

'Give Me a Laboratory and I Will Lower Your Carbon Footprint!' – Urban Laboratories and the Governance of Low-Carbon Futures

JAMES EVANS and ANDREW KARVONEN

Abstract

The increasing threat of climate change has created a pressing need for cities to lower their carbon footprints. Urban laboratories are emerging in numerous cities around the world as a strategy for local governments to partner with public and private property owners to reduce carbon emissions, while simultaneously stimulating economic growth. In this article, we use insights from laboratory studies to analyse the notion of urban laboratories as they relate to experimental governance, the carbonization agenda and the transition to low-carbon economies. We present a case study of the Oxford Road corridor in Manchester in the UK that is emerging as a low-carbon urban laboratory, with important policy implications for the city's future. The corridor is a bounded space where a public-private partnership comprised of the City Council, two universities and other large property owners is redeveloping the physical infrastructure and installing monitoring equipment to create a recursive feedback loop intended to facilitate adaptive learning. This low-carbon urban laboratory represents a classic sustainable development formula for coupling environmental protection with economic growth, using innovation and partnership as principal drivers. However, it also has significant implications in reworking the interplay of knowledge production and local governance, while reinforcing spatial differentiation and uneven participation in urban development.

Introduction

The climate-change agenda is reinvigorating a need to 'cultivate new techniques of governance' for urban sustainability (Hodson and Marvin, 2007: 303). One such technique involves policymakers, researchers and practitioners branding cities, or parts of them, as 'urban laboratories' in which to experiment with new approaches to sustainability. Urban laboratories present an attractive mode of governance that promises to transform cities into sites of knowledge production that will make them simultaneously more economically viable, socially robust and environmentally friendly. While the development of high-profile exemplars to showcase sustainable technologies in cities is widespread (Joss, 2009), the way in which urban landscapes are being used as experimental devices to *produce* knowledge about sustainability has received less attention. Urban laboratories are mechanisms that mobilize place to generate economic wealth and stimulate more resilient urban conditions, both through the creation of new landscapes and the retrofitting of

existing ones. In the context of a growing emphasis on partnership between universities, government and industry, such approaches to sustainability are blossoming, while their origins, impacts and implications for urban governance remain largely unexamined.

The aim of this article is to examine how the emphasis on data gathering and place-based innovation is influencing knowledge production and urban governance in the pursuit of more sustainable futures. To do so, we explore the application of the concept of the urban laboratory to sustainable governance through an empirical study of the emerging low-carbon urban laboratory on the Oxford Road corridor in Manchester, in the UK. The corridor is indicative of the key issues of deploying urban laboratories for sustainability; it provides a real-world project in which an innovative carbon agenda is currently unfolding and highlights the importance of place as well as willing local actors with a shared vision to realize a low-carbon future. To complete the study, we collected primary data from 2009 to 2011 through semi-structured interviews with key actors involved in revitalizing the Oxford Road corridor, including representatives from the Corridor Manchester public-private partnership, the University of Manchester and the Manchester City Council. In addition, we attended meetings and public events related to the corridor redevelopment to observe the dialogue on low-carbon futures, and collected secondary data from research funding proposals, progress reports, working papers, consultancy reports and action plans. We then used qualitative data-analysis software to analyse the collected information and develop key themes for analysis and reflection. The empirical evidence reveals that urban laboratories provide governance by other means through an explicit emphasis on scientific knowledge production. In this sense, the promise of urban laboratories lies in their potential to respond to the carbon crisis in new, more effective ways. However, this mode of knowledge production privileges particular urban actors and neglects others, reinforcing the existing mode of technocratic governance in Manchester that is dominated by elites. In this sense, the Oxford Road corridor does not transcend governance-as-usual in the city-region but rather perpetuates and enhances the existing mode of governance that is shaping the future of the city.

In this article, we begin by situating the study within the growing literature on urban experiments and carbon governance. We then conceptualize the city as an urban laboratory, using insights from Robert Kohler's work on laboratories and field sites to make sense of the concept of the 'urban laboratory'. The two substantive sections that follow identify why and how the low-carbon urban laboratory was established in Manchester at this specific time and how it is developing in practice. We argue that a defining feature of urban laboratories is the ability to change the knowledge-production process that underpins urban change through a recursive process of experimentation and policymaking, and that its appeal as a mode of governance is based largely on this transformative promise. Indeed, the practical challenges and political implications of bounding and monitoring a space are relevant to a wide range of approaches to eco-urban governance, including adaptive governance, resilient cities and Smart Cities, all of which presume an ability to 'know' the city as a basis for subsequent decision making. However, we also point to the limited focus of laboratorization and its retrenchment of existing actors and power relations. To conclude, we reflect briefly on the risks and pitfalls related to urban laboratories and eco-city governance more widely.

Urban experiments and carbon governance

The emergence of urban laboratories for sustainability coincides with three contemporary trends of governance: the carbonization of urban governance, experimental governance and the transition to a low-carbon economy (Evans, 2012). The carbonization of urban governance identifies the management of carbon emissions as a new model for governing cities (Bulkeley and Betsill, 2003; 2005; Lerch, 2008; While, 2008; While *et al.*, 2009; Bulkeley *et al.*, 2011). National commitments to reduce emissions are cascaded down to subnational levels such as regions and cities because it

is assumed that rapid, context-specific action can be facilitated at these smaller scales (Bulkeley and Betsill, 2003; 2005). There is also evidence that territorializing carbon emissions at these subnational levels empowers actors to enact more stringent carbon reduction measures (Rice, 2010). In other words, it is recognized that the local and regional scale is where the greatest gains can be made in reducing carbon footprints and thus in addressing climate change.

Early studies suggest that low-carbon governance may hold greater transformative potential than existing approaches to sustainable development, which are not only subservient to the dominant urban regimes of capitalist development but are oftentimes complicit with them (While *et al.*, 2009). As discrete, bounded areas in which new forms of sustainability and low-carbon technology are developed and fast-tracked, urban laboratories clearly reproduce the territorializing logic of carbon governance. However, previous studies of the carbonization of urban governance have highlighted how the techno-managerial focus on 'carbon' is a contested and uneven process (Rutland and Aylett, 2008). Indeed, what could be more uneven than designating a certain part of a city as an urban laboratory? The explicit purpose of a laboratory is to create a space apart from the norm and by bounding space, urban laboratories not only territorialize carbon emissions at a small, manageable scale but also inscribe a privileged space of innovation. Thus, urban laboratories offer a sub-local space to implement government approaches to climate-change mitigation and adaptation but achieve this through spatial differentiation that has both positive and negative implications.

Bulkeley and Castán Broto (2012) identify three types of experimental governance in response to climate change. The first is the policy experiment, which builds on a longstanding literature arguing that all policy interventions are to some extent experimental. In other words, the effects of a specific measure cannot be known in advance, and thus all policies function as open-ended experiments. One problem with this understanding of the notion of experiment is that the term becomes synonymous with any new policy measure, thereby losing any unique meaning. The second type of experiment relates to the Dutch sustainable transitions literature. This literature, studying the way in which large-scale shifts in technology occur, sees experimentation as occurring in specific niches or protected environments that are sheltered from wider political and economic pressures (Kemp *et al.*, 2001; Geels, 2002; Hoogma, 2002; Geels, 2004; 2005; Smith *et al.*, 2005; Geels and Schot, 2007). The strategic niche management literature recognizes that innovation rarely conforms to the traditional linear model of knowledge transfer, but is better conceptualized as an iterative process of feedback between public and private stakeholders that occurs in specific types of places (van Heur, 2010). The final type of experiment is that of urban laboratories, where processes of innovation and learning are formalized (Evans and Karvonen, 2010). In bounding space, urban laboratories represent a specific type of niche that is often created by university-led partnerships to emphasize the importance of knowledge production (Perry, 2006; Krueger and Buckingham, 2009). It is their emphasis on formalized knowledge production that sets urban laboratories apart from policy experiments and niches of innovation.

The use of experimentation to drive innovation, learning and knowledge creation brings us neatly to the final body of work around urban climate governance, namely the transition to a low-carbon economy. Urban laboratories offer a potential silver bullet for cities aiming to make the transition to a low-carbon economy, producing knowledge that will help them reduce their environmental impacts and resource consumption, generate new economic growth and develop reputations as leaders in sustainable development. There is an assumption that by producing knowledge 'in the real world' and 'for the real world', urban laboratories can catalyze rapid technical and economic transformation. While highly appealing, the marriage of low-carbon urban futures to the economic transformation of cities raises a series of questions. In their study of the Clean Urban Transport Europe Programme that is establishing demonstration sites for green transport solutions in major European cities, Hodson and Marvin (2009) argue that demonstration projects are simply 'dropped into' urban areas rather than integrated with their local

contexts. Furthermore, the corporate partnerships charged with sustainable urban innovation tend to focus on the ecological, technical and economic aspects of pilot projects, with little regard for social issues, and in some cases have actually met with local resistance. Hodson and Marvin (2007) argue that the language of testing is indicative of attempts to trial new technologies in the field rather than experimenting with genuinely new ideas and learning from them. These conclusions are echoed by While *et al.* (2004; 2009) who suggest that it is too early to tell whether carbon-management approaches will escape the fate of the sustainability agenda, which has been largely co-opted by economic development interests.

Despite the aforementioned concerns about the social implications of innovation and experimentation, urban laboratories suggest a new mode of urban climate governance that promises to marry de-carbonization and economic growth by fostering innovative knowledge production. An important implication of this form of governance is that research organizations such as universities and government funding bodies are being more closely drawn into the ecosystem of sustainable urban development to help address gaps in knowledge and finance. It is no wonder that such laboratories are springing up in cities all over the world in places as varied as Sweden, China, Germany, South Korea and the United Arab Emirates. However, these projects embrace the 'laboratory' term without considering the specific implications of experimentation and laboratorization. We build upon an emerging literature that applies insights from Science and Technology Studies (STS) to sustainable urban development and design problematics (Jamison and Rohrer, 2002; Brand, 2005; Guy and Moore, 2005; Moore, 2007; Powell, 2007; Moore and Karvonen, 2008; Monstadt, 2009; Guy *et al.*, 2010; Guy and Karvonen, 2011; Karvonen, 2011) to focus specifically on urban laboratories as bounded areas of innovation that create a venue for knowledge generation aimed at transforming urban governance.

Conceptualizing the city as laboratory

From a traditional perspective, conceptualizing the city as a laboratory is nonsensical. Cities are messy, multivariate, open systems — the very opposite of the scientific laboratories that are valued for being hermetically sealed off from the world. Laboratories are spaces that are distinctly and purposefully created to be separate from the lived world; they are artificially controlled environments where variables can be carefully manipulated and hypotheses can be tested (Knorr-Cetina, 1995). Laboratorization is about setting boundaries within which controlled experiments can take place and be recorded. The purpose of these spaces is to allow the staging of experiments that can be repeated dependably anywhere, transforming *events* (experiments) into *facts* (knowledge). The power of the laboratory to produce knowledge that is generally valid depends upon placelessness and the ability to replicate experimental results anywhere and at any time (Kohler, 2002). This universal knowledge can purportedly be transferred to other places and applied easily and unproblematically.

The concept of the urban laboratory is odd because it implies that the real world can function as a laboratory. Studies taking place in the real world (or 'the field', as natural scientists call it) are generally understood to be situated in particular places at particular times, and thus incapable of producing generally valid knowledge. They tend to be descriptive and specific in their applicability owing to the inability to manipulate variables and isolate cause-and-effect mechanisms. In claiming to be a laboratory in the field, the very notion of an urban laboratory violates this distinction. While science is always situated, and made credible in a particular place at a particular time, knowledge that is geographically specific is generally viewed as not being authentically true (Powell, 2007). An important strand of the laboratory-studies literature engages with exactly this tension to show how traditional laboratory spaces are indelibly mixed up with the outside world in a variety of ways (Gieryn, 2000; Henke, 2001; Kohler, 2002; Livingstone, 2003; Gieryn, 2006; Gross, 2006; Henke and Gieryn, 2008; Meusburger *et al.*, 2010).

Robert Kohler's (2002) historical account of biological studies in the US explicitly considers the laboratory–field dichotomy as a semi-permeable border zone, with particular emphasis on the role of place in facilitating different types of knowledge production. Kohler tells the story of successive attempts by researchers to reconcile the supposed superiority of laboratory methods with the necessity of working on problems such as speciation, which by their nature cannot be reproduced in laboratories and thus require field studies. He states, 'laboratory workers eliminate the element of place from their experiments. Field biologists use places actively in their work as tools; they do not just work *in* a place, as lab biologists do, but *on it*' (*ibid.*: 6). Put another way, 'in the field, deciding what to do is often the same as deciding where to do it' (*ibid.*: 136). By picking the 'proper' place in which nature's experiments are occurring, it is possible to mimic the control of a lab while using the particularity of place to generate knowledge about nature. Indeed, Charles Darwin referred to the Galapagos Islands as a 'living laboratory' for the study of evolution because of its unique geographical isolation. By carefully selecting the proper place in which to conduct studies, Kohler argues that 'field practices of observing and comparing were refashioned into instruments of causal analysis' (*ibid.*: 212).

Kohler charts the frequent use of the expression 'natural laboratory' in field biologists' public and private writings from the late nineteenth to the mid-twentieth century. The idea formed part of what he calls biologists' 'imaginative infrastructure' — an implicit but powerful framework for thinking about how human experimenters can know nature. This 'imaginative infrastructure' resonates with the way in which the concept of urban laboratories is currently applied to sustainability. Urban laboratories share the assumption that such experiments are superior in their 'adherence to life as it is really lived' (Kohler, 2002: 215) and are capable of producing knowledge that will be useful and hence transformative, even if it falls short of the more controlled conditions offered in laboratory activities. The rhetoric surrounding the use of urban laboratories today attests to the desire to capture the authority of experimentation without giving up the authenticity of the real world.

In a chapter titled 'Border practices', Kohler considers how the pioneers of population biology worked in the field, developing a systematic approach to data collection over wide areas that allowed them to replicate the causal analysis associated with laboratories. The requirements of the field site were very different for these field biologists. Rather than unique settings in which to observe the more unusual of nature's experiments unfold, site selection was driven by ease of access and the practicalities of collecting large amounts of data. The paradigmatic example discussed is Raymond Lindeman's field studies of Cedar Creek Bog in Minnesota, which yielded the trophic-dynamic theory of energy flow that underpins the systems logic of modern ecology. Cedar Creek was chosen because it was easy to access and revealed its secrets cheaply; it was shallow, with a very simple species structure, and, if that was not enough, it could be cored to reveal species compositions over many years. In this way, population biologists managed to develop explanatory analyses from field studies by collecting such a surfeit of data that it became possible to identify variables and causal links between them. Musing on this hybrid, Kohler (2002: 218) asks, 'what are we to make of a practice whose techniques are of the field, but whose rules of knowing are of the lab?'

Like Kohler's natural experiments, urban laboratories are highly privileged spaces of experimentation that promise relevance by dint of their adherence to life 'as it is really lived'. Like Darwin's Galapagos Islands, they are 'living laboratories' that are located in cities and focus on the myriad complexities of urban development processes. And like the activities of early population biologists, the epistemological credentials of these laboratories are predicated on a systematic approach to data collection. In order to produce laboratory knowledge in the field, urban laboratories need to be able to provide a richness of data that allows statistical patterns to emerge. Furthermore, to create spaces that are capable of providing the conditions required to experiment in this way, material, institutional and conceptual boundaries have to be set. The setting of boundaries produces what Kohler calls a 'proper place' for experimentation and involves the

negotiation of how place specificity affects knowledge production (Hodson and Marvin, 2009). The importance of built form and bounded space in facilitating knowledge production and urban adaptation has largely been ignored by urban and regional researchers (van Heur, 2010; Evans, 2011). In the next section, we turn to the case study in order to illuminate the space of knowledge production inscribed by the urban laboratory and its implications on carbon governance.

Manchester's Oxford Road corridor

The *UK White Paper on Low Carbon Economy* (UK DTI, 2003), published by the national government's Department of Trade and Industry, called on local and regional authorities to develop demonstration and pilot projects to reduce carbon emissions while bolstering the national economy. Within this context, the 'greening' of Manchester and the City Council's embrace of the low-carbon economy concept is the next iteration of its contemporary urban-development narrative, following the revitalization of the city centre in the late 1990s and early 2000s (Williams, 2000; Peck and Ward, 2002; Harding *et al.*, 2010). The City of Manchester has a target to reduce carbon emissions by 41% by 2020 compared to 2005 levels (Manchester City Council, 2009) and the city-region is designated as one of four Low Carbon Economic Areas (LCEA) in the UK (UK Government, 2009). LCEA status allows for the deployment of new technologies and economic investment to lower the region's carbon footprint, and the Manchester LCEA is the only one that is focused on the built environment. The emphasis on carbon reduction at local and regional levels is paralleled by changes to university funding that focus on the same goal. For example, the Higher Education Funding Council of England has stated that its grants will be dependent upon meeting specific carbon targets (HEFCE, 2010). This moves the low-carbon agenda up on university agendas and begins to resonate with the ambitions of the City Council. Manchester has well-established relations between its higher-education institutions and the City Council, creating an ideal opportunity for a partnership around decarbonization and economic growth.

