to host a sensor and contribute their own data.

Birmingham's Urban Observatory forms the basis to both monitor and visualise the city. However, the potential is far greater. The federated data approach provides unprecedented capabilities to mash and mine data at the city scale to generate entirely new insights pertaining to the liveability of our urban environments. The data can be used to model and assess local or city-scale system interventions (an urban digital twin *per se*), ultimately providing evidence to shape local policy. For example, the implementation of the Birmingham Clean Air Zone in June 2021 (BCC, 2021b) demanded extensive 'before and after' monitoring coupled with modelling which required a range of disparate datasets including meteorology and traffic data (Bannister et al., 2020).

4 Discussion

There is a perennial debate about the value of research where this does not immediately lead to spin out companies, patents and suchlike means of financial rewards – enablers of economic growth. In academic circles, the discourse around value has focused on impact. Over the past 20 years, research funded by the UK Research Councils has been judged in part on the proposers' description of pathways to impact. Impact delivery must be described as part of the core research activity and remains an important criterion for success. This is only reasonable: with public funding for research should come a responsibility to make efforts to realise the beneficial outcomes of this research.

Placing a value on social, and especially environmental, benefits has traditionally involved degrees of uncertainty and therefore strays into the 'nice to have' category of outcomes when economic pressure is brought to bear. This has changed greatly for the better over recent years, in part due to monetisation of these benefits. For example, authoritative documents such as the Dasgupta (2021)

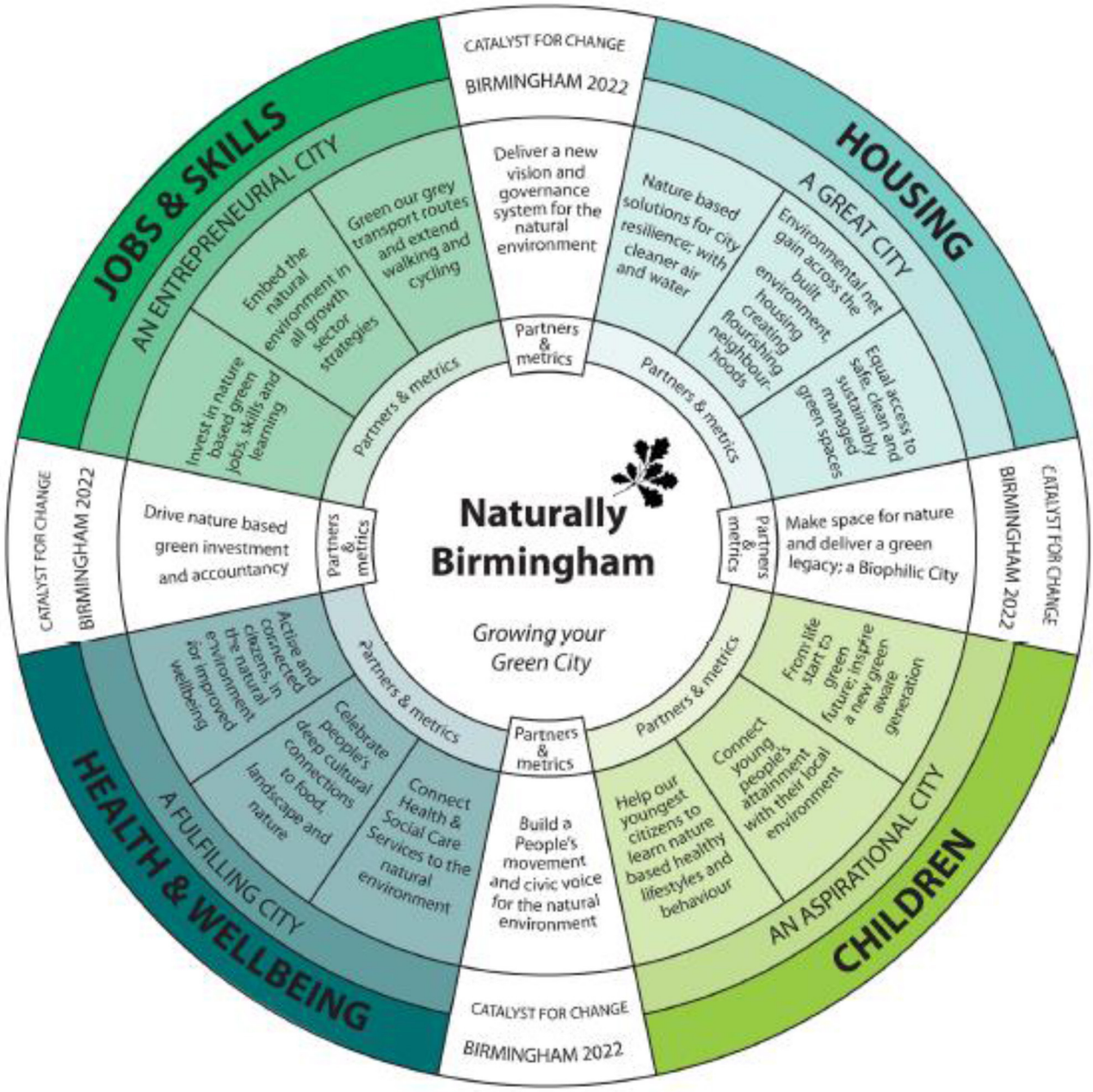

FIGURE 5
The vision for Birmingham's Future Parks Accelerator.

report on the economic value of biodiversity are now starting to influence the UK Treasury. Indeed, the valuation of projects according to the HM Treasury Green Book has shifted from considerations of additionality to a more considered approach to social and environmental value inclusion (HM Treasury, 2022a,b). This has strengthened the opportunities for the more pervasive adoption of nature-based solutions to the challenges facing cities (Frantzeskaki, 2019) and their multiple benefits across the three pillars of sustainability (see Albert et al., 2019, who discuss also governance as an enabler of their adoption). In relation to this paper, the discourse includes such fundamental questions as what value we place on sustainability and resilience. Even more fundamentally, perhaps, it is a question of to what degree we should invest in the far future when there is inherent uncertainty as to what might be needed in the future? Although there is scientific consensus and a general acceptance that investing now to limit climate change has enormous potential value, immediate societal and economic problems often strongly influence political decisions.

At the other end of this process, the importance of the impact of research has been progressively highlighted in the seven-yearly assessment of the research performance of all research-active staff in universities when determining the research funding allocated to UK universities under the dual funding mechanism. This

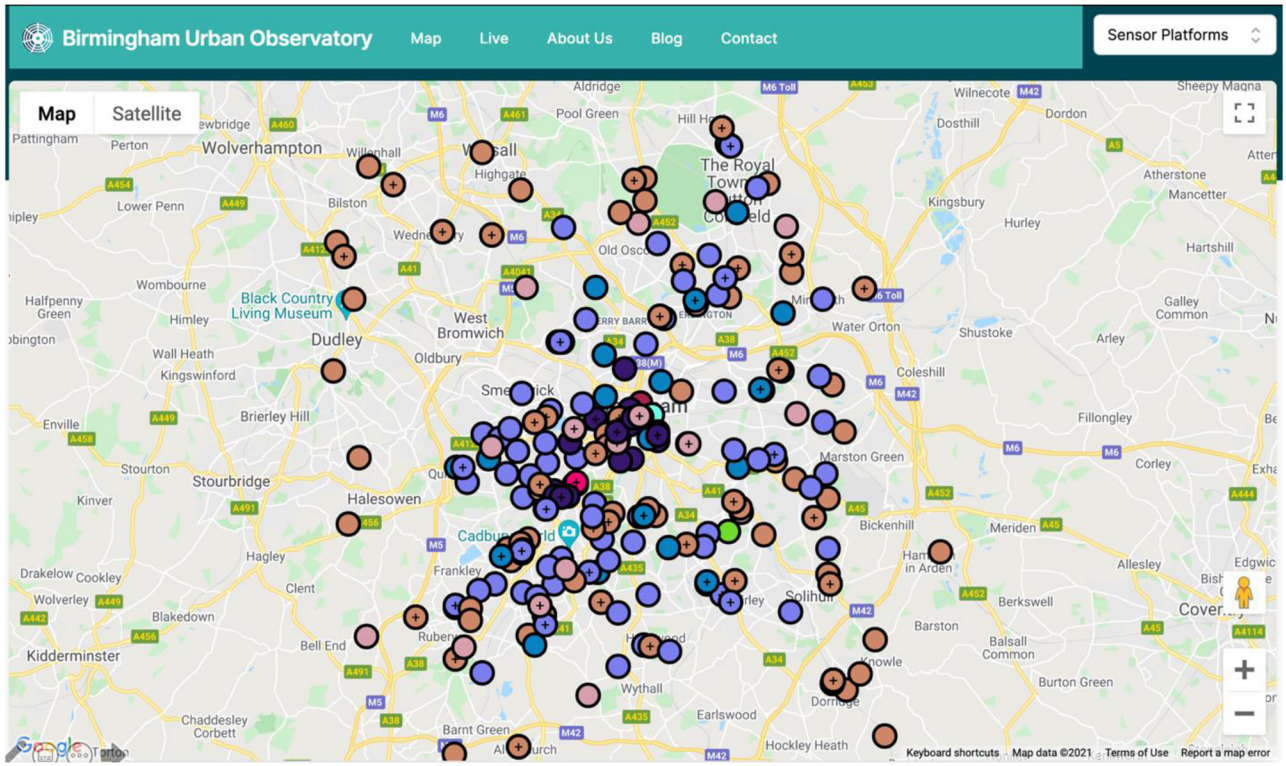

FIGURE 6
The Birmingham Urban Observatory platform showing availability of point sensor data as of 17/09/2021.

assessment, formerly known as the Research Assessment Exercise (RAE) and currently entitled the Research Excellence Framework (REF), now includes substantial credit for case studies of impact on practice, policy or some other class of beneficiary from one or more research projects over a period of many years after completion of the original research. The topic of this paper is a case in point.

The research base from which the impact reported in this paper has derived extends over 20 years and consists of research projects covering sustainability, resilience, infrastructure and urban systems, alternative business models, and most directly the liveability of urban places. A common theme underpinning all of this research is the acknowledgement that people lie at the heart of the intended outcomes: "sustainability, resilience, liveability and infrastructure service provision for whom?" As the ultimate beneficiaries and service users, they should have the opportunity to co-create the research and a responsibility where possible to co-design and operate (or at least collaborate in the successful use of) the infrastructure systems and allied urban systems that result.

The call for such opportunities and responsibilities has been reinforced by numerous initiatives on future cities, such as the Future Urban Living Policy Commission (Rogers et al., 2014) and the UK Government Foresight Future of Cities project (GOfS, 2018a,b; Rogers, 2018). Co-creation and participatory planning are notoriously difficult, however, and potentially both time consuming and costly if carried out using traditional, very detailed, consensus-building approaches. This is because every citizen of a town or city has a unique personal view of what it is like and what it should be, and synthesising all of these diverse, multi-dimensional views is far too complex a task. However, synthesising the *high-level aspirations* of a place, if it is sufficiently large, and its people (those who live, work and/or visit) is far more straightforward – it can indeed offer a variety of experiences and different things at different times. The Aspirational Futures methodology described above (Step 2 of the methodologies) provides a mechanism for this, and it can be applied at whatever level of detail (hence cost) is feasible. Moreover, this methodology, like all of the methodologies and processes described in this paper, is context-dependent: the context is critical, but it matters not what that context is or which place provides the point of focus – the lessons reported herein for Birmingham can be translated to any place or scale.

While there is a role for Environmental, Social and Governance (ESG) polices and activities by private sector organisations in a city, it is to local government and its officers that citizens typically look for the lead on such matters. One way to achieve this, and the adoption of co-creation and participatory planning (and the mechanism reported in this paper), is to provide a direct link to local government since this organisation would have a deep understanding of the needs and wants of the local communities and people they serve. The research programme in which this took place (*Liveable Cities*) had this intention as one of its core aims and it was therefore possible to introduce a senior manager of Birmingham City Council into the project team, as described above. It was considered important that this secondment should provide sufficient opportunity to shape the research, rather than being solely an active link to those who govern, and therefore the secondment was for 50% time over 3 years.

There has been significant experience of embedding city officials into research teams, with such intimate collaboration yielding two-way benefits that (critically) include informing and co-designing policy (Carroll and Crawford, 2020). Of course, research funding has always been associated with national governments (hence the shaping of top-down governance), but this represents a different scale of collaboration in which the shared goals between academic thinking and decision-making in the policy realm are considered deeply (Mawson, 2007). Such collaboration has a particular value due to the scientific process, the academic environment allowing a different path to policy design and policymaking through a non-organised and non-top-down route (Kinder, 2009). The UK Government recognised this by making available toolkits for policy innovation prototyping, involving policy design models underpinned by participation and novel methodologies (Policy Lab, 2017).

Building on such experiences and evidence, including that reported herein, Mistra Urban Futures (2019) implemented co-creation methodologies to support sustainable development across the local and global context with partners from city and university platforms. Co-production needs to happen in places of security, with freedom of opinions, enabling radical transformation for sustainability to be explored unhindered by commercial, political or other influences and allowing for risk-free experimentation between governance and academia (Culwick et al., 2019; Palmer et al., 2020). Certainly, the benefits to the research team of the BCC secondment were considerable and the findings have undoubtedly been enriched. The remarkably profound results of the transfer of the findings to the City Council are reported above.

This successful experiment reflects one of the primary ambitions of UKCRIC (2022): every major project related to infrastructure or urban systems should be an observatory in its own right, and to achieve this effectively requires deep collaboration between practitioners and the research community. This is because major projects of this nature are highly complex, primarily due to the fact that their success is dependent upon the awareness, understanding, attitudes and behaviours of people (Topal et al., 2021). This complexity in turn presents as uncertainty, and when working with uncertain data it is wise to use a trial-and-error approach, or 'learning while advancing and advancing in response to this learning'.

Geotechnical engineers and engineering geologists term this 'the observational approach', in their case because the ground with which they work is potentially highly variable and of uncertain properties: this means that engineering processes will elicit an uncertain response from the ground and therefore the design of the processes must progress as the properties of the ground, and their reaction to some sort of change (e.g. additional loading or unloading), becomes progressively better known. This requires a process of monitoring while carrying out the works and designs that are nimble enough to respond to the progressively more reliable information obtained. Translating this example of systemic thinking to some aspect of the performance of infrastructure and urban systems as people react to them and use them makes perfect sense. Indeed, this performance can equally relate to a policy, a strategy, the construction of a physical artefact, an altered operating system or some other change (Rogers et al., 2022).

While the academic community is aware of the uncertainty that people and society bring to the use of infrastructure and urban systems, those who design them tend to be educated and trained in disciplines that are underpinned by certainty. Engineering researchers and practitioners in general fall into this category – it is geotechnical engineers that provide the strongest exception – and they therefore tend towards designs that assume individual and collective behaviours that will be supportive of the infrastructure and urban systems that are created for them. This enables numerical models to be created to test the designs, and therefore artificial certainty is often introduced into the process, albeit unintentionally.

One way to bring realism into this process is to engage practitioners as part of the research team, and if these practitioners understand the variety of different attitudes and behaviours that exist amongst the user community, as those who are experienced in working for City Councils do, then the research, and the practice that flows from it, will necessarily become more effective. The secondment and its transformative effect on the operation of Birmingham City Council therefore provide an unusually powerful exemplar of UKCRIC's systemic thinking being translated to practice. The net result for the City is the formulation of an adopted 25-year City of Nature Plan for Birmingham in which a new governance mechanism is embedded to enable the delivery of the Council's stated aspirations when it became the only UK founder member of the global Biophilic Cities Network (BC, 2023).

5 Conclusions

Cities are places shaped by their geographical location in relation to the natural environment and social needs associated with settlements, including trade routes and the different transport systems that have operated over their history to facilitate this trade. If they are to prosper, cities must equally be places of invention in which the entrepreneurial spirit thrives to provide the engine for economic activity and economic growth. It follows that it is important to balance their physical development and the systems by which they operate across the three pillars of sustainability – economy, society and environment – if they are to work effectively today. This feature of cities might be described as liveability. For cities to prosper in the future another feature – resilience – must be introduced into this balance. This makes for a complex set of challenges, for which the only effective means of advancing is to adopt systemic thinking and systemic practice. A 15-step sequence of methodologies is presented to enable any town or city to implement this systemic approach, at whatever scale and of whatever nature (e.g., building something new, changing an operational practice, developing a policy, introducing a technological development, altering citizens' attitudes and behaviours).

Against this backdrop, city governance, at heart, is about looking after the interests of communities of people (primarily) and the planet – the natural environment and the ecosystems that support communities, specifically via the ecological ecosystem services they provide. City governance is therefore about the people who live, work and engage in leisure activities in the city, its

constructed landscape, the infrastructure systems supporting the social and economic activity that enables cities to function and thrive, and the natural environment in which all of this is situated. This governance needs to be sympathetic and responsive to these core needs, and receptive to improvements to (interventions in) this complex system-of-systems. The logical thread is, or should be, circular, since people elect those who govern.

This paper reports the findings of a long history of research by the HE community in Birmingham on the sustainability, resilience and liveability of Birmingham, and the critical role of governance in enabling these agendas to be delivered effectively. This was enhanced in later research programmes by integrating, and subsequently formally seconding, a senior member of staff at Birmingham City Council into the research team. The most important lesson from this research collaboration from the city's perspective is that effective governance must be founded on a profound understanding of what changes are required, and why they are justified – the reasoning, all likely impacts and the underpinning evidence base.

The system mapping methodology developed while this secondment was in place identifies the value-generating opportunities of a particular type of change (accepting that value can be both positive and negative). Uniquely, a system map for urban green space is presented to demonstrate the value-generating opportunities for the baseline provision, and opportunities for enhancement, of the ecological ecosystem services that deliver such a wide range of benefits to people and communities; first and foremost, the health and wellbeing of residents, workers and visitors. Moreover, the responsibilities of and opportunities for those who govern have been identified with the aid of such a system map, and lead to the critical finding that applying this methodology, alongside others developed by the *Liveable Cities* programme and advanced by UKCRIC (see Rogers et al., 2022) enables a city to commission and implement policies formulated precisely in accordance with its needs and unique context, as opposed to implementing generic national (Government) policies regardless of local uncertainties and/or barriers to effectiveness. This reflects a primary finding from the research that actions in support of sustainability, resilience and liveability must be context-dependent and co-created with all relevant stakeholders, particularly the communities that are impacted most by them, if they are to be truly effective. This, in turn, will guide the capture and use of data for 'smart' technology, ensuring that technology does not drive change but should only be harnessed specifically to support planned changes in city form and function.

One profound benefit from this collaboration between research and governance has been the introduction of environmental considerations to the heart of all decision-making in Birmingham City Council, the benefits of which have been made transparent by implementation of the Star Framework. This was formulated to make explicit the need for, and the benefits of, Natural Capital when advancing city governance to deliver positive change in Birmingham's four priority areas based on Manufactured Capital (material goods or fixed assets which contribute to the production process), Social Capital, Human Capital and Financial Capital. This prime example of system interdependencies between the five Capitals in effect describes the route to delivering city liveability and reflects the same integrated, systemic thinking required for delivery of sustainability and resilience – were a fifth BCC priority area focussed on Natural Capital to have been introduced, then the tendency to siloed activity would naturally have emerged and the effectiveness of BCC's governance would have been severely compromised: excellent siloed activity cannot achieve the same effectiveness as holistic activity.

It was these profound developments in the approach to city governance that led to Birmingham securing the largest of the UK's Future Parks Accelerator programme. The Birmingham Future Parks Accelerator, *Naturally Birmingham*, is introducing a suite of profound transformative actions (preferred "design options") that are estimated to increase the value of Birmingham's Natural Capital from its current value of £11.0 billion to £14.4 billion - a remarkable return on investment from the *Liveable Cities* conception of Birmingham's urban greenspace as a "business" (with attendant business models). *Naturally Birmingham* has paved the way for a new way of working in which those who practice (e.g., industry, business), those who govern and those who research combine in genuine, transdisciplinary partnerships – ones that work seamlessly across academic, professional, sectoral and governance silos with a common purpose. The imperatives of transdisciplinary collaboration, thinking systemically and practising systemically underpinned the creation of the UK Collaboratorium for Research on Infrastructure and Cities, and lead to a final crucial conclusion: all city and infrastructure system policy development and implementation, which is inherently complex, should be treated as 'an observatory' in which all involved learn while advancing and advance as a result of the learning. This results in nimble, responsive and adaptable solutions to problems rather than fixed solutions that are implemented in the expectation and hope that the end users (the people and communities who live, work and engage in leisure activities in the city) will embrace them and behave accordingly.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

CR conceived and designed the framework for the paper and wrote the first draught of the manuscript based on collaborative work with all other authors. NG and LC added substantive material to the first draught, and JS, CB, MC, and JL made substantive additions, and all provided comments. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The reviewer JE is currently organising a research topic with the author CR.

Publisher's note

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