Strategies for exploring urban futures in, and across, disciplines

Abstract

The EPSRC Urban Futures project aims to assess the resilience of urban regeneration to a range of possible futures. The project uses narrative scenarios, rather than quantitative extrapolation techniques. Some scenario storylines include tipping points and paradigm shifts, leading to societal patterns quite different from those in the present day UK. The scenarios are honed from existing futures literature by deducing characteristics of each scenario that are relevant for urban regeneration. To make these deductions, each scenario is interrogated from eight disciplinary standpoints: biogeography, air pollution, water resources, the surface built environment, the underground built environment, design, organisational behaviour, and social policy. The refined scenarios are then used as 'test rigs' in which the resilience of current regeneration strategy and practice can be assessed.

Trees and green space in cities have emerged as a cross-cutting theme in Urban Futures. Street trees, parkland, and green walls and roofs are often cited as important contributors to the sustainability of a regeneration project. We discuss our strategy for assessing such claims, using the West Midlands and Lancaster as UK case study areas, and provide examples of project outcomes (building on our previously published Urban Tree Air Quality Score). We also describe the limits to our assessments, which are due to (i) the scope of the scenarios used, (ii) difficulties in passing useable information between disciplines and/or (iii) discipline-specific technical limitations (e.g. incorporating the aerodynamic, thermal, and chemical effects of trees and green spaces in models of urban air pollution).

Introduction

Across the world, most people now live in cities (http://nature.com/cities and references therein). These cities are diverse, but they all contribute to, and must adapt to, the changing environment. Hence, most environmental, economic, and social planning and policy-making for cities advocates sustainable development. Many remedial actions have been proposed in response to the widely acknowledged unsustainability of contemporary urban living (Droege, 2006; Roger Evans Associates *et al*., 2007; Beatley, 2010; Gehl, 2010; Suzuki *et al*., 2010). Below, we refer to specific remedial actions as 'sustainability solutions' or, simply, 'solutions'. Very many sustainability solutions involve significant increases in urban green space: installation of green walls, green roofs, and other 'living infrastructure' (Hollander *et al*., 2010), expansion of parkland (Harnik and Bloomberg, 2010; Suzuki *et al*., 2010, p.76), and planting many more street trees (http://thebigtreeplant.direct.gov.uk/about.html). In what follows we concentrate on sustainability solutions that have been proposed in the context of urban regeneration, and on solutions that involve urban vegetation.

Our research, described below, concerns the claims to sustainability of solutions in two respects: (i) the discipline-specific evidence base for particular solutions, and (ii) the multi-disciplinary evidence base for the resilience of solutions, as measured against a range of future scenarios. This research is part of the Urban Futures project (http://urban-futures.org/), which has the multi-disciplinary assessment of sustainability solutions at its core and is informed by disciplinary-based research in biogeography, air pollution, water resources, the surface built environment, the underground built environment, design, organisational behaviour, and social policy.

Below, we describe a method to establish the resilience of sustainability solutions for urban regeneration that draws on futures research and a multi-disciplinary perspective. We begin

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with a brief description of how scenarios can be used to establish a range of settings in which the solution must be capable of functioning. We then derive from our chosen future scenarios characteristics that are specific to UK urban environments, and provide examples of applying this scenario-based method to a specific planning case in Lancaster, UK. From this we generalise some aspects of work on trees and green spaces as sustainability solutions, using the West Midlands, UK, as an example. Finally, we acknowledge the limitations that remain in our methodology as a result of the difficulties of multi-disciplinary work and the requirement for further disciplinary research.

Futures scenarios

Our approach to the use of future scenarios is described in detail elsewhere (Hunt *et al*., 2011). Briefly, our approach requires the use of future scenarios, rather than extrapolation, because resilience implies continued functioning across a range of possible futures, ranging from the probable to the plausible. Scenario-building allows for social, economic, or environmental tipping points in a way that extrapolation cannot (Slaughter, 1995; Fischer-Kowalski and Halberl, 2007; Samet, 2008). Another key distinction between futures research and extrapolation is picked up in our conclusions. A survey of recent futures literature found more than 400 future scenarios (Hunt *et al*., 2011). Rather than add to this list, we elected to use existing scenarios and develop their treatment of (UK) urban characteristics, as described below.

Our chosen scenarios come from the work of the Global Scenarios Group (GSG): see http://www.gsg.org/, for general introductory material on GSG, and http://www.polestarproject.org/globalscen.html for more quantitative technical details. We develop the GSG descriptions of Market Forces, Policy Reform, New Sustainability Paradigm, and Fortress World scenarios. These scenarios cover extrapolated conventional or business-as-usual futures (Market Forces, which was originally called 'Business-as-usual', and Policy Reform), a future characterised by civil breakdown or barbarisation (Fortress World), and a future in which communitarian value systems emerge (New Sustainability Paradigm).

In Market Forces (MF), as the name suggests, there is continued strong belief that the invisible hand of the market will produce, purely through the self-interest of individuals, the most good for the most people. Concerns about depletion of natural resources or contamination of the Commons are subordinated to this belief in the market as engine of economic improvement. As an extrapolated business-as-usual scenario, MF therefore includes the continued urbanisation of world population, as described in http://nature.com/cities and references therein.

The Policy Reform (PR) scenario retains the primacy of individual self-interest, but tempers the free-running of the market, through implementation of strong regulations, in order to slow the depletion of natural resources and limit the contamination of the Commons.

Since natural resources are finite, the GSG authors argue that the extrapolated MF and PR futures will inevitably collapse, to produce radically different futures. In the Fortress World (FW) scenario, the selfishness inherent in MF and PR becomes exacerbated as resources diminish, leading to enclaves of 'haves' who protect their privileged access to resources against a large majority of 'have-nots'. Because of the concentration of economic and political power in cities, the FW enclaves centre on highly developed urban areas but also encapsulate the dispersed infrastructure and utility networks that allow the enclaves to function.

The GSG authors provide an alternative to FW, in which the collapse of MF and PR causes a wholesale re-evaluation of the primacy of self-interest. The New Sustainability Paradigm (NSP) is characterised by concern for the preservation of natural systems, to the extent that individuals seek material sufficiency (rather than excess) and prefer to live in societies with equitable distributions of wealth. In order to avoid a turn towards localism, global networks are maintained, principally through the maintenance of cities and their metabolic infrastructure.

UK urban characteristics

The GSG scenarios provide qualitative and quantitative descriptions of each future at global and continental scales. To bring futures thinking into planning practice, however, local environmental, societal, and economic contexts must be considered, in order to avoid a one-size-fits-all mind-set that imposes a single grand vision with its attendant unforeseen consequences. Local here encompasses all scales from the street corner to the city (Roger Evans Associates *et al*., 2007; Suzuki *et al*., 2010), and often extends further than expected. For instance, installation of bat boxes can only work as a solution to preserve biodiversity if unlit tree corridors, connecting the bat roosts to feeding areas, are also in place. This also implies that the topology of tree cover can be as important as overall area and species composition. Sustainability solutions can be vulnerable if they are applied without due regard to their local context even before considering the resilience of a solution to possible futures. Moreover, urban planners have in the past sometimes neglected the 'human scale' and championed designs in which the aesthetic value becomes apparent only when seen from a distance or even from the air (Gehl, 2010), and it is important that futures thinking about city living does not make the same mistake.

To down-scale the scenarios to the scales relevant for urban planning and regeneration, we have identified over 50 characteristics that describe the aspects of the UK urban environment relevant to the Urban Futures research (the full list of characteristics is available at http://urban-futures.org/). These characteristics range from population density, through brownfield recycling, above-ground and underground infrastructure, street patterns, and traffic levels, to levels of personal income and patterns of ownership. We have then used the evidence presented in the descriptions of the scenarios to deduce how each urban characteristic will change under each scenario (Boyko *et al*., 2011).

