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Justin Bishop *Editor*

Building Sustainable Cities of the Future

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Introduction

Justin Bishop

In 2007, the proportion of the global population living in the urban environment was over 50%. Urbanisation has been underway in high-income[1] countries for several decades. In 1950, 57% of the population of these countries lived in cities. By 2014, more than 80% of the population in each of Northern America, Latin America, the Caribbean and Europe were living in the urban environment.

Not only are cities where most people live, they are also responsible for 80% of global gross domestic product, two-thirds of energy use and 70% of greenhouse gas (GHG) emissions (IEA 2016). It is projected that all population growth through to 2050 will occur in the urban environment (UN 2015). Therefore, this is the context in which most future human activity will occur and the associated challenges will be overcome.

The cities of the future are the cities of today in most cases. Therefore, there is a need to place existing cities on a more sustainable evolution path. Cities vary in size, land area, population, climate, topography and global importance. At one end of the scale, megacities of at least 10 million inhabitants are major regional economic and financial hubs. At the other end, the largest class of city, by number and proportion of global population now and through to 2030, is the urban area of fewer than 300,000 inhabitants (UN 2015).

Achieving sustainable cities requires some appreciation of what sustainability is and how it can be incorporated into our cities' development. Rockström et al. (2009) proposed a 'planetary boundaries' framework which outlines the safe operating space for human activity to exist within. This concept necessarily gives

[1]Countries with gross national income per capita of at least $12,615 are classified as high-income. See http://www.un.org/en/development/desa/policy/wesp/wesp_current/2014wesp_country_classification.pdf for further classifications and lists of countries.

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precedence to the environment by allowing Holocene-like conditions to persist (Steffen et al. 2015). When this concept was developed, human activities were exceeding the safe boundaries for climate change (350 parts per million greenhouse gases (GHG) by volume (ppmv) and 1 W/m^2 radiative forcing), rate of biodiversity loss (10 species per million annually), and interference with the nitrogen cycle (million tonnes removed from the atmosphere annually).

Climate change and biosphere integrity, which incorporates genetic diversity and biodiversity loss, are core planetary boundaries, through which the others operate (Steffen et al. 2015). The monthly average GHG concentration exceeded 400 parts per million by volume (ppmv) in September 2016 for the first time—this concentration continues to rise and scientists expect we have now tipped into a new age of human–climate interaction (Kahn 2016). Overall, 2016 marked the hottest year on record, continuing a streak of annual mean temperature increases globally (NOAA 2017).

Biodiversity loss has direct impact on the existence of ecosystems. Good ecosystem functioning is required to provide the products and services that all species depend upon for their existence. The earth has an annual productive capacity, known as net primary productivity (NPP), which is the total amount of carbon dioxide CO_2 fixed by autotrophs minus that used by plants in respiration. Humans appropriate 25% of total NPP through land-use changes, agriculture and settlements (Haberl et al. 2014). Consequently, more than 75% of the ice-free land area has been altered significantly by human actions (Ellis and Ramankutty 2008).

The aim of this book has been to investigate how lessons and best, or 'next' practice can be transferred across cities and how bespoke the sustainable city must be. The contributing authors' mandates have been to identify the problem and challenges, identify which cities are making progress or not towards solutions and comment on the applicability of these solutions further afield. The chapters address a subset of the challenges facing modern cities, focusing on both the physical environment—such as transport, energy and sanitation—and how cities can meet the human needs of food, health and equity in infrastructure planning. The authors' findings show how incorporating 'best' and 'next' practice in one sector results in secondary benefits elsewhere and is further evidence of the integrated nature of achieving sustainability in cities.

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Energy for Cities: Supply, Demand and Infrastructure Investment

Colin J. Axon and Simon H. Roberts

Abstract Energy is essential to all activities in all regions of a country. However the density of energy use in, and our economic dependence on, cities means that it is more critical for urban areas. Nevertheless we suggest that the provision of energy for urban areas cannot be considered separately from the national context. We will demonstrate how to assess the ability of a nation to invest in energy infrastructure for the benefit of cities. Our approach exploits data sets which are available in most industrialised countries, and we select two quite different case studies to illustrate our method: the Colombia (Bogota) and UK (London). Our focus for energy sustainability in cities is quality of life and reduced fossil-fuel emissions. We will show that the main target for cities should be to improve air quality and reduce energy demand by improving energy efficiency.

1 Introduction

In all nations, the numbers and size of cities have grown since the onset of the industrial revolution and with it the increasing demand for energy (Ayres and Warr 2009; Kander et al. 2014; Wrigley 2010). Growing economies and expanding cities are symbiotic, most likely in a system boot-strapping sense. However, it is clear that the economy drives the creation, expansion and ongoing existence of cities.

Much of the national economic activity can be grouped as 'service industry' (Roberts et al. 2015), so we need to look at this industry along with intra-city transport. Apart from cities being where jobs are, many people choose to be in cities to access available services such as education, healthcare and entertainment. There is a virtuous circle of the service industry providing jobs and thus income, which in

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turn is used to pay for services. There are two main constraints on this growth. The first is enterprises having to conceive new services and expand. But the most significant is the physical constraint of the time taken to build more accommodation for both the service industry and dwellings to house consumers and employees.

Until the last third of the twentieth century, settlements of all sizes needed to generate power and heat by converting the fuel at the location of the final use. Even into the 1980s in the UK for instance, small (100–200 MW) electricity generating stations were still operating in built-up areas. As the demand for electricity grew, the generating capacity of each station increased. Where possible these larger plants were located close to coalfields—outside the city boundary—and not at the point of final use. Schultz et al. (2013) note that the energy demand density of cities is such that localised renewables are mismatched in their power output density to meet the demand. This means that if cities are sustainably to support highly dense populations, the fuels must be derived and the power generated outside of the city. Relying on renewables within urban areas to create zero-carbon cities is not an appropriate solution. Other driving forces for this displacement in the UK were the Clean Air Act and the rising value of land in the city. As land prices rose, many industries with high-volume, low-value manufactured products moved out of the city too. Businesses remaining in cities became part of the burgeoning service industry. Thus the patterns of energy have shifted, but remain governed by the behaviour of the economy in general.

Our analytical approach is to fuse together and mine independent national data sets which (preferably) meet international standards for collation and curation. As an interesting case study we will compare two nations with three contrasting characteristics: (1) non-OECD and OECD, (2) equatorial and temperate climates and (3) developing and developed. We chose Colombia (Bogota) and the UK (London) as comparators (Fig. 1; Table 1), both having suitable data available. Urban economic activity as measured by services is increasing for both countries, while energy use by services and number of urban dwellings is increasing only for Colombia. Fuel use for urban transport by private car is decreasing for both countries, while bus use is increasing in the UK. The transport of goods is vital for economic activity. Although the majority of the distance travelled by light commercial vehicles and heavy good vehicles is likely to be outside of the city, their increasing urban energy use matches services increase. Energy demand by transport has both direct and indirect consequences. The direct demand is for fuel, and the indirect demand is an increase in air pollution and building cooling requirements resulting from thermal pollution from vehicle engines. In addition, transport air pollution and noise discourage the incorporation or use of natural ventilation in buildings, exacerbating over-heating in the hot months.

An important factor affecting the ability of a city to reduce energy use is its point in development. Established cities, such as London, have placed value in the land across the whole area. By contrast, the sprawl of a rapidly developing city, such as Bogota, through informal settlements on the periphery offers opportunities for visionary urban planning and new buildings of high efficiency. Retrofitting of

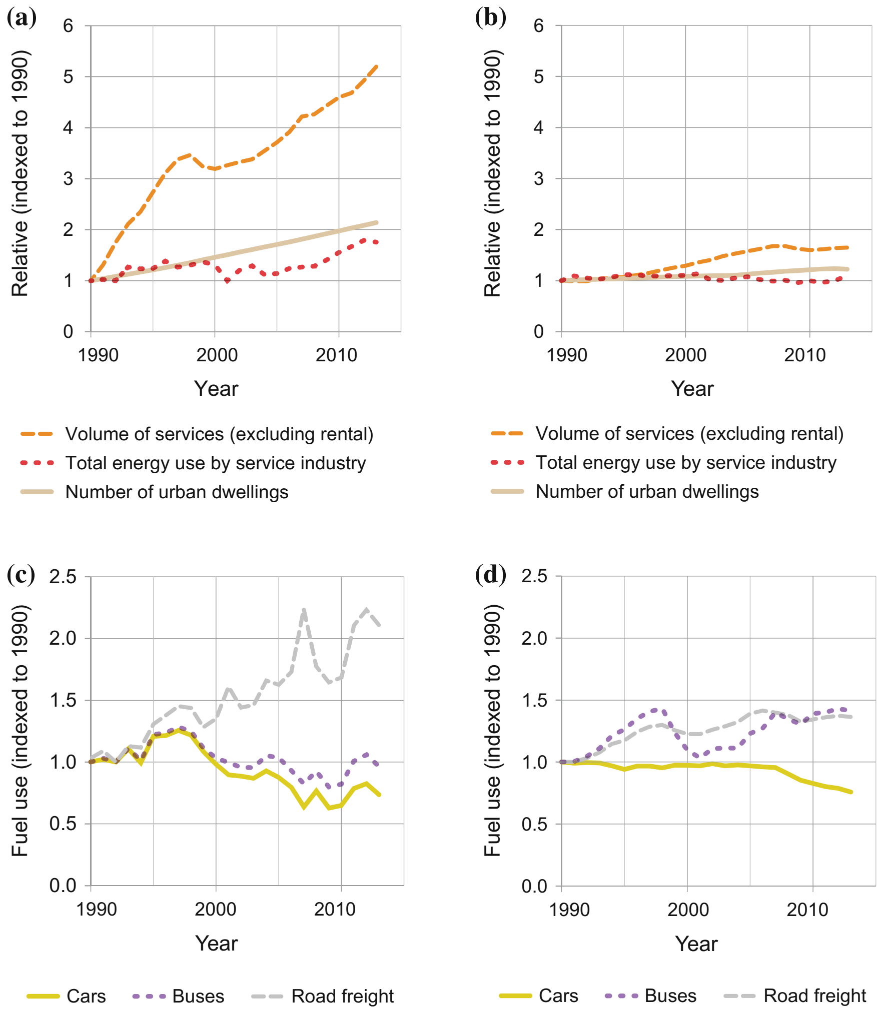

Fig. 1 Urban indicators. Energy consumption and economic volume output of the service industry and number of urban dwellings, indexed to 1990 for **a** Colombia and **b** the UK. Fuel consumption for urban private passenger transport by car and bus and freight transport, indexed to 1990 for **c** Colombia and **d** the UK. *Source* Banco de la República (2016), DANE (2013, 2016a), DCLG (2015a, b), DfT (2015), IEA (2015), MME (2016) and ONS (2015)

existing buildings is an inefficient, slow and less effective, though still necessary solution. In Bogota's 'formal' city, the main reason for avoiding retrofitting is the implementation of regulations that aim to densify.

We suggest that to understand the energy supply for cities, we must start with the structure of the macroeconomy. Then we must incorporate socio-technical, transport and energy data, and finally derive the split between the urban and rural demands.

Table 1 Selected statistics for Colombia and the UK

Statistic	Units	Type	Colombia	UK
Population	Million	Urban	35.4	52.5
	Million	Total	46.6	63.7
Households	Million	Urban	9.9	21.6
	Million	Total	12.7	26.6
Dwellings	Million	Urban	9.6	23.0
	Million	Total	12.6	27.8

All data for 2012
Source DANE (2011, 2016a), DCLG (2012) and ONS (2014)

The key data source for economic activity is the internationally agreed System of National Accounts (United Nations et al. 2009). The data are available for all countries, comprehensive, comparable and have good time granularity over the historical period. Additional data sources are employment, national household survey, housing stock, national energy balance and transport statistics.

As a bridge from national level to urban, we define the rural/urban split in part depending on what data are available. Dwellings are by location, households and population from the census or household survey, and transport as vehicle-km by class of road.

2 Energy and Its Changing Demands

In Figs. 2 and 3 we show socio-economic and energy statistics for our case-study countries. Although our focus for this chapter is on energy, we gain insights by relating energy flows to the economy, investment and jobs which are included in the diagrams. Thus we can assess the ability of a nation to invest in energy infrastructure or to mitigate the effects of energy demand in cities.

All the boxes in the left halves of Figs. 2 and 3 represent physical infrastructure, also known as fixed capital (FC). For the FC of industry we disaggregate the economy into six groups: agriculture, extraction, utilities, manufacturing, construction and the service industry (Roberts et al. 2015). We then make a simple division shown by the dashed line between rural above this line and urban below. We assign service industry as wholly urban because it is both labour intensive and needs to be near the majority of the population. We assign construction also to urban because, as we show later, most construction takes place in urban areas. Dwellings are another type of FC, and we show these in the diagrams in both the rural and urban sections. Since we have a focus on energy, we show some additional boxes for energy-specific FC. All the FC boxes in each diagram lie within an overall rectangle, which represents the trading border of the economy. Imports enter on the left, and exports leave on the right.

The main purpose of these diagrams is to show and quantify using Sankey lines[1] the various flows of energy, jobs, goods and services to and between the types of FC and final use, and then, how these relate to urban areas. Each FC box has just one line emerging on the right which represents the single type of product it produces, such as goods from manufacturing. The lines on the left represent inputs needed for production, such as raw materials, so we think of these as starting on the left and flowing to the right into boxes where they are consumed. A blue line, representing investment, enters the top or bottom of each box to account for what is needed to increase and maintain the FC. These flows are referred to as fixed capital formation (FCF).

Economic production by industries is known as gross value added (GVA), where the output form of gross domestic product (GDP) of the economy equals the sum of GVA by all industries plus rental. Although rental of dwellings is normally categorised as a service, it is more accurate to represent it here as originating from dwellings rather than from the service industry FC. This disaggregation helps with the urban energy analysis.

One aspect of economies is how products pass between industries, referred to as intermediate consumption (IC) (Roberts et al. 2016). Only after IC are products in their final form, such as for use by households. IC is detailed in the diagrams just for the three larger industries, which is why they are shown as pairs of boxes. The addition of tax on products is shown explicitly so that the products in their final form, on the right, are at purchasers' prices.

The final destinations of products in the economy are shown in the right halves of Figs. 2 and 3. All the Sankey lines for economic volume flows come together, marked 'final supply', such that their total Sankey width corresponds to the expenditure form of GDP summed with total imports. Most final consumption is by households according to whether in rural or urban. In this national accounts formalism, one component of final demand is investment, the source of FCF essential for all the FC boxes. The FCF flow has contributions from manufacturing, construction and services, but their Sankey colours are blended into blue for clarity in the diagrams.

The great value of combining energy, jobs and economic volume flows in these diagrams is the ability to reveal how energy is attributed across the economy. The purpose of an economy could be viewed as the fulfilment of final demand of household consumers (on the right). The Sankey format shows how this consumption maps back on to all forms of source energy. It explains the concepts, shows a complete picture (with no under- or double accounting) and quantifies dependencies.

So what do the Sankey diagrams tell us about urban energy and sustainability? We note that our division between rural and urban is crude in putting all manufacturing into rural and all of service industry into urban, though more detailed data

[1]In Sankey diagrams, the widths of the lines are proportional to the size of the flows which they represent.

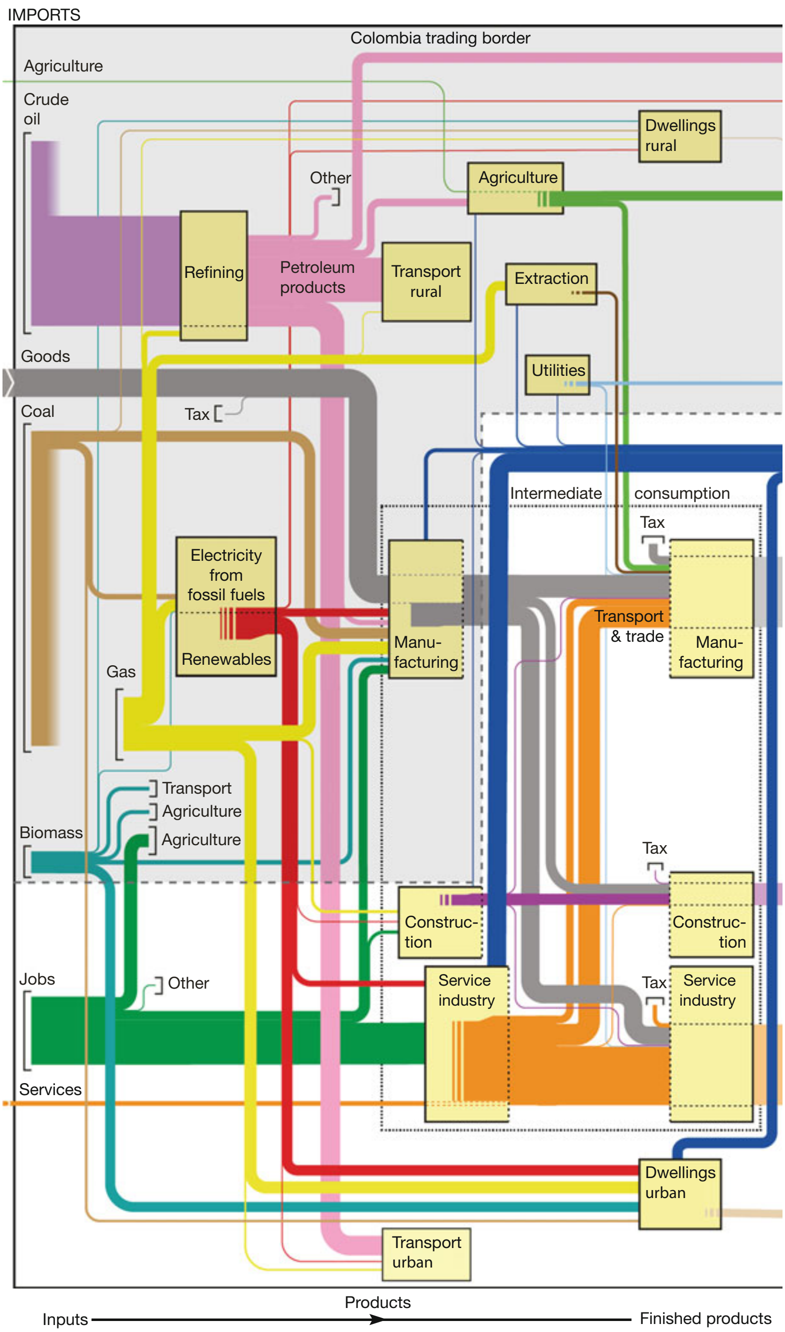

Fig. 2 Sankey diagram of the Colombian economy using data for 2012. On the *left*, physical infrastructure (*beige boxes*) with energy, jobs and economic volume flows. On the *right*, component economic volume flows of final demand. [NPISH (non-profit institutions serving households), TCO$ (tera Colombian dollars)]. *Source* Banco de la República (2016), DANE (2015, 2016b), IEA (2015) and MME (2016)

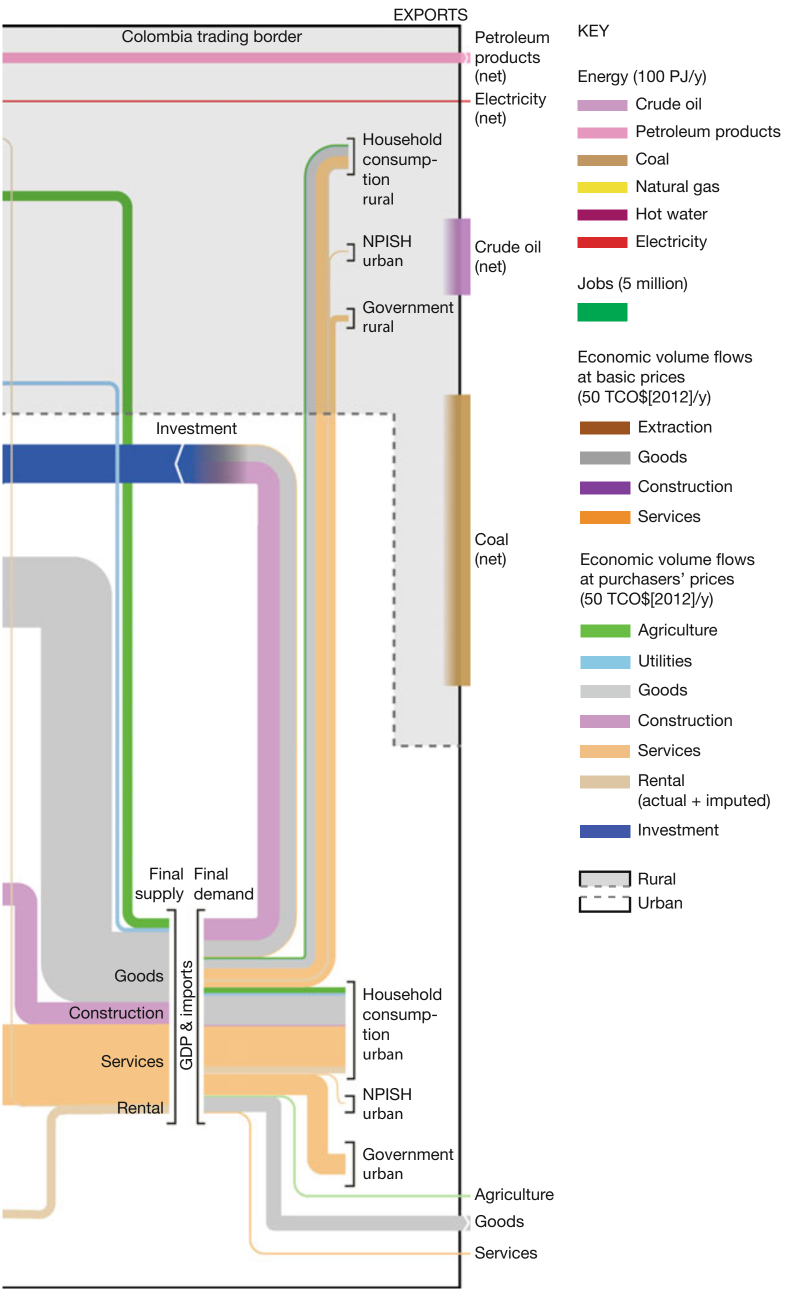

Fig. 2 (continued)

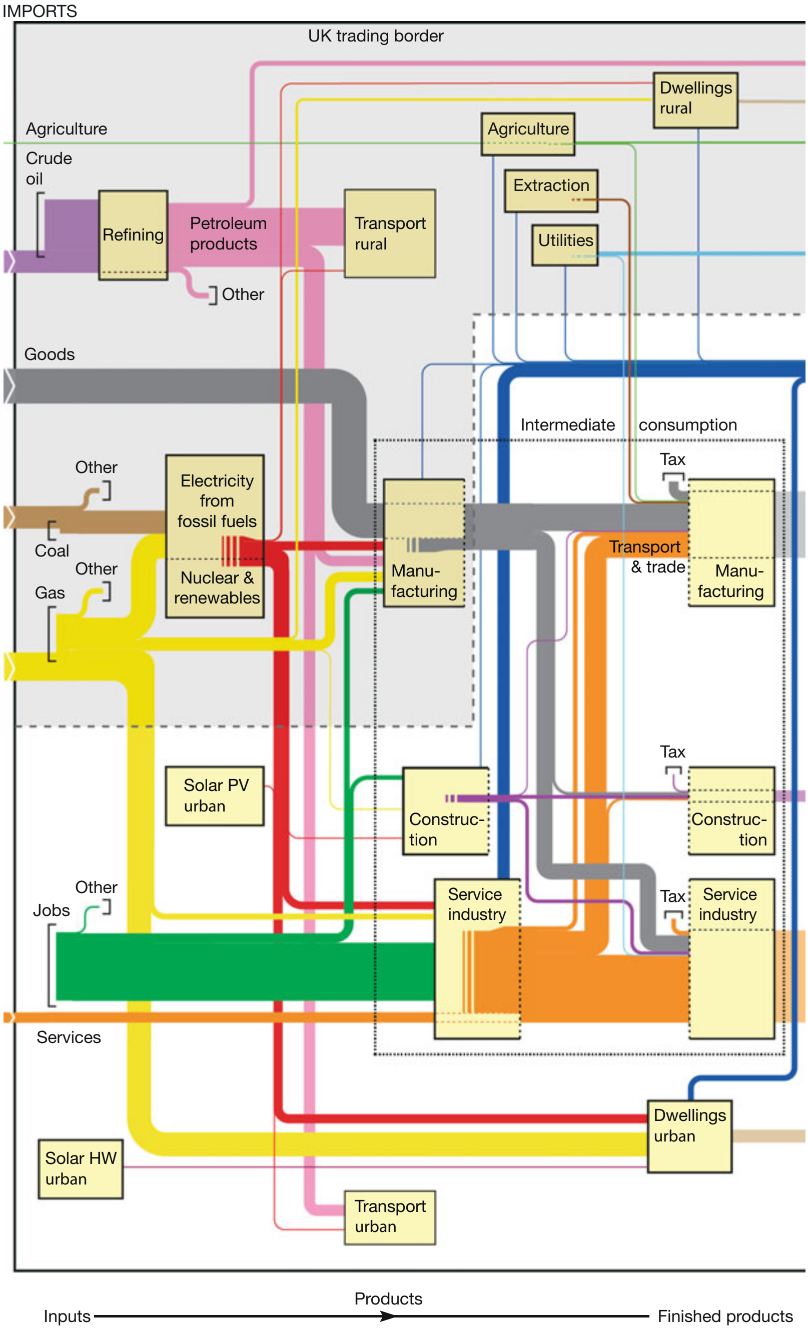

Fig. 3 Sankey diagram of the UK economy using data for 2012. On the *left*, physical infrastructure (*beige boxes*) with energy, jobs and economic volume flows. On the *right*, component economic volume flows of final demand. [NPISH (non-profit institutions serving households)]. *Source* DCLG (2015a, b), DfT (2015), IEA (2015) and ONS (2015, 2016)