The Oxford Road corridor is key to achieving Manchester's low-carbon future, generating 22% of the city's gross value and housing the University of Manchester, Manchester Metropolitan University, the Central Manchester Hospitals NHS Foundation Trust (the Hospital Trust), a science park and several cultural institutions of note. And yet the corridor suffers from a series of problems, most notably relating to traffic congestion and the associated detriments of air pollution and noise (see Figure 1). As such, there is a mismatch between the world-class institutions situated on the corridor and the urban fabric of the corridor itself. The corridor is a place that begs for experimentation by sheer dint of the fact that it is currently not functioning very well, let alone in a sustainable way. A City Council staff member summarizes this perspective clearly, stating that 'it's got everything we need to look at climate change and the urban heat-island effect because it's got very little green infrastructure, it's got lots of traffic, it's got lots of people, it's got lots of pollution, it's a perfect little test bed' (interview, 25 November 2010).

The Corridor Manchester Partnership (originally called the Manchester City South Partnership) was established in 2008 between Manchester City Council, the universities and the Hospital Trust. By pooling their resources, the partners hope to realize synergistic benefits and catalyze trickle-down effects of economic and cultural development in the surrounding areas. As stated in the partnership's literature:

The Partnership's core objective is to maximize the economic potential of the area by harnessing the investment currently being made by key institutions (Universities, the Health Trust and the private sector); by stimulating future improvement and growth at key locations within the area; and by capturing economic benefit from this investment for disadvantaged local residents in the wards surrounding the area and in the city as a whole (MCSP, 2008: 5).



Figure 1 The current Oxford Road environment is dominated by bus traffic (photos by James Evans and Andrew Karvonen)

The Oxford Road corridor is slated to become a ‘physical global exemplar of knowledge-based growth’ (Corridor Manchester, 2010b) through strategic capital investments based on five integrated themes: transport; environment and infrastructure; research and innovation; employment, business and skills; and sense of place (*ibid.*). Over the coming years, the corridor will receive significant upgrades to its transportation and communication networks, high-tech business activities and cultural amenities, effectively doubling the number of workers in this part of the city. These upgrades are intended to maximize the economic potential of the city’s knowledge base, adding value to the £1.5 billion of capital investment that is committed to or planned on the corridor by the three main partners over a 5-year period (*ibid.*). The economic potential of the corridor is promoted as being critical to the fortunes of Manchester, the North West and the UK as a whole; it is recognized as having ‘the most significant concentration of knowledge-based assets and potential for growth in the UK today’ (*ibid.*: 5).

The corridor stretches from St Peter’s Square in the central business district to Whitworth Park at the southern extent of the University of Manchester, a narrow sliver of high value and intensive-activity land comprising 243 hectares (see Figure 2) (*ibid.*). The shape of the corridor was driven by institutional necessity; limiting the partnership geography to relatively few landowners expedites decision-making processes and avoids conflicts over different notions of Manchester’s future. Conceptually, the city’s focus was on economic growth, and the city was happy to set the boundaries at the edge of the core university campus areas. As a Corridor Manchester representative states, ‘the boundaries are partly drawn by the City Council with a view to capture as much potential for growth as possible’ (interview, 1 September 2010). Based on the logic of area-based initiatives (Jones and Evans, 2008), the inscription of a place (whether real or invented) offers a common focus around which partnerships can coalesce. These boundaries also create an area in which interventions can be made rapidly, as the partners are also the principal landowners. A University of Manchester working paper, commenting on the promise of the urban laboratory, states that ‘[i]n an increasingly urbanized world, cities

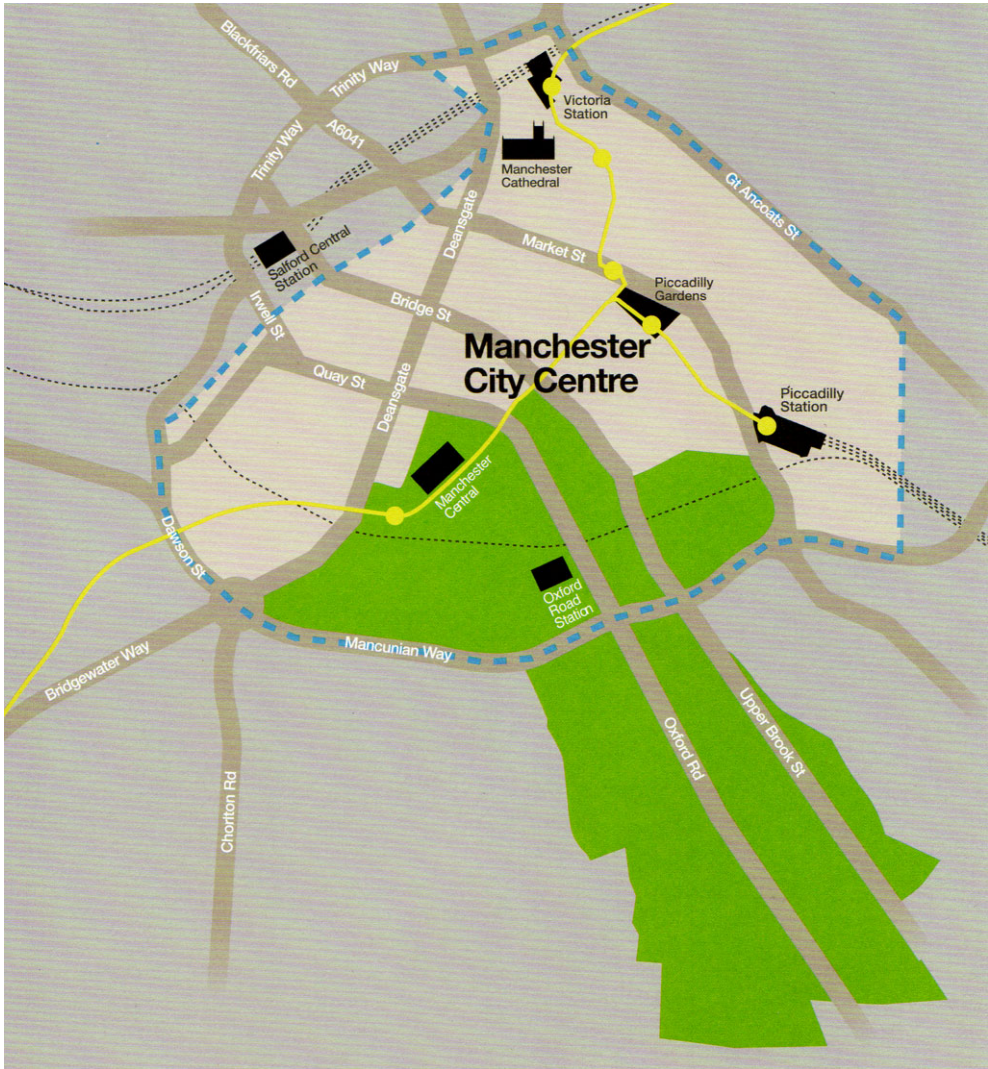


Figure 2 The Corridor Manchester bounded space extends from the city centre to the southeast (source: MCSP, 2008: 3)

and city-regions are sites of cutting-edge experiments and provide a test bed for innovations that grow out of academic endeavour across the “hard” sciences as well as the social sciences’ (Fell, 2010a: 1).

The concept of the urban laboratory is seen as an ideal vehicle to achieve a low-carbon economy, promising to develop innovative energy solutions, stimulate greater cross-disciplinary research in the universities and enhance the ties between the institutions that *create* knowledge and those that *use* it. A Corridor Manchester representative, echoing the goals of ecological modernization to improve economic performance while simultaneously reducing environmental impacts, phrased the particular challenge that the corridor presents as ‘realizing the potential for growth at the same time as meeting low-carbon targets at each of the institutions’ (interview, 1 September 2010). Furthermore, the City Council sees the development of the low-carbon urban laboratory as a highly desirable proving ground for innovative urban development strategies. A staff member notes that ‘having data like that around air quality, urban

heat-island effect, potential cool paving, canopy cover, all that sort of stuff, would be really useful' (interview, 25 November 2010). In addition to transportation upgrades, opportunities for experimentation exist for cutting-edge energy strategies such as combined heat and power, heat transfer, energy efficiency retrofits, smart metering and smart grids. The City Council staff member argues that 'the evidence base that is required to change planning policy is really quite stringent, so we need *peer-reviewed science*. You can't just decide that something would be quite nice and write a planning policy around it. In order to make things enforceable, it really makes a difference' (emphasis added). Marres (2009: 119), in his writing about experiments in green living, calls this an 'empirical mode of presentation', whereby measurement, recording, visualization and detailed reporting are used to literally 'materialize' the empirical (*ibid.*: 127). The appeal of the low-carbon urban laboratory lies in its potential to provide an evidence base for making drastic changes to urban development policies, particularly those related to infrastructure design and management, and the associated material urban environment.

The partnership's promotional materials employ a familiar rhetoric of predicted transformative benefits of such knowledge, claiming that the corridor will link science with practice, allow new ideas to be developed, produce commercial spin-offs, attract academic researchers seeking to do this kind of research and establish global best practices (MCSP, 2008; Corridor Manchester 2009, 2010a; 2010b; 2011). But knowledge that is locally applicable is often by its very nature specific to certain contexts, making it resistant to the production of generally valid truth claims that usually constitute academic research (Evans, 2006). While the emergence of a low-carbon urban laboratory in Manchester provides an enticing storyline for sustainable change (Guy and Marvin, 2001; Eckstein and Throgmorton, 2003; Moore, 2007), it is unclear how these goals will be achieved in practice. In this sense, the urban laboratory serves as a rhetorical device for the aspirational goals of influential urban actors in Manchester, but does not in and of itself provide a means for realizing real change on the ground. The practical challenges of collecting and manipulating data dovetail with a series of governance challenges surrounding how they will subsequently be fed into decision making.

'Give me a laboratory and I will lower your carbon footprint!'

The physical redevelopment strategy of Corridor Manchester creates an opportunity to hardwire monitoring equipment into the urban landscape. A major, if rarely discussed, barrier to conducting environmental research in cities is the ability of research teams to install monitoring equipment in the landscape (Oke, 1982; Fell, 2010a). Obtaining permission to install experimental design features, sustainable technologies, green infrastructure, and the equipment to monitor their subsequent performance, would in theory be a simpler task than it often is in practice because of the challenges associated with negotiating between multiple landowners. As the Corridor Manchester representative states, 'we are going to be digging the road up to get the funding for the bus corridor and we thought, "wouldn't it be great if we could put equipment in to monitor, and have all this data available for research purposes?"' (interview, 1 September 2010). The configuration of the partnership circumvents many of the practical barriers that hamper urban environmental research, and the partnership has consulted widely with university researchers on the types of equipment that would ideally be required in order to use the corridor as a laboratory for research.

The laboratorization of the Corridor so far has revolved around the establishment of Lodanet, a coherent wireless network to provide super-cheap, mega-bandwidth wireless infrastructure in the city centre and along the corridor. Lodanet uses Libelium's Meshlium Xtreme all-weather routers that support five different radio interfaces (Wifi

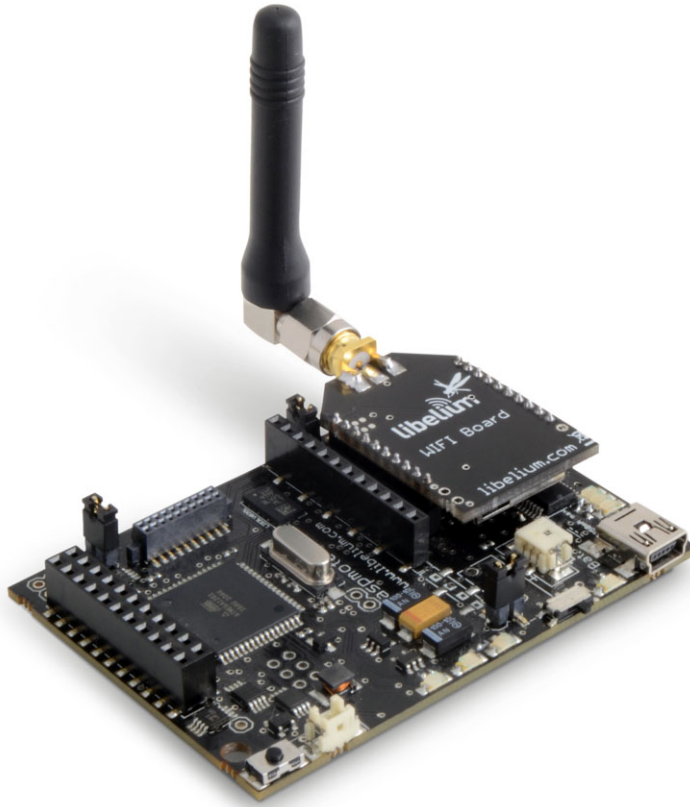


Figure 3 A Wasp mote sensor, such as those installed on the Oxford Road corridor to measure environmental data (source: Libelium, photo reproduced by permission)

2.4GHz, Wifi 5GHz, GPRS, Bluetooth and ZigBee), located on the roofs of city-centre buildings such as the Town Hall and Portland Tower, as well as on buildings along the corridor such as the Palace Hotel, Cornerhouse and St. James House. Wasp mote environmental sensors with custom-made gas sensor boards have been installed at strategic points along the Oxford Road corridor to collect environmental data on temperature, humidity, carbon dioxide, carbon monoxide, nitrogen monoxide, noise and dust (see Figure 3). Connectivity is helped by the fact that Oxford Road is relatively straight, ensuring sightlines between the radios. The Wasp motes, which have a range of around 1 km, then transmit these data to Lodanet via ZigBee radio.

Beyond these technicalities, setting up the wireless network and monitors has entailed negotiating a number of practicalities. Most of the sensors so far have been attached to lampposts, as this allows them to be placed at standard heights high enough to avoid vandalism (approximately four metres). Green papier-mâché covers have been added to make them less conspicuous. Lampposts also provide a convenient source of power for the low-powered radio transmitters, although infrastructure maintenance firm Amey, responsible for street lighting in Manchester, were concerned about the weight of the monitoring equipment, and considerable liaison was required to get permission to tap into the street-lighting network (Harding, 2011). The installation of the network fell to the Manchester Digital Development Agency (MDDA), who is responsible for developing and implementing Manchester's digital development strategy. Located in the city's regeneration team, they obtain funding from a variety of sources for specific projects and are part of the EU Smart-IP project, which seeks to involve citizens in the installation and

Table 1 Provisional list of environmental, transport and socioeconomic variables that require measurement in the low-carbon urban laboratory

Atmosphere/Climate	Solar gain and natural-light levels; temperature (air, surface, global); precipitation; water run-off (volume and speed); water evaporation; air quality (particulates, greenhouse gases, pollutants)
Environment	Wind strength and direction; water quality (turbidity, oxygen content, pollutants); tree-sap flow; noise levels; biodiversity (including flora and fauna patterns and trends); extent, type and use of green space (including ecosystem services); waste management; water consumption
Carbon Use	Energy (heating and cooling demand); building energy consumption (volume and time distribution); traffic composition and movement (including fuel use and pollutant emissions); public-realm lighting levels; IT usage; water-cycle use; embodied and operational carbon; sustainable procurement
Socio-technical	Traffic movement (public transport, taxis, cars and goods vehicles); cycle movement; road traffic accidents/incidents; people movements (including footfall into premises, along pavements, crossing carriageways, boarding/alighting public transport/taxis, etc.); commuting and business-travel patterns (employees, students, patients); attitudinal change of employees, students and visitors to climate-change issues; behavioural change in carbon use, crime patterns; health data
Economic	Building use, patterns (room occupancy, voids, etc.); rents; property prices; building types and ownership; business takings; business footfall; jobs; skills demand; skills development and training provision at HE and FE institutions

Source: Based on Fell (2010b)

maintenance of smart networks. Part of this project involves training residents to be able to calibrate the sensors and take ownership over the ongoing management and maintenance of sensor networks. The degree to which the Smart-IP project succeeds in including residents in the production of data is critical in tempering the top-down scientific model inherent in the laboratory approach, but is in its infancy. In the meantime, the MDDA will remain responsible for managing and maintaining the sensors.

Beyond the wireless network being established, researchers are proposing to collect a wide range of data to monitor under themes of climate, natural environment, carbon use, socio-technical and economy (see Table 1). This level of data collection is intended to provide a complete picture of how the corridor functions and allow the impacts of various experimental interventions to be tested. As a City Council staff member states, ‘the environmental monitoring stations up and down the corridor is kind-of the baseline. And once you start introducing pilot schemes — and god knows how you would stop them interfering with one another — you can then use the monitoring stations to validate the pilot schemes’ (interview, 25 November 2010). As in a conventional laboratory, there is a control or baseline and an experiment, although they occur here sequentially (i.e. before and after) rather than side by side. The parallels with equipping a traditional scientific laboratory were made openly by the University of Manchester representative: ‘[Y]ou then start to build up the spec for the kit you need to work in this part of town, the same as if you were a biochemist and you were “spec-ing” your laboratory’ (interview, 16 June 2010).

The production of scientific knowledge about the causes and effects of different interventions in the urban landscape is based upon statistical ways of knowing, whereby the power to control environmental conditions is substituted for the ability to detect patterns and correlations between data sets. Returning to Kohler’s observations on how population biologists recreated laboratory ways of knowing in the field, the institutional, legal and physical simplicity of the corridor parallels the ecological simplicity of the



Figure 4 An i-trees experimental plot in All Saints Park on the Manchester Metropolitan University campus, with the Oxford Road corridor in the background (photo by James Evans and Andrew Karvonen)

Cedar Creek bog. It presents an environment in which a breadth of longitudinal data can be collected relatively simply, using modern, light-weight sensors.

One of the more publicized experiments in the low-carbon lab is the i-trees project, a joint venture between the University of Manchester, Manchester City Council, Corridor Manchester and Red Rose Forest (a regional charity that works with communities to develop and protect forests). The project comprises nine experimental plots consisting of three grids of tarmac, grass and a tree, each plot comprising a different combination of trees and surface-cover types to study the effects of differing urban morphologies on urban climate and hydrology (see Figure 4). Because monitoring equipment was hardwired into the landscape when the plots were constructed, the equipment is less vulnerable to vandalism or damage and is easily accessible. Data loggers measure air temperature, air quality and the amount and rate of surface water runoff for each site. The i-trees experiment is being scaled up to test the impacts of planting trees in different soils, using different species and planting at varying distances from roads. While the i-trees experiments are small, they provide copious amounts of data. As the i-trees principal investigator states, 'it's a living laboratory to see how effective trees and grass are at preventing runoff and flash flooding' (interview with University of Manchester staff member, 30 March 2010).

The project has attracted considerable interest, and, returning to Kohler's term, represents an important place in which the 'imaginary infrastructure' of the low-carbon laboratory is being put into practice. As the principal investigator on the i-trees project stated, the City Council and Red Rose Forest did 'all the negotiating with people . . . making sure everyone is happy with it, getting all the descriptions and getting all the specifications and producing the plots and then getting the contractors in, all that sort of stuff we're not trained to do as a university' (*ibid.*). The university researchers are allowed to gather data, while the City Council takes care of the messy social side of urban change. For those involved in the low-carbon urban laboratory, i-trees forms a model for the larger data-collection agenda.

While interesting parallels with the literature on laboratories exist between the data collection and knowledge-production aspects of the low-carbon urban laboratory, it is distinguished from the activities of Kohler's population biologists by its transformative promise. The kind of carbon governance found in the Oxford Road corridor constitutes a three-stage feedback loop, whereby (1) the laboratory is established and experiments conducted, which (2) generate data and results that (3) are fed into policy development. The process then begins anew with the conducting of further experiments. This is, in theory, what differentiates the urban laboratory from existing forms of governance: its explicit and formalized emphasis on *recursive learning*. The City Council staff member, reflecting on the i-trees project, states: 'Once we have locally applicable, geographically relevant data sets around surface water runoff and the amount of green infrastructure that would offset X amount of surface water runoff, it gives us something solid to aim for, it gives us a reason to write a policy that says "we need to increase green infrastructure in the city centre by X amount"' (interview, 25 November 2010). Similarly, the University of Manchester representative states: 'The City Council looks great because it's real-time evaluation. The research produces live data in a real environment and if the data stacks up, it will change the way in which investments are made in future. So everyone wins' (interview, 16 June 2010). The City Council staff member concurs: '[H]aving data around on air quality, the urban heat-island effect, cool paving, canopy cover, all that sort of stuff, would be really useful for introducing new development policies' (interview, 25 November 2010).

The low-carbon laboratory thus frames innovation in an urban context as a process of recursive knowledge production and application — generating data, applying it to policy, assessing the results, generating more data, revising policy, and so on. As the Corridor Manchester representative states, 'it is actually quite hard for them [the city and regional governmental bodies] to make things happen' (interview, 1 September 2010). The low-carbon urban laboratory is appealing because it provides an alternative venue for innovation, one that is underpinned by the objective knowledge of scientific practice. The visibility of the urban laboratory as an experimental space is a crucial part of the transformation process (Gieryn, 2008). The low-carbon urban laboratory on the Oxford Road corridor operates according to this logic, empiricizing the urban landscape through monitoring and instrumentation, and then materializing these empirics by feeding them into subsequent planning policy that will shape the urban form.

The imaginary infrastructure that attaches itself to urban laboratories is based precisely upon an implicit understanding of this power of experiments to transform reality through framing new futures and sets of options (Callon *et al.*, 2009; Davies, 2010). The 'empirical mode of presentation' is political in that what gets measured is what matters (Marres, 2009: 127). Put more succinctly, it is not so much that 'reality is being tested as that testing is constitutive of what can be designated as real' (Ronell, 2003: 665). The politics of the laboratory mode of governance lies in what is measured and how, which, as part of a wider technocratization of decision making in the public sphere (Brand and Karvonen, 2007; Karvonen and Brand, 2009; Swyngedouw, 2009; Evans, 2011), forms a significant research agenda for the emerging socio-technical study of urban sustainability. What then happens to the data remains somewhat unclear. Returning to the practicalities of how the recursive loop between monitoring and decision making might actually be established, it is rather worrying that there is no standard format for storing the data that is being collected, let alone an established protocol for its subsequent incorporation into decision making.

A further issue regarding the corridor that has not been addressed is the unevenness of laboratorization; in short, the experimental capacities of cities are not distributed evenly (Hodson and Marvin, 2009). This is an inherent characteristic of defining the spatial extent of the urban laboratory and is exacerbated by the framing of experimentation as a means to realizing economic development. Meanwhile, the social aspects of urban development and issues that do not fit into the nexus of economic development and environmental protection are largely ignored. This is particularly evident in the Oxford

Road corridor, where adjacent low-income communities are being framed as beneficiaries of the infrastructure upgrades but not considered as participants in the experimental process. The corridor is bounded on three sides by low-income communities that have historically had an antagonistic relationship with the universities and, to a lesser extent, the cultural institutions on the Oxford Road corridor.

A significant challenge for Corridor Manchester and the low-carbon urban laboratory is to expand the partnership beyond the current partners and include all stakeholders on whom the revitalization and experimental activities have an impact. As a University of Manchester staff member states, '[i]f you look at the way that the university is sort-of oriented inwards rather than outwards and you want to start to change that, there is a whole host of political and cultural issues to address' (interview, 16 June 2010). Rather than addressing these challenging political and cultural issues, the Corridor Manchester partnership short-circuits the politics of urban development by creating a closed feedback loop of measurement and policy development. As such, the partnership and the laboratory tend to reinforce the divide between the knowledge community and the surrounding neighbourhoods rather than integrate these in new ways. While the Smart-IP project is a laudable attempt to involve citizens in the monitoring process, empowerment is still limited to their enrolment in what is largely a technocratic procedure. This is a particularly important drawback of the urban laboratory in Manchester and suggests that laboratorization here currently involves the retrenchment of existing modes of governance under the guise of innovation. That said, it would be overly pessimistic to disavow the potential of laboratorization to realize new forms of urban politics based upon the democratization of knowledge production and use. The question is how these emancipatory currents intermingle with the more familiar modes of urban development, and how they might inform different urban futures.

Conclusions

To summarize his famous laboratory study of Pasteur's success in microbiology, Bruno Latour (1983: 141) writes: 'Give me a laboratory and I will raise the world'. He attributes Pasteur's success as a scientist to his ability to translate the findings from his laboratory to the outside world in very effective ways. Latour disrupts the common conception of inside and outside, micro and macro and, in the process, reinterprets the way we understand activities of knowledge production and application. This suggests that practices of science are far from being a neutral observation of the world but rather politics by another means with a variety of crucial implications. In many ways, the low-carbon urban laboratory on the Oxford Road corridor operates in a similar manner by constructing a laboratory to achieve a low-carbon society. The laboratory operates according to an experimental logic, empiricizing the urban landscape through monitoring and instrumentation, and then materializing these empirics by feeding them into subsequent planning policy that will shape urban development. In its rhetoric at least, laboratory governance promises to enhance the links between universities and cities, dissolving the boundaries between knowledge makers and knowledge users. In the pursuit of urban sustainability, science is increasingly intermingled with governance.

At the same time, the corridor is being used as a means to reinforce the dominance of those in power and to further solidify their agenda for shaping Manchester's future. The knowledge being produced in the laboratory can be circulated through the existing network of ecological modernization actors while doing little to engage with or improve the everyday lives of those who are not included in the existing governance regime in Manchester. This is, of course, the classic critique of ecological modernization with its promise to alter environmental impacts without challenging larger unequal structural issues (Hajer, 1995; Karvonen, 2011; Karvonen and Yocom, 2011).

But even within the narrow ecological modernization framework of the corridor actors, there are unacknowledged challenges associated with the risk and open-endedness

inherent in experimental activities. A City Council staff member directly acknowledges this issue, stating that ‘there’s a lot of risk involved . . . an awful lot of money has gone down the drain trying to set up pilot schemes that weren’t that successful. It’s the price you pay for chasing an innovative approach . . . Is Corridor Manchester going to save the world? Not sure’ (interview, 25 November 2010). This suggests that innovation continues to be a tenuous endeavour, and it is crucial for the partners to have realistic expectations for their laboratory work; it is likely that their experiments will not turn out as planned, but this is rarely acknowledged (at least publicly). As such, managing the expectations of the Oxford Road corridor and the potential of the low-carbon urban laboratory may become as important as nurturing the feedback loop of experimentation and policy change.

Despite these significant issues of exclusion and risk, scientific knowledge generation is increasingly becoming a ‘transformational agent’ in the competitive fortunes of cities (Perry, 2006: 202). Cities are racing to attract scientists and companies with scientific infrastructure to enhance their economies and improve their international reputations while also tapping into the local capacity for knowledge generation through partnerships with universities. Within this context, urban laboratories present an attractive mode of governance that foregrounds knowledge and innovation. The appeal of the urban laboratory as a mode of governance lies in its potential to transform the economic and social landscape, but this process relies upon the creation of specific spaces to facilitate new processes of scientific knowledge being translated into government policy. The setting of boundaries, and the issuing of guarantees that it represents, thus reduces uncertainty for potential experimenters, whether they be academic or commercial. The potential for realizing low-carbon futures relies on developing and applying locally relevant knowledge to the real world, and urban laboratories can help to achieve this by reinventing the way in which scientific knowledge is translated into urban development activities.

To conclude, it is perhaps worth noting that the assumption that we can in some way ‘know’ the city through scientific monitoring forms one of the largely ignored assumptions of the sustainable city, finding broad expression in the rhetoric and claims of adaptive governance, resilience, Smart Cities and eco-cities. Urban laboratories provide a valuable window on these issues by drawing our attention to both the practicalities and politics of monitoring as well as the larger issues of spatial bounding and knowledge production. The success of certain cities and failure of others in addressing climate change will be determined in large part by their ability to harness flows of knowledge for their particular contexts, successfully translating empirical findings into reality, and this surely warrants closer study.

James Evans (james.z.evans@manchester.ac.uk) and **Andrew Karvonen** (andrew.karvonen@manchester.ac.uk), School of Environment, Education and Development, University of Manchester, Oxford Road, Manchester M13 9PL, UK.

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