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'Give me a laboratory and I will lower your carbon footprint!' – Urban Laboratories and the Pursuit of Low Carbon Futures

By 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 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 paper, 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 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 including 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 of knowledge production. This low carbon urban laboratory represents a classic sustainable development formula of 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, providing an intriguing approach to radically transform cities to address climate change.

Keywords

Urban laboratories, climate change, governance, knowledge production, Manchester UK

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 policy-makers, 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 production sites for knowledge 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 to mobilise place to generate economic wealth and stimulate more resilient urban conditions. In the context of the growing emphasis on partnerships between universities, government, and industry, such approaches to sustainability are blossoming while their origins, impacts, and implications for urban governance remain largely unexamined.

In this article, we explore the application of the urban laboratory concept to sustainable governance through an empirical study of the emerging low carbon urban laboratory on the Oxford Road corridor in Manchester UK. Focusing on a single case study allows us to explore a range of questions in the literature surrounding cities, decarbonization, and the low carbon economy in direct relation to the phenomena 'as they unfold in practice' (Flyvbjerg, 2001: 82). The low carbon urban laboratory on the Oxford Road corridor is indicative of the key issues of deploying urban laboratories for sustainability. To complete the study, we collected primary data from early 2009 to early 2011 through semi-structured interviews with four key actors involved in revitalising the Oxford Road corridor, including representatives from the Corridor Manchester public/private partnership, the University of Manchester, and Manchester City Council. In addition, we regularly 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 discussion. The empirical evidence reveals that urban laboratories provide governance by another means by 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.

Building upon an emerging literature that applies insights from Science and Technology Studies to sustainable urban development and design problematics (Brand, 2005; Guy and Moore, 2005; Guy et al., 2010; Jamison and Rohracher, 2002; Karvonen, 2011; Monstadt, 2009; Moore, 2007; Moore and Karvonen, 2008; Powell, 2007), we focus specifically on the knowledge generation aspects of urban laboratories. We define urban laboratories as bounded areas of innovation that create a venue for knowledge generation aimed at transforming urban governance. The Oxford Road corridor provides a real world project where an innovative carbon agenda is currently unfolding and highlights the importance of place as well as willing local actors with a shared vision to realise a low carbon future. We begin by reviewing some concepts on low carbon governance and the emerging low carbon agenda, and then use insights from Robert Kohler's work on laboratories and field sites to make sense of the 'urban laboratory' concept. 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 unfolding in practice. We argue that a defining feature of urban laboratories is the ability to change the knowledge production underpinning 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. To conclude, we reflect briefly on a few risks and pitfalls related to laboratory governance and low carbon transition.

Governance toward a low carbon economy

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. The carbonization of urban governance identifies the management of carbon emissions as a new model for governing cities (Bulkeley and Betsill, 2003; 2005; Bulkeley et al., 2011; Lerch, 2008; While, 2008; While et al., 2009). National commitments to reduce emissions are cascaded down to sub-national levels, like regions and cities, because it is assumed that these smaller scales can facilitate rapid, context-specific action (Bulkeley and Betsill, 2003; 2005). There is also evidence that territorializing carbon emissions at these sub-national levels empowers actors to take greater measures to reduce their emissions (Rice, 2010). In other words, it is recognised that the local and regional scale is where the greatest gains can be made in reducing carbon footprints and thus, addressing climate change. Early studies suggest that low carbon governance may hold greater transformative potential than existing approaches of 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 that this 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 labs offer a sub-local space to implement government approaches to climate change mitigation and adaptation but achieve this through differentiation.

Bulkeley and Castán-Broto (forthcoming) 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. The problem with this understanding 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 technical transitions literature. Studying the way in which large-scale shifts in technology occur, this literature sees experimentation as occurring in specific niches or protected environments that are sheltered from wider political and economic pressures (Geels, 2002; 2004; 2005; Geels and Schot, 2007; Hoogma, 2002; Kemp et al., 2001; Smith et al., 2005). The strategic niche management literature recognises that innovation rarely conforms to the traditional linear model of knowledge transfer, but is better conceptualised 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 formalised (Evans and Karvonen, 2010). In bounding space, urban laboratories represent a specific type of niche that is often created by university-led partnerships to emphasise the importance of knowledge production (Krueger and Buckingham, 2009; Perry, 2006). It is this emphasis on formalised 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 catalyse 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 in' to 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 and colleagues (2004; 2009) who suggest that it is too early to tell whether carbon management approaches will escape the fate of sustainability agenda and avoid being 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. It is no wonder that such laboratories are springing up in cities all over the world in places as varied as Dongtan, Abu Dhabi, and Trondheim. However, these projects embrace the 'laboratory' term without considering the specific implications of experimentation and laboratorisation. Before moving on to consider how urban laboratories for low carbon governance are playing out in practice, it is helpful to consider how the city might be conceived as a laboratory, particularly in terms of how place can facilitate different kinds of knowledge production.

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). Laboratisation 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 laboratory ways of knowing to produce generally valid knowledge thus depends upon their placeless-ness, or the ability to replicate experimental results anywhere and at anytime (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 due 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 (see Gieryn, 2000; 2006; Gross, 2006; Henke, 2001; Henke and Gieryn, 2008).

Robert Kohler's (2002) historical account of biological studies in the US explicitly considers the laboratory-field dichotomy as a semi-permeable border zone, paying particular attention to the role of place in facilitating different types of knowledge production. Kohler tells the story of successive researchers attempting to reconcile the supposed superiority of laboratory methods with the necessity of working on problems like speciation, which, by their nature cannot be reproduced in labs and thus require field studies. He (2002: 6) 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.' Put another way, 'in the field, deciding what to do is often the same as deciding where to do it' (2002: 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' (2002: 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 upon a systematic approach to data collection. In order to produce laboratory knowledge in the field, urban labs need to be able to provide a richness of data that allows for statistical patterns to emerge. Further, 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 afforded by the urban laboratory.

Manchester and the Oxford Road Corridor

The *UK White Paper on Low Carbon Economy* published by the national government's Department of Trade and Industry calls on local and regional authorities to develop demonstration and pilot projects that can reduce carbon emissions while bolstering the national economy (UK DTI, 2003). 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 rebuilding of city centre in the late 1990s and early 2000s (Harding et al., 2010; Peck and Ward, 2002; Williams, 2000). 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. The 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 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 on 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 decarbonisation and economic growth.

The Oxford Road corridor is key to achieving this low carbon future, generating 22% of Manchester'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 noted cultural institutions. And yet it suffers from a series of problems, most notably relating to traffic congestion and the associated detriments of air pollution and noise (**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 states, '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 testbed.'

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 realise synergistic benefits and catalyse trickle-down effects of economic and cultural development in the surrounding areas. As stated in the partnership's literature (MCSP, 2008: 5):

> The Partnership's core objective is to maximise 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.

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 (Corridor Manchester, 2010b). Over the coming years, the corridor will receive significant upgrades to the transportation and communication networks, high tech business activities, cultural amenities, and effectively double the number of workers in this part of the city. These upgrades are intended to maximise the economic potential of the city's knowledge base, adding value to the £1.5 billion of capital investment that is committed or planned on the corridor by the main three partners over a five-year period (Corridor Manchester, 2010b). 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 recognised as having 'the most significant concentration of knowledge-based assets and potential for growth in the UK today' (Corridor Manchester, 2010b: 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 (**Figure 2**) (Corridor Manchester, 2010b). The shape of the corridor was driven by institutional necessity; limiting the partnership geography to relatively few landowners expedites decision-making processes and avoid conflicts over different notions of Manchester's future. Conceptually, the city's focus was on economic growth, and they were 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'. Following 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. Commenting on the promise of the urban laboratory, a University of Manchester working paper states that, 'In an increasingly urbanised world, cities 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 urban laboratory concept 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. Echoing the goals of ecological modernisation to improve economic performance while simultaneously reducing environmental impacts, a Corridor Manchester representative phrased the particular challenge that the corridor presents in terms of 'realizing the potential for growth at the same time as meeting low carbon targets at each of the institutions.'

The development of low carbon urban laboratory is seen as highly desirable by the City Council. A staff member notes, '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.' 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* [emphasis added]. 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.' Writing about experiments in green living, Marres (2009: 119) calls this an 'empirical mode of presentation', whereby measurement, recording, visualisation, and detailed reporting are used to literally 'materialize' the empirical (2009: 127). The low carbon urban laboratory provides 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 deploy 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 (Corridor Manchester 2010a; 2010b; 2011; MCSP, 2008). 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 (Eckstein and Throgmorton, 2003; Guy and Marvin, 2001; Moore, 2007), there are tensions surrounding the ways in which these goals are to be achieved in practice.

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

The physical redevelopment strategy of Corridor Manchester created 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 (Fell, 2010a; Oke, 1982). 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 when dealing with 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?"' The configuration of the partnership circumvents many of the practical barriers that hamper urban environmental research. 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. **Table 1** summarises the breadth of data that researchers and partners could potentially collect, structured under themes of climate, natural environment, carbon use, socio-technical, and economy. 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 the 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.' Just like 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. And the parallels with equipping a traditional scientific laboratory were made openly by the University of Manchester representative: 'you 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 bio chemist and you were "spec-ing" your laboratory'.

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 datasets. Returning to Kohler's observations on how population biologists recreated laboratory ways of knowing in the field, the institutional and legal simplicity of the corridor parallels the ecological simplicity of the Cedar Creek bog. It presents an environment in which a breadth of longitudinal data has the potential to be collected relatively simply. That said, the level of data collection currently occurring in the Oxford Road Low Carbon Lab is fairly modest.

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 work with communities to develop and protect forests. The project comprises nine experimental plots consisting of three grids of tarmac, grass and a tree, with each plot using a different combination of trees and surface cover types to study the effects of differing urban morphologies on urban climate and hydrology. 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 measuring 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.' 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.' 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) generates data and results that (3) are fed into policy development. The process then begins anew with the conducting of further experiments. The City Council staff member, reflecting on the i-Trees project, states, 'Once we have locally applicable, geographically relevant datasets 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".' 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.' The City Council staff member concurs: 'having 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.'

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 (**Figure 3**). As the Corridor Manchester representative states, 'it is actually quite hard for them [the city and regional governmental bodies] to make things happen'. The low carbon urban laboratory is appealing because it provides an alternative venue for development, 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, empiricising the urban landscape through monitoring and instrumentation, and then materialising 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 technocratisation of decision-making in the public sphere (Evans, 2011;

Swyngedouw, 2009), forms a significant research agenda for the emerging socio-technical study of urban sustainability.

Conclusions

To summarise his famous laboratory study of Pasteur success in microbiology, Bruno Latour writes, 'Give me a laboratory and I will raise the world' (Latour, 1983). He attributes Pasteur's success as a scientist to his ability of translating 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 that we understand processes 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, empiricising the urban landscape through monitoring and instrumentation, and then materialising these empirics by feeding them into subsequent planning policy that will shape urban development. The new form of governance promised by urban laboratories can 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.

One issue that has not been addressed on the Oxford Road corridor is the unevenness of laboratorisation; 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 realise 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 with adjacent low-income communities being framed as beneficiaries of the infrastructure upgrades but not considered as participants in the experimental process. A significant challenge for Corridor Manchester and the low carbon urban laboratory is to expand the partnership beyond the current partners and include all of those stakeholders who are impacted by the revitalisation and experimental activities. As the University of Manchester staff member states, 'If 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.' 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 integrate them in new ways.

A second challenge of urban laboratories is to embrace the risk and open-endedness inherent in experimental activities. The 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.' This suggests that 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 acknowledge (at least publicly). Managing the expectations of the Oxford Road corridor and the potential of the low carbon urban laboratory may become just 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 realising 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 that scientific knowledge is translated into urban development activities. 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.

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Figure 1 The current Oxford Road environment is dominated by bus traffic

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

Table 1 Provisional list of environmental, transport and socio economic variables that require measurement in the low carbon urban laboratory (after Fell, 2010b)

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 accident/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; skill demand; skill development and training provision at HE and FE institutions

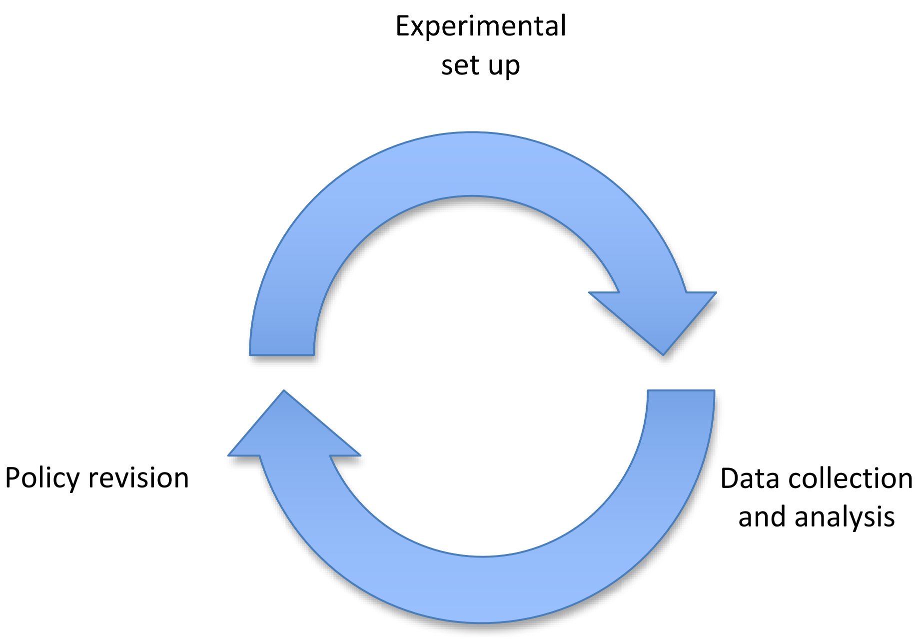

Figure 3 The recursive cycle of experimental set up, data collection and analysis, and policy revision, as envisioned for Manchester's low carbon urban laboratory