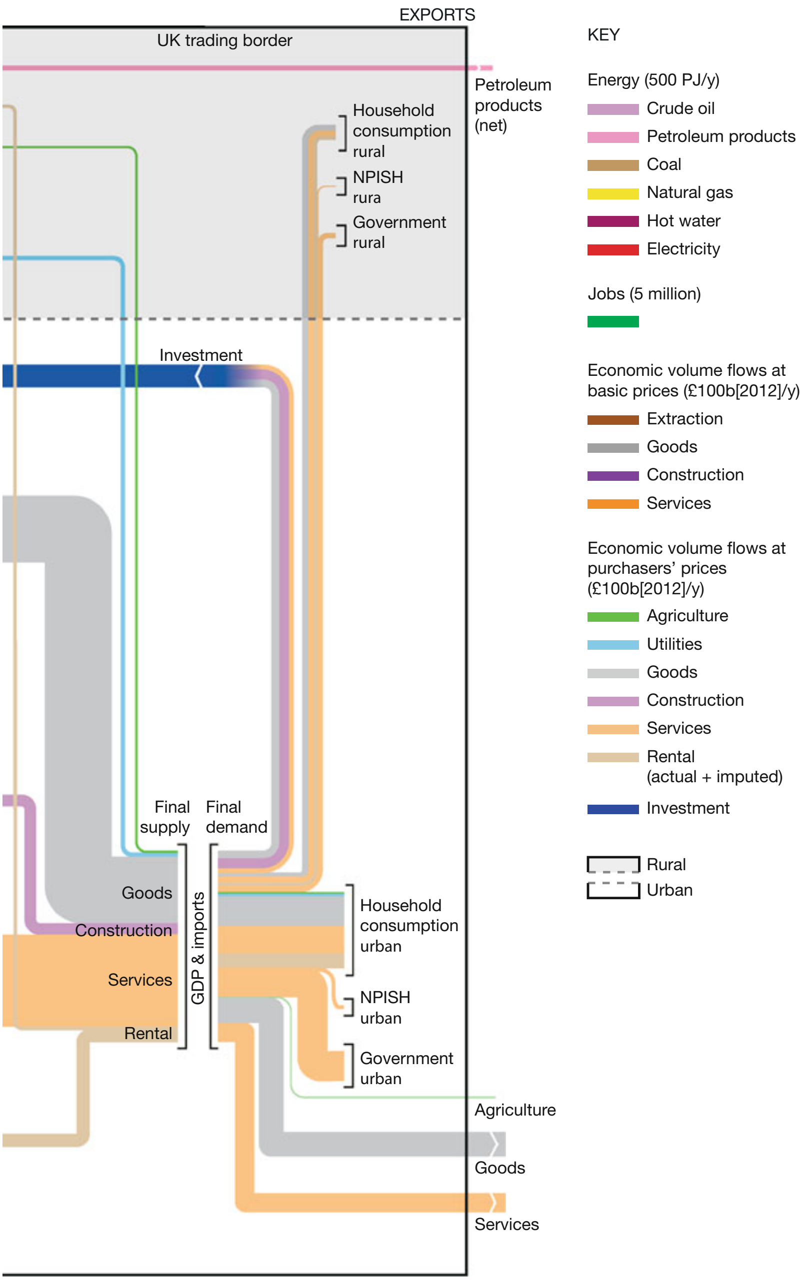

Fig. 3 (continued)

are either not available or difficult to obtain. Despite this approach to the division, we suggest it does not devalue some key observations we now make:

- For both Colombia and the UK, most economic activity is in the service industry (the FC box) and thus urban by our assignment. Services as the product (the Sankey line) include the IC of retail which is a significant proportion of goods in their final form. The Sankey diagrams for Colombia and the UK are surprisingly similar within their IC dotted boxes;
- Investment, represented by the vertical blue lines, shows that most construction is of service industry and dwellings, so mostly urban, thus appropriate that we assign construction here;
- Most jobs are in the service industry with significant numbers in construction, thus mostly urban;
- Virtually all energy is sourced, or generated (electricity), in the rural areas. Urban energy sources, e.g. solar photovoltaics and hot water (Fig. 3), are very small by comparison;
- For the fossil-fuel intensity of electricity, this is low in Colombia because of the high proportion of renewables (79%, mainly hydropower with some biomass), whereas it is a high proportion in the UK since there the contribution of nuclear and renewables is 29% only;
- Biomass delivers 13% of all thermal energy in Colombia, all from rural;
- For transport, most energy use is rural (69%), but this would include passenger travel to urban areas and between urban areas, and freight transport serving urban needs.

These observations support what is well known about urban areas as a focus for jobs, economic activity, construction and a significant proportion of transport.

The demand for energy in the urban areas can be categorised by type of delivery according to the practical use of the engineered system: electricity, heat and transport. This typology fits well with the readily available socio-economic and energy data where the percentage global division between these is roughly 20/50/30. Figure 4 shows how these energy proportions vary, either by delivery type or by use, as in the Sankey diagrams of service industry, dwellings and transport. Service industry and dwellings data incorporate electricity and heat use, while transport is considered separately.

The electricity proportion is very similar between the two countries rising from about 20 to 30%, while the heating proportion declines by 5–10%, between 1990 and 2013. At present it is not possible to fully determine whether this is due to fuel switching or heating reduction through efficiency (biomass to gas, or better insulation). For urban use of heat, this is mostly by urban dwellings for space heating, cooking and hot water. Heating or cooling is rare in Bogota for housing, but cooling is used in office buildings. Transport energy demand is high in Colombia peaking at 50% and only recently getting below 40%, while the UK has been stable at 20%. For both Colombia and the UK the proportion of urban energy demand for buildings, to service industry, is comparable at about a third.

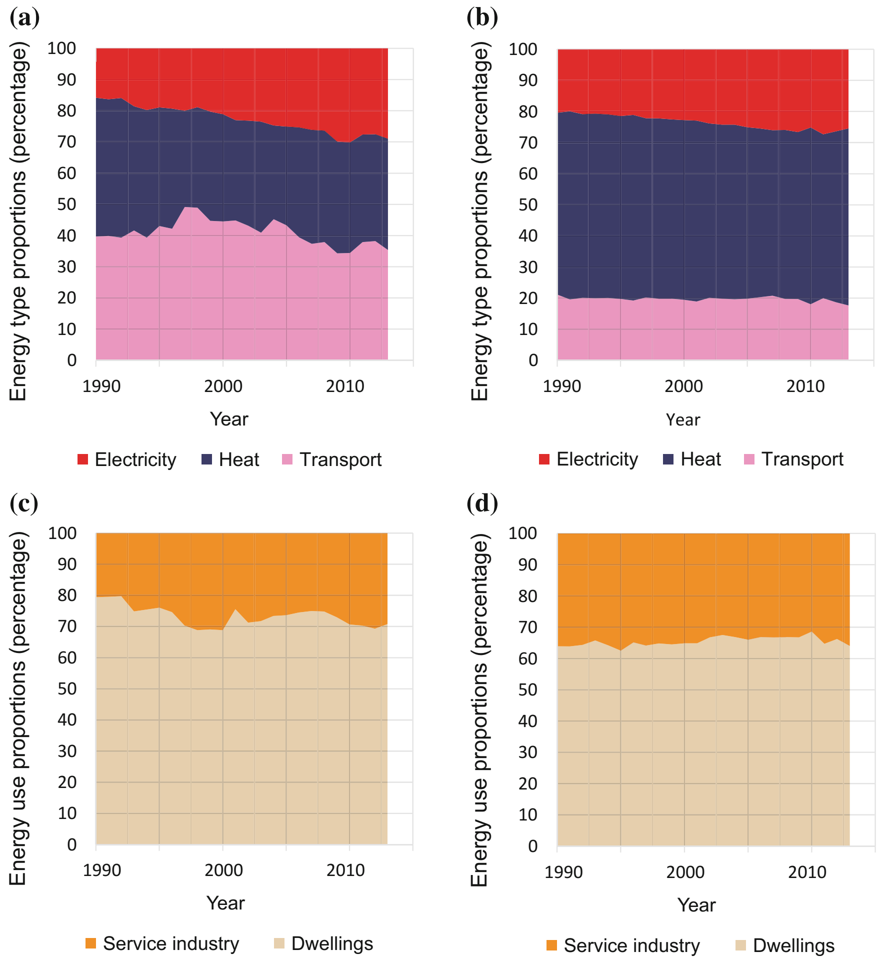

Fig. 4 Ratio of energy types, urban: electricity, heating, transportation, for **a** Colombia, **b** the UK. Ratio of energy uses, urban: service industry, urban dwellings, for **c** Colombia, **d** the UK. DANE (2013, 2016a), DCLG (2015a, b), DfT (2015), IEA (2015) and MME (2016)

3 Interpreting the Urban Context

We consider future changes and pressures on the urban environment for energy by examining five issues (Table 2) arising from the three delivery types: electricity, heat and transport.

Combustion of fuels (fossil and biomass) in built-up areas gives rise to poor air quality. The principal culprits are carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), low-level ozone (O_3), black carbon, particulate matter (PM) and heavy metals (WHO 2016) with volatile organic compounds (VOCs) to a

Table 2 Principal energy types and their issues for cities

Issue	Delivery type		
	Electricity	Heat	Transport
Air quality		●	●
Fixed infrastructure	●	○	○
Thermal pollution	○		●
Noise			●
CO_2 emissions	○	●	●

Key ● major issue; ○ minor issue

lesser extent. According to the air pollution index of Buehn and Farzanegan (2013) Colombia's air quality improved by 8.6% between 1985 and 2005 and the UK by 6.8%.

A useful indicator of air quality is the concentration of PM_{10} (particulate matter with diameter of 10 μm or less). For Bogota in 2007 the annual mean was 77 μg/m^3. For London in 2008 the annual mean was 29 μg/m^3, mostly caused by vehicles. The resuspension of PM also affects air quality (Keuken et al. 2013). Tyre and brake wear are significant contributors (Smith et al. 2013) and will not be reduced by the introduction of electric vehicles. The 2015 level of PM_{10} in Bogota is similar to that of London through the 1960s when the combustion of wood and coal in dwellings was prevalent. Even modest levels of biomass combustion in urban areas may lead to PM_{10} concentrations exceeding that from traffic (Ries et al. 2009). Likewise, Fuller et al. (2014) suggest that increases in wood burning in London seen in recent years may undermine the reductions in PM_{10} from vehicles. Smith et al. (2013) estimate that approximately 5600 UK deaths in 2005 were attributable to transport emissions.

Each delivery type requires some fixed infrastructure which constrains the rate at which each can expand. For electricity the fixed infrastructure comprises the generating stations and transmission (high voltage) and distribution grids. For heat this would be mostly gas and its need for a pipe network. For district heating systems, an expanding city may have opportunities to install the required fixed infrastructure. Transport's fixed infrastructure would be rail, light rail, underground metro, trolley and tram and dedicated bus roads (such as Bogota's TransMilenio Bus Rapid Transit System).

Thermal pollution results from the emission of low-grade heat from sources such as air-conditioning units and vehicle engines into the canyons formed by the city streets creating an urban heat island (UHI) (Mavrogianni et al. 2011). It gives rise to heat stress in work, moving around outside and sleeping, particularly affecting the infirmed and elderly. Air conditioning in small offices, refrigeration in retail and mechanical air handling with large-scale HVAC equipment are growing sources of thermal pollution. This triggers further increases in cooling demand (maladaptation feedback), increasing the demand for energy. Other contributory factors of thermal pollution are the thermal capacity and conductivity of all the elements that make up the city (not just buildings and roads), solar absorptivity, weather conditions and levels (and type) of vegetation (Kolokotroni and Giridharan 2008).

Table 3 Summary of the approximate energy intensities for 2013

	Colombia	UK
Heating		
Service industry (GJ/y per job)	2	16
Dwellings (GJ/y per dwelling)	11	47
Electricity		
Service industry (GJ/y per job)	3	13
Dwellings (GJ/y per dwelling)	6	15

Source Banco de la República (2016), DANE (2015, 2016b), DCLG (2012), IEA (2015), MME (2016) and ONS (2016)

Noise from transport, and to a much lesser extent from the motors and fans of air-conditioning units, affects energy use by restricting when windows can be opened. This increases the level of cooling demand met by air conditioning.

The amount of attributable CO_2 emissions results from the type of energy used and the total demand. For the heating of buildings, a useful measure of the way cold weather conditions affect energy demand is heating degree days (HDD).[2] Bogota at latitude 5°N and altitude 2640 m had about 800 HDD in 2015, while London at latitude 51°N and altitude 5 m had about 1500 HDD. The UK had notably cold winters in 1996 and 2010, which show up as spikes in Fig. 7d (in Sect. 4). This difference in HDD partly accounts for the much lower heating requirements in Table 3 of Colombia. Currently in the UK the UHI is viewed as a positive effect in winter.

While the use of electricity has no issues of air quality and minimal from noise, its issues are overall demand, thermal pollution and CO_2 emissions. It is helpful to use three groups for the uses of electrical power. The first is lighting, low and medium power devices, all of which can most effectively be supplied by electricity. The second is cooling (air conditioning). The third is some requirement for space and water heating. The rate of change in demand for these three groups will be different. So what is driving the increase in electricity demand when many electrical devices such as lighting are becoming more efficient? The number of types of device and the growing use of information and communication technologies all contribute to the first group. But the electrification of heating of water and space is a bigger factor, as is the requirement for cooling.

For the part of electricity demand for cooling in the service industry, cooling degree days (CDD)[3] are one factor in quantifying the activation of air conditioning. The CDD for Bogota (due to its altitude) was zero in 2015, and 27 CDD for London, but these might increase if climate change leads to more severe summer

[2]HDD: for each day, the number of degrees that the outside temperature is below a nominal threshold requirement for indoor heating. The reference value for the UK is 15.5 °C. Data can be calculated using http://www.degreedays.net/.

[3]CDD: for each day, the number of degrees that the outside temperature is above a nominal threshold requirement for indoor cooling. Most countries reference to 22 °C. Data can be calculated using http://www.degreedays.net.

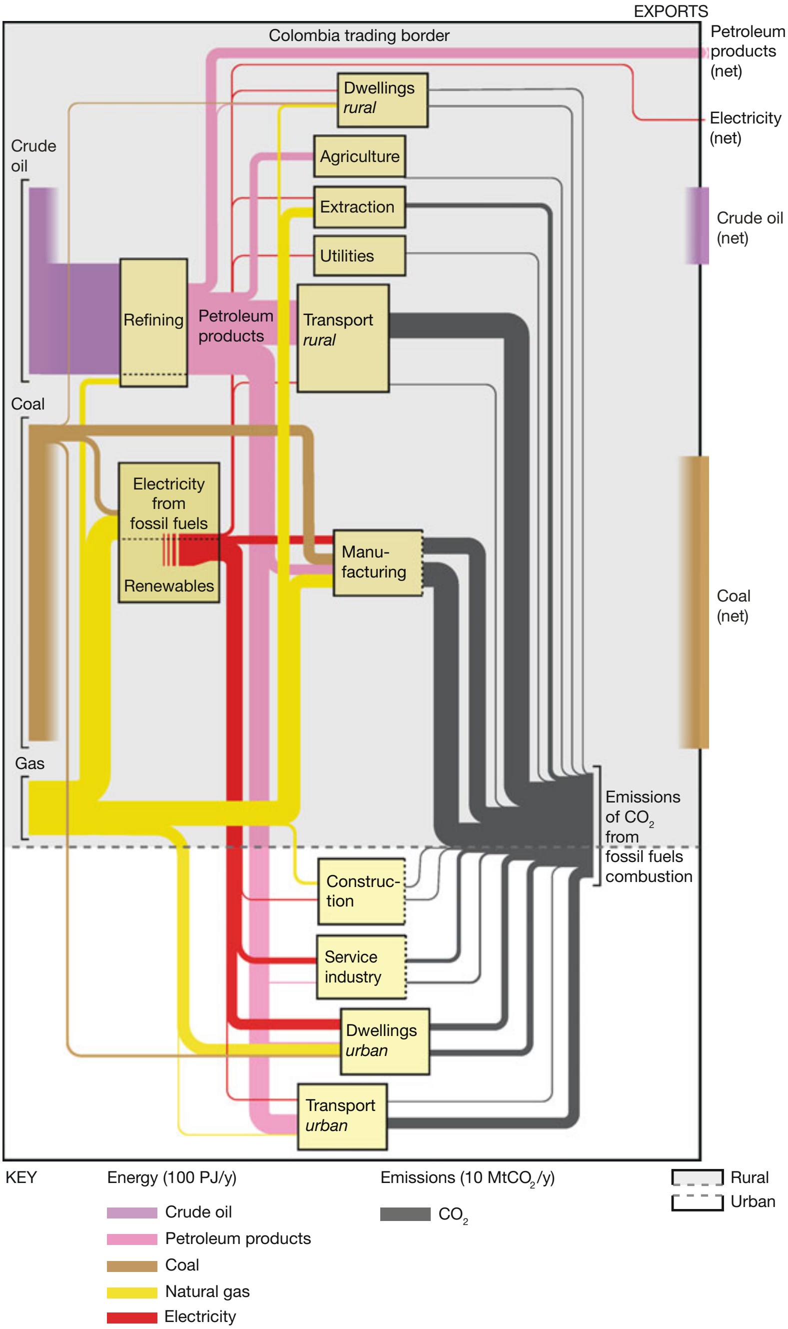

Fig. 5 Sankey diagram for Colombia of CO_2 emissions in 2012 resulting from combustion of fossil fuels. Biomass is not included since we take the complete biomass cycle as making no net contribution of emissions to the atmosphere. *Source* DANE (2015, 2016b), IEA (2015) and MME (2016)

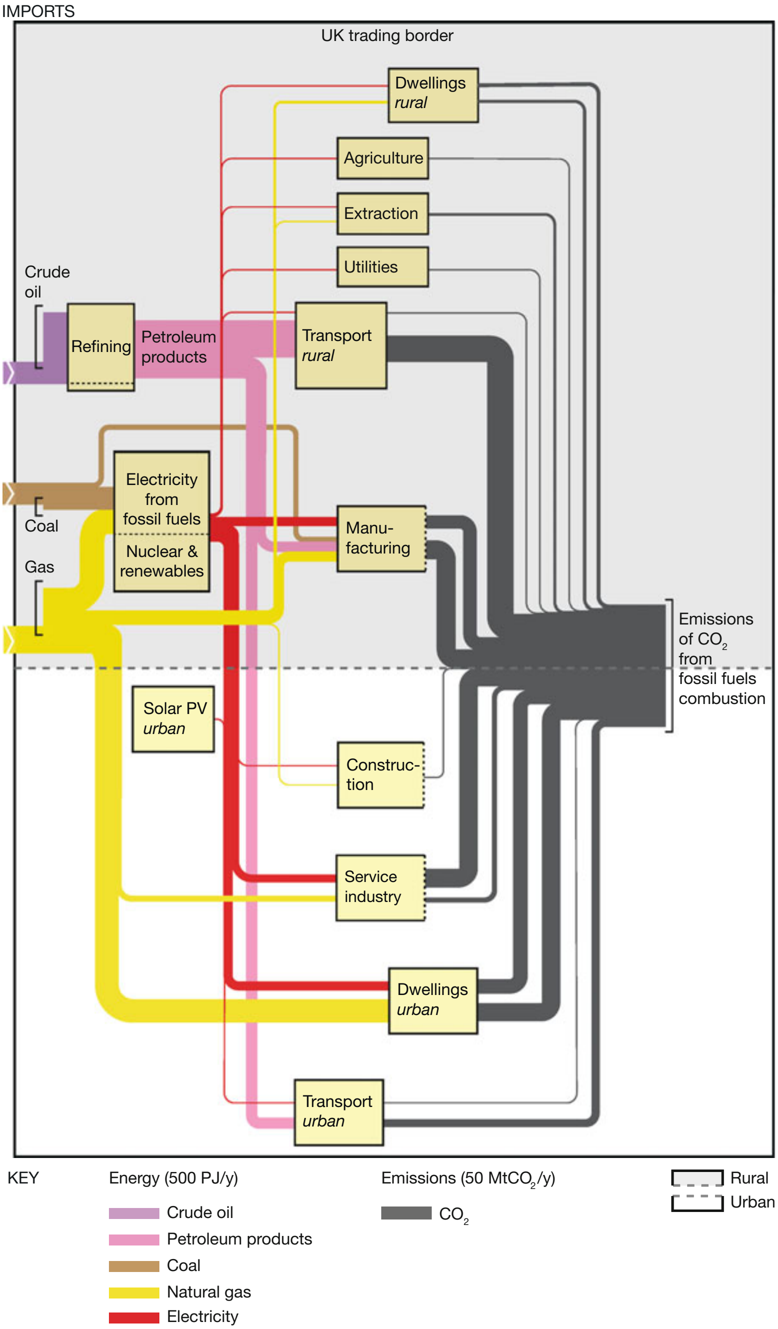

Fig. 6 Sankey diagram for the UK of CO_2 emissions in 2012 resulting from combustion of fossil fuels. *Source* DCLG (2015a, b), DfT (2015) and IEA (2015)

heat waves and their associated health impacts (Kovats and Hajat 2008). A better—but imperfect—indicator of cooling needs is 'weighted cooling degree hours', which is more closely related to the likelihood of thermal discomfort than CDD (CIBSE 2014). Air temperature alone is an incomplete indicator of the human thermal environment; Jendritzky and Kalkstein (2015) describe more suitable indices.

Overall demand for the three types of energy can be drawn together by looking at the contribution to CO_2 emissions that can be directly attributed to each urban activity. We show application of the Sankey format for mapping CO_2 emissions to industries, dwellings and transport in Figs. 5 (Colombia) and 6 (UK). They show urban proportions of total national emissions as 20% for Colombia and 50% for the UK. This gives a widely differing urban per capita emission of 0.49 tCO_2/y for Colombia and 4.7 tCO_2/y for the UK.

4 Reducing the Demand for Energy and Its Impacts

Sustainability of energy in cities is about addressing the issues in Table 2. The principal solution to these is to reduce the demand for energy, followed by substitution of energy type. We can see from the relationships between energy types and their uses (Fig. 7) that some progress has been made in both Colombia and the UK. There are downward trends in both Colombia and the UK for the heat intensities per service industry job and per dwelling. However, the electricity intensities have little changed since 1990. The essential features are summarised in Table 3. In Fig. 7 the huge reduction in heat intensity for dwellings throughout the 1990s for Colombia was due to replacing the use of solid fuel with gas as part of a programme of providing energy services to the poorest households (Barrera-Hernandez 2004; Grubler et al. 2012).

4.1 Dealing with the Effect of Location on Demand

The geographical context for a city has an impact on its options for energy efficiency and reducing energy demand. A city's latitude and climate determine the needs of occupants' thermal comfort and its potential for solar generation. Furthermore, a city's point in development affects the available options. A city with an established set of infrastructures is difficult and expensive to change, while new and growing cities have better opportunities in the master planning of the layout. For both established and new cities, standards and regulations of building efficiency need to be expanded in scope and enforced (IEA and United Nations 2013).

The proximity to energy sources by pipe, wire, road, rail and water is a key determinant of the range of actions which are possible. Having identified the need to site the main electricity generation outside of the urban environment, we note that

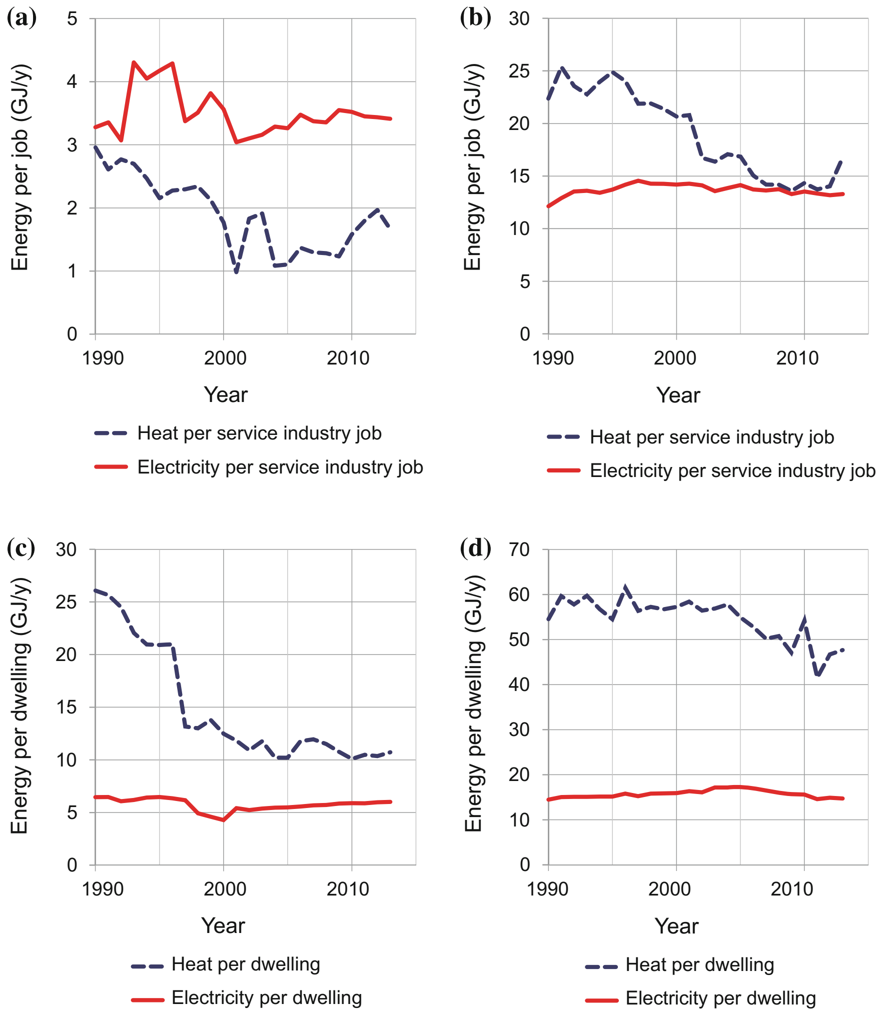

Fig. 7 Energy intensity by jobs in services, **a** Colombia, **b** the UK. Energy intensity by each dwelling (not able to distinguish between rural and urban), **c** Colombia, **d** the UK. *Source* Banco de la República (2016), DANE (2015, 2016b), DCLG (2012), IEA (2015), MME (2016) and ONS (2016)

transporting low-grade thermal energy more than a few hundred metres is impractical. The production of hot water using solar gain is only feasible at the point of use. Good conditions for solar hot water, along with photovoltaics, are latitudes within about 50° of the equator as long as the conditions can avoid sand which would otherwise severely reduce solar efficiency. But even in the right climatic conditions, Webb (2015) shows that city-scale governance can be a barrier if at odds with the national regulatory framework.

The key features of climate that affect energy demand for thermal comfort are:

- Whether the winters can be very cold or just mild;
- Whether the summers are very hot or very humid;
- Whether there are prevailing winds that could be harnessed for summer cooling.

A high number of HDDs mean that building regulations should focus on insulation of walls and windows and reduction of uncontrolled drafts so that ventilation is optimal to avoid moisture build-up and condensation. Shielding of buildings from high winter winds also helps to reduce heat losses. If solar conditions are sufficient in winter, then glazing should be optimised towards the equator for solar gain. For new-build housing, optimal solar orientation can reduce both heating and cooling loads at minimal cost for any given size of dwelling (Hemsath 2016).

By contrast, for a city with a high number of CDDs, an obvious step is to minimise the glazing to wall area ratio and maximise solar shading of any glazing from the sun to avoid compounding high air temperatures. Kolokotroni et al. (2012) suggest that if internal heat gains are reduced, night cooling when available using natural ventilation will have a beneficial effect on energy performance. If there is prevailing wind, then buildings should have windows that open for this natural ventilation while still maintaining security and minimising incursion of noise. Where there is little wind, tall buildings can exploit the stack effect of thermal buoyancy to drive their own natural ventilation. Increasing vegetation, parks, green roofs and green walls will add shading and increase evaporative cooling (Kolokotroni and Giridharan 2008). At the same time, increasing the albedo of surfaces, cool roofs and pavements are useful additional measures (Hirano and Fujita 2012). These will help to reduce the UHI effect and thus reduce the energy demand for cooling.

Mitigating the impact of heat waves should not simply mean increasing the use of air conditioning. In hot conditions the distribution cable capacity is reduced, jeopardising electrical stability (Choobineh et al. 2016) and increasing the likelihood of power failures, at the time of additional electricity demand (Salagnac 2007). Hicks and Menne (2015) give several examples of national and regional heat wave plans for public health interventions. Recommended actions include health education, contacting high-risk individuals and the opening of cooling centres (Kovats and Hajat 2008).

Transport remains in both countries mostly a single fuel user, i.e. petroleum products. As the rate of car ownership in Colombia is lower than the UK, it is reasonable to expect that as the Colombian economy grows, so too will the total number of cars in the country and their use. It is likely too that the cheapest fuel source will be used; thus, the provision of energy for transport will remain dominated by petroleum products for the near and medium terms. The infrastructure for the internal combustion engine is entrenched in terms of both economics and skills. Improving vehicle efficiency and traffic management is of central importance to reducing energy demand (Erickson and Tempest 2014). Some potentially helpful actions are to remove the heavy metal and SO_2 at source, so promote the use of lead-free and low-sulphur fuels. Remaining tailpipe emissions such as carbon monoxide, VOCs and NO_2 can be reduced by the mandatory fitting of catalytic converters. Reducing VOCs and NO_2 will lower the rate of formation of ground-level ozone. Increased use of diesel particulate filters will reduce PM.

A transition away from petrol and diesel may be facilitated by bioliquids, liquefied petroleum gas (LPG), natural gas and perhaps hydrogen. But the replacement of the internal combustion engine by the electric motor is dominated by the need for investment in a different infrastructure. Although suggested by many, there is no serious prospect of electric vehicles (EVs) participating in the electricity grid as short-term energy storage to offset the operating and ownership costs (Bishop et al. 2016). Furthermore, there is uncertainty whether the overall lifecycle assessment for EVs is better than of the internal combustion engine (Hawkins et al. 2012). With a mostly low carbon electricity generation portfolio, Hawkins et al. (2013) suggest that CO_2 and global warming potential (GWP) from using EVs may be better than using gasoline, but still indistinguishable from using diesel. Hawkins et al. (2013) also suggest that environmental impacts of EV battery and powertrain manufacturing may be greater than for the internal combustion engine. Within the city, however, the potential for zero tailpipe emissions confers significant benefits for air quality with a positive knock-on effect for building energy use.

There is a clear-cut need for demand reduction of electricity and heating. Bogota households and businesses would benefit from energy efficiency measures. However, without city-wide resilient energy infrastructure, the need for new supply remains an important requirement. For a city such as London, all buildings benefit from reliable power supply. Although some London households are in fuel poverty, making the housing stock more energy efficient and reducing the need for travel improves their state and the overall state of the city (Erickson and Tempest 2014). This brings us back to the socio-economic energy modelling of the macroeconomy in Sect. 2—what, how much and how fast can a national economy support (and maintain) growing cities? Investment represented by the vertical blue lines in Figs. 2 and 3 shows there is much construction of service industry and dwellings with opportunities to implement new energy priorities.

5 Conclusions

We have shown that by bringing together national data sets on energy, population, transport and the economy we can gain insight to energy use in the city context. Nations need to be aware of indicators that demonstrate non-sustainable trends. Our case study consists of contrasting countries with some markedly different indicators, but also some surprising similarities.

One of the key differences is that the energy proportion for transport in urban Colombia is almost double that of the UK. Furthermore, the urban per capita emissions of Colombia are a tenth that of the UK. The expected differences according to stage of economic development are accentuated by Colombia's particularly high proportion of hydropower as a primary energy source.

Perhaps of more interest are the many similarities. The ratio of energy use of service industry to urban dwellings is 1:2 for both countries. From a sustainability perspective, the downward trends in heating intensities both per service industry job and per (national) dwelling are encouraging. For both Colombia and the UK the electricity intensities per job and per dwelling are constant, meaning that total power demand scales with urban growth. For both economies the greatest investment is in the service industry, followed by dwellings. Thus they have similar opportunities to implement more ambitious energy efficiency targets in a cost-effective manner. Also similar between the two countries has been the growth in energy use for urban freight transportation. Accepting that the movement of freight is inherent to highly populated cities, the focus for freight transport needs to be on mitigating the consequences of worsening air pollution and improving efficiency. The data fusion method we have used is one way to visualise the links between economic activity, energy and power demand and the consequences on society (including CO_2 emissions). Chasing the unattainable dream of zero-carbon cities may lead to distorted national priorities and policy objectives. The potential for urban areas to generate their own energy is very low. If the climate is right for solar input, then urban areas can make a contribution. Big energy facilities—along with agriculture and manufacturing—are best-suited to rural areas. However, that does not absolve cities and their authorities from 'getting their own house in order' by reducing energy demand for electricity, heat and transport. How a city goes about this is location and climate dependent, but the key priorities for sustainability should be improving air quality and reducing energy demand directly by a radical step-up in energy efficiency. But improving the energy efficiency of buildings and reducing the emissions from vehicles needs more stringent regulation which is then enforced.

Mitigating the UHI is a virtuous feedback system. If the air quality is improved, then natural ventilation becomes a realistic prospect. A logical first step is to reduce the use of the internal combustion engine within the city. This also reduces thermal pollution from the engines and exhaust gases. Then anthropogenic heat emitted from buildings can reduce. Pursuing these objectives simultaneously addresses fuel poverty, indoor comfort, health, infrastructure resilience and several types of pollution. Particular attention is needed to address heat stress without immediately resorting to increases in the use of air conditioning.

Understanding the sustainability implications of energy use in cities starts by disaggregating the types of demand. Their infrastructure requires investment over-and-above simply meeting the basic needs for increasing services, more dwellings and growing transport. But would this additional investment be affordable?

Most new economic activity is associated with the urban environment. The blue lines in the Sankey diagrams (Figs. 2 and 3) show where currently investment is being made. The width of the blue lines vies with household consumption as its competing component of final demand in the economy. Increasing total investment (for all activities) by 10% translates as a reduction in household consumption of approximately 3%. While this relatively small price to households would have a significant leverage, any move to slow the growth or reduce household demand is difficult politically. Reducing air pollution not only has health benefits, but also has the potential to enable energy demand reduction measures to be more effective. Energy use in cities can only be understood and acted upon if all of the activities in cities are considered together. The essence of our approach is captured in Fig. 7. This forms the basis of identifying benchmarks to probe the potential for energy demand reduction in other urban areas.

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Future-Proofed Design of Low-Energy Housing Developments: Case Studies from the UK and Sweden

Maria Christina Georgiadou

Abstract This study examines the concept of 'future-proofing' the energy design of housing developments so as to achieve low levels of energy consumption and carbon emissions over their lifecycle. This refers particularly to the selection of fabric energy efficiency measures and onsite low- or zero-carbon technologies (microgeneration or local energy networks) at an early design stage. The research adopts a multiple case study method with data gathered from two 'best-practice' housing developments in the UK and Sweden, namely North West Cambridge (Cambridgeshire) and Välle Broar (Växjö). The research explores the future-proofed approaches used in the two cases in relation to a pre-established conceptual framework, which involves two aspects, namely adopting lifecycle thinking and accommodating risks and uncertainties. The cross-case analysis reveals that there is widespread experimentation, which demonstrates that future-proofing is still in its infancy. Drivers for future-proofing mostly prompt strategies to accommodate risks and uncertainties in the UK, whereas in Sweden, they lead to the adoption of lifecycle thinking. This is due to unique context-specific governance and institutional factors at both national (country) and local (case study) levels. The chapter concludes with the need to transfer knowledge to mainstream housing construction and inform policy-making in relation to long-term performance over a project's full lifecycle.

Keywords Energy · Future-proofing · Housing developments · Lifecycle · Uncertainty

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1 Introduction

The building sector has the greatest potential to deliver long-term, significant and cost-effective carbon emissions reduction compared to other major emitting sectors, such as transport or industry (IPCC 2007). However, despite advances in energy efficiency of materials, components and energy systems, total resource consumption continues unabated. The building sector across the world is responsible for about 40% of global energy, 25% of global water, 40% of global resources, and one third of greenhouse gas emissions (UNEP 2009). In Europe, buildings account for around 40% of total energy use and 30% of associated carbon emissions (BPIE 2011). Housing is different from any other sector. It is the type with the longest lifecycle and one with the least available funds to apply sophisticated design approaches. *As Bosher et al. (2007, p. 28) suggest: 'residential developers are not proactive, motivated by profits and legal aspects, possibly at the cost of resilience and sustainability [...] resilience and flexibility is left as the responsibility of the person who will be likely to live or work in the building'.*

To address the challenge of planning and designing buildings in accordance with the principles of sustainable development (SD) and a changing climate, 'sustainable communities' have emerged as 'best-practice' case studies around the world. These refer to eco-developments of various scales, from eco-quarters, eco-neighbourhoods or 'green' city districts to larger schemes, such as eco-towns or eco-cities, as part of the 'compact city' model, which demonstrate (Jenks and Jones 2010):

- low- or zero-carbon design, with energy efficient facades, use of control systems, sustainable materials and construction components, and low- or zero-carbon technologies (LZCs);
- connection with eco-friendly public transportation, walking and cycling routes that reduce motor vehicle dependence;
- flood risk management and water harvesting systems, which capture rainwater and control run-off, such as sustainable urban drainage systems;
- domestic waste management systems, wastewater re-use and recycling, and sewage treatment processes; and
- other features, such as local employment, green and public open spaces, proximity to community facilities (health centres, schools and local shops), efforts to maintain biodiversity, cultural heritage preservation, and local food supply.

Community-scale schemes drive sustainability from the bottom up and offer opportunities to disseminate 'best-practice' and share lessons learnt at the local level. Key success factors in their roll-out are: systems thinking; empowered local authorities that generate decentralised solutions; and multidisciplinary collaboration between the involved stakeholders (Killip 2008; Moffatt et al. 2012). Unlike individual buildings, the community-level has the potential to upscale low-carbon solutions through the integration of energy, water and waste networks, information and communication technologies to achieve resilient and adaptable solutions (Jewell et al. 2010; Nielsen 2006). It also provides better economies-of-scale (technical and economic viability) for novel building solutions and sustainability measures. This is due to the 'long-tail' feature of the built environment; i.e. there are many small opportunities to save carbon emissions spread across millions of buildings and it is increasingly difficult to achieve large reductions as the size of the development gets smaller (UN 2010; UNEP 2009).

The issue of long-term thinking in the energy design of buildings is inherent in the SD principles (WCED 1987). Under the label 'future-proofing', this study examines the *temporal* component of SD as an unexplored, yet fundamental ingredient in the delivery of low-energy housing developments. 'Future-proofed' design or 'designing for the future' refers to sustainable, low-energy buildings, able to accommodate social, technological, economic, environmental, and regulatory changes over the long-term, thus maximising lifecycle value (Jones Lang Lasalle 2010; Pitts 2008). Future-proofing seeks to facilitate the selection of robust building solutions that will be 'fit-for-purpose' under a diversity of future scenarios, especially in situations of high uncertainty. Hence, a low-energy design does not necessarily constitute a future-proofed one, but represents a baseline from which to develop further this concept, which is more comprehensive. Buildings are complex systems with a slow turnover. Design solutions cannot be easily revised and they determine whether or not a building project will remain 'fit-for-purpose' or become prematurely obsolete (Soetanto et al. 2006; Stasinopoulos et al. 2009). Design approaches should therefore proactively accommodate future trends and drivers, thus shifting from the current 'build-it-now and fix-it-later' philosophy (NHBC 2013; Ravetz 2008; TCPA 2006).

The motivation for this research is rooted in the disconnect between the appeal of future-proofing as a principle or 'philosophy' aligned with SD at a policy level and readily available design approaches required for its effective implementation by building professionals. In the UK, for example, the construction industry still barely meets existing regulatory requirements rather than surpassing the regulatory targets. Nevertheless, future-proofed design is promoted implicitly within the increasingly stringent environmental legislation, building regulations and standards both at European and national (UK) levels up to at least 2050. These include:

- the revised European Performance Building Directive 2010/31/EU, which sets a target for all new buildings to be nearly zero-energy by 2020 (EC 2010);
- the constant tightening of *Part L* (*Conservation of Fuel and Power*) in England (DCLG 2012); and
- the *Climate Change Act* with a binding target of an 80% reduction in carbon emissions for the building sector by 2050 (CCC 2008; DEFRA 2007).

The gap on future-proofing in policy and construction practice has led to a number of recent changes in the UK. In 2015, the UK Government withdrew officially *the Code for Sustainable Homes* (*CSH*). CSH was a checklist-type environmental assessment tool for rating and certifying the performance of new dwellings in England, Wales and Northern Ireland (DCLG 2010). It became legally binding in 2008 and it was the single national standard to drive future-proofing in the house building industry. CSH was expected to be harmonised with the Part L 2016 update and become the compulsory standard for all dwellings so as to meeting the target of zero-carbon by 2016 (Al-Hassan 2009; NHBC 2014). Furthermore, in 2015, the UK target of *zero-carbon new homes* from 2016 onwards was also scrapped, leading to uncertainty as to what qualifies as 'zero-carbon' and with a widely accepted definition yet to be confirmed (Planning Source 2015). Key reasons for the gap in future-proofing are: (Bosher et al. 2007; Glass et al. 2013, 2008; Sahagun and Moncaster 2012):

- the fragmentation and short-term mindset of the construction industry which deal with the design (or, at best, construction) phase rather than the full lifecycle;
- legislation which regulates operational energy; and
- existing building environmental assessment methods focusing predominantly on the design phase.

This study seeks to lay the foundation for an evidence base of future-proofed design approaches and examine how these can inform the selection of building solutions. The research builds on an established conceptual framework for future-proofed design (Georgiadou 2014; Georgiadou et al. 2012). A case study method is adopted with data gathered from two 'best-practice' housing developments in the UK and Sweden; namely, North West Cambridge (Cambridgeshire) and Välle Broar (Växjö). The research design involved analysing the two 'best-practice' cases against the conceptual framework to establish the extent to which the future-proofed design approaches proposed in the literature were applied in practice and to identify any additional features that may have been used. The focus was explicitly on 'best-practice' developments, since they are most likely to contain future-proofed design approaches and provide the best platform from which to develop any improvements with regard to future-proofing. Analysis of the case material and interviews with key stakeholders provided insights which could not be obtained from the general literature and helped to 'test' the developed framework. Fieldwork was carried out between February 2011 to August 2012, where data was gathered through project documentation and 23 semi-structured interviews with buildings professionals involved in the energy design and construction of the two projects. 'Appendix 1' contains the list of interviewees, their affiliation, interview date, and venue; however, the responses have been kept anonymous and are cited as [interview number–interview date].

2 Future-Proofed Design Approaches

Future-proofing can be defined as '*a design approach that entails "stress-testing" building solutions against a range of plausible futures to ensure that they remain functional over the lifecycle of a housing development; hence, avoiding disruptive* *refurbishments or premature decommissioning*' (Georgiadou 2014, p. 7). This is a framework with three aspects, namely (Georgiadou 2014; Georgiadou et al. 2012):

- *Coverage of SD Issues*: Degree to which the three sustainability 'pillars' (social economic, environmental) and their financial implications are covered in order to achieve a holistic energy design process;
- *Adopting Lifecycle Thinking*: Extent to which the implications of the energy design are considered throughout all lifecycle stages, i.e. from 'cradle-to-grave' (from extraction up to final disposal) or 'cradle-to-cradle' (future deconstruction, re-use and recycling) so as to minimise the associated environmental impacts (Ekundayo et al. 2012; Pelsmakers 2012);
- *Accommodating Risks and Uncertainties*: Degree to which predictable, reasonably foreseeable, and uncertain trends and drivers that can affect the energy use are accommodated over the long-term (Lane et al. 2005; O'Brien et al. 2009).

Existing literature addresses extensively the first aspect, which covers the thematic component of SD. However, the contribution of the conceptual framework is that it introduces two *additional categories* to account for the temporal aspect of sustainability (Table 1).

From the review of the background literature, two general categories of long-term impacts that dwellings can cause and experience have been identified. They are often neglected or erroneously treated interchangeably in design decision-making by building professionals. These are the:

- impacts *of* domestic buildings on the environment due to their long lifecycles (*adopting lifecycle thinking*); and
- impacts *on* domestic buildings due to (predictable and/or unforeseeable) high-impact social, technological, economic, environmental and policy trends and drivers affecting the energy performance (*accommodating risks and uncertainties*).

Table 1 Categorisation of future-proofed design approaches

Adopting lifecycle thinking	Accommodating risks and uncertainties
Operational energy performance • Predictive studies • Post-construction audit (PCA) • Post-occupancy evaluation (POE) *Embodied energy and carbon* • Design for 'cradle-to-gate' • Design for 'cradle-to-grave' • Design for 'cradle-to-cradle' *Lifecycle Assessment* • Building material and/or construction component scale • Building scale	*Adoption of standards beyond statutory minima* *Design for adaptive capacity* • Design for resilience • To overheating • Design for flexibility *Advanced future-oriented analysis* • Dynamic building performance evaluation • Stochastic modelling of future overheating risk

Source Georgiadou (2014), Georgiadou et al. (2012)

Along each category, there is a spectrum of design approaches that can be used, with their position from the top reflecting the degree of complexity typically associated with their use. The empirical data gathered from the two ‘best-practice’ developments were ‘tested’ against the above conceptual framework to determine the degree of alignment between theory and practice. The findings are summarised in the following sections.

3 Analysing the Case Studies

3.1 Välle Broar

Sweden is a country regarded as a European leader in promoting integrated eco-city planning, environmental protection, innovation in energy efficiency and renewable energy, as well as, civic empowerment and involvement, thus offering the potential for the transfer of ‘best-practice’ experience to the UK. The city of Växjö is located in the south central part of Sweden (Fig. 1). In 2011, the domestic sector accounted for about 30% of total energy, of which 87.5% was from renewable energy sources (Int.22-16/05/2011), with biomass accounting for about half and grid electricity mainly from hydropower and nuclear.

Between 2006 and 2011, Växjö participated in the Sustainable Energy Systems in Advanced Cities (SESAC) project, which was part of the CONCERTO (2011) initiative within the 6th European Framework for Research and Development. SESAC sought to demonstrate how cities address current energy challenges and enhance technological innovation, together with good local governance and novel cooperation (Int.21-19/05/2011; Int.23-19/05/2011; SESAC 2011b). The key partners involved in the SESAC contract were: the municipality of Växjö; VEAB: the municipal energy company that provides 25–30% of the electricity and all district heating and cooling needs in Växjö; Hyresbostäder and Växjöhem AB:

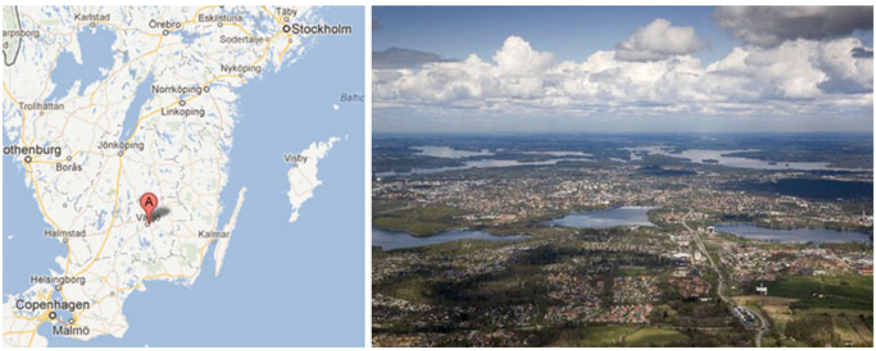

Fig. 1 City of Växjö

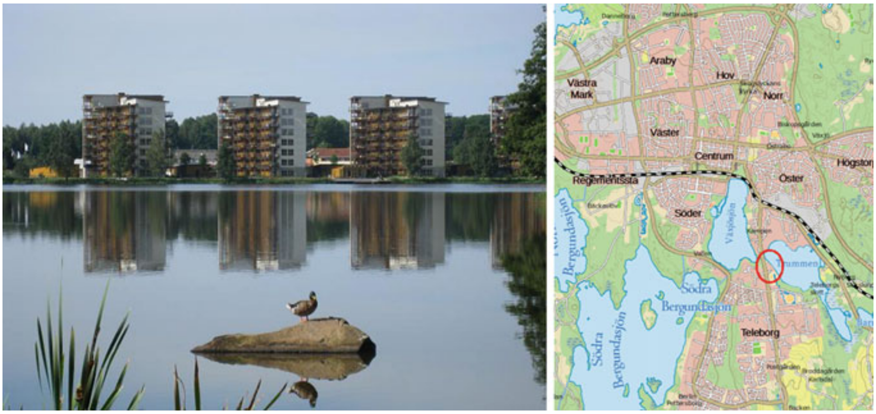

Fig. 2 Wooden houses in Limnologen

the two municipal rental housing companies, who own about 12,000 apartments in the city under the control of the Växjö Municipality Company AB (VKAB).

Data collection focused on two demonstration projects in Välle Broar, an area south of the city centre; namely, Limnologen and Southern Portvakten. These are new apartment blocks constructed between 2008 and 2009, which at the time of fieldwork had entered their operational stage. The two projects demonstrate the following innovative features (Ahlrot 2011b):

- 30% reduction in energy performance compared to the National Board of Housing, Building and Planning (BBR)[1] 2006 levels, as outlined in the SESAC contract;
- Connection to the biomass-fuelled Combined Heat and Power (CHP) district heating plant, unless buildings were designed as passive houses;
- A full-scale test area for high-rise low-energy timber-framed buildings.

Although Sweden is a country with low population density that has made it impractical to adopt centralised decision-making processes, the majority of housing in cities is high density apartment blocks. Limnologen (Fig. 2) consists of four eight-storey buildings with 134 low-energy privately owned apartments.

Midroc, a private developer, was responsible for financing and supplying the construction and supported the use of prefabricated wooden building components (SESAC 2011a). The load-bearing structure consisted of solid wood panels and the cross-laminated timber (CLT) building system, which consisted of lightweight

[1]BBR refers to the Swedish Building Regulations (Byggregler) for new buildings and refurbishment or extension projects. It has been updated frequently and most recently in 2008 and 2012. The 2012 update sought to align the BBR with the revised EPBD 2010/32/EC (BBR 2011). In Sweden, total regulated energy is the sum of all residential energy consumption including microgeneration.

Fig. 3 Passive houses in southern Portvakten

prefabricated panels. Southern Portvakten (Fig. 3) is an eight-storey development built by the municipal rental housing company Hyresbostäder (Int.22-19/05/2011). The project demonstrates novelty as it incorporates lessons learnt from Limnologen in relation to the energy design process, high-rise CLT-framed load-bearing construction and prefabrication in a passive house approach (Ahlrot 2011a; SESAC 2011a).

Southern Portvakten is the first high-rise timber-framed building that followed the voluntary passive house methodology developed by the Swedish Forum for Energy Efficient Buildings (FEBY). In Sweden, passive houses (Fig. 3) were developed following the positive experiences of the PassivHaus movement in Germany. The FEBY standard was developed in 2007 after it was recognised that the climatic and building regulations differences between Sweden and Germany would not allow for the rigorous adoption of the German methodology. This is important as certain standards cannot be easily replicated elsewhere depending on the climate and location. PassivHaus buildings in Sweden comprise a super-insulated and completely airtight fabric, where the only heating is from the occupants, internal lighting and domestic appliances, i.e. there is no traditional heating system (FEBY 2009; Kildsgaard and Prejer 2011). According to the FEBY 2008:1 version, for a passive house located in the Southern climate zone the maximum peak load for space heating should not exceed 17 W/m^2 (Danielski et al. 2013).

The Managing Director of the Energy Agency for Southeast Sweden (Int.20-16/05/2011) underlined that the energy design of Limnologen and Southern Portvakten followed a hierarchical approach to low-carbon development, prioritising fabric energy efficiency measures. Local authorities prescribed the connection to the district heating system for all developments in Välle Broar, except the FEBY passive houses, and there were no microgeneration technologies installed (Table 2).

Table 2 Energy design of Limnologen and southern Portvakten

• Solar orientation with south-facing windows to capture as much solar gains and daylighting as possible, especially during wintertime
• Super insulation, airtightness, and advanced triple glazing
• Timber-framed, load-bearing construction with prefabricated building components
• Connection to the biomass-fuelled district heating system for all heating and Domestic Hot Water (DHW) in Limnologen, and extra heating during periods of extreme cold in Southern Portvakten
• A novel double-flux Flow Through heat exchanger (FTx) ventilation system
• Heat recovery on the wastewater systems in Southern Portvakten
• Individual metering system with displays for space heating, DHW, and electricity
• A-labelled appliances in all apartments, specified in the contract between the developer and local authorities

Ahlrot (2011a) and Int.10-16/05/2011

3.1.1 Välle Broar: Adopting Lifecycle Thinking

Operational Energy Performance

Detailed predictive studies entailing energy modelling of Limnologen and Southern Portvakten were carried out at the design stage. In addition, a key focus area during the post-construction phase was to monitor systematically the actual energy performance of the two projects. This followed a two-stage process, namely (Int.18-18/05/2011; In.20-18/05/2011):

- conducting PCAs in 2009 to test apartments before and after construction to identify weaknesses of the fabric efficiency and correct them before occupation; and
- carrying out POEs in 2010 after the first occupants moved into reveal discrepancies between the design and actual energy performance. For these studies, primary data was gathered from four Demand Side Management (DSM) systems installed in four different apartment types, as described below.

Seventy-two apartments were set as reference, in which heating and DHW were incorporated in the price of the rent as normal without any direct financial incentive to save energy (Ehrlen 2011). With the objective of lowering occupants' consumption patterns by 10%, four different DSM strategies were employed including a combination of temperature sensors, displays, individual meters, and smart meters, as follows:

- *Type 1* buildings have a measurement system with separate displays for electricity, and DHW, showing both cost and energy consumption. The apartment is also equipped with comfort metering, for which occupants are charged for heating based on the actual temperature in the apartment;
- *Type 2* buildings have a measurement system with displays for all uses, i.e. electricity, heating, DHW, and cold water. Occupants can follow the electricity consumption on EnergiKollen[2] and consumption of heat, DHW, and cold water on a display mounted in the apartment and pay for each energy use separately (individual billing);
- *Type 4* buildings have a measurement system for electricity, heating, and DHW, and there is individual billing of energy uses. Residents can follow the electricity consumption on EnergiKollen;
- *Type 7* buildings have a measurement system and individual billing for electricity and DHW. Residents can follow the electricity consumption on EnergiKollen and also the DHW consumption on a wall-mounted display.

Results showed electricity consumption patterns of 2–42% and DHW of 35–70% less than those of the reference apartments. Eriksson (2010) argues that the success of carrying out effective POEs was a result of:

- installing individual meters for heating, DHW, and smart meters for electricity;
- charging occupants for their actual consumption instead of adding the energy bills to the price of the rent (real-time billing);
- setting up EnergiKollen and installing displays in the apartments to help occupants understand their consumption patterns; and
- the existence of municipal energy and housing companies (VEAB, VKAB) and the overall SESAC umbrella, which ensured the provision of publicly available local statistics. If private companies were involved, there would probably be restrictions on data transferability and sharing due to issues of data ownership and control.

Embodied Energy and Carbon

As Växjö is surrounded by abundant forests, the local forest industry could provide timber and wood waste, such as wood chips and sawdust in the construction and heating of buildings. A local timber promotion programme has also been in place for the past 20 years (Ahlrot 2011a, b). Gustavsson et al. (2010) argue that as the operational energy decreases, it becomes relatively more important to consider the other phases of a building's lifecycle. The CLT-framed load-bearing construction featuring in the two projects helped to reduce implicitly the embodied carbon from 'cradle-to-gate' and from 'cradle-to-cradle', particularly when compared to concrete

[2]This is an interactive web-based service developed by the municipal energy company VEAB, where customers can log in and check energy costs and average electricity consumption over hourly, daily, monthly, or yearly periods.

or steel (Fremrot 2011). The use of timber for construction is considered a future-proofed design approach with the following benefits (Gustavsson et al. 2010; Int.8-10/05/2011; Int.16-17/05/2011):

- Wood is around 6% less energy- and carbon-intensive during production and assembly of prefabricated components, as compared to concrete, and also acts as a carbon sink (‘cradle-to-gate’);
- Even though most of the wooden components used were produced and transported from Northern Sweden, they were prefabricated and lightweight leading to simpler supply logistics, transport efficiency, and assembly compared to conventional onsite methods (‘cradle-to-gate’);
- Additional bio-energy can be obtained at the end of the lifecycle if wood-based demolition residues are reused and recovered as biofuels at the local CHP plant (‘cradle-to-cradle’).

Lifecycle Assessment

A comprehensive lifecycle assessment (LCA) was carried out by Linnaeus University during operation to determine the primary energy use and carbon emissions of the wooden structure in Limnologen (Serrano 2009). The analysis covered all lifecycle phases, namely: collection of raw materials; process of raw materials into building materials; construction/assembly; occupation/use; decommissioning/disassembly; and final disposal/waste management (Int.16-17/05/2011). The LCA followed a methodology discussed by Gustavsson et al. (2006), Gustavsson and Sathre (2006), and Sathre (2007). Swedish databases were used to gather data on specific energy use for extraction, processing and transport of materials, and forest production energy. The primary energy use was calculated by taking into account the total material mass input (including construction waste), the specific energy demand data for manufacturing and transportation, and the efficiencies of the fuel, conversion, and distribution systems. All calculations were conducted under two scenarios: a 50-, and 100-year building lifespan. The energy use for space heating and ventilation during the operational phase was estimated via the ENORM, i.e. a standard Swedish energy modelling software, comparable to the UK Standard Assessment Procedure (SAP) methodology. The primary energy used for operation was calculated via the ENSYST modelling tool (Karlsson 2003).

3.1.2 Välle Broar: Accommodating Risks and Uncertainties

Adoption of Standards Beyond Statutory Minima

The SESAC contract required energy performance targets of around 30% lower than the BBR 2006 levels (Int.10-16/05/2011; Int.22-19/05/2011). This means that the SESAC requirements *future-proofed* the dwelling energy performance against

Table 3 Energy consumption in Limnologen and southern Portvakten

	BBR 2006 baseline	SESAC targets	Actual	Difference to baseline
Space heating and DHW [kWh/m^2 p.a.]				
Limnologen	135	95	69	−66
Southern Portvakten			43	−92
Electricity [kWh/m^2 p.a.]				
Limnologen	30	20	9	−21
Southern Portvakten			10	−20

future stringent national and European building regulations and standards. When combining all heating, DHW, and electricity, dwellings Limnologen and Southern Portvakten corresponded to a significant overall energy reduction compared to the BBR 2006 baseline, thus exceeding the SESAC targets. Moreover, Southern Portvakten consumed around 60% less energy compared to Limnologen due to greater savings during the operational stage (Int.22-19/05/2011). This is due to improved airtightness and U-values of the building fabric so as to achieve the passive house FEBY standard (Kildsgaard and Prejer 2011).

At the time of the project planning, the BBR 2006 set an energy benchmark of 135 kWh/m^2 p.a. for heating (including DHW) and 30 kWh/m^2 p.a. for electricity. Following the future-proofed standards, the SESAC targets were set to 95 kWh/m^2 p.a. for heating and 20 kWh/m^2 p.a. for electricity. These were the initial design targets but, in practice, the total energy performance achieved was around 53 and 68% less for Limnologen and Southern Portvakten, respectively, compared to the national indices. This means that space heating in both project was lower even compared to the updated BBR 2008 and 2012 standards, which were set to 110 kWh/m^2 p.a. and 90 kWh/m^2 p.a., respectively (BBR 2011). Furthermore, the energy design of Southern Portvakten outperforms statutory minima further by exceeding the FEBY standard. FEBY (2009) has a benchmark of 10 W/m^2, which translates to a maximum 45 kWh/m^2 p.a., when the actual performance of Southern Portvakten was 43 kWh/m^2 p.a. (Table 3).

Design for Adaptive Capacity

This aspect is integrated to a limited manner into the energy design of Limnologen and Southern Portvakten, as it demonstrates mostly building strategies for climate change mitigation. A climate strategist explained that (Int.12-16/05/2011): *'even though we are in Sweden, there is a false perception that occupants freeze inside a passive house but overheating can be a real problem, which is not covered yet extensively'*. In addition, the reflection of the interviewees was that there were no design approaches for integrating flexibility into the energy design, even though the municipality recognised that population growth, ageing population, and ageing infrastructure could be risks affecting the energy mix in the future

(Int.10-16/05/2011; Int.13-16/05/2011; Int.14-16/05/2011). The only example of incorporating flexibility was the consideration of PV-ready roofs in Limnologen. PVs were initially planned, but during detailed design, proposals were rejected due to high capital costs and the lack of financial incentives to support their installation.

Advanced Future-Oriented Analysis

Energy calculations for Limnologen and Southern Portvakten were carried out using the dynamic simulation software DEROB-LTH 2008:v2.0 (Kildsgaard and Prejer 2011). This is a design tool, which assesses the complex dynamic behaviour of the selected building solutions and their impact on the total energy performance. The simulation takes hourly input data of maximum indoor temperature, airtightness options, various heat exchangers efficiencies and produces output for total space heating, peak loads for heating and cooling, and the effect of different set-point indoor temperatures on them. Simulations were undertaken successively for each building block (Kildsgaard and Prejer 2011). One weakness of the simulation is that it does not account for thermal bridges,[3] which were re-calculated manually to incorporate them into the thermal properties of construction elements. The DEROB-LTH calculations were conducted in parallel to ENORM simulations. As expected, the steady-state ENORM calculations showed lower consumption levels compared to DEROB. In order to understand the discrepancy between the two models, additional simulations were carried out using the dynamic IDA Simulation Environment model, which also showed higher consumption than ENORM. However, there was no use of probabilistic weather files to account for future temperature increase in overheating analysis (Int.19-18/05/2011).

3.2 North West Cambridge

North West Cambridge (NWC) is a 150 ha strategic urban extension to the City of Cambridge, UK (Fig. 4). The vision is to deliver a new mixed-use 'eco-quarter' with 3,000 dwellings, student accommodation, commercial and education buildings, retail facilities, a community centre, a school, police, a primary health care unit, nurseries, a hotel and an energy centre (AECOM 2011a, b; CCC and SCDC 2009). Cambridge is unusual in many ways, having been shaped by the 800-year history of the University, which sets a clear precedent for future-proofing and the adoption of a long-term perspective.

The vision has evolved since 2003, through a collaborative process of stakeholder engagement with the University, Cambridge City Council, South

[3]Thermal bridges are junctions where insulation is interrupted by construction details (e.g. openings), thus causing additional heat loss.

Fig. 4 NWC site. *Source* CCC and SCDC (2009)

Cambridgeshire District Council, Cambridgeshire County Council, AECOM (leading the University consultancy team), Bidwells with KJ Tait Engineers, and local residents. The University is the landowner and main, but not the sole, developer of the site. An Outline Planning Application was granted planning permission in 2012. This has led to a series of Reserved Matters applications to provide the design guidelines, design codes and construction details for each Phase of development. A phased approach is adopted and construction is expected to be completed by 2030 (Int.1-16/02/2011).

The scale and significance of NWC has led to the development of an Area Action Plan (AAP), which was adopted in 2009. This has been the central policy document developed by the Councils providing a framework to systemically incorporate sustainability and climate-proofing into the design. The AAP sets a number of challenging energy and carbon emissions requirements, which seek to be in line with the UK policy framework both now and into the future (Table 4). In order to ensure that all dwellings reduce carbon emissions and meet the requirements of CSH Level 5,

Table 4 Area Action Plan—climate change and sustainable design and construction

All domestic buildings are required to demonstrate:
• Minimum Fabric Energy Efficiency Standard (FEES), i.e. 39 kWh/m^2 p.a. for apartment blocks and mid terraced houses and 46 kWh/m^2 p.a. for semi-detached, end-of-terrace, and detached houses
• CSH Level 5, with a 100% reduction in regulated carbon emissions using onsite energy generation
• Part L 2016 for 'zero-carbon' homes built post 2016
• Connection to a low-carbon and decentralised Combined Heat and Power (CHP) district heating network
• Solar PV panels to meet carbon reduction targets at a microgeneration level
• Adaptability and resilience to the unavoidable temperature increase and predicted effects of overheating, without the installation of mechanical cooling systems

Source AECOM (2011a, b, c), CCC and SCDC (2009)

AECOM has adopted a ‘fabric first’ approach as proposed by the Zero Carbon Hub. Building solutions that are most likely to yield the greatest carbon emissions reduction via maximising energy efficiency are pursued first, followed by the use of control systems and low- or zero-carbon technologies (ZCH 2009, 2010, 2011).

3.2.1 NWC: Adopting Lifecycle Thinking

Operational Energy Performance

The energy assessment in NWC focuses predominantly on the operational phase. The consultants modelled the energy consumption of three broad dwelling types (flats, semi-detached and detached properties), if built to the baseline Part L 2006 and FEES. The total energy consumption of dwellings is expected to be around 85–113 kWh/m^2 p.a. depending on the type. The University is committed to evaluate systematically the building performance by conducting PCAs and POEs when residents will move into the dwellings (AECOM 2011a; Int.3-23/03/2012; Int.7-23/03/2012). Since the development will be ongoing, it is expected that the lessons learnt will inform the subsequent phases of NWC. Methods for conducting PCA studies will include thermographic imaging, co-heating tests and detailed monitoring of thermal bridging (Int.4-03/03/2011; Int.5-03/03/2011). POE studies will include environmental monitoring (temperature, humidity and indoor air quality sensors), electricity monitoring (whole house, circuit and appliance meters), energy monitoring associated with space and water heating and occupant surveys (Int.4-03/03/2011). Also, data from smart meters may be linked to the community intranet to allow for centralised recording and monitoring of energy use (AECOM 2011a).

Embodied Energy and Carbon

An Associate Director from AECOM (Int.4-03/03/2011) justified this prioritisation by arguing that: ‘*the proportion of embodied energy is really small compared to the detriment of the running costs, which is more significant*’. Standard sustainability measures have reduced indirectly the embodied carbon, such as (AECOM 2011c, d, e):

- selection of suppliers with environmental management schemes in place to supply certified materials based on international standards (‘cradle-to-gate’);
- the use of Modern Methods of Construction (MMCs), such as off-site manufacturing to reduce construction waste (‘cradle-to-gate’);
- the AAP requirement for the supply of sustainable materials procured locally (‘cradle-to-gate’);

- use of A-rated materials based on the BRE Green Guide[4] to ensure minimum environmental impact ('cradle-to-grave'); and
- strategies for deconstruction that favour re-use and recycling over demolition, where possible ('cradle-to-cradle').

Lifecycle Assessment

Overall, buildings in NWC are designed for a lifespan of 60 years and AECOM was briefed to consider LCA as a decision-support tool. The consultants argued that where feasible, LCA might be conducted for the most commonly used construction components in the next project phases (Int.6-03/03/2012).

3.2.2 NWC: Accommodating Risks and Uncertainties

Adoption of Standards Beyond Statutory Minima

The AAP requires housing to surpass Part L at each construction period. Since construction was estimated to begin around 2013–2014, the target was to achieve CSH Level 5 from the outset for all domestic buildings, thus being one step ahead of the national trajectory, which at that time mandated Level 4 (Table 5). This was —at that time—quite ambitious given that the UK policy has currently abandoned the 2016 zero-carbon target and abolished the CSH. There is also potential for some of the detached houses to be future-proofed by adopting the German PassivHaus standard (AECOM 2011a).

Design for Adaptive Capacity

NWC is one of the first sites in the UK where the local planning policy acknowledges the imperative for adapting the design to the adverse effects of climate change (Int.2-18/02/2011). Buildings will need to cope with future predicted higher temperatures, which has led to a systematic approach to address overheating in development proposals. In particular, the AAP suggests that (CCC and SCDC 2009, p. 37): *"New development will need to be resilient to overheating without active cooling systems. There is much that can be achieved through passive*

[4]The Green Guide to Specification is a tool developed by BRE to assess the environmental impact (in kg CO_2 e/m^2) of more than 1500 building products over a 60-year period. The Guide is an embodied carbon accounting tool from 'cradle-to-grave' and includes emissions from manufacturing, initial construction, maintenance and repair to dismantling, demolition, and waste management at the end-of-life stages (Anderson et al. 2009; BRE 2007, 2008; Ekundayo et al. 2012).

Table 5 Adaptation strategies to address the risk of overheating

High thermal mass with a heavyweight construction (brick and concrete)
Advanced triple glazing systems
Natural (cross-flow) ventilation
Shading devices, such as shutters, overhangs, and pergolas
Higher ceilings to allow stratification and punkah fans
Materials and coatings with high reflectivity for building roofs and external surface finishes to reduce heat absorption in the summer

AECOM (2011c, d) and Int.6-06/03/2012

measures, such as the location, layout, orientation, external design of buildings and landscaping that can help occupants to cope more easily with overheating".

Table 5 presents the dwelling adaptation strategies that will be implemented in NWC, where practicable, so that temperatures do not exceed 28 °C in living spaces and 25 °C in bedrooms for more than 1% of the occupied hours. Domestic air-conditioning will not be permitted as a method to reduce summer temperatures to acceptable levels.

Flexibility is integrated into the overall energy strategy of the master plan, thus cascading down to the energy design of dwellings and it is considered in relation to accommodating novel technologies in the building fabric and occupants' changing needs and behaviours. The AAP states the need for a flexible energy strategy in order to accommodate new technologies and avoid technology 'lock-in' phenomena. The need to retain fuel flexibility and have multiple low-carbon fuel sources is also important for energy security purposes (Int.2-18/02/2011; Int.4-03/03/2011; Int.6-06/03/2012; Int.7-23/03/2012). An example is the CHP district heating network, which is 'fuel agnostic' to allow for different heating technologies and fuels to be connected in the future. Although it will be based initially on natural gas, as the most viable option, over time the fuel source could potentially be changed as technologies improve (e.g. biomass-fuelled CHP, heat pumps, fuel cells, and energy from waste) and gas becomes scarcer or prohibitively expensive due to a carbon price. For this reason, the parameter plan in the OPA includes a 1 ha space for a future energy centre (AECOM 2011a).

With regard to accommodating both present and future occupants' changing needs and behaviours, the master plan proposals have evolved to ensure that a suitable proportion of dwellings will meet the Government's Lifetime Homes standard. This will address the needs of multi-functionality for elderly and disabled people as well as the growth of home-working patterns. An Associate Director from AECOM (Int.6-06/03/2012) argues that '*although not directly energy-related, this standard ensures that the design will not become obsolete, requiring substantial and often energy-intensive refurbishment in the future*'.

Advanced Future-Oriented Analysis

There has been no systematic use of dynamic energy modelling to calculate the total energy consumption due to the cost and lack of relevant data required for such models (Int.6-06/03/2012). AECOM used the latest version of SAP (2010) for carrying out building performance evaluation for the market and key worker housing units, which is a steady-state tool incorporating various assumptions and leading to miscalculation of energy loads. However, AECOM undertook stochastic analysis of overheating risk so that dwellings are designed to meet the comfort criteria predicted for 2050 and 2080 temperatures under climate change (Int.6-03/03/2011; Int.7-23/03/2012). This presents a shift away from current deterministic overheating analysis required by the Building Regulations (AECOM 2011a). Based on the UK Climate Projections (UKCP09 2010) 2050 medium and high scenarios, PROMETHEUS weather files have been incorporated into the IES VE (dynamic) modelling tool to assess natural ventilation strategies and inform the overheating analysis on indicative dwelling energy design (Int.6-03/03/2011). This is an established algorithm to account for stochastic overheating analysis developed by the University of Exeter (Eames et al., 2011; Gul et al. 2012; Jenkins et al. 2011).

4 Cross-Case Analysis and Discussion

The overarching driver for future-proofed energy design differs in the two case-studies. In NWC, it is the University's vision to meet its long-term needs regarding key worker housing, together with the Council's target for housing provision and delivery of a sustainable urban development. In Sweden, the driver was the SESAC project aiming at demonstrating European 'best-practice' guidelines for sustainable local energy management, together with the objective to provide a decision-support framework for deploying wood housing technologies and demonstrating the market potential for wooden multi-storey apartment blocks.

The case study research has revealed that the building professionals involved in the two projects:

- endorse that future-proofing should be considered at the (very) early design stages;
- seek to design dwellings for long lifecycles (between 60 to 100 years); hence, demolition is undesirable; and
- understand that future-proofing the energy design entails considering not only fabric efficiency, but also accounting for occupants' behaviour.

Evidence shows that future-proofing is still in its infancy with widespread experimentation in design approaches even for 'best-practice' schemes. None of the examined housing developments comprehensively future-proofed the energy design and the two cases demonstrate patchy coverage of the conceptual framework, which, in fact, is ahead of actual practice. In fact, in the UK future-proofing is translated mostly into design approaches that accommodate risks and uncertainties, whereas in the Swedish it is in the adoption of lifecycle thinking. Furthermore, there is no design approach identified in the four cases that is not covered by the conceptual framework.

The cross-case analysis reveals that there is a strong focus on operational energy, as it is the phase that contributes the most to total energy consumption. There are embodied energy considerations in both cases and use of LCA for the wooden building structure in Limnologen. However, none of the cases demonstrates comprehensive use of an established LCA tool at a building level, which signals the need for future work in the field. With regard to accommodating risks and uncertainties, both cases adopted dwelling energy performance standards beyond statutory minima and these future-proofed requirements derive from local planning policies. Design for adaptive capacity is not equally addressed between the two case studies. NWC is among the first sites in the UK that have developed local policies (AAP) that require explicitly 'climate-proofing'. Evidence shows that designing for adaptation is not yet seen as a priority in Välle Broar, even though local authorities have a strong tradition in environmental planning and climate change awareness.

This section explores the design approaches that can be transferred more widely from the two cases to new conventional housing developments in the UK in order to future-proof their energy design. It should be underlined, however, that transferability relates to the design approaches that informed decision-making not the actual building solutions (e.g. choice of materials, structural system, or heating strategy). There are two types of transferable findings; namely, those transferred from a single case study; and those arising from the cross-country comparison. The cross-case analysis reveals that there is a strong alignment between the unique case- or country-specific drivers and the identified future-proofed design approaches. These should be examined prior to considering wider application and transferability of the research findings. Most of them exist due to the two cases representing 'best-practice' developments. Furthermore, the unique governance and institutional characteristics present at both national and local levels in the UK and Sweden, respectively, demonstrate that the two societies operate differently when it comes to local planning, housing provision, construction practices, and energy consumption. Table 6 presents a summary of the unique context-specific drivers that have led to the adoption of different future-proofed design approaches.

4.1 The General Planning and Policy Context

The wider UK energy policy prioritises resilience and flexibility for experimentation and innovation in sustainable energy plans and design decision-making; while, providing energy security and reliable services (Chaudry et al. 2009; Greenwood 2010, 2012). This is why NWC examines issues related to climate change, ageing population, energy-intensive behaviours, and new working and living patterns.

Table 6 Unique context-specific drivers for future-proofed design approaches

Drivers	Case studies	
	UK	Sweden
	NWC	Välle Broar
The general planning and policy context		
Resilience and flexibility in the national energy system	√	x
Strong local authorities	o	√
The long-term perspective of local authorities		
Local planning policies	√	√
Land lease contracts with environmental clauses	x	√
Integrated planning process	x	√
The long-term perspective of the developer		
Expertise and reputation in sustainable building practices	√	√
Ongoing management and monitoring	√	√

Key (√) influential/present, (x) not influential/present, (o) not currently influential/present but could be in the future

Moreover, North European countries including Sweden, municipalities have been traditionally strong and financially more independent than their UK counterparts with a considerable amount of autonomy in energy and environmental planning (Collier and Löfstedt 1997). According to the SESAC Project Coordinator (Int.10-16/05/2011): *"Swedish municipalities are empowered to take their own decisions and set the energy and environmental standards that development projects have to meet. They are not reliant on big national or international private companies. Some projects receive funding from the central government but the majority of them run independently".*

This is due to the low population density that has made it impractical to adopt centralised decision-making processes. As a result of this empowerment, Swedish environmental goals remain generally unaffected by political changes, whereas in the UK there is often a short-term outlook to environmental policies (e.g. 'eco-town' initiative, zero-carbon target) due to changes in governments. In Sweden there is also a long-standing tradition in municipal ownership of energy distribution and housing companies (Int.9-16/05/2011; Int.11-16/05/2011). Lifecycle thinking, and particularly LCA, is supported by the Swedish local planning policy, while in the UK this is seldom considered (Int.3-23/03/2012). This explains potentially why Välle Broar adopted design approaches for lifecycle thinking to a greater extent than NWC.

4.2 *The Long-Term Perspective of Local Authorities*

The cross-case analysis demonstrates that future-proofing is an outcome of the strong sustainability vision of the local authorities, who through local planning policies mandated the adoption of standards beyond national legislation, i.e. AAP for NWC and the SESAC project the City's Environmental Programme in the case of Välle Broar. Another common aspect in Sweden are the *Quality Programmes*, i.e. lease contracts through which municipally owned land is sold via a competitive bidding process with environmental clauses that prospective (municipal or private) developers need to meet. The Quality Programme in Välle Broar specified, among others, the levels of energy efficiency, such as U-values, total energy performance (kWh/m^2 p.a.), and connection to the district heating system (Ahlrot 2011b; Int.12-16/05/2011; Int.13-16/05/2011). The Managing Director of the Energy Agency for Southeast Sweden argued that (Int.11-16/05/2011): *"The power is in owning the land and a Quality Programme is a means for driving new market conditions and educating the local construction industry […] it is much easier to apply sustainability requirements in publicly owned land, which has explicitly a long-term interest […] but with the tendering processes and contractual agreements of the Quality Programmes we can make developers comply with specific rules".*

Evidence from Välle Broar also reveals that Sweden is a leader in integrated planning, which is a driver for future-proofed design. There is a novel cross-sectoral organisational structure established by local authorities at two levels: *within local authorities* (also called 'the network of planners'), which refers to bringing together planners from four different tiers to work on the same development phase; and *between local authorities and the developer, contractor, and/or design teams* via the establishment of temporary interdisciplinary teams, thus facilitating a shift from a narrow focus towards integration of design themes. Integrated planning offers the first essential step for future-proofed design, by setting a clear and commonly agreed vision of a low-energy home (Int.11-16/05/2011): *"With the integrated planning process you develop the soul of the project in the beginning and this raises commitment and engagement between city officers, building companies, housing associations, architects, technical staff, and even the end-users. The initial design statement in Välle Broar was the most important thing, as it is very difficult to go back and change the building strategies".*

4.3 The Long-Term Perspective of the Developer

Evident in both cases is the developer's experience in sustainable building, commitment to corporate social responsibility, and desire to enhance brand name and reputation. In addition, one common aspect between the two cases is the long-term interest of the developers, who unlike speculative ones take a long-term view of the development regardless of whether they are private or municipal. In NWC, the University is different from commercial developers in that it intends to retain ownership and control over the long-term. An interviewee argued that (Int.6-06/03/2012): *'the University is interested in design quality over the long-term, unlike a typical developer who wants to dispose of or sell the site as quickly as possible […] it is almost like building on publicly-owned land'* . Usually in the UK, sites of such large scale are under multiple and complex ownership structures, which may result in conflicting interests. The long-term ownership also offers the opportunity to recover the initial investment through lower operation and maintenance costs.

4.4 Transferability and Application of Research Findings

The research has demonstrated that unique governance and institutional characteristics have influenced strongly the adoption of future-proofed design approaches in the two case-studies. Given the absence of the above context-specific drivers it would be unreasonable to expect to replicate the future-proofed approaches in mainstream UK construction or elsewhere. In addition, many of the future-proofed design approaches explored in this research are currently not scalable due to the high cost of the studies, inadequate data, lack of experience, and shortage of specialised-resources required for their use. For instance, embodied energy is increasingly considered in design decision-making to foster a whole life approach to carbon emissions assessment. Although lifecycle thinking is conceptually simple, it is challenging to be applied more rigorously to conventional practice due to data requirements and high costs. LCA studies are expected to be applied mostly at building material, construction component, or energy systems level rather than the building or district scales.

Apart from new construction, which was the scope of this research, there is significant potential to apply the transferable design approaches to retrofit projects. Arguably, transforming the existing housing stock should be central to any national decarbonisation strategy as around 75–85% of buildings in use today are expected to be standing in 2050 and new buildings comprise a relative small share. If the construction industry is to successfully address the ambitious 80% carbon reduction target by 2050, then it will be imperative that actions address existing dwellings. This entails a detailed understanding of how energy retrofit projects work in practice and the barriers to driving low-energy behaviours. There is also significant potential to apply the proposed conceptual framework in the emerging context of standardising PCA and POE studies. The examples of the Building Information Modelling (BIM) and Soft Landings frameworks in the UK are a starting point in an effort to address the 'performance gap'[5] and ensure design quality in mainstream construction (Leaman et al. 2010; Pelsmakers 2012; UBT 2009).

[5]The difference between anticipated ('as-designed') and actual ('as built') performance.

5 Conclusions

The research has shown that a future-proofed design seeks to ensure the delivery of resilient and adaptable low-energy buildings with the potential for sustainability benefits and cost savings over the long-term. If future-proofing is viewed strategically during the design process, it can bring added-value, as anticipating change is cost-effective. There are three key reasons for proactively integrating future-proofing into the energy design of dwellings from the outset rather than adding it as an extra later on; namely:

- anticipating future (increasingly stringent) policy requirements (environmental legislation, building regulations and standards) related to building energy performance;
- the need to adapt to a changing climate and, in particular, the risk of overheating due to predicted higher temperatures; and
- the unique features of the domestic stock, which result in long lifecycles.

The research has found that although the case-studies follow a similar approach to the coverage of SD issues, in the UK case, future-proofing is translated into design approaches that accommodate risks and uncertainties; whereas in Sweden it is the adoption of lifecycle thinking. Despite the fact that future-proofing is a desirable design ambition, the cross-case analysis revealed that future-proofing is considered to be still a challenging task even for 'best-practice' schemes.

The proposed conceptual framework represents a foundation for further research through the development of practical guidelines and initiatives to encourage future-proofing within industry practices. Many aspects are yet to be comprehensively defined. Time, costs and regulations are still the dominant considerations in the energy design of housing developments; however, long lifecycles, risks and uncertainties are associated with energy consumption in buildings. In this study, the focus has been on new housing developments, i.e. residential stock at a community-level. The research findings, however, have implications for both new and refurbished projects, which reach far beyond housing developments to the wider UK policy landscape and construction industry.

Further research should reveal the potential for applying the conceptual framework in the decision-support context for the energy design of other types, such as low-energy commercial, public, educational, or industrial buildings and large infrastructure projects. In addition, the research, though carried out with a holistic view of sustainability, has concentrated on only one aspect, i.e. energy. A systems approach to sustainability in the built environment requires consideration of, *inter alia*, energy, water, sewage or wastewater, and waste, as there is the potential for future-proofing to be applied more widely to cover these other aspects. Any further research conducted would also benefit greatly from the analysis of additional 'best-practice' housing developments. A spectrum of cases could be selected from different regions in the UK or Sweden or other countries which are also considered to be leaders in sustainability, energy efficiency, and low-carbon development, such as Germany, Denmark, the Netherlands, the US, Canada, and Hong Kong. This wider cross-case comparison would enhance learning and help to identify additional future-proofed design approaches to further refine the conceptual framework.

Finally, specific opportunities pertaining to future research in the field of future-proofing include:

- the business case for future-proofing by quantifying the cost of future upgrading or demolition, thus showing that future-proofed buildings are less risky and have higher value (easier to sell and achieving higher prices);
- the development of databases, performance indicators and assessment methods to account for future-proofing; and
- new generation of skills and competencies so that building professionals are able to support the design and delivery of future-proofed solutions. These include: climate change adaptation strategies; undertaking PCAs and POEs for quantifying the 'performance gap', conducting LCA at building scale; and employing dynamic and stochastic models in design decision-making.

Appendix 1: Interview Respondents During Fieldwork

Int. no.	Affiliation	Organisation	Date	Location
1	Project Director	North West Cambridge Project	16/02/2011	Cambridge
2, 3	Senior Sustainability Officer	Design and Construction Cambridge City Council	18/02/2011 23/03/2012	
4	Associate Director	Sustainability, Building and Engineering AECOM	03/03/2011	
5, 6	Associate Director	Sustainability, Building and Engineering AECOM	03/03/2011 06/03/2012	Cambridge
7	Team Leader Sustainable Communities	South Cambridgeshire District Council	23/03/2012	
8	Professor of Eco-Technology	Department of Building and Energy Technology Linnaeus University	10/05/2011	Linköping
9	Director	VKAB (municipal housing company)	16/05/2011	Växjö
10	SESAC Project Coordinator	Municipality of Växjö		
11	Managing Director	EASS		
12	Climate Strategist	Municipality of Växjö	16/05/2011	Växjö
13	Strategic Planning Officer			

(continued)

(continued)

Int. no.	Affiliation	Organisation	Date	Location
14	Development Manager			
15	Group Manager and Environmental Strategist		17/05/2011	
16	Senior Lecturer	Department of Civil Engineering Linnaeus University		
17	Business Area Manager	VEAB (municipal energy company)	18/05/2011	
18	Marketing Director			
19	Architect	Arkitektbolaget		
20	SESAC Project Leader	Municipality of Växjö		
21	Chief Executive Officer	Sustainable Småland	19/05/2011	
22	Project Manager	Midroc Property Development AB		
23	Technical Visit Coordinator	Municipality of Växjö		

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On the Move—or Moving On? Reimagining the Future of Travel

Malek Al-Chalabi

Abstract With rising energy demand and an increase in global population, facilitating a sustainable energy transition in cities is of interest to many. The focus of this chapter is to illustrate and analyse the role that transport can play in facilitating and enabling change. In order to do so, this chapter is compromised of the following four parts: (1) an illustrative description of the transport challenge, which includes describing the impacts that transport has on society and the environment, (2) the drivers and the thinking behind transport's high-carbon use, (3) an alternative framing to the transport debate will be introduced alongside 'next' practices for the future, and (4) the points made in the previous three parts will be further illustrated through the use of relevant international case studies. Case studies include Bogota, Colombia, Dubai, United Arab Emirates, and Montreal, Canada, from a supply-side and demand-side perspective. A discussion with implications for the future is provided alongside a conclusion.

1 Introduction

A transition is upon us. Whether or not it will be sustainable remains to be seen. It is, without question, a difficult task, and it is particularly challenging in transport. The objective of this chapter is to illustrate why.

As highlighted in previous chapters, achieving sustainability in cities is a challenge. The human impacts are known—urban environments are where over 50% of the human population resides, where 75% of global energy is used, and where approximately 80% of all carbon dioxide is emitted. The world population is expected to increase (Al-Chalabi 2015)—it is anticipated that the population will reach 9 billion in 2050 (United Nations 2015). This must be managed in order to achieve global sustainability.

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The role that transport has to play in the challenge mentioned above will be addressed in this chapter. This will be done in four parts. First, an illustrative description of the challenge will be given, which includes describing the impacts that transport has on society and the environment. Second, the drivers and the thinking behind transport's high-carbon use will be provided. This provides a segway (no pun intended) to the third part of the chapter, where an alternative framing to the transport debate will be given, and technological and behavioural options will be introduced, alongside 'next' practices. Finally, an international outlook that showcases relevant case studies that illustrate the points made in the previous three parts will be provided.

It is important to highlight what this chapter does/does not cover. Part I describes the challenge—this is primarily based on work from the International Energy Agency (IEA) (2014) and Intergovernmental Panel on Climate Change (IPCC) (Sims et al. 2014). The framing and scope of Parts II and III are developed from the research of Givoni and Banister (2013a).[1] Part IV is based on relevant authorities pertaining to the respective case study. Limitations, where relevant, of these resources are acknowledged in the chapter—supplementary material/evidence/sources will be provided where appropriate.

2 Part I: The Challenge: Impact of Transport on Society and the Environment

The transport sector has experienced growth. The transport sector accounts for 23–24% of global CO_2 emissions (Sims et al. 2014), and oil is the fuel that primarily drives this sector. Approximately 64% of global oil consumption is attributed to transport (IEA 2014). A depiction of the growth is illustrated in Fig. 1.

As the figure illustrates, demand for oil from the transport sector has grown—45% of world oil consumption was attributed to transport in 1973, in comparison with 64% in 2012 (IEA 2014). This is illustrated further in Fig. 2.

What Fig. 2 also illustrates is that this growth is primarily attributed to road vehicles from 1970 to 2010. What Fig. 2 also demonstrates, less obviously, is that greenhouse gas emissions have more than doubled since 1970 in the transport sector. What the figure does not show is that in comparison with other sectors, the transport sector 'increased at a faster rate than any other energy end-use sector to reach 7.0 Gt CO_2eq in 2010' (Sims et al. 2014, p. 605). Given this, the focus of this chapter will be on urban/road transport—aviation and maritime are not.

[1]The rationale behind basing parts 2 and 3 on this resource is because it provides a clear and succinct overview of the scope outlined. The alternative option was to base these parts on various resources (with different underlying assumptions, drivers, and scopes)—which can be quite burdensome/unhelpful to the reader. Therefore, the limitations of this are acknowledged, and relevant resources are cited where appropriate to overcome any gaps.

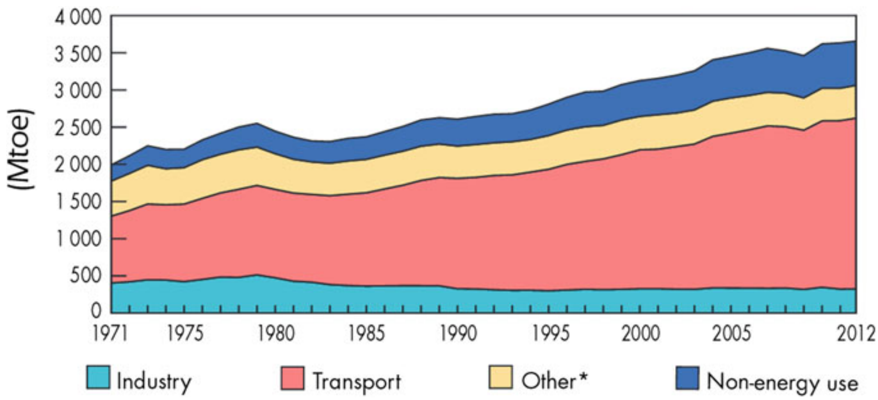

Fig. 1 Consumption of oil by sector (1971–2012). *Source* IEA (2014), p. 33

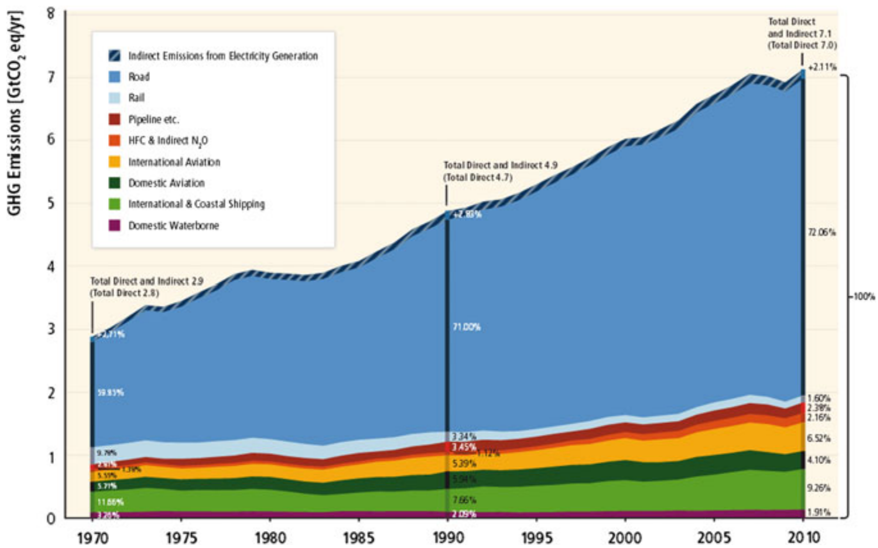

Fig. 2 Growth in the transport sector (1970–2010). *Source* Simms et al. (2014), p. 606

This carries implications. First, it is important to realize that this growing demand is expected to continue, primarily in non-OECD countries (IEA 2009) due to growing incomes and development in infrastructure (Sims et al. 2014). The IEA predicts that the number of light duty vehicles on the road will grow to around 2 billion in 2050 (IEA 2015). Secondly, this growth is interlinked across other sectors. The IPCC recognizes that the 'continuing growth in passenger and freight activity could outweigh all mitigation measures unless transport emissions can be strongly decoupled from GDP growth' (Sims et al. 2014, p. 603). This leads to the third point, which is that the continued reliance on oil has a series of consequences

(Givoni and Banister 2013b), including but not limited to: carbon emissions, pollution, volatile oil prices (Ebrahim et al. 2014), and health effects (Ristovski et al. 2012; Kim et al. 2015) (Givoni and Banister 2013b).

In order to address these, it is important to evaluate the drivers and the rationale behind transport's high-carbon use, which according to Banister et al. are travel time and infrastructure (2013). This will be addressed in the next section.

3 Part II: Understanding Transport's High-Carbon Derivation

Travel time can be defined as the amount of time that it takes to travel from A to B (Carrion and Levinson 2012). Historically, this has been understood as a utility that is negative or non-useful (Lyons and Urry 2005). The reason behind this is because travel time is generally conceptualized as being a form of 'opportunity cost'—any time spent 'travelling' could be spent more beneficially on other things/not travelling[2] (Banister et al. 2013).

Given that travel time is generally viewed in this manner, it has led to the underlying view that individuals would like to spend the least amount of time 'travelling' and/or take the quickest route possible (Banister et al. 2013; Campbell 1992; Banister 2008). From a transport perspective, this leads to the thinking that any improvements towards a low-carbon future should be as quick as current conditions or quicker (Banister et al. 2013; Nakamura and Hayashi 2013). The driving assumption is that alternatives that do not meet these criteria will not result in change for future adoption because it does not provide an improvement from the status quo (Banister et al. 2013).

This leads to the second related factor—the focus on infrastructure. If travel time is one of the driving forces behind transport thinking and if the agenda is to focus on quicker journeys, then the 'solution' will be on providing and developing the relevant infrastructure. This line of thinking, known as the 'logic of provision,' inherently takes for granted that change shall go through the *provision* of the transport infrastructure—meaning that shifting to low-carbon intensive modes of transport would be through providing the relevant types of infrastructure[3] (Schwanen et al. 2011; Banister et al. 2013). Examples include debates on bus rapid transport, cycling infrastructure, walking infrastructure, and high-speed trains (Banister et al. 2013; Bridge et al. 2013).

According to Banister et al., these two ideas (travel time and focus on infrastructure) are embedded within transport planning history—and facilitated the

[2]For more information on the value of travel time, the reader is referred to the work of Ettema and Verschuren (2007).

[3]The reader is referred to the work of Hickman et al. for more information on the challenges associated with the logic of provision 'thinking' (2012) and the work of Schwanen et al. (2011).

growth of car use[4] (2013). This view, however, is inherently elementary and incomplete (Banister et al. 2013). The next part of the chapter will (1) illustrate why this perspective is incomplete and provide an alternative framing to the transport debate, (2) suggest technological and behavioural options for change, and (3) highlight potential ‘next’ practices.

4 Part III: Multidimensional Proposal

4.1 An Alternative Framing to the Transport Debate

The transport framing must move away from speed and infrastructure and adopt a more complete perspective (Banister et al. 2013). While travel time and low-carbon transport are an important part of the story, focusing on them completely would be an incomplete scope. Other areas that require consideration, but are not yet fully integrated into the debate are highlighted in Table 1.

Table 1 is not exhaustive—but demonstrates areas where more attention could be focused in the transport debate. As the table highlights, the focus on access and accessibility should be broadened to encompass the relevant elements (Markovich 2013; Banister et al. 2013). Recognizing the cultures, values, and meanings of and around travel mobility has a role to play as they are embedded/engrained in various elements of society (Aldred and Jungnickel 2014; Vannini 2010; Banister et al. 2013). Perceived safety of certain travel modes can also enable or disable travel mode change (Taylor and Ampt 2003). Additionally, concentrating on the quality of the travel has tremendous potential (Martens 2007; Banister et al. 2013). As Banister et al. highlight:

> “With regard to the quality of travel time, it is useful to think in terms of opportunity. Given that one has to travel on a certain mode of transport, what is made possible in that interval? How can the experience of that interval be made as positive as possible? The idea here is that transport policy should make it possible for travellers to use and experience travel in ways that align with their needs and preferences”
>
> (Banister et al. 2013, p. 274).

Expanding and incorporating multidimensional aspects that include more than speed and transport into the transport debate can be done in many ways, including the use of various technological and behavioural options. Technological and behavioural options include, but are not limited to, integrated transport, walking and cycling, use of pricing, land use planning, and various other measures (Banister et al. 2013).

This broader focus—incorporating accessibility, culture, safety, and quality—can give low-carbon transport modes advantages not found in their carbon-based

[4]The reader is referred to the work of Geels (2005), Owens (1995), and Kenworthy (2006).

Table 1 Factors to incorporate into the transport debate

Factor	Rationale	Sources
Access and accessibility	– Including, but not limited to, temporal, financial, physical, and organizational (Markovich 2013) – Door-to-door travel experience	Morris et al. (1979), Lucas (2006), Fransen et al. (2015)
Culture	– Recognizing the cultures of and around mobility	Aldred and Jungnickel (2014), Vannini (2010)
Safety	– Can be an (dis)enabler for travel mode change	Weinert et al. (2007), Kenyons and Lyons (2003)
Quantity versus quality	– Moving away from quantity of travel and concentrating on the quality of travel – Provide opportunities to take up different/heterogeneous activities in travelling environments	Martens (2007)

Source Developed from Banister et al. (2013)

cousins[5] (Banister et al. 2013). In addition, there are also a set of 'next' practices that could be given more attention. This is the focus of the next section.

4.2 'Next' Practices

There are a set of elements (based on the work of Banister et al. 2013) that are described here as 'next' practices that can be explored in order to achieve the goals set out (Banister et al. 2013). These are not comprehensive—but rather a selection of choices that may be most relevant to the audience of this chapter. These are described in detail first and subsequently summarized in Table 2.

First, the debate needs to highlight the advantages of low-carbon mobility and less on the difficulties and perils of high-carbon mobility (Giddens 2009; Banister et al. 2013). This will be, as highlighted earlier, able to showcase advantages of low-carbon mobility (Banister et al. 2013). The work of Moriarty and Honnery (2008) is one such example—where the benefits of active and public transport are illustrated.

Secondly, there lie various opportunities where these advantages can be developed in social/digital media. This includes providing up-to-date information on various travel services through the use of social media or developing mechanisms to use travel time more innovatively or efficiently (Banister et al. 2013). While not used in real time, Scott and Orlikowski demonstrate the value that this has shown in the travel sector (2012).

Third, the focus of the transport system should focus less on station to station (airport to airport is another example) and more on door-to-door travel while

[5]The implementation and use of these tools are best illustrated through the use of examples and are the focus of this chapter in the final part of this paper (Part IV).

Table 2 Current practices and next practices

Current practice	Next practice	Tools	Further reading
– Conflicting messages from public authorities	– Systematic messaging from public authorities	– Policy packages	Sims et al. (2014), Tuominen et al. (2014), Guzman et al. (2015)
– Difficulties and perils of high-carbon mobility	– Advantages of low-carbon mobility	– Detailed alternative pathways – Showcasing advantages	Giddens (2009), Pathak and Shukla (2015), Rabl and Nazelle (2012)
– Use of social/digital media in transport space	– Further integration of social/digital media – Innovative use of travel time	– Up-to-date information – Customized to audience based on heterogeneous needs – App-based transport tools	Lyons and Urry (2005), Xiang et al. (2015)
– Focus on single mode – Station to station – Airport to airport	– Focus on multimodal travel – Door-to-door focus	– Evaluate tools available in freight transport	Wang and Zhou (2015)

Based on: Banister et al. (2013), Inspired from Banister (2008) (which was developed from Marshall 2001).

simultaneously focusing less on individual modes and focusing more on a combination of modes (Banister et al. 2013). The work of Givoni and Banister illustrates the value of door-to-door travel time in public transportation (2012).

Fourth, there is opportunity for messages from public authorities to be more systematic (Banister et al. 2013). These ‘next’ practices are noted in Table 2.

In the next section, case studies that have adopted some of these features will be illustrated next. Our journey will start in Bogota, Colombia, make a stop in Dubai, United Arab Emirates, and end in Montreal, Canada. These three cases have been chosen because of the changes that have taken place in accessibility, culture, safety, and quality (see Table 1) from a supply-side and a demand-side perspective.

5 Part IV: International Outlook

5.1 Bogota, Colombia

Bogota’s transport infrastructure has had its series of challenges. Despacio illustrates the state of public transportation before 1998—this includes potholes, lack of proper cycling lanes, challenges associated with using buses (poor signage, unsafe), and the power of the car (2008). Additionally, the political and economic elite were the ones that owned cars (Peñalosa 2011).

In 1998, a new government had come in and had a vision that was quite unique.[6] Instead of seeing separate challenges, many synergies were identified (Peñalosa 2011). Instead of prolonging the status quo, the mayor (Enrique Penalosa) and the new government put in place a variety of plans that started to build the foundation of a city that would capture the fascination of many from a transport, accessibility, equality, and cultural perspective.

Instead of promoting car use, the administration limited car use (Cevero 2005). This includes but is not limited to: (1) bollards were put in place to stop cars parking on cycle paths/sidewalks, (2) a car-free Thursday every February (on the first Thursday) was developed, and (3) during holidays and Sundays, pedestrians, skaters, and cyclists are able to (for 7 hours) use the main roads, which were car-free (Cevero 2005). These initiatives not only changed the social and cultural norms around the use of the car—but also provided a stimulus for an efficient transport system.

A bus rapid transit system was developed with inspiration from Brasil (Cevero 2005). Cycling lanes were built.[7] Within a year, there was 'a 32% reduction in average travel times by bus, a 93% drop in bus accidents, a 98% passenger approval rating, and higher property values along the busway corridor (from not only enhanced access but also lower crime rates and noise levels)' (Cevero 2005, p. 26). The 250-km network of cycle paths alongside streets led to an increase in cycling daily trips from 0.9 to 4% (Cevero 2005).

New public spaces were built or improved upon (Cevero et al. 2009). The money that was not spent on traditional road development and infrastructure investment was instead used to fund these programmes and build nurseries, schools, libraries, and community centres (Peñalosa 2011). An insight to the vision that was adopted can be illustrated in the quote as follows:

> "For a child from a very poor neighbourhood whose home may have a dirt floor or at best a rough cement one, free access to a beautiful, almost luxurious library, where admission is not dependent on wealth, educational attainment or social status, but simply on their rights as a citizen, citizenship acquires real meaning. A library in a poor neighbourhood symbolises society's confidence in the intelligence and capacity of the young citizens around it; just as a free food programme, despite its eventual necessity, expresses the opposite" (Peñalosa 2011, p. 95).

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[6]As Penalosa highlights: 'A majority of upper- and upper-middle-class citizens in developing cities pull out of their garages in the morning and may go for weeks without walking a block on a city street. They consider the absolute priority for government to be the construction of more and bigger roads. Which is why even in some very poor African cities where most of the population does not even have access to clean water, it is still possible to find highways. Car infrastructure absorbs most of the budget. There is a conflict for funds between the needs of the automobile and the needs of the poor for such imperatives as schools, parks, housing or public transport. And there is a conflict for space between cars, pedestrians, cyclists and buses' (2011, pp. 92–93).

[7]'Three quarters (75%) of daily trips in the city are less than ten kilometers' (Cevero 2005, p. 27).

There are many reasons for Bogota's success. As the quote has highlighted, Penalosa had a clear vision of accessibility for people. Peñalosa (2011) has noted that 'the fundamental criterion guiding our work was the construction of equality' (p. 91) and 'if it works well, a city centre integrates people from all parts of the city and all income brackets' (p. 92). This is illustrated in his emphasis on cycling.

> "As important as the safety a protected cycle path affords cyclists is its symbolic power: it enhances the cyclist's social status, since a citizen on a $30 bicycle is as important as one in a $30,000 car"
>
> (Peñalosa 2011, p. 95).

With the focus on accessibility and a changing cultural emphasis from the car to the person, various features improved as outlined earlier. This emphasis changed the culture that was associated with the car, people, and the city, which resulted in various benefits[8] (Cevero et al. 2009).

5.2 *Dubai, United Arab Emirates*

The United Arab Emirates is a small country located on the Arabian Gulf. It has seven emirates, including Abu Dhabi and Dubai. The country possesses one of the top ten proven reserves of oil and gas (EIA 2015)—most of which are found in Abu Dhabi.

Since its independence in 1971, the United Arab Emirates has experienced population growth and urbanization. The population in 1971 was approximately 275,000—this has grown to 1.9 million in 1991 and 8.7 million in 2011 (United Nations Department of Economic and Social Affairs 2015). The population is expected to grow at 2.3% (on average) annually from 2010–2020 (Everington 2013) with an urban population of 7.9 million in 2020. 84% of the population lived in cities in 2010, and it is estimated to increase to 86.7% in 2020 (Everington 2013). This has implications for transport.

There were approximately 6.2 people per car in Dubai a little over 2 decades ago (Al-Mehairi 1995). The latest figures indicate there are now two people per car (Shahbandari 2015)—a significant change in approximately 20 years. Furthermore, from 2006–2014, vehicles in Dubai have increased from 740,000 to 1.4 million in that time span (it has doubled) (Shahbandari 2015). This has, understandably, led to congestion and traffic (Shahbandari 2015).

As a city that is a global tourist, economic, and transportation hub, there have been a variety of innovative, high-tech, 'hard' and 'soft' measures that have been put in place in Dubai that aim to decrease traffic and promote alternative mode choices. Due to the rapid amount of urbanization, the innovative technological solutions that have been used, and the success at implementing the tools and

[8]More information on Penalosa's vision can be found here (Penalosa 2015).

altering the transportation sector, Dubai provides a unique case study to evaluate how this has been done. A sample of those measures will be discussed here.

One of those mechanisms is Salik, the system used for collecting tolls on the roads in Dubai (Road and Transport Authority 2015). Salik uses radio frequency identification technology, which helps recognize a car as it travels on the road and through the various tolling points (Road and Transport Authority 2015). However, one innovative feature (unlike many other toll collection systems) is that it does *not* have any toll booths for manual payment (where cash or card is used to pay for the journey) (Road and Transport Authority 2015). This facilitates the flow of traffic without any interruption to the journey and also generates income (Road and Transport Authority 2015).

Secondly, Dubai has made serious advances in their public transport system. According to the Executive Director of the Road and Transport Authority: 'the share of public transport in the mobility of people has leapfrogged from 6% in 2006 to 14% in 2014 and the Road and Transport Authority is endeavoring to push it to as much as 20% by 2020' (Emirates 24/7 News 2015). There are two public transport modes that are worth elaborating on further—the metro and the bus system (Emirates 24/7 News 2015).

Dubai has the world's 'longest driverless metro' system (Khaleej Times 2012) (Fig. 3). It is 75 km long and is made up of the red and green line (Khaleej Times 2012). It opened in 2009 and has seen growing daily passenger use (Shahbandari 2014). Daily passenger use in 2009 was 60,000 passengers per day, and this grew in 2014 to 500,000 (Shahbandari 2014).

Fig. 3 Inside the Dubai Metro. The Dubai Metro is one of the most technologically advanced, which has helped contributed towards a mode shift in the city. The above ground platforms are a noticeable sight around the city. Used under licence (CC0 1.0)

There are various reasons of success. One is that it has a punctuality rate of 99.8% (Shahbandari 2014). Additionally, it is one of the safest metro systems in the world—crime and vandalism are approximately at zero—which is a unique feature compared to other metros (Shahbandari 2014). Due to the high use of the metro and user requests, the weekend service schedule is now open for longer, starting the service at 10AM on Friday—it was previously 1PM (Gulf News 2015).

Public buses have seen similar increase in ridership. Average daily ridership in Dubai in 2012 was 299,000, 321,000 in 2013, and 371,000 in 2014 (Emirates 24/7 News 2015). Given the increased use of buses, this leads to the third innovative measure that has taken place, which are 'sleepiness detectors.' The aim of the detector is to evaluate the bus driver and identify any indicators of tiredness/fatigue/exhaustion/etc. This is done by installing an instrument on the bus that helps evaluate those signs, and this has already been installed on fifty buses (Emirates 24/7 News 2015).

The focus on safety has led to the fourth and final innovative measure. One of the road safety issues that is predominate in the UAE is tailgating. In addition to launching awareness campaigns, high-tech radars have been installed that will be able to not only measure the distance between two cars, but will also fine any driver that is in violation of the 5-meter rule (Twaha 2015).

These examples (Salik toll system, Dubai metro, public buses, sleepiness detectors, and high-tech radars) contribute towards developing a multifaceted transport system that also supports the aims and objectives of the 'Smart Dubai' programme. The objective is to make Dubai the 'smartest' city on the planet, and this programme was envisioned and developed by the Vice President, Sheikh Mohammed Bin Rashid Al Maktoum (Smart Dubai 2016a, b). It is built on six dimensions, which are smart living, mobility, economy, environment, people, and governance[9] (Smart Dubai 2016c).

Mobility examples include app-based carsharing programmes for Dubai (Smart Dubai 2016d) and an innovative waste notification system, where a notification is sent to a server when the waste bin can no longer accommodate any more waste and requires disposal. As the collection will then take place when the waste bin is completely occupied (and not half occupied), this saves fuel, streamlines schedules and trips across the city, and decreases carbon emissions (Smart Dubai 2016e).

While these initiatives are currently helping develop Dubai as a smart city, there are ambitious plans for the future. Recently, there has been an announcement that by 2030, smart/driverless transport will compromise 25% of the transportation system (Achkhanian 2016). This vision will aim to deliver 22 billion UAE Dirhams (almost 6 billion USD) of savings a year by removing environmental impacts, decreasing costs associated with transport, improving safety, and various other benefits (Achkhanian 2016).

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[9]'Smart Dubai' is a multifaceted programme based on fostering partnerships with and across relevant stakeholders, including government, institutions, and the private sector (Smart Dubai 2016a, b).

These examples give a glimpse of how a transportation system that focuses on more than just speed and infrastructure can help develop a city in the twenty-first century. The emphasis on innovative mode shift and safety are tools that can help improve the journey experience, encourage travel mode changes, and has helped Dubai transform and continue to develop its transportation system to work towards its twenty-first century objectives with population growth and urbanization.

5.3 Montreal, Canada

In the city of Montreal (Fig. 4), the largest source of greenhouse gas emissions is in transport (39%) (City of Montreal 2013). Public bike-sharing programmes are popular in Europe (Fuller et al. 2011; Shaheen et al. 2010), and Montreal[10] is recognized as the 'North American leader' in cycling (Larsen and El-Geneidy 2011) as it has been referenced as having the largest bike-sharing programme (in North America) (Pucher et al. 2011; Fuller et al. 2011; Shaheen et al. 2010).

BIXI which is a combination of the word 'bicycle' and 'taxi' (Bixi 2016) was launched in 2009 with 300 stations including 300 bicycles (Faghih-Imani et al. 2014). It has since grown—there are currently 460 stations including 5200 bicycles across the city (Bixi 2016).

What factors played a role in the success and uptake of Montreal's bike-sharing programme? There are a few, which are related to Tables 1 and 2 presented earlier. According to Bachand-Marleau et al., first was the location/accessibility to the docking station—there was a higher likelihood to use BIXI if it was near the point of origin for the user (2012). Secondly, the safety of the bicycle sharing system was likely to encourage bicycle use. Interestingly enough, those who had bikes stolen or those who were worried about bicycle safety were more likely to use BIXI as they viewed this as a safer alternative to ownership (Bachand-Marleau et al. 2012). Thirdly, the use of BIXI was associated with being 'trendy' and 'environmentally friendly'—which helped boost its popularity and further develop the culture around cycling (Bachand-Marleau et al. 2012, pp. 70, 71).

Studies have shown that the use of BIXI did contribute towards a mode shift (walking, cycling, etc.) in Montreal (Fuller et al. 2013; Fishman et al. 2013). The reasons for this shift are supported by other sources of the literature, as noted by Fishman et al. (2013). Location and accessibility near the home were found to be an important factor (Fuller et al. 2011). As one study found in London, 'shorter distance to the nearest docking station was associated with making progressively more trips per month, as was having more docking stations within 250 m of the

[10]For an overview of Montreal and cycling infrastructure, the reader is referred to these sources: Pucher et al. (2011), Larsen and El-Geneidy (2011).

Fig. 4 Cycling in Montreal. Montreal is recognized as a cycling frontrunner in North America in part because of the cycling sharing programs. Used under licence (CC0 1.0)

residential address'[11] (Ogilvie and Goodman 2012, p. 43). Secondly, other studies have confirmed that those who perceive public cycling sharing programmes as being safer (or associated with having fewer safety risks) are more likely to use public bicycles (as was found in Spain) (Molina-García et al. 2013). Finally, Aldred and Jungnickel have illustrated that culture does have a role to play in shifting transportation practices (2014) as was the case in Montreal.

This is not to state that Bixi has not had its share of problems. The company declared bankruptcy in 2014 (Mátrai and Tóth 2016; CBC News 2014). It was purchased by PBSC Urban Solutions (CBC News 2016) and through cost cutting and reorganizing obtained a surplus in 2015 (CBC News 2015a).

6 Discussion

The case studies presented earlier have shown how a focus outside of speed and infrastructure can help develop transportation systems in the twenty-first century. Colombia's focus on accessibility and equality, Dubai's focus on multimodal

[11]Put another way, as Fishman et al. note, those 'who lived close to docking stations used the system more than members living further away' (2015, p. 136).

transport and safety, and Montreal's focus on accessibility and culture (among other factors) demonstrate how broadening the transportation focus can link up various parts of the city together. Cities that are able connect transport with other aspects of the city/life are best suited to help facilitate a transition towards low-carbon transport.

This is supported by the IPCC. The IPCC recognizes that 'mutually supportive policies' are required not only to decarbonize transport, but also for the 'co-benefits' to be realized (Sims et al. 2014, p. 604) and policy packages[12] are an example of how this can take place. This includes working with/across in transport and non-transport arenas (including but not limited to political, social, economic spectrums), as well as health, mobility, security, and safety (Sims et al. 2014, p. 604). This will be implemented differently in different regions due to cost and policy contexts (Sims et al. 2014).

Major opportunities still exist around low-carbon options, particularly in the developing world, as this is where most of the future urban growth will take place as highlighted earlier (Sims et al. 2014). As demonstrated in the case studies and highlighted in the IPCC report, 'transport can be an agent of sustained urban development that prioritizes goals for equity and emphasizes accessibility, traffic safety, and time-savings for the poor while reducing emissions, with minimal detriment to the environment and human health' (Sims et al. 2014, p. 604).

7 Conclusion

This chapter has described the impacts that transport has on society and the environment and the framing around the current 'transport' debate. Subsequently, an alternative framing to the transport debate was provided, where a broader scope was rationalized, technological and behavioural options were introduced, and 'next' practices were illustrated. Examples from Bogota, Dubai, and Montreal were given that showcased how these can be implemented.

The role that transport has to play in achieving sustainability has been the scope of this chapter. We have, as a society, been 'on the move' for a some time. Is it time to move on?

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[12]The challenge lies not only in the options that are available to use—but rather the way in which they are used (Banister et al. 2013). In order to address this challenge, relevant policies can be executed in an integrated fashion, such as a package (May and Roberts 1995; Givoni et al. 2013; Tønnesen 2015). Tønnesen defines a policy package as a 'structure [that is] used to combine different policy measures and address multiple objectives' (2015, p. 89).

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Water: An Essential Resource and a Critical Hazard

Richard A. Fenner

Abstract Urban water managers must provide adequate water supplies to meet growing demands for a range of water uses (including essential drinking water) whilst mitigating the negative effects of water in the wrong place, which occur at times of flood arising from extreme weather events. Many urban areas around the world are becoming increasingly water stressed, and cities such as London are developing solutions to address expected future shortages. As well as physical challenges, this chapter discusses problems of effective water governance and how decision-making across multiple scales is needed for effective water resource management—combining both technical and non-technical innovations. Current practice is characterised by many unsustainable activities, with many cities locked into a legacy of ageing infrastructure systems developed in the past. Key characteristics of more sustainable water systems are presented which represent the paradigm shift that is required in how urban water is dealt with. Features of urban water resilience are examined which can be achieved through an iterative adaptive management approach to water management. Examples are given that relate to the use of green infrastructure to achieve water-sensitive urban design, which mitigates the adverse effects of storm water at locations where the rain falls, whilst simultaneously providing a range of other benefits. Multifunctional infrastructure is described where innovative engineering can deliver more than one service from a single purpose project. The chapter concludes by stressing the need to see the urban water system as part of the wider urban fabric which positively adds to the layout, security and liveability of future cities.

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1 The Challenge

Forty per cent of the world's population live in regular water stressed areas (taken by UNEP to be less than 1700 cubic metres per person per year). As the uncertainties and extreme conditions expected under climate change unfold, and as the world's population continues to increase this century, the challenges surrounding water will increase. These include meeting basic needs through the provision of engineered services to provide safe drinking water and basic sanitation (Target 6.1 of the Sustainable Development Goals (UNDP 2015)) whilst protecting life and property from the extremes of drought and flood. This illustrates the essential dichotomy about water. It is both an essential resource—vital for life—and yet can form a catastrophic hazard through flood inundation and disease transmission. Evidence of how closely water resources and water hazards are interrelated can be found during the UK floods of 2007 with dramatic effects on electricity power substations, water and sewage treatment works, and the road and rail network. As a consequence of the events, there was a strong possibility of the loss of power to 750,000 people leading to discussions about evacuation. Drinking water was lost to 350,000 people for up to 17 days. Tens of thousands of people lost power, some for more than 2 days, and tens of thousands of people were stranded as the road and rail networks ground to a halt (The Pitt Review 2008). These events highlight the dependencies that exist between critical infrastructure.

But water is needed for more reasons than just to provide these basic services. It is used extensively in power generation and in agriculture, and so our energy and food systems are dependant on water too. Much thought has been given recently to this water–energy–food nexus with a recognition that these critical resources need to be more effectively managed in an integrated and coupled way (Curmi et al. 2013a), often with difficult tradeoffs between competing water uses having to be made. Part of the balance that needs to be struck is ensuring enough water remains in the natural environment to make sure essential ecosystem services are maintained.

In addressing these issues, complex problems become apparent. In the developing world, much needs to be done to bring water and sanitation to communities who have not hitherto had access to even the most basic services. In the developed world, much of urban water in cities is managed through ageing infrastructure with pipeline and other asset failures commonplace. One water utility (Suez) has estimated that more than 49 billion m^3 of expensively treated water is lost from distribution systems every year due to ageing pipes.

Ban Ki Moon (2011) captures the essence of the problem as follows: "We must connect the dots between climate change, water scarcity, energy shortages, global health, food security and women's empowerment. Solutions to one problem must be solutions for all".

1.1 A Critical Resource

In developing countries, as much as 80% of illnesses are linked to poor water and sanitation conditions (Kofi Annan UN Statement 2003) and half of the world's hospital beds are filled with people suffering from a water-related disease (UNDP 2006). One out of every 5 deaths of people under the age of 5 worldwide is due to a water-related disease (WHO 2009).

Currently, 1 billion people live in water scarce regions, and by 2025, the World Bank estimates as many as 3.5 billion people could face water shortages. When annual water supplies drop below 1000 m^3 per person, the population faces water scarcity, and below 500 cubic metres "absolute scarcity". The fifth assessment report of the Intergovernmental Panel on Climate Change (2015) forecast that for each degree of warming around 7% of the global population will face almost 20% decrease in renewable water resources. This is against a background of already increasing pressure. For example, since 1980 the rate of groundwater withdrawals has increased 1% per year with some regions such as California far exceeding replenishment rates (Curmi et al. 2013b). Around 500 million people globally live in places where water consumption is double the amount replenished by rain, making them highly vulnerable as ground water levels continue to fall.

A recent study analysed water supplies in 71 surface water-supplied cities having a population of more than 750,000 in 39 countries (Padowski and Gorelick 2014). Twenty-five of these cities (36%) were already considered vulnerable by being unable to meet demands from human, environmental and agricultural users to a level of 4600 l/person per day (which includes a volume of "virtual water" to produce and process commodities and services). The work also showed that by 2040 this number is likely to grow to thirty two cities (45%), driven by increased agricultural and urban demands. Of these vulnerable cities, the majority are river supplied with very low mean flows. Reservoirs supply the majority of cities facing individual future threats, revealing that constructed storage potentially provides tenuous water security. Padowski and Gorelick suggest that in 2040, 13 vulnerable cities would reduce their vulnerability via reallocating water by reducing environmental flows (i.e. water left in natural watercourse to maintain ecosystems services) and 15 would similarly benefit by transferring water from irrigated agriculture. This would require very difficult tradeoffs to be made. Most alarmingly, this analysis does not account for climate change, which is likely to significantly influence future urban water supply vulnerability.

Sir John Beddington (former UK Chief Scientist) has famously referred to a "perfect storm" which we can expect by 2030 (Beddington 2009). This is driven by the following factors coming together simultaneously with population growth driving 40% more demand for water (Shen et al. 2008), 45% more energy (IEA 2008) and 50% more food according to the UN (FAO 2008). These figures will require much greater reuse of water in the future.

1.2 Water in Cities

Water crises, however, are not restricted to low-income developing countries in hot climates. California has had several episodes of below average precipitation in 1917–1921, 1922–1926, 1928–1937, 1943–1951, 1959–1962, 1976–1977, 1987–1992, 2007–2009 and most recently in 2012–2015. This most recent drought in the last few years has led to emergency regulations requiring the imposition of an immediate 25% reduction in overall potable water use—difficult to enforce when the Pacific Institute estimates 30% of domestic homes do not have water meters. A 60-km water transfer tunnel estimated at costing billions of dollars is proposed to move surface water from northern to southern California, but is being opposed on environmental grounds. Meanwhile, the Carlsbad Desalination plant is providing San Diego with 230 Ml/day of drinking water and has been described as the biggest in the Western Hemisphere (Bliss 2015).

In the UK, Defra (2016) has pointed to a population increase of 10 million by 2050 coinciding with increasing summer temperatures and decreasing rainfall leading to the likelihood of short-duration droughts. This situation too will require new water resources to safeguard public supplies. London expects a population increase of 40% by 2050, rising from 8 to 11 million. This will lead to demand for water exceeding supply by 10% in 2025 and by 21% in 2040. The costs of drought also need to be recognised. A report by the Institution of Civil Engineers Water Panel (Sugarman 2016) has estimated that a drought order invoking a temporary ban cutting off, for example, car washes and fountains would cost London between £4.3 million and £9.5 million a day, or approximately £300 million a month. More serious emergency drought orders would result in restricting other uses of water and would lead to air conditioning being switched off (impacting on computer rooms across the city) and could lead to the closure of London Underground if the pressure and volume of water required for firefighting could not be guaranteed. In these circumstances, the cost would soar to between £236 million and £330 million a day or a vast £7 to £9 billion a month (based on A Non-Essential Use Drought Order for London: Economic Impact Assessment, NERA 2012). Solutions being considered include water transfer from the River Severn to the Thames, industrial scale water reuse by returning filtered water from Beckton Sewage Treatment Works to be mixed with raw water at Coppermills Water treatment plant, and a new reservoir for storing high winter flows in the upper Thames catchment.

Problems with water do not always arise because of physical water shortages. Often water crises are a result of crises of governance, involving more than hydrology, finance and infrastructure issues. They frequently arise because of confusion and conflict over who does what, at what level of government, and how and why public policies are designed and implemented. In cities around the world, there is pressing need for coordination across multiple scales, authorities and policy domains. A report by OECD (2016) reported some key challenges:

- Inequality in access and affordability to services exists even in countries such as Greece, Italy and Portugal;
- 75% of 48 cities from OECD countries identify water pollution as a challenge, with further investment in wastewater treatment needed. Part of the population is connected to primary wastewater treatment only or to a sewerage network with no treatment;
- Cities are increasingly exposed to water-related disasters with huge damages and economic losses (e.g. floods in Copenhagen in 2011 caused about EUR 700 million of damage and New York in 2012 in the aftermath of Hurricane Sandy suffered USD 19 billion of economic losses). Nearly 20% of the global population is at risk from floods by 2050, while some cities are already suffering heavy droughts even in water-rich countries like Brazil;
- 90% of the OECD cities surveyed reported ageing or no infrastructure restricting access to water and sanitation, diminishing the capacity to respond to water-related crises exacerbated by climate change, economic stress, demographic growth and other urban trends;
- In two-thirds of cities OECD report that lack of staff and managerial competences are a challenge compounded by unstable or insufficient revenues from local governments.

Water in cities is affected by decisions taken in other sectors and vice versa, in particular with respect to energy, finance, solid waste, transport and land use. The OECD (2016) captures the challenges well: “There is a need to address public investment issues including multi-level co-ordination and capacity challenges; foster cross sectoral approaches to infrastructure; adopt an approach that encompasses multiple purposes, especially water, energy, environmental protection and spatial planning; manage tradeoffs across water users in rural and urban areas and between current and future generations in terms of who pays for what; and reduce investment needs by ensuring stable regulatory frameworks to catalyse finance and enhance efficiency”.

Furthermore, in managing water there needs to be greater cooperation between cities and their surrounding areas, especially where administrative and hydrological boundaries cut across each other. Addressing scale issues is vital. The appropriate scale at which water is managed depends on the function. The local or metropolitan level is most suitable for water supply and sanitation, while water resources are best addressed at the larger sub-catchment scale and flood protection needs a catchment wide strategy. Decision-making across multiple scales therefore needs to be combined for efficient use of water resources, information sharing and cost savings (OECD 2016). Forward looking management practices combining technical (e.g. smart water systems, distributed systems, green infrastructure) and non-technical innovations (e.g. information system, water-sensitive urban design) are required as part of strategies for future organisation of water in cities (OECD 2015a). The OECD Principles of Water Governance (OECD 2015b) suggest that a water resilient city is: “one that can mange water in a sustainable integrated and inclusive way, at an acceptable cost, and in a reasonable timeframe”.

The way cities have evolved and are laid out spatially has a significant influence on their water consumption, infrastructure development and water footprint. Cirilli and Veneri (2014) have shown that sprawl cities put greater pressure on the environment than compact cities due to land use stress, fragmentation of natural habitats and increasing air pollution emissions. While low-density cities are likely to incur greater maintenance costs, they may be better at dealing with stormwater runoff, groundwater recharge and flood management. Conversely, compact cities may need lower levels of infrastructure (such as avoiding the need for long pipelines) and may be cheaper to maintain and operate water supply systems. Problems arise in such high-dense cites in relation to incorporating green infrastructure, and retrofitting such assets as sustainable drainage systems (SuDS), which provide local source control for urban drainage whilst mimicking pre-development hydrology, can be difficult. These systems are discussed in more detail in Sect. 3.1.

2 Achieving Sustainable Urban Water Management

2.1 Unsustainable Practices

Many cities are "locked-in" to infrastructure systems that were developed in the past, in some cases as long ago as the nineteenth century. These have served many city communities well and have been essential in protecting public health in areas of high-density living where otherwise the spread of disease would be a chronic problem. Indeed before the middle of the twentieth century, it was the engineered systems that delivered freshwater and removed the resultant wastewater for safe disposal that had by far the greatest impact on disease reduction in urban populations, with medical science having far less effect (until the discovery and widespread use of antibiotics, etc).

However, such systems also gave rise to many unsustainable practices. These include the irreversible loss of land and habitat through inundation of valleys for reservoirs and water resource schemes. The trend has been towards a centralisation of facilities in high-technology solutions at the end of pipe networks, which incurs high energy (and carbon) costs in pumping and the operation of treatment processes, as well as generating large quantities of sludges which are difficult to dispose of. Moreover, the discharge of nutrients in the form of phosphorous and nitrogen from wastewater treatment plants has led to eutrophication problems in the receiving rivers. At the same time, intermittent spills in wet weather from combined sewer overflows have been a major source of pollution of urban watercourses.

Such watercourses are often highly modified natural streams which may have been replaced by concrete and steel-lined channels and culverts. These are fed by outfalls and flap valves surrounded with concrete, and often have their banks protected with concrete and steel. In cities they can be artificially straightened channels with no meanders, pools or riffles and have high flood embankments, with mechanically excavated channels—with steep, sparsely vegetated banks. Such urban water courses are often cut off from the life of the town, hidden behind fences and walls, buried in pipes, with no public access. Most urban development excludes watercourses, placing them at the back of buildings and gardens. There is an "out-of-sight out-of-mind" mentality which regards watercourses as a safety hazard and an inconvenience and frequently are marred by refuse and litter—including large items such as shopping trolleys (SEPA 2000). Many of London's natural rivers such as the Fleet were lost underground as London developed.

In water treatment the practice has been towards the use of chemical additives for the removal of colloidal solids through coagulation processes and for disinfection, but these have been linked to Alzheimer's disease (aluminium) and the development of carcinogens (chlorine). The rapid and efficient movement of excess stormwater through pipe networks has often given rise to downstream flooding.

Precious potable water, which carries a high embodied carbon, is used in large quantities simply as a transport medium to flush human waste through the sewerage/drainage network and often becomes contaminated with the contents of industrial effluents, which eventually require separation at the treatment plant. Over-abstraction of groundwater for water supply in some areas has led to critically low flows in rivers, while many properties remain at the risk of flooding.

2.2 *Characteristics of a Sustainable Urban Water System*

The key characteristics of a more sustainable water system would be one where:

- Less water is consumed;
- Human waste is treated locally and recycled;
- Stormwater is retained at source;
- Installations and assets are climate resilient;
- The corresponding energy footprint is minimised.

These changes give rise to some important challenges and have been addressed by others. In particular, Novotny and Brown (2007) have considered water in cities of the future and have made suggestions for integrated sustainable water and land use management. These ideas have been followed up by a vision for how water management and the creation of water infrastructure might develop sustainably in the future (Novotny et al. 2010). This envisages an urban water system with the following features:

1. Water should be kept, stored, reused and rainwater infiltrated on-site or locally, with extensive use of rain gardens, and drainage dealt with mostly on the surface;
2. A significant portion of wastewater should be treated and reclaimed locally for use in large buildings and irrigation, and for maintaining minimum ecological low flows to streams and nearby watercourses;
3. Green buildings with water-saving plumbing fixtures should, where possible, incorporate green roofs and allow infiltration within their site boundary;

Table 1 New paradigm for water management

Topic	Current practice	New paradigm
Water use	Single-use water is used only once before treatment and disposal	Greater emphasis is placed on water reuse and reclamation, use water multiple times (e.g. household greywater for irrigation) and reclaim treated water
Water quality (supplied)	Treat all supply-side water to potable standards	Apply "right water for right use"—level of water quality supplied is based on the intended use
Wastewater	After one-pass use, treat the resulting "waste" water and return it to the environment	Cyclical "close the loop"—recognise the value in "wastes"; recover resources (reclaimed water, nutrients, carbon, metal and biosolids) for beneficial uses including potable water off-set, fertilisers and generating power
Stormwater	Convey stormwater off-site as quickly as possible with no regard for maintaining hydrological integrity of ecosystems	Harvesting stormwater for water supply, irrigation, and/or infiltration benefits
Increase system capacity	Add capacity to water and wastewater facilities and collection/distribution systems as water demand increases	Implement cost-effective demand side measures and green infrastructure options before increasing grey infrastructure
Type of water infrastructure	Primarily use **grey** infrastructure—engineered and constructed materials (pipes and treatment facilities and pumps)	Integrate the natural capacities of soil and vegetation to capture, infiltrate and treat water (**green** infrastructure) with grey infrastructure
Centralised infrastructure	Preference for large, centralised treatment and distribution systems that focus on economies of scale at the treatment facility without considering the whole system, which includes collections and distribution systems as well	Favour distributed approach evaluating the spectrum from small decentralised systems (including combinations based on local needs and the triple bottom line)
Complex design	Administrative procedures tend to favour more well known (established) less complex standard infrastructure design and technologies	Since today's problems cannot always be solved with today's standard solutions, new technologies and strategies are encouraged (tested at demonstration scale as appropriate)
Infrastructure integration	Water, stormwater and waste water are typically managed as separate systems (creating management "silos")	Water is water—integrate infrastructure and management of all types of water regionally, as appropriate
Public involvement	Stakeholders are informed when approval of pre-chosen solution sis required	Stakeholders are engaged in the decision-making system from the beginning

(continued)

Table 1 (continued)

Topic	Current practice	New paradigm
Monitoring and maintenance	Water and wastewater facilities use computerised Supervisory Control and Data Acquisition (SCADA) to monitor and control processes	Moves smart systems out to end users to provide real time feedback regarding energy use and water use rates to build understanding, modify behaviour for higher efficiencies and notify for maintenance
Cost–benefit analysis	Use estimates of capital and recurring costs as the primary quantitative factor for cost–benefit analysis	Develop an understanding of the full cost and benefits of infrastructure, including environmental and social externalities

Adapted from Rocky Mountain Institute (Pinkham 1999) and Ainger and Fenner (2016)

4. More generally, soft approaches as part of the overall solution will mimic nature, with an emphasis on best management practices to reduce water pollution;
5. Opportunities should be taken to recover energy from the heat in wastewater and use it locally to avoid carbon emissions, and biogas produced from the organics in both solid waste and wastewater;
6. The use of treated drinking water from distant source should be limited to potable uses only, with long distances for water transfers, and losses in the distribution network (leakage) reduced;
7. Other areas of water use should be met from reused water and local sources;
8. The value of neighbourhoods will be enhanced by "daylighting" or naturalising water bodies, with green corridors connecting biodiverse areas in urban centres;
9. The use of flood plain "eco-zones" (i.e. areas with similar geography, vegetation and animal life) will increase the resilience of watersheds to handle extreme flows and provide water during times of shortage, in addition to providing storage and enhanced infiltration capacity.

This requires a paradigm shift in how urban water is managed. Ainger and Fenner (2016) have described ways in which current water practice must change to achieve this, with how essential activities and services must adapt summarised in Table 1. It is important to explore practical ways in which the gaps between current and future practice can be bridged. Table 2 suggests a series of steps professionals in the water sector can take at each of the stages of managing the urban water cycle.

2.3 *Resilience and Innovation in Managing Urban Water*

Several themes recur in Table 2, especially in relation to concepts of *resilience* and *innovation*. Resilience is a frequently cited term which often refers to the ability of a system to return to an equilibrium state after it has been perturbed or subjected to a

Table 2 How professionals can make changes to urban water management

Aspect of the urban water cycle	What water professionals can do
Water resources	• Operate water supply infrastructure with demand-side measures to ensure more efficient use of water • Integrate water resource management with wide catchment management methods • Seek resilient systems by adopting a mix of infrastructure types by operating in combination • Develop semi-closed loop systems to enable greater water reuse before it is returned to the environment
Managing water in rural systems	• When faced with any water quality or quantity (flooding or drought) problem, engineers should first consider catchment management, before any other engineering intervention • Address the situation as a "source, transmitter, receptor" problem and deal with each element in turn • Do not just consider engineering options but widen the scope by surveying all other stakeholders needs as well, so as to optimise opportunities for multiple-benefit solutions (possibly with multiple funding sources too) • Learn new collaborative skills needed to work with disparate stakeholders • Invest in continued data collection and analysis to improve the evidence for, and reduce the uncertainty of, the solutions • Continue to develop incentives for wider benefits (such as payment for ecosystem services)
Managing water in urban systems	• Look for opportunities to integrate all aspects of the water cycle into the wider urban systems seeing this as an opportunity and not a problem • See water as part of the complex interconnected web of urban services • Seek stronger dialogue and cooperation with other agencies responsible for urban infrastructure • Actively consider decentralised water systems that include green infrastructure and provide a range of ecosystem services • Adopt an innovative approach which recognises that much previous knowledge and practice of managing urban water will no longer be relevant • Acknowledge uncertainties so that decisions around alternative (non-traditional) options can be properly informed • Work with other disciplines to ensure that social impacts of engineering decisions are fully revealed and understood
Water supply	• Understand the component cycles and systems and their inefficiencies through audit • Optimise the sources of water supply, treatment and distribution, based on sustainable options • Eliminate the unnecessary use of water where possible • Minimise the use of potable water in non-drinking applications • Seek and deploy more efficient alternative treatment technologies • Develop, install and operate "smart" network systems • Set and meet cost affordability and carbon reduction targets • Continually engage with customers and other stakeholders to agree plans and encourage water efficiency • Close the loop on water supply and develop more localisation of solutions
Wastewater disposal	Multidisciplinary teams focussing on maximum benefit for the least cost in terms of agreed metrics should: • Define problems in terms of objectives, metrics and targets that reflect the specific drivers and constraints as well as the concerns of customers and wider stakeholders within a catchment context

(continued)

Table 2 (continued)

Aspect of the urban water cycle	What water professionals can do
	• Identify innovative options with the aid of relevant challenge questions and collaborative, integrated approaches, with a focus on value efficiency and multiple benefits • Assess alternative approaches in terms of critical thresholds and agreed metrics within the appropriate boundary in a multi-criteria approach • Maximise operational efficiency and resilience • Ensure chosen solutions are delivered so that project objectives and targets are met and processes put in place to ensure performance and standards are maintained over time. • Focus on sustainable wastewater service outcomes for customers, communities and the environment
Drainage and flood resilience	• Understand the performance of the existing drainage system • Apply the "source-pathway-receptor" model to convert stormwater to a safe for point for discharge, effectively manage flood risk and safeguard receiving waters from pollution • Challenge convention in seeking solutions (e.g. consider non-pipe options) • Recognise that the developed drainage systems will have a finite capacity and plan for exceedance • Build in resilience against flooding and other impacts • Manage other receptor impacts
Water in development	• Focus on the goals of improved socio-economic well being, whilst bearing in mind environmental limits and the principle of intergenerational stewardship • Water development operates in a complex context in which interventions often do not have the intended consequences • Developing countries have differing complex mixes of culture, history, politics, economics and ways of working; therefore, sustainable solutions are developed through investing in relationships, supporting systemic change, building national capacity and autonomy, and helping to create shared visions. The physical infrastructure is only a small component of this process • There is need to work top down (governments, institutions, systems and regulations) and from the bottom up (community, developing basic needs) simultaneously • There needs to be realism about management and financing capacities • Judge outcomes against the question "Is this a good change which will continue to work over time?". Does it threaten harm or impoverishment to downstream neighbours and communities (with the first being hard to achieve and the second being hard to predict, manage or avoid)?

Adapted from Ainger and Fenner (2016)

disturbance. Past solutions to water management issues have often been to look for technically optimum solutions that deliver the greatest efficiencies. This approach, however, is not always suited to nonlinear systems which are subject to extreme events. Optimising around efficient solutions seeks to eliminate all redundancies in the system and avoid any unnecessary provision of overcapacity, so that only those components are retained that have an immediate benefit and meet an acceptable level of risk, based on the past knowledge of the system behaviour. This is an appropriate approach when change occurs slowly and incrementally through average day-to-day events. However retaining some of the apparent redundancies allows more flexible possibilities to adapt to unprecedented and unanticipated changes, such as the nonlinear responses we might expect from global warming and its influence on urban water resources (too much, too little).

Building in resilience to the urban water system can be achieved in a number of ways. Firstly, multi-functionality can be incorporated which is simply the practice of doing more than one thing in one place. This can give rise to a number of valuable co-benefits (as demonstrated in Sect. 3 which examines the multiple benefits that can follow from the use of green infrastructure as a flood management measure). It is also useful to actively seek redundancy, so that multiple elements of a solution provide the same or similar backup strategies, such that if one element fails the whole system is not lost. The adoption of distributed modular systems is the key here, such as the decentralisation of treatment facilities into multiple smaller units rather than expensive single end of pipe facilities. Modular solutions can also be used singly or collectively over different scales, again providing a more adaptable service over a range of circumstances than if the whole function was provided by a large single piece of infrastructure.

Little information is available from cities that have adopted these approaches, and it would be potentially misleading to draw generalised conclusions based just on a single or a few case studies which are very location specific. In the absence of real-world case study examples, a study by Sitzenfrei et al. (2013) conducted an analysis of 80 virtual and one real-world case study to compare performance in systems of different sizes. By performing an integrated city-scale analysis, the technical effect of the transition from existing central to decentralised urban water systems could be studied. In relation to hydraulic performance, large systems were found to be more stable because of their larger capacities and redundant features with small systems identified as having less stable integrated performance. Conversely, on the basis of a life-cycle analysis of material and energy needs an unpublished study by Cambridge University showed that 5 distributed small wastewater treatment plants considerably outperformed a single large works (of equivalent capacity) for the same planned urban development.

Nelson (2008) argues that the advantages of decentralisation emerge as reuse is emphasised. Using and reusing water at the local site costs less than piping water in, wastewater out, and treated water back in for reuse. In addition, many of the new values being discovered from decentralisation, such as green space, are by definition local and dispersed throughout the community. She points out that until now our centralised, big-pipe infrastructure has relied on an industrial model of specialisation and economies of scale. This industrial model has more than adequately protected the public from pathogens and floods, largely by storing and piping clean water long distances into population centres and then transporting wastewater pollutants away. But the approach is also wasteful, environmentally disruptive, and ultimately not sustainable as populations increase and more and more land is developed over time. Climate change-related extremes of heavy storms and droughts will place even greater stresses on this centralised, natural-manmade water system that have uncritically been built piece by piece.

Achieving new ways of thinking which advocate and adopt such approaches requires a new innovation mindset in delivery and management of water in urban environments, which will be a key feature in building cities of the future. Ainger and Fenner (2016) review much good practice that already exists and summarise important actions that can be taken to innovate towards sustainability. This begins by integrating and making sense of the sustainability challenges that must be met in any wider urban strategy or policy arena (specifically working within resource limits, improving socio-economic conditions of people, balancing present and future needs and recognising complexities, inter-dependencies and the feedback loops these give rise to). To guide innovation, a future vision and clear strategy is required with stretching goals and targets against which performance is continually measured and judged. In seeking new solutions, it is always good practice to be a little more ambitious than may seem possible. Importantly, individuals need to be empowered to get on with innovation, from water company employees, customers, supply chains and local water users such as businesses and communities. It is important to understand the roles each of these stakeholder groups play, so they can be innovation champions and leaders creating the demand and purpose for change.

An essential ingredient is to tolerate and not stigmatise failure, whilst learning from it. This is at the heart of an adaptive management approach to water which allows small failures to be made in an iterative process described sometimes as "Do-Fix-Learn". Problems need to be fully understood before solutions are generated or accepted and this can be coupled with creating new measurement systems to meet new goals (such as understanding the carbon footprint of an asset in order to choose systems which reduce the water industry impact on global warming). Another innovation is to make the most use of current assets by actively looking for ways to not build new capacity, but to be smarter about using the capacity that already exists. In order to make nuanced and transparent solution choices, more effort should be directed at understanding and quantifying uncertainty and risk. Sometimes understanding a problem in a different way can be a driver for a new approach and avoid a risk averse barrier that holds back new thinking. Finally, opportunities exist for sharing best practice and ideas with other sectors, such as in agriculture and energy.

Overall, the most effective sustainable solutions need to improve the end users' water service, protect the environment and increase affordability. This may well involve helping a water company's customers to use less water, setting challenging carbon emissions reduction targets (as well as cost reduction targets and seeking solutions across the interfaces with customers and with the surrounding urban areas and catchments).

Ainger and Fenner (2016) conclude: "Looking at sustainability enabling action it is striking how they interact with and reinforce each other. Outcomes regulation with collaboration can open up the problem space for more sustainable multi-benefit solutions. Measurement standardisation and new boundaries for targets like CO_2-e can widen the sustainability targets and performance driven by that regulation. Clever modelling and data analysis can help understanding and prediction, and thus reduce uncertainty in using management based solutions with the complexity of asset operations and customer interaction. Procurement innovation can bring together and incentivise the whole value chain to use all of these approaches".

3 The Challenges for the Future

In establishing key goals which drive all of the above, the following is adapted from the UK Water Industry Research search for big questions which will drive the water industry forward to 2050 (UKWIR 2015). They represent big goals intended to inspire long-term strategy:

1. 100% universal affordable access to water and sanitation;
2. Zero leakage;
3. Zero unnecessary water use;
4. Zero agricultural/urban pollution of into rivers, lakes and seas;
5. 100% appropriate quality water for potable and other uses;
6. 100% separation of surface water from foul sewage;
7. Zero pollution discharge exceeding local environmental capacity;
8. 100% recovery of all potential resources from sewage streams;
9. Zero net carbon emissions;
10. Zero flooding risk beyond local resilience capacities;
11. 100% evidence-based justification for all standards and business structures.

Achieving this will require a paradigm shift in the way water is managed in cities. Water management has always changed and evolved to meet new concerns and constraints. In the ancient world, attention focused on basic water supply to meet local needs. Moving forward to the Middle Ages saw the engineered conveyance of water supply and runoff through early pipe systems. This seriously impacted on the quality of receiving waters, and there were widespread epidemics from waterborne diseases. From the mid-nineteenth century, faster and longer conveyance of water became common, whilst treatment processes were developed to protect both public health and the environment. The current approach is driven by environmental regulation and also recognises the importance of non-point source pollution and nutrient recovery. New technologies in wastewater reclamation and reuse, energy recovery and the development of green buildings are enabling a further shift in water management. The future lies in applying the principles of integrated resource management (IRM) where "Blue-Green" Cities and their infrastructure will combine drainage, landscape and receiving waters in an aesthetically desirable way.

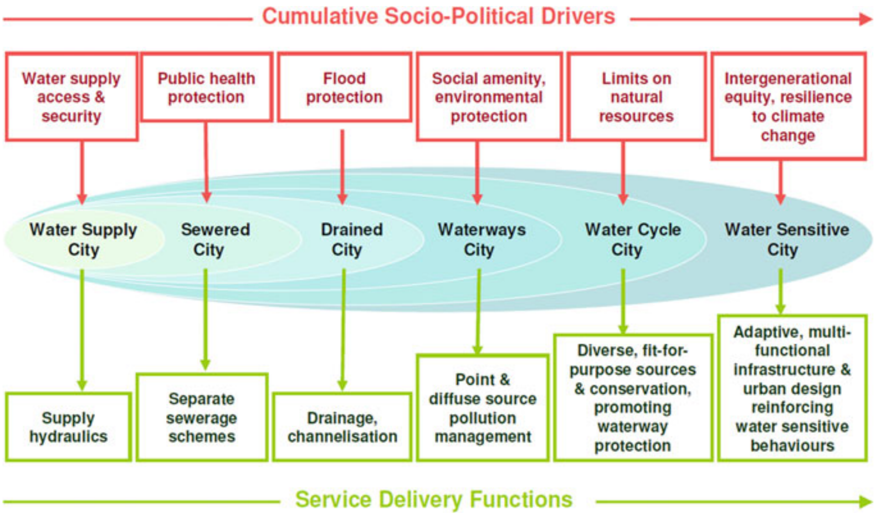

Fig. 1 Changing paradigms of water management. Brown et al. (2008)

In this new paradigm, the urban hydrological cycle will be connected with multiple uses and functions.

This journey from a simple and restricted “water supply city” to a fully “water-sensitive city” is clearly shown in Fig. 1, in which Brown et al. (2008) show that as socio-political drivers increase, so do the service delivery functions needed to address them. The final result, arguably not yet achieved in any city, is where adaptive and multifunctional infrastructure provides both resilience to climate change, public amenity and protection from all hydrological extremes. However, there seems to be difficulty in making the transition from a “Drained City”, representing large technical, single-source water systems, energy-intensive distribution and treatment systems and drainage systems that continue to degrade aquatic ecosystems, to the more complex, adaptive practices represented on the right-hand side of Fig. 1 (Howe and Mitchell 2012).

An important step is to connect the use of Green Infrastructure (GI) in urban planning (parks, public open cities, wildlife refuges) with the surface water drainage networks and SuDS to transform areas of high-density living into “Blue-Green Cities”. A formal definition has been given by the Blue-Green Cities research consortium (see http://www.bluegreencities.ac.uk) as follows: “A Blue-Green City aims to recreate a naturally oriented water cycle while contributing to the amenity of the city by bringing together water management and green infrastructure. This is achieved by combining and protecting the hydrological and ecological values of the urban landscape while providing resilient and adaptive measures to deal with flood events”.

The SWITCH project (Hoyer et al. 2012) established criteria by which such integration could be assessed with performance judged against:

i. water sensitivity (the extent to which management practices bring urban water closer to the natural water cycle);
ii. aesthetics (flood water visibility in public spaces—integration into the surrounding area);
iii. functionality (appropriate site-specific design and maintenance and adaptable to changing baseline conditions, including climate and demographics);
iv. usability (both recreational and conservational purposes);
v. public perception and acceptance (public involvement in the planning process, and acceptable whole life costs);
vi. integrative planning (combining function, aesthetics and use through interdisciplinary planning to improve public acceptability of Flood Risk Management measures).

The SWITCH project also highlights many examples of best practice in urban water management from cities across four continents—Lima, Santiago de Cali, Bogota, Belo Horizonte, Accra, Alexandria, Birmingham, Zaragoza, Hamburg, Lodz, Tel Aviv, and Beijing, which is reported by Butterworth et al. (2011). The focus is on promoting stakeholder engagement through the creation of learning action alliances which can promote and hasten the transition to the new practices and approaches reviewed in this chapter.

3.1 Blue-Green Cities and Water-Sensitive Urban Design

These approaches are gaining traction around the world. In 2016 Newcastle declared it will adopt policies which will make it the first Blue-Green City in the UK. Stakeholders in the city ranging from Newcastle Council, the Environment Agency, Northumbrian Water and land owners and developers are meeting regularly in a Learning Action Alliance collectively to develop this vision for the city.

Portland, Oregon, has been at the forefront of such initiatives for some years with a “grey to green” downspout disconnection programme aimed at relieving pressure on pipe networks operating above their design capacity and alleviating combined sewer overflow (CSO) spills into the Willamette River. Instead stormwater is handled at source and fed to a series of attractive street gardens, wetlands and bioswales. Bioswales are long, channelled depressions or trenches with gently sloped sides (less than 6%) and filled with vegetation, compost and/or riprap that receive rainwater runoff (e.g. from paved parking areas) and utilise grasses, flowering herbs, and shrubs and organic matter (such as mulch) to slow water infiltration and filter out pollutants. Examples of street gardens and wetland planting in Portland are shown in Fig. 2.

Stuttgart in Germany saves costs of stormwater management through the application of green roofs, cisterns and pervious pavement instead of enlarging sewer system for rainwater drainage. The Augustenborg area of Malmo in Sweden has achieved considerable socio-economic regeneration through a process of

Fig. 2 Wetland storage for local stormwater and street gardens in Portland USA. Author's own

Fig. 3 *Blue-Green* features provide regeneration uplift in Malmo Sweden. Author's own

"daylighting" its drainage network on the surface to provide an uplift in the aesthetic quality of the neighbourhood (Fig. 3). There are many other examples of good practice, for example in Philadelphia, Chicago, Seattle, San Francisco, New York, Cardiff, Rotterdam, Melbourne, Nanjing, Ningbo, to list just a few.

To achieve this, new paradigm of "water-sensitive urban design" requires greater collaboration and dialogue between professional groups. Water-sensitive urban

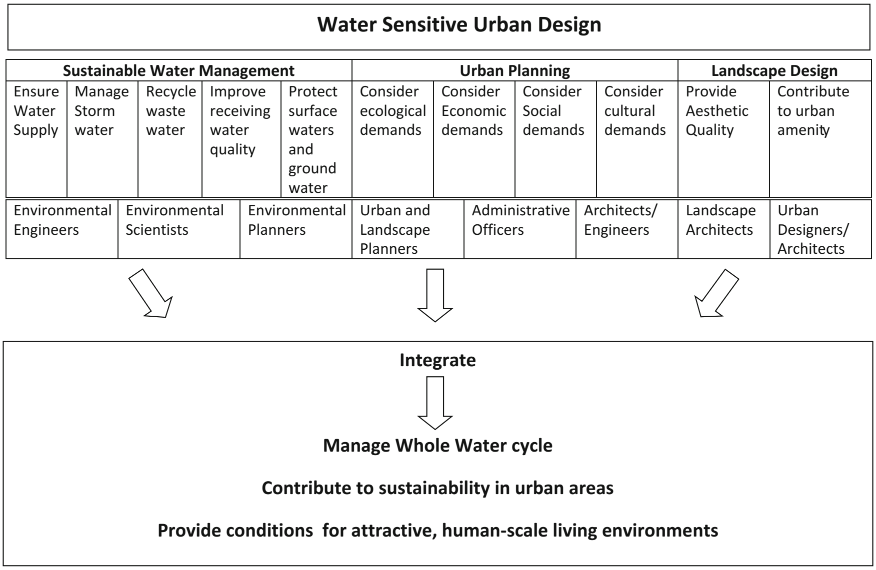

Fig. 4 Components of water-sensitive urban design. Adapted from Hoyer et al. (2012)

design (WSUD) is the interdisciplinary cooperation of water management, urban design, and landscape planning and its principles and key actors are shown in Fig. 4.

3.2 Multifunctional Infrastructure

Seeking opportunities for engineered assets to deliver more than one function is at the heart of modern water management practices. For example, CIRIA (2013) suggest that the range of benefits which can be attributed to the adoption of SuDS can be summarised in terms of:

1. Direct economic value—e.g. increased land value due to flood reduction; more productive fisheries, etc., because of pollution control (e.g. Penning Rowsell et al. 2005);
2. Added aesthetic and amenity value, e.g. additional green infrastructure (e.g. Natural England 2009);
3. Added environmental or ecosystem value due to less stress on environmental systems or the creation of new biodiversity in urban areas—many of these benefits relate to ecosystem services (Sukhdev et al. 2010);
4. Social benefits which tend to be diverse and less easily quantifiable, but attempts such as Social Return on Investment have been made (SROI 2012).

Source: Photo by CEphoto, Uwe Aranas. Used under license (CC BY-SA 3.0)

Source : http://www.i45parkway.com/i45-underconstruction.htm

Fig. 5 Singapore's Marina Bay Barrage and Kuala Lumpur's SMART multi-functional tunnel

Generally, the use of vegetated surfaces for storage and infiltration of excess surface water can also provide pollutant trapping, biodiversity opportunities, noise reduction, traffic calming (where street gardens take up parts of a carriageway), carbon sequestration, reduction in urban heat island effects, groundwater recharge, uplift in property value, increase in amenity and recreational opportunities with associated improvements in health, and so on (Hoang et al. 2016). Much work has been done in quantifying (Morgan and Fenner 2017) and monetising (CIRIA 2015) these diverse range of benefits, but their relative performance depends on site-specific circumstances and prevailing environmental conditions in given locations.

At a bigger scale, other large water infrastructure projects can serve more than one purpose. For example, Singapore's Marina Barrage (Fig. 5) provides three main benefits (Harley 2012): as a tidal barrier and pumping station for flood control, as a reservoir for augmented water supply serving around 4.8 million people, and as a new lifestyle amenity attraction around the reservoir and tributary rivers in the heart of urban Singapore. Completed in 2008, it creates a unique and active public interface with Singapore's water infrastructure and the practice of integrated water management.

In normal conditions, the steel crest gates remain closed in order to isolate the reservoir from the ocean; outflow is directed through low-level sluice gates underlying the pumping station. During heavy rains, and when the tide is low, the gates are lowered sequentially to release excess flow from stormwater arriving from the rivers draining the 10,000 ha catchment. When the tide levels are high, however, the gates are raised again and the pumping station is put into operation, capable of moving almost 3.8 million m^3/day per pump. The design allows the barrage and pumping station to work in tandem to respond to a range of storm flows and tide levels, and this maintains near constant level in the reservoir whilst allowing the natural flushing of salt water as the formerly saline basin is transformed into a freshwater reservoir (Harley 2012).

In the Malaysian capital Kuala Lumpur (Fig. 5), there is the longest multi-purpose tunnel in the world combining stormwater management and road transport. The SMART (Stormwater Management and Road Tunnel) project was in response to serious flooding problems in the city centre and is a dual-purpose tunnel incorporating a double-deck motorway within the middle section of a motorway tunnel and was competed in 2007. Its primary function is flood control and can be operated in three modes. In Mode 1 (which occurs most of the time), there is no storm and only low rainfall so the road section operates normally and traffic is connected from the city centre to Seremban Highway. In Mode 2, during minor storms when river flows exceed 70 m^3/s, the stormwater tunnel is activated to semi-open status by allowing water flow from the Klang and Ampang rivers through only the lowest channel. During a major storm, under Mode 3, if river levels exceed 150 m^3/s the fully open status is activated and radial gates at the diversion weir are lowered. At the same time, entrances to the motorways section are closed to traffic while all vehicles in the tunnel are evacuated and the entire structure checked, a process that takes less than an hour. Once the storm has passed and the weather is back to normal, flood water is pumped out of the tunnel and the tunnel is cleaned of mud and small debris. The 9.7-km-long tunnel can hold up to one million cubic metres of water, which is released into the river downstream from the city to prevent flooding.

In the normal process of cleaning and inspection of the tunnel condition, the SMART tunnel is reinstated within 48 h after the water channelisation is made and traffic for the motorway section is allowed back for usage as normal thereafter. In its first 5 years of operation, Mode 3 operation was activated to prevent potentially severe flooding of Kuala Lumpur city centre a total of seven times: two times each in 2007, 2008 and 2012 (up to May) and once in 2011. Mode 2 operation, which does not affect use the road tunnel, was activated dozens of time in the same period.

4 Summary

Water is a critical resource, which is scarce in many parts of the world and yet retains the power to create catastrophic damage and threat to life and property through floods which are increasingly driven by the uncertainties of extreme rainfall events. Managing water in urban environments has developed from the basic provision of essential water supply service to the integration of essential water management practices with wider urban form. Many challenges need to be overcome for this vision to be fully realised, but opportunities exist to achieve a range of positive and sustainable outcomes and strongly influence the fabric, layout and liveability of future cities.

There are no universal rules about how this can be achieved and the local environmental and hydrological conditions together with prevailing land use patterns and population pressures will dictate how appropriate solutions need to be developed in each city. However, seeing the water system as an integrated part of the wider urban fabric is a good starting point.

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Health and Well-being in Urban Environments

Anja Mizdrak and Adam John Ritchie

Abstract As more people move into urban environments, so grows the negative impacts of city living on human health. Yet we need not be passive victims of this relationship; governments and communities can take steps to make things work better and ensure improved health outcomes. This chapter explores the concept of the *Healthy City* and the scale of the global challenges being faced. It draws on case studies from Africa, Europe, and South America that focus on successes in improving physical activity and nutrition, to show how these challenges can be overcome.

1 Introduction

Globally, health is still improving: life expectancy at birth has increased by 6 years since 1990 (World Health Organisation 2011) and there has been a 48% drop in child mortality in the same timeframe (Institute for Health Metrics and Evaluation 2014). However, there is considerable variation in these patterns at regional, national, and local levels. Differing rates and natures of urbanisation influence this variation, with cities presenting both challenges and opportunities for health and well-being.

Given the high and increasing proportion of the global population that live in urban areas, it is vital that cities play a positive role in promoting health and well-being. In this chapter, we will discuss how cities influence the health of the populations within them. We start by arguing that cities' impacts on health fall

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along a continuum. At one end of this continuum are health impacts that are caused by the urban environment. At the other are health issues that are fundamental to all people, regardless of where they live. Understanding the nature of the impact of cities and urbanisation on health issues along this continuum can help ensure that we are better able to address health challenges. We proceed by looking at the concept of a healthy city and what this might mean for citizens. We then examine the issues of physical inactivity and food security and how the urban environment can both help and hinder health promotion. Throughout, we give city-level examples from a range of contexts to illustrate how the urban environment could be better adapted to promote health.

The multitude of health risks, diversity in urban environments, and range of solutions available have meant that it has not been possible to cover everything. In this chapter, we focus mostly on the impact of urbanisation on non-communicable, physical diseases, yet infectious diseases, mental health, and social inclusion all have major impacts on well-being in most urban centres. The World Health Organisation defines health as a "complete state of social, mental and physical well-being and not merely the absence of disease or infirmity" (World Health Organisation 2006), and anyone influencing the lives of urban citizens should keep this broad definition in mind when considering the impacts of policies. We hope that the concepts that we discuss, and the case studies we provide, will serve to illustrate the nature of the relationships between urbanisation and health beyond the specific cases and risks discussed.

2 The Links Between Health and Urbanisation

Non-communicable diseases such as heart diseases, stroke, and cancers account for 88% of deaths in developed countries and 64% in developing countries (Institute for Health Metrics and Evaluation 2015). Overall, seventy per cent of global deaths were attributed to non-communicable diseases in 2013, an absolute increase of 13% from 1990 (Institute for Health Metrics and Evaluation 2015). The high and increasing burden of non-communicable diseases relative to communicable diseases is in part a reflection of the tremendous successes in addressing the latter. The burden of communicable diseases has decreased due to improvements in living conditions (including sanitation), widespread primary prevention through vaccination, improved treatments and access to healthcare.

The changing global patterns of disease are also the result of changing lifestyle patterns that are associated with increasing urbanisation and linked to increases in the risk of non-communicable diseases (Angkurawaranon et al. 2014). Risk factors that contribute to the development of non-communicable diseases include poor diet (e.g. low fruit and vegetable intake, high sodium intake), smoking, low physical activity, overweight and obesity, high blood pressure, alcohol intake, and air pollution. These are consequently the risk factors that are the most important to address if overall improvements in health are to be maximised, though the relative importance of each of these, plus other location specific factors, will vary from city to city.

The impact of cities on health has been discussed since ancient times, with the balance and nature of these impacts varying across time and space. Ancient Greek and Roman scholars noted that living in a bad city, or in a bad location in a good city, could have negative health impacts (Hope and Marshall 2000). In nineteenth-century Britain, town dwellers had considerably worse health outcomes than their rural counterparts, including a 2.2 times higher infant mortality rate (Godfrey and Julien 2005). In contrast, in the Southeast Asia region today, urban centres generally have more positive indices of health and healthcare services and are marked by economic prosperity (World Health Organisation Regional Office for South-East Asia 2011). Within a city, there can be considerable variation in the health status of different populations. Even in modern, developed cities such as London, life expectancy at birth ranges from 75 to 96 across different areas (Cheshire 2012). This illustrates that cities do not have a constant impact on health, and the health impact that they have is modifiable.

Cities have a direct impact on the health of their citizens through a variety of processes. Increases in population density can enable infectious disease transmission (Neiderud 2015). City dwellers have a higher rate of mental health disorders (Peen et al. 2010). Urban sprawl results in an increased reliance on mechanised transport, reducing physical activity rates and increasing air pollution. The inadequate separation of pedestrians, cyclists, and motorised vehicles contributes to increased road traffic accidents, the seventh leading cause of death worldwide and the second leading cause of death for 15–49 year olds (Institute for Health Metrics and Evaluation 2015). Associations have been observed between urban environments and range of risk factors for cardiovascular disease (Sun et al. 2015). These examples serve to illustrate that at one end of the continuum of the impact of cities on health there are direct, causal relationships between the urban environment and health risk. These direct impacts of urbanisation need not be negative: higher population densities make it easier to deliver many health services, and urban environments dramatically reduce transmission of some vector-borne diseases such as malaria (Hay et al. 2005).

There is also a wide-range of health issues which are not caused by the urban environment directly, but that nevertheless need to be addressed there. Access to safe, affordable, and nutritious food is necessary to ensure healthy dietary practices regardless of location. Basic health services such as vaccination, family planning, and screening need to be implemented universally. At this end of the continuum of the impact of cities on health, the city is passive and provides the environment to address existing health issues and practices. However, the urban environment in part influences even these universal health needs. For example, dietary practices are limited by the availability of food items, which in turn is partly determined by town planning policies regarding store location, transport infrastructure, and the broader economic climate of an urban area.

Overall, health impacts (positive and negative) can be broadly arranged along a continuum of those that are caused by urbanisation, and those that are common to the human experience. Whilst issues may fall towards one of these extremes, most issues are complex and can take on different characteristics in different settings. What is clear is that the increasing proportion of the global population that live in cities means that this is a key environment in which to address health promotion. The next section addresses the concept of healthy cities, and the progress that has been made to date in implementing healthy city principles. This is followed by looking at physical activity and food security; issues that fall on different parts of the direct versus indirect level city health impact continuum. Cities can influence health through a variety of direct processes, or they may simply be the context in which existing health issues are addressed.

3 Healthy Cities

The health of a city is more than the sum of the health of the individual citizens, and cities themselves can be considered healthy or unhealthy. The modern concept of the healthy city came about at the Healthy Toronto 2000 convention in 1984 and the subsequent work of the WHO European Regional Office in translating these ideas into a tangible, global programme of action to promote health (Awofeso 2003). In harmony with their definition of health, the WHO defines a *Healthy City* as “one that is continually developing those public policies and creating those physical and social environments which enable its people to mutually support each other in carrying out all functions of life and achieving their full potential” (World Health Organisation 1998).

A healthy city is one that aims to meet the basic needs of all citizens, has a clean, safe physical environment, a stable and sustainable ecosystem, supportive community, high citizen participation, access to a variety of experiences and resources, connectedness with the past, and appropriate public health and sickness care services accessible to all (World Health Organisation 2016). Under this process, a city can be considered healthy if it is working to meet these goals. However, the *Healthy Cities* programme does not capture all the cities that might be making progress towards these goals, as cities must apply to be considered part of the official network. Yet it does provide a useful framework against which we can measure success even outside the official network. It is also a measurement based on policies and steps taken by a city, rather than based on direct metrics of health. The impacts of such programmes are likely to be felt over years and decades, making short-term measurement of impact difficult.

Towns and cities in Europe that are successful in demonstrating they are working to promote health are supported through the WHO Europe Healthy Cities Network (World Health Organisation Regional Office for Europe 2016), and a number of countries have similar national-level forums (Lafond et al. 2003). The ability to share experiences is important to generate ideas, evaluate effectiveness, and develop best practice. However, the WHO Europe Healthy Cities programme's effectiveness is limited by non-participation of major cities in the region, such as London (Network 2011), leading to a self-selection bias where the towns and cities that are the most health aware to begin with are the most likely to participate. The *Healthy Cities* initiative has also largely been restricted to industrialised countries (Awofeso 2003), though there are frameworks in place to scale up healthy cities initiatives elsewhere (World Health Organisation Western Pacific Regional Office 2011).

Healthy cities are defined by the process of encouraging a healthy environment, and not by their current health outcomes. Any city can become a healthy city by recognising the impact of the urban environment on the health of its citizens, and working to improve it. Recognising healthy cities through their processes rather than outcomes ensures continual progress towards improving health and ensures that novel health risks and opportunities can be incorporated into the agenda. Healthy cities should work to address the full range of health risks and opportunities present in the urban environment; the extent of particular risks will vary and the process-driven definition of healthy cities enables relevant health risks to be addressed and redefined over time.

3.1 Physical Activity in the Urban Environment

The relative decrease in physical activity of citizens in the urban environment is one of the most apparent and direct impacts of urbanisation on health and well-being. There is strong evidence that physical activity reduces the rates of coronary heart disease, high blood pressure, obesity, stroke, type 2 diabetes, depression, some cancers, and other major health problems (Lee et al. 2012). It is recommended that adults aged 18–64 should do at least 150 min of moderate intensity (e.g. brisk walking) or 75 min of vigorous aerobic physical activity throughout the week or an equivalent combination of moderate and vigorous activity (World Health Organization 2010). Recommendations are also in place for muscle strengthening activities and the health benefits of physical activity continue well beyond the minimum recommended levels (World Health Organization 2010a).

Worldwide, 31.5% of adults are not sufficiently physically active (inactive). This varies by country with the highest rates of physical inactivity observed in Malta (71.9%) and the lowest rates in Bangladesh (4.7%) (Hallal et al. 2012). Physical inactivity is estimated to cause 9% of premature mortality, and global life expectancy could be increased by 0.68 years if physical inactivity was eliminated (Lee et al. 2012).

Physical activity is comprised of activity in multiple domains: transport, leisure, household, and occupational activity all contribute. There is evidence that rapid urbanisation has resulted in decreased occupational physical activity in China (Monda et al. 2007), and that individuals in urban environments have lower physical activity levels than their rural counterparts in a number of settings (Yamauchi et al. 2001; Ojiambo et al. 2012; Yadav and Krishnan 2008), but not universally

(Parks 2003). Although evidence on causation is limited, relative income levels and the nature of occupations available in rural and urban areas in different countries may contribute to this variation. Rapid urbanisation is thought to be a cause of reductions in physical activity over the last few decades. Unfortunately, finding proof of causation and not merely correlation is difficult; current empirical evidence is poor owing partly to inconsistent, inaccurate measurement (Hallal et al. 2012).

Cities can influence the physical activity of their citizens in a number of ways. Geographic separation of living, working, learning, and shopping promote increased car reliance (Edwards and Tsouros 2006) and therefore decreased active transport. People who live in areas with a high density of recreation facilities are more likely to participate in active leisure activities (Roux et al. 2007). The design of individual building elements within cities, such as stairs and exercise rooms, can promote or deter activity (Zimring et al. 2005). Building features may contribute to occupational physical activity with as little as 2 min of additional stair climbing per day resulting in a weight reduction of >1.2 lb (~0.5 kg) per year (Zimring et al. 2005). These examples demonstrate the far-reaching ways in which features of the urban environment can promote health in relation to increasing physical activity and influence other health risks such as obesity.

Promoting an active urban environment can be achieved whilst simultaneously addressing other urban issues. The London congestion charge was introduced in 2003 with the primary objective of reducing congestion in the city centre. Since the introduction of the congestion charge, cycle journeys have increased by 20% with a 7% reduction in crashes (Edwards and Tsouros 2008). In addition, measures introduced in Bogota to promote transport equality have improved infrastructure for active travel through the increased provision of cycle lanes (see the Transport chapter for further details about Bogota). Encouraging physical activity in the urban environment can also have social benefits: in an Irish study, people living in more walkable neighbourhoods were shown to have higher social capital than those in car-oriented neighbourhoods (Leyden 2003).

Encouraging physical activity in the urban environment may also have considerable advantages for sustainability. Around half of all car trips in the UK, Netherlands, and USA are less than 5 miles (Maibach et al. 2009). EU data suggest there is a high frequency of journeys currently made by car which could be made using a different form of transport without a significant impact on journey time (Dekoster and Schollaert 1999). There may also be high public support for encouraging active transport: 83% of Europeans agree that public transport should receive preferential treatment over private vehicles (Dekoster and Schollaert 1999).

Copenhagen provides an excellent example of how physical activity can be promoted whilst simultaneously addressing sustainability issues (Fig. 1). The greater city of Copenhagen has a population of 1.26 million (Ministry of Planning 2015), and 45% of people working or studying there cycle to their place of work or education (City of Copenhagen 2014). Every weekday, 1.34 million kilometres are cycled in Copenhagen (City of Copenhagen 2014). It is estimated that there is an overall socioeconomic benefit of DKK 1.62 (approx. £0.16) for every additional kilometre of new cycle journeys made during rush hour (City of Copenhagen 2014).

Fig. 1 Copehagen cycle culture by Dylan Passmore. Used under license (CC BY-NC 2.0)

The city of Copenhagen's Bicycle Strategy 2011–2025 outlines that Copenhagen aims to become the world's best cycling city as an integral part of the vision of Copenhagen as an Environmental Capital. Copenhagen aims to be carbon neutral by 2025, and the cycling strategy is part of the city's official health strategy.

The city of Copenhagen currently has 368 km of cycle tracks, and this does not include the many more kilometres of cycle tracks managed by bordering municipalities (City of Copenhagen 2014). Cycle tracks are separated from vehicular traffic by kerbs, increasing the safety of cyclists. In addition, there are 58 km of green cycle routes leading primarily through areas with little or no vehicular traffic (City of Copenhagen 2014). The green routes provide spaces for recreational cycling and reduce congestion on primary routes. Recent additions to the cycling infrastructure include new bicycle bridges linking areas that previously had poor bicycle accessibility, enabling contraflow cycling on selected one-way streets to decrease distances and avoid cyclists having to make detours, and a cycle route planning app to enable citizens to find the optimal cycle routes (City of Copenhagen 2014). Innovative strategies are also being piloted: funding has already been allocated to intelligent traffic systems that use light emitting diode (LED) lighting to change the prioritisation of different transport modes throughout the day (City of Copenhagen 2011). For example, these could be used to widen cycle tracks or to make stretches of road one-way during peak times.

These developments are designed to further increase the proportions of journeys made by bicycle, reduce casualties, reduce journey times, and increase the proportion of cycling Copenhageners that feel secure (City of Copenhagen 2011).

Fig. 2 Copehagen by Tony Webster. Used under license (CC BY 2.0)

If the target of 50% of commuter journeys being cycled by 2015 is achieved, it is estimated to prevent 10,000–20,000 tonnes of carbon dioxide emissions per year (City of Copenhagen 2014). Health impact assessments have also demonstrated that increases in the proportion of commuter trips made by bicycle would have positive health effects, even after accounting for negative impacts such as increased exposure to air pollution and accidents (Holm et al. 2012) (Fig. 2).

The cost of developing the cycling infrastructure is high: each additional kilometre of cycle track is estimated to cost DKK 16 million (€2.2 million) (City of Copenhagen 2011). This may be seen as a limitation to developing cycling infrastructure, especially in low- and middle-income countries where resources are more limited. However, the cost of encouraging active transport should be considered in relation to the cost of investments in other infrastructure. For example, the cost of developing 1 km of Metro in Copenhagen is DKK 1 billion (€134.5 million), over six times the cost of 1 km of cycle track (City of Copenhagen 2011). The equity of infrastructural developments should also be considered, investing in cycling infrastructure might be more equitable as the cost of owning a bicycle is much smaller than the cost of car ownership or public transport passes. Tackling the issue of upfront costs in low- and middle-income settings is crucial if healthy, sustainable infrastructure is to develop alongside the expansion of cities. Case studies such as Bogota demonstrate that an equitable approach to developing transport infrastructure, encouraging more active forms of transport; ensuring health promoting, sustainable, equitable investment in transport is also achievable in low- and middle-income settings.

Case studies such as Copenhagen and Bogota demonstrate that cities need not have a negative impact on physical activity. This clearly shows that there is the potential to overcome at least some of the negative effects of urbanisation on health and well-being, where deliberate and well-constructed policies are adapted. The existing physical, structural, and social features of cities contribute to the ease with which active transport can be encouraged. Suitable strategies to encourage physical activity in sprawling cities where distances are large between places of work, leisure, and residence may be different to measures in compact urban environments. Leadership on prioritising active transport policies is pivotal in their success in all settings, with competing demands on financial and political capital resources being a limiting factor. Once strategies are in place, management and incentive structures within local government will influence the ease of coordinating activities across the multiple, diverse departments that have a role in designing and implementing physical activity promoting cities.

3.2 Food Security in the Urban Environment

Food security is "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life" (World Food Summit 1996). This includes being able to access stores, restaurants, or markets to acquire food, having the means to prepare food, available food to be culturally and nutritionally acceptable, and for food prices to be affordable. Although food security is an issue facing all people, with an increasing proportion of the global population living in urban areas, cities have become the key setting in which food security needs to be addressed.

Malnutrition is the result of inadequate food security and is manifested in several ways including calorie deficiency, micronutrient deficiencies, and obesity. Globally, 2 billion people experience micronutrient malnutrition, 1.9 billion adults are overweight or obese, and 794 million people are calorie deficient (International Food Policy Research Institute 2015). A double burden of over- and under-nutrition exists in many countries (World Health Organization 2003) and is present even in school-aged children (Jafar et al. 2008; Ene-Obong et al. 2012). Improving food security and nutrition would have considerable health impact. Globally, dietary risks are estimated to account for over 20% of total deaths and there is an additional burden from diet-related risks such as high blood pressure, high total cholesterol, and overweight and obesity (Institute for Health Metrics and Evaluation 2015). Diet quality has an impact on communicable and non-communicable diseases, mental health, and disease risk across at all ages.

Transitions in the nutritional landscape have been noted in many countries concurrently experiencing urbanisation (Kosulwat 2002; Galal 2006; Albala et al. 2002; Shetty 2002). Everywhere, cities affect food security because they are the environments in which residents obtain foods regardless of the overall extent of urbanisation. In the USA, research suggests that neighbourhood residents who have better access to supermarkets and limited access to convenience stores tend to have healthier diets and lower levels of obesity (Larson et al. 2009). Even in developed countries, food insecurity may be prevalent in disadvantaged urban neighbourhoods (Ramsey et al. 2012).

The urbanisation process itself may also lead to shifts in diet as evidenced by rural–urban differences in countries undergoing rapid urbanisation. There are mixed results from studies looking at the impact of urbanisation on diets; urban environments are associated with both positive (e.g. higher fruit and vegetable intake) and negative (e.g. lower fibre intake) dietary behaviours (Bowen et al. 2011; Mayén et al. 2014). Differences in dietary intakes and obesity rates in rural versus urban areas are also observed in children and adolescents (Cui and Dibley 2012; Justo et al. 2012; Aounallah-Skhiri et al. 2008; Ochola and Masibo 2014). Disentangling the impact of urbanisation compared to other societal changes such as increasing incomes is difficult; observed associations between urbanisation and diets do not provide sufficient evidence to conclude a causal relationship.

Regardless of their direct impacts on diet, urban environments clearly have the potential to implement strategies to help improve the food security of their citizens. In the UK, local government policy options include limiting the development of (new) hot food takeaways using local planning policy, and requiring fast food vans to provide healthy product choices as a condition of a license to trade (Mitchell et al. 2011). However, there are limits to the power of cities, as was demonstrated in New York when Mayor Michael Bloomberg was unsuccessful in implementing a sugary drinks portion cap rule owing to the proposed measures exceeding the scope of the relevant regulatory authority (Renwick 2013).

Food security can be promoted in cities but requires an understanding of context-specific environmental variables that influence dietary choices. In the UK, the majority of food is purchased in supermarket chains (Office for National Statistics 2015) and the average distance to the nearest store is around 2 miles (Future Foundation 2007). In the UK, the number and overall healthfulness (e.g. number of healthy options available, placement of healthy foods) of stores do not appear to have an association with neighbourhood deprivation (Black et al. 2013; Macdonald et al. 2009) but there is evidence of greater prevalence of takeaway food outlets in deprived areas (Maguire et al. 2015). In contrast, the US-based evidence suggests there are considerable neighbourhood disparities in access to food (Larson et al. 2009) and that supermarkets closer to disadvantaged populations stock fewer healthful foods (Cannuscio et al. 2013). Effective interventions will differ in these two contexts as the threats to food security, particularly the food security of low-income populations, are different. The dietary needs of the population in question must also be considered: for instance, reducing salt in areas with high consumption and hypertension rates, and increasing fruit and vegetable consumption in areas with considerable micronutrient deficiencies.

Urban sack gardening provides an example of an intervention for addressing food security in the urban slum context (Fig. 3). Globally, estimates suggest that nearly 900 million people reside in slums, without adequate access to food, shelter, water, and sanitation (World Health Organization 2010b). The urban poor in rapidly

Fig. 3 The advocacy project by Christy Gillmore. Used under license (CC BY-NC-SA 2.0)

urbanising countries may be particularly vulnerable to food insecurity due to their reliance on the market to acquire foods (Cohen and Garrett 2009). Urban sack gardening is practised in most Kenyan cities and others around the world (Gallaher 2015), and we draw specifically on evidence from the Kibera slum in Nairobi for this case study.

Nairobi's current population is the result of rapid urbanisation, and the (census) population increased from 350,000 in 1962 to 3,375,000 in 2009 (Survey 2014). The Kibera slum is the largest informal settlement in Nairobi and has a population of approximately 200,000 (Desgroppes and Taupin 2011). These population estimates, based on GIS and survey data, suggest the population is considerably smaller than previous estimates of up to 1 million that ranked Kibