Editorial
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Editorial: Environmental data, governance and the sustainable city

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Editorial on the Research Topic
Environmental data, governance and the sustainable city

The availability of new types of environmental data has the potential to change the ways in which cities are governed to improve their sustainability, resilience, and livability. Distributed sensors delivering real-time data can improve the monitoring and management of urban systems, as well as enabling robust assessments of policy and planning interventions. Real-time high-resolution sensor data provides a wealth of new opportunities for understanding systems and the interaction of physical, technical and anthropogenic activity. These benefits include long (multi-year) data baselines of high-resolution data enabling new statistical and artificial intelligence approaches; real-time analytics and visualizations supporting decision support systems; vulnerability or incipient failure detection to enable (proactive) maintenance rather than (subsequent, reactive) repair; parameterization of urban digital twins of physical and natural systems for simulation and prediction and what-if scenario testing; post-event analysis and post-intervention analysis across multiple phenomena at different timescales; and digital playback of systems when singularities, oversights, mistakes or other unforeseen events occur.

More than ever, better environmental data is required to address urban challenges ranging from poor air quality (addressing the symptoms) to climate change (addressing the causes) in a joined-up way across the "Five Capitals," i.e., Natural, Human, Social, Built/Manufactured, and Financial (Forum for the Future, 2018). However, the distributed nature of many environmental challenges makes it hard to create business cases for real-time data. The proliferation of IoT (Internet of Things) monitoring devices is enabling cities to gather data from embedded, remotely accessed, sensors to give hitherto unprecedented spatial, temporal, and sectoral coverage of urban processes. Further, it is possible to expose this data, along with related insights, through information portals, APIs and real-time decision support and visualization systems to vast and disparate stakeholder audiences, including the public, private industry, government and researchers to generate insights, promote behavior change and drive new partnerships (e.g., Bai et al., 2018; Creutzig et al., 2019). Real-time environmental data can support societal goals, such as improvements in human health and wellbeing, achieving a zero-carbon economy and securing net environmental gain, as well as supplying evidence to inform major infrastructure investments around resilience to climate change, population pressures, changing demographics, and food/water security in the face of increasing urbanization. Sustainable Development Goal 17 to "Strengthen the means of implementation and revitalize the global partnership for sustainable development" provides the overarching framework for the delivery of the other 16 goals, and identifies "Data, Monitoring and Accountability" as one of six key enabling factors.

The smart city initiatives of the past 15 years has offered useful insights into the challenges of using data to improve the management of cities. A significant body of research shows the need to avoid overly top-down approaches, as pre-made technical solutions, often fail to address the specific needs of places and communities (Kitchin, 2014). This approach has been criticized for outsourcing urban challenges and the budgets to address them to largely unaccountable tech firms (Viitanen and Kingston, 2014). Despite these challenges, in the context of the great digital acceleration promoted by the Covid pandemic, the push toward smart cities is gaining rather than losing momentum. In response, smart city initiatives are increasingly focusing on bottom-up solutions that are more organic, and the ways to strengthen governance to ensure technology addresses the needs of its communities (Karvonen et al., 2019). When it is divorced from the needs of specific communities and places, real-time data can actually reinforce existing inequalities. For example, sensors can produce data showing how poorer parts of cities are affected disproportionately by issues such as air pollution, the type of insight which can be used to leverage political action and investment. But research shows that real-time sensors are overwhelmingly located in richer parts of cities. This tendency not only obscures the environmental problems facing disadvantaged communities, but directs limited resources available to combat problems toward already privileged places. For example, the poorest areas of most of the UK cities are "sensor deserts," severely limiting the ability to use real-time data to improve those areas facing the greatest challenges (Robinson and Franklin, 2021).

The potential to deploy new technologies at scale and use real-time data to address the needs of citizens and decision-makers is huge, but the practicalities of doing so are challenging. Firstly, there is the need to invest (today) to enable the (mix of short-term and long-term) benefits to be realized, and there are very many calls on constrained budgets; another example of business cases (here, for funding to yield expected long-term outcomes) being difficult to land. This reflection means that all too often municipalities make decisions based on remarkably sparse data, and decision-making processes and timelines are not designed around the capabilities of real-time data. Cities are political environments, and identifying how best to use sensors can involve understanding and liaising with the needs of different departments, communities and politicians. Co-creation with users and co-design of IoT and data centric solutions to address specific urban challenges is essential to secure deeper understanding and societal engagement. Governance approaches like living labs, which bring communities and data together to generate place-based solutions, and urban observatories, which seek to link data to user needs, offer useful approaches to secure credible and robust interaction between all stakeholders, including data providers, interpreters, regulators, and citizens (Voytenko et al., 2016). Finally, IoT technology requires considerable organizational capacity and expertise to be able to deploy and maintain (Chapman et al., 2015), including technical and digital competences as well as sectoral expertise in different disciplinary aspects such as environmental science, transport planning, civil engineering and public health. The current hype around real-time data and smart cities contrasts sharply with the technology, working practices, modeling capability, and baseline understanding of environmental systems in cities. Despite the convergence of smart and sustainable discourses on the city as a site of action, practical challenges mean that real-time environmental data rarely informs urban governance and planning decisions.

This Research Topic seeks to gather the experiences of cities around the world that have been exploring how to use real-time environmental data to inform decision-making. It focuses on how digital technology makes new forms of governance, politics and planning possible, bringing data and monitoring logics to the fore and connecting people, governments and resources in new ways. The Research Topic offers perspectives on the technical, social, economic, and political limitations of these technologies to secure urban sustainability, and the uncertainties surrounding how they can and should be governed. As Rogers et al. suggest, the very concept of "smart" is "only "truly smart" if it helps to deliver on the sustainability, resilience and livability agendas." This concept requires the data underpinning smartness to be conceived and designed based on, and responsive to, local needs. The studies interrogate how environmental data and associated technologies are reshaping governance and policy in cities, particularly from interdisciplinary teams and perspectives. The resulting areas of interest relate to the practicalities, politics and governance of urban environmental data worldwide, and can be grouped under four main themes.

Theme 1: using data

This theme includes: societal and scientific challenges, including the opportunities and barriers for municipal authorities to use real-time environmental data and analytics in cities; the different uses of environmental data, from monitoring discrete interventions to informing operational decision-making and monitoring progress against policy goals; and, finally, the challenges of managing and presenting environmental data to make it usable by practitioners, citizens, policy makers and researchers.

Theme 2: enabling the new

This theme includes: new forms of data and processing methods (such as Artificial Intelligence) and their implications for understanding urban systems and their governance; the networks, markets and innovation ecosystems that have emerged around real-time environmental data in cities; new forms of governance enabled by real-time analytics, for example through the use of digital twins to simulate, predict and test what-if scenarios, and their political implications; and, finally, the new modes of urban experimentation and adaptive governance, and/or new forms of international benchmarking or collaboration, enabled by environmental data.

Theme 3: tackling practical monitoring challenges

This theme includes: the practical challenges and effects of instrumenting urban infrastructure with sensor technologies; the organizational infrastructure and skills required to capture, maintain and use real-time environmental data; and challenges to the long-term sustainability of monitoring systems and sensor networks.

Theme 4: managing data

This theme includes: the management, use, access and distribution of environmental data to support decision-making by city authorities under the rubric of smart and digital strategies; the role of organizations (e.g., urban observatories) and/or intermediaries (e.g., third sector) in supporting cities; and, finally, the effects of exposing data, along with related insights, through information portals, APIs, and real-time decision support and visualization systems to vast and disparate stakeholder audiences, including the public, private industry, government, and researchers.

This Research Topic includes eight papers. Three papers present the results from projects embedded in Urban Observatories, which have emerged as platforms to support the use of IoT sensors and data to address the needs of municipalities in the UK. The first two address the use of data in cities and practicalities associated with managing sensor networks that address local needs. James et al. illustrate the Newcastle Urban Observatory, discussing the "socio-technical and practical challenges of developing and maintaining smart city networks of sensors" within modern cities. The paper offers a complete overview of the practical, technical and political dimensions of deploying and maintaining an urban real-time sensor network, and curated data platform that is responsive to decision-maker needs. Bannan et al. complement this paper, presenting the Manchester Urban Observatory through a study based on a "mixed-method cross-disciplinary approach" which brings together "atmospheric [...] data, measurements of activity in public areas and novel methods to assess wellbeing-promoting behaviors." This paper focuses on the interdisciplinary expertise and working that is required to be able to co-design sensor networks with stakeholders, deploy and maintain them, and use them to answer transdisciplinary questions that involve understanding the relationship between urban planning, mobility, air quality and health and wellbeing. Rogers et al. describe a case study of collaboration with a city council reflecting on "effective governance;" this effectiveness was founded on a profound understanding of the required changes, alongside processes encompassing systems mapping, city assessment frameworks and futures analyses.

The next three papers address governance issues triggered by use of real-time sensor technology. Coraggio et al. present the Bristol Urban Observatory, and in particular the analysis of sampling frequency of critical parameters (e.g., temperature, dissolved oxygen) as indicators of water quality for the Bristol's Floating Harbor. The paper examines the potential of IoT sensors to provide far greater sampling frequencies for water quality than have traditionally been used, and discuss how different levels of resolution can address different regulatory needs. Shrimpton et al. present an example showing how a new sensing technology disrupts traditional governance practices. The Pipebots project designs "miniature robots to gather physical condition and environmental data on buried pipe networks, using potable water distribution and wastewater pipe systems as the initial target applications." This project develops the discussion on the relationship between real-time data and governance. The authors show how the pervasive sensing technology of Pipebots will require a complete shift in industry practices and governance to be adopted. Traditionally utility companies respond to failures, fixing pipes that break, rather than proactively predicting and mitigating failures. Goulas et al. explore "public perceptions of smart water meters that use Internet of Things (IoT)" to detect water usage and anomalies in households. While the previous two papers focused on the relationship between real-time data and regulators and companies respectively, this paper focuses on the relationship between real-time data and citizens. The authors show how user perceptions drive the uptake of domestic water meters, with implications for the resulting representativeness of the data.

On the topic of new technologies and approaches, Truong et al. build "an explanatory framework that conceptually joins the literature on socio-technical systems and on urban consumption," looking into "the principal socio-technical systems [...] that influence consumption behavior" and the interaction between these systems and unsustainable consumption behavior. The paper shows how real-time data both requires and can reinforce new frameworks that understand the system-wide interactions between people and infrastructure. Finally, Topping et al. discuss the "interplay between available data and state of the science on air quality," reflecting on the "infrastructure needs and areas of opportunities that should drive subsequent planning of the digital twin ecosystem and associated components." The authors identify the challenge of creating an inclusive governance framework for the development of digital twins that can enable co-creation and the robust and effective sharing of data and models.

Our intention is that this Research Topic stimulates a wider conversation about how IoT sensors, real-time data, and governance intersect in urban settings. Realizing the possibilities and benefits of these technologies requires new combinations of expertise across disciplines. The contributors to this Research Topic include a range of disciplinary backgrounds, from data science to human geography to civil engineering. Realizing the benefits of real-time data requires new modes of governance to ensure that technical solutions address societal goals and produce usable results and services. Public and private organizations need new ways of working that enable them to use new forms of data and sensors. Universities are well-placed to lead the way and develop new platforms and governance arrangements that bring together expertise, technology and stakeholders. As the development of new technologies like digital twins continues apace, and challenges like decarburization become ever more urgent, the importance of this task only grows.

Author contributions

JE: Conceptualization, Writing – original draft, Writing – review & editing. MP: Conceptualization, Writing – original draft, Writing – review & editing. DT: Conceptualization, Writing – original draft, Writing – review & editing. JH: Conceptualization, Writing – original draft, Writing – review & editing. CR: Conceptualization, Writing – original draft, Writing – review & editing.

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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.

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