An example may serve to illustrate the method. Two important characteristics of the UK urban environment are (i) area and pattern of tree cover, and (ii) tree species present. We can know the present situation with regard to tree cover through remote sensing (Huang *et al*., 2007) and with regard to tree species abundance through survey work (Donovan *et al*., 2010, whose survey results are available at http://urgent.nerc.ac.uk/dataset%20html%20pages/dataset_2066225676.htm). The descriptions of the scenarios provide evidence for the direction of travel of these characteristics: in the MF scenario, social and environmental concerns are secondary (Raskin *et al*., 2002). Maintenance of protected forest areas and biodiversity is hampered by the free market (Gallopin *et al*., 1997; Raskin *et al*., 1998). This may also apply to city parks. There is a need for high-density housing for people with low income. Income disparity between rich and poor is manifested in environmental inequality, where the rich have disproportionate access to nature reserves. From these descriptions we deduce that the change in tree cover in this scenario depends on the affluence of the area under study. Under MF, tree/hedge coverage may be static or even increase in affluent areas, but may be virtually eliminated in poor neighbourhoods due to space considerations and the cost of maintenance. Tree planting in affluent areas will be dictated by fashion, with a tendency towards planting non-native exotics. The NSP description also provides many signposts for the likely change in tree cover and speciation under that scenario. In a NSP future, large native trees are protected for their intrinsic biodiversity value. New planting is with native species where possible and located to facilitate connectivity. More fruit trees are planted because citizens value local and self-reliant production and amenity land is converted to be agriculturally productive (Gallopin *et al*., 1997). Hedges and boundary trees are planted for microclimate modification and/or fruit/wood production and/or biodiversity, rather than privacy (hence brambles rather than leylandii) because a new sense of community springs up (Gallopin *et al*., 1997). In general, people place a high value on nature (deduced from the NSP storyline in Gallopin *et al*., 1997) and there is a renaissance in craft production. More biomass species (poplar and willow) are planted to give decentralised renewable energy (Gallopin *et al*., 1997). For all these reasons, tree cover is likely to increase under the NSP scenario, subject to the particular constraints of a given locale.

Trees and green space as sustainability solutions

It is often regarded as self-evident that there should be more trees in towns. When discussing aspects of building 'the Renewable City', Droege (2006) writes 'at the very least, streets should always be heavily lined with trees'. Whilst happy to acknowledge the many beneficial effects of urban trees, we have argued elsewhere (MacKenzie *et al*., 2010) that ensuring that trees provide a continuing positive outcome – that is, act as sustainability solutions in the strict sense – requires careful consideration of competing and shifting costs and benefits. From an air quality perspective, all urban trees provide efficient surfaces for the dry deposition of nitrogen dioxide, ozone, carbon monoxide, acid gases, and particulate matter (Tyrvainen *et al*., 2005; McDonald *et al*., 2007; Fowler *et al*., 2009) but some trees also produce significant quantities of volatile organic compounds (VOCs), particularly isoprene, which can take part in atmospheric photochemistry to produce ozone and particulate matter (MacKenzie *et al*., 1991). We used air quality modelling and existing air quality standards to quantify the balance between these positive and negative effects of trees on air quality, for a UK West Midlands case study (Donovan *et al*., 2005). Running the air quality model with and without enhanced tree cover produced changes to simulated atmospheric composition which were then compared to air quality standards to produce an urban tree air quality score (UTAQS):

$$\text{UTASQS} = -100\left(\frac{\Delta O_3}{AQS_{O3}} + \frac{\Delta NO_2}{AQS_{NO2}} + \frac{\Delta HNO_3}{AQS_{PM10}}\right)$$

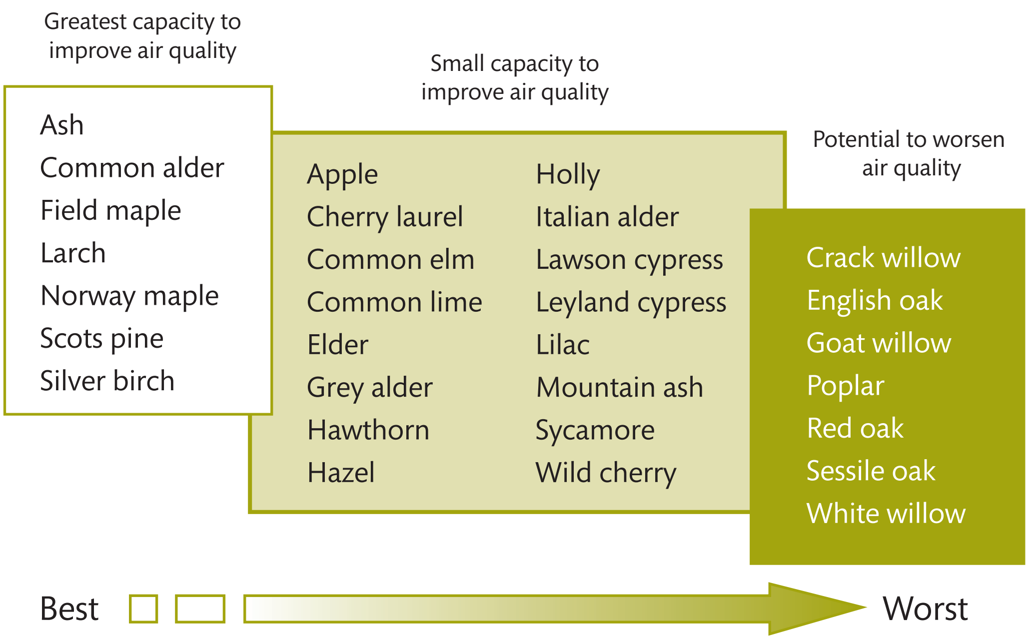
where ΔO_3 is the difference between the UTAQS model run and the control run, in the peak 8-hour running mean concentration of O_3 on the fifth day; ΔNO_2 is the difference in the peak 1-hour concentration of NO_2 on the fifth day; ΔHNO_3 is the difference in the modelled 24-hour running mean of HNO_3 on the fifth day (in $\mu g\ m^{-3}$); and AQS_{O3}, AQS_{NO2}, and AQS_{PM10} are the air quality standards for O_3 (50 ppb), NO_2 (150 ppb), and PM10 (50 µg m^{-3}), respectively. The values are multiplied by -100 to give a positive value for an improvement in air quality when compared to the control tree population and to scale UTAQS scores to be between -10 and +10. From this model study, which was built on intensive survey work (Donovan *et al*., 2010), land use classification (Owen *et al*., 2006), and laboratory and field studies of VOC emissions from trees (Owen *et al*., 2003; Stewart *et al*., 2003), we were able to produce 'traffic light' guidance for the impact of tree species on air quality (Figure 1).

The implication is that our native oaks, willows, and poplars could be detrimental to air quality for the conditions modelled (stagnant, summer-time, anticyclonic conditions). Of course, one should not forget that native trees have very high year-round ecological and aesthetic value and there is much to be said in favour of a comprehensive, rather than partial, cost-benefit analysis. Our point is that, if large-scale tree planting schemes are to be used specifically to enhance air quality, then species with low-ranking UTAQS should be avoided. We discuss limitations of the Donovan *et al*. (2005) study in the next section.

As well as providing surfaces for dry deposition, and emitting VOCs, urban trees and green spaces can affect the dispersion of air pollutants by affecting wind flow. Urban green space will not, in general, have the same aerodynamic roughness as the surrounding built environment (Oke, 1989) and so will change wind speeds by providing a larger or smaller sink for atmospheric momentum. Urban green space also interacts differently with incoming solar energy; the built environment gives rise to the well-known urban heat island (Oke, 1973), which is ameliorated by urban green space (Oke, 1989). The effect of green space is visible at the city scale (Tyrvainen *et al*., 2005). There are also important local effects. Air flow in street canyons depends on the wind speed, wind direction, and canyon geometry (Salmond and McKendry, 2009; Llewellyn Davies for English Partnerships with Commission for Architecture and the Built Environment and the Housing Corporation, 2000). For canyon height-to-width ratios above about 0.7, internal circulations are set up in the canyons, cut-off, except by turbulent mixing, from the flow above, which skims over the urban landscape (Oke, 1988; Xie *et al*., 2005). Street trees can exacerbate the decoupling of canyon air from the skimming flow above, increasing street-level pollution in streets with a ground-level source such as traffic (Buccolieri *et al*., 2009).

Before describing how futures scenarios can help assess the resilience of a proposed solution, it is worth noting that some proposed solutions do not pass the pre-requisite of being fit-for-purpose now. For example, in 2005, a local council in London constructed a green wall, believed to be the first of its type in the UK. Within four years the rainwater watering system had failed and the living wall died (http://news.bbc.co.uk/1/hi/england/london/8215035.stm).

Figure 1 The potential for trees of a given species to impact urban air quality, based on model simulations for the West Midlands, UK (adapted from Donovan *et al*., 2005).

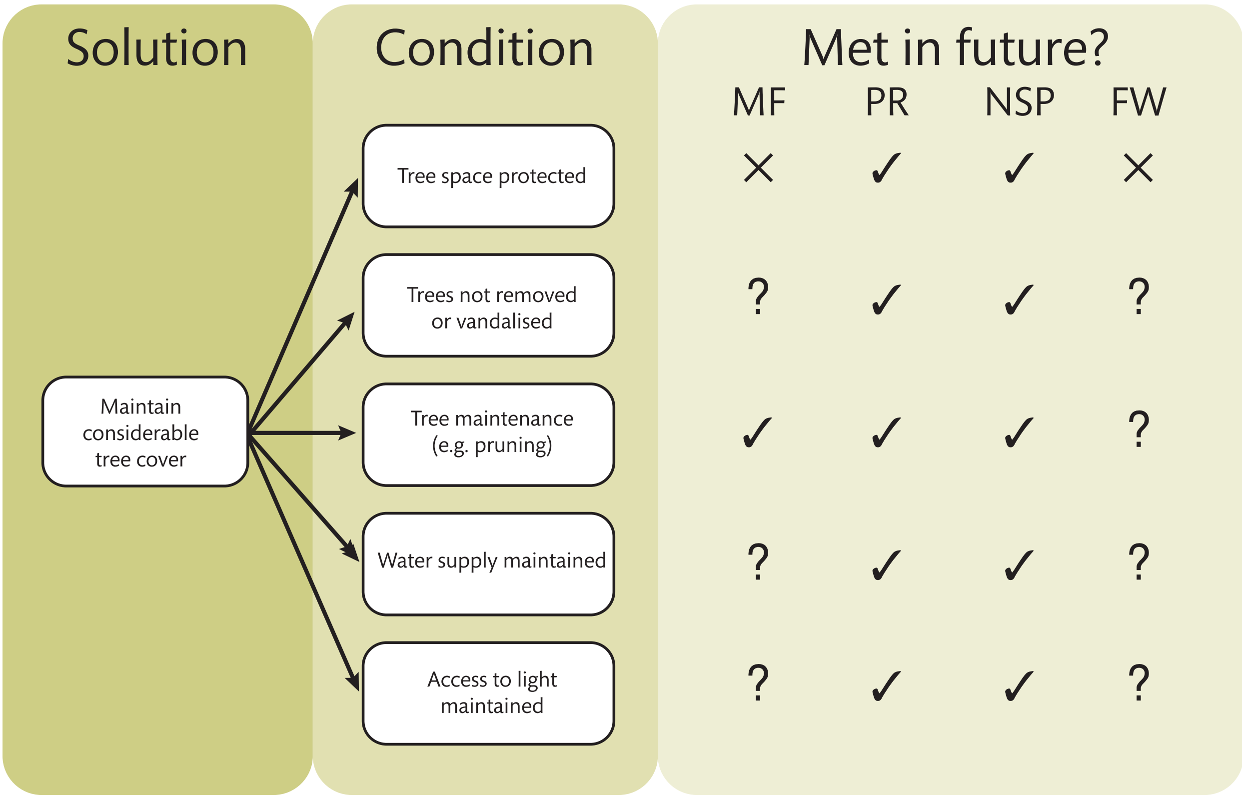


Although a laudable effort, and although clearly the risks for early adopters are greater than for those following behind, local conditions must be capable of sustaining a solution if it is to be implemented successfully.

Having established that a proposed solution is fit-for-purpose under the current conditions pertaining to a particular site, futures scenarios can then be used as 'test rigs' to assess the resilience of a solution in the face of change. Figure 2 shows the necessary conditions for the sustainability solution 'maintaining considerable tree cover'. This particular analysis is for a recent case study in Lancaster, UK; we choose to discuss this example here because it relates to urban vegetation and because, once the present fitness-for-purpose has been established in this particular location, the results are not case-study specific. By analysing the scenario characteristics it has been determined whether or not these conditions are met in each of the four Urban Futures scenarios. For instance, the first condition is that tree space is protected in the future. This condition is met in both the PR and NSP scenarios where strong planning controls are applied which recognise ecological and social imperatives. However, in the MF scenario, planning policy is weak, and enforcement of that policy favours the power of the market, meaning that tree space will not be protected if it is wanted for some more profitable use. In the FW scenario trees may be valued by the wealthy, but planning policy does not extend much past the priority issues of resource protection.

Figure 2 can be read in different ways. Reading across the figure provides guidance on which conditions, necessary for the sustainability solution, are most at risk of ceasing to be met. Reading down the columns in the right-most panel makes clear which futures scenario carries the most risk for the solution and, hence, which drivers and characteristics, embodied in the futures, should be targeted to try to avoid failure. It may seem self-evident that the 'rosy' futures provide the most positive outcomes, but this is not always the case. Hunt *et al*. (2011) provide an example in which grey-water recycling schemes become obsolete in the NSP scenario because of behavioural change; from a futures perspective, sustainability solutions which depend on the continuation of current consumer behaviour have obsolescence built in. Note that neither the UTAQS nor the solution examined in Figure 2 capture the importance of tree cover topology, as discussed briefly above with respect to bat boxes.

Figure 2 Necessary conditions for the continuing operation of the sustainability solution 'maintaining considerable tree cover', for a case study in Lancaster, UK. The likelihood that each necessary condition will continue to be met in each future scenario is assessed in the right-most panel. A tick denotes that there is a high likelihood of the condition being met; a cross denotes that there is a high likelihood of the condition not being met. Ambiguous or uncertain assessments are denoted by a question mark. Some of the rationale behind the assessments is given in the main text.



Limitations

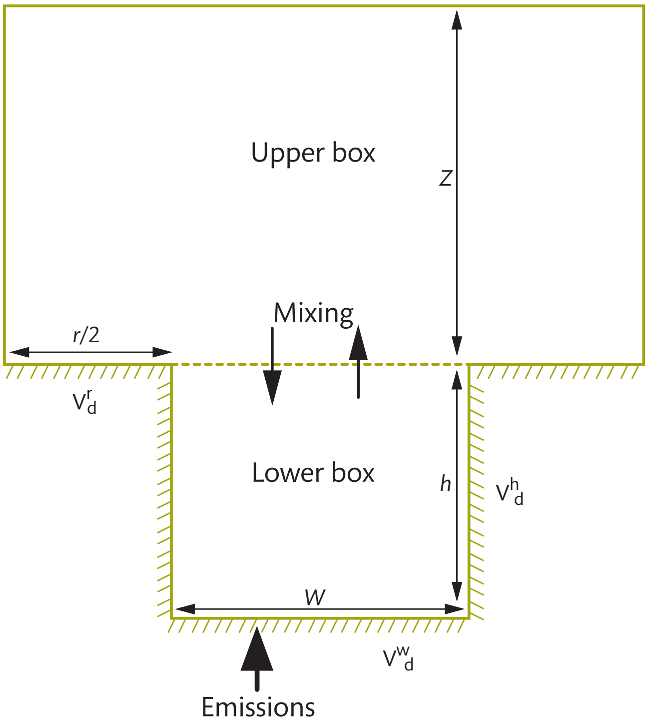
There are limitations in our method for establishing the resilience of sustainability solutions. Broadly, the limitations fall into three categories: the futures space exercised in our scenario 'test rigs'; limits to knowledge in discipline-specific assessments; and difficulties in multi-disciplinary working.

Our chosen scenarios cannot cover all eventualities. Four scenarios have been chosen that cover a wide range of possible futures for which there is extensive literature. The existence of an extensive literature, including detailed quantitative and qualitative indicators, for each scenario is useful to us, because it provides an audit trail for our derivation of the UK urban characteristics. Nevertheless, it is quite possible to derive urban futures from first principles and to then use these to test the resilience of solutions. It also possible, and more straightforward, to add characteristics to our existing UK urban futures, in order to cover aspects of urban living not considered by the Urban Futures project. This is discussed further in Boyko *et al*. (2011).

No discipline-based assessment is final. The provisional nature of any discipline-based assessment can be one of the factors that make multi-disciplinary work difficult. Multi-disciplinary work shares this problem with public understanding of science and with the provision of scientific advice to policy-makers. Best practice in multi-disciplinary collaboration will likely closely mirror best practice in these areas of knowledge exchange (People Science and Policy Ltd, 2003).

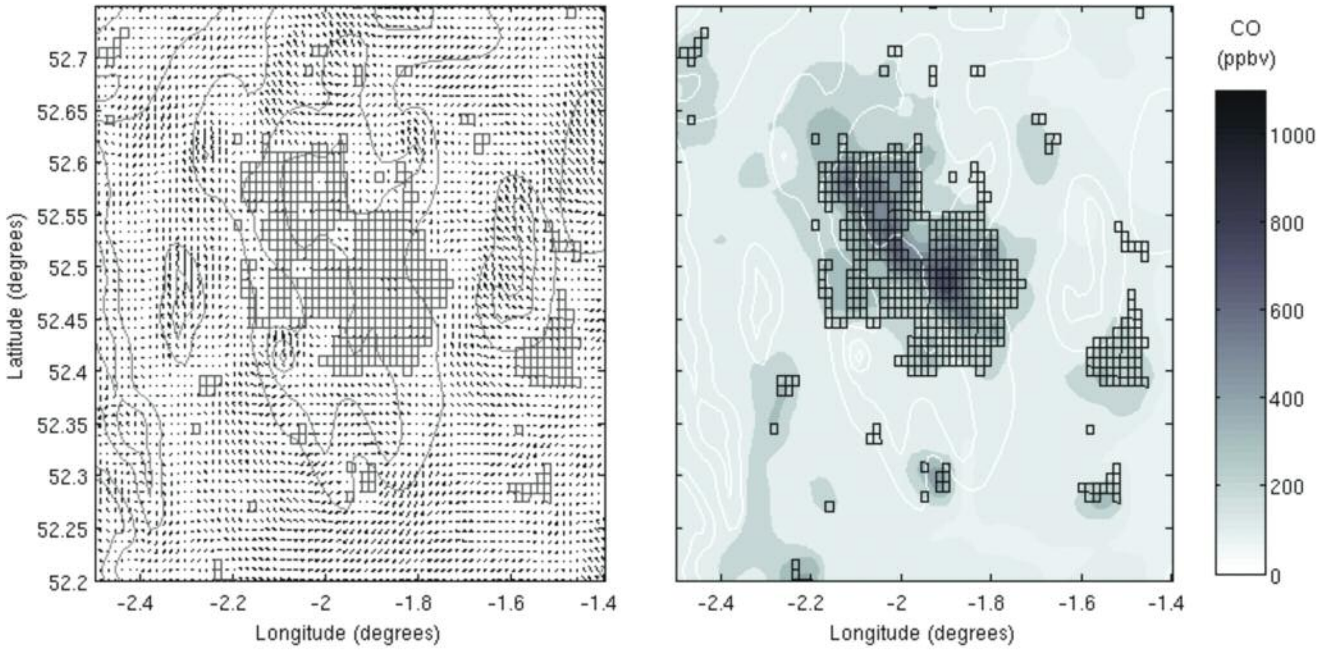
As our disciplinary knowledge expands and assessment tools are refined, assessments can become increasingly sophisticated. For instance, the model used in the UTAQS study describe in the previous section has been updated (Pugh *et al*., 2011) to include a new scheme for the photo-oxidation of isoprene (Taraborrelli *et al*., 2009) and is now being set up to simulate the air inside and above urban street canyons (Figure 3). We expect that this new model configuration will more accurately account for time traffic emissions spend within the urban canopy before being vented into the atmospheric boundary layer above (see, e.g., Oke and Cleugh, 1987, for descriptions and definitions of the urban canopy and the atmospheric boundary layer, or Llewellyn Davies for English Partnerships with Commission for Architecture and the Built Environment and the Housing Corporation, 2000, for a very brief overview). Even then, this air quality model will not represent the horizontal heterogeneity of urban landscapes. To represent this heterogeneity, a three-dimensional mesoscale model is required (Zhang *et al*., 2009; Zou *et al*., 2009). Figure 4 shows an example of three-dimensional urban air quality modelling from the work that is currently under way as part of the Urban Futures project. Again using the West Midlands, UK as a case study, the model shown incorporates an urban surface scheme with spatially varying aerodynamic roughness elements that protrude into the model atmosphere (rather than providing a boundary condition for the lowest atmospheric layer only). The result is a highly heterogeneous wind field, with a concomitant effect on the dispersion of air pollutants such as carbon monoxide.

Figure 3 Schematic diagram of the modification of the CiTTyCAT air quality model to incorporate street canyon effects. The upper box simulates the well-mixed atmospheric boundary layer, depth, z, where 100 < z < 1500 m, typically. The lower box simulates a well-mixed street canyon of height, h (typically 10 m), and width, w (0.5 < height:width < 2, typically). The ratio w/r specifies the density of canyons in the urban fabric. Turbulent mixing between the boxes is modelled using an exchange rate calculated in computational fluid dynamics studies (Liu *et al*., 2005). Deposition of pollutants can be to the canyon walls, with deposition velocity $V^w d$, canyon floor ($V^w d$), or to the roofs ($V^r d$). These deposition velocities can be modified from default values for building materials to simulate installation of green walls and roofs.



A detailed critical assessment of the multi-disciplinarity in the Urban Futures project is outside the scope of this discussion, but some remarks are appropriate, since implicit in everything preceding is the requirement to assess solutions simultaneously from as many perspectives as possible (MacKenzie *et al*., 2010). In the Urban Futures project, we have enacted a 'talking cure' for the problems of multi-disciplinary work: project researchers have met monthly and, at times, more frequently. Project-wide tasks

Figure 4 Example output for the WRF/CHEM three-dimensional mesoscale model, run at 1-km horizontal resolution over the West Midlands, UK, for the sunny anticyclonic period 15–19 July 2006. Results shown are for at 04:00 UT on 18/07/06. The hatched areas are urban (Birmingham is near the centre of the picture and Coventry on the right-hand edge). Contours are height above sea level at 50-m intervals. Left panel: 10-m wind arrows showing deceleration over the urban area. Right panel: surface-level carbon monoxide (CO) mixing ratios (parts-per-billion by volume, ppbv). CO emissions originate predominantly from urban traffic emissions and disperse downwind.



have been set, and tackled alongside an extensive discipline-based research programme across natural and social science. Issues regarding methodology and terminology have been accommodated, and project-wide tasks progressed, in the frequent researcher meetings. By focusing on multi-disciplinary tasks in researcher meetings, and by refusing to allocate multi-disciplinary aspects of the programme to 'multi-disciplinarity specialists', we have avoided bolting an ill-fitting multi-disciplinary superstructure onto the disciplinary research programme. Meeting and talking can make progress seem slow. Concepts in sustainability are notoriously slippery and it can often feel as if ground has to be covered and re-covered. Nevertheless, we argue, as do others, that this dialogue and team-working, however tortuous it may sometimes appear, is an essential part of the kind of multi-disciplinary work that will yield progress on grand challenges such as sustainable urban development (see input to the SUE Research Dialogues Workshop, available at http://suedialogues.wordpress.com/events/the-workshop/). In passing, we observe that, in our experience, tools for virtual meetings are not yet sufficiently robust to replace face-to-face meetings and so, in this respect, our own project has not reached best practice in terms of decarbonisation.

Conclusions

Sustainability, regardless of which definition is chosen, is all about putting in place now sustainability solutions that will yield positive rather than negative future legacies. The essential underlying question is 'how sustainable are these solutions?' The answer is inevitably 'it depends on local conditions now and in the future'. At present, our approach to implementing solutions is very front-loaded; most of the funding, research, planning, publicity, and policy enforcement occur when a solution is installed. We have described above a method to assess whether a solution will continue to yield benefits for a very wide range of possible futures.

That we note in passing the potential for sustainable solutions to fail in the here-and-now suggests that the best practice of designing solutions to fit local conditions is not yet being achieved routinely. Uncritical adoption of solutions – rainwater recycling, green roofs, etc. – might be a result of successful advocacy by academics, non-governmental organisations, and activists. Such simple advocacy of urban greening may be appropriate in policy debates, but is of limited use when trying to ensure best practice. Assessing the sustainability of a solution requires a critical and multi-disciplinary approach with due regard for local conditions. It is because multi-disciplinary team-working is not always practicable that we have developed the Urban Futures method and its attendant materials.

The disciplinary knowledge used in sustainability assessments is perforce provisional. We have discussed how the assessment of the impacts of urban trees on air quality is model dependent, and set out recent advances in the modelling of urban areas that may affect the assessment.

The Urban Futures method makes use of established future scenarios. It is no accident that some of the futures appear better than others. The GSG scenarios are not morally, ethically, or politically neutral; they explicitly extend current tendencies – dominant or not – to generate a range of outcomes, and so make it clear what must be done to ensure an outcome that is favourable in the authors' terms. All futures research is underpinned by this utopianism or, at the very least, by a recognition that talking about the future alters it (Bell, 1996), which, along with the ability to incorporate tipping points, differentiates futures research from conventional extrapolation studies. For the GSG authors, their studies make evident the need for a 'great transition' towards sustainability (Raskin *et al*., 2002). Urban Futures is not so directly utopian in its use of futures; we use scenarios as 'test rigs' that exercise solutions in a very wide range of future conditions. Nevertheless, as a tool for policy-making, the Urban Futures method can show which solutions have the best chance of continuing to work into the future and, hence, of bringing about the move to sustainability that policy seeks.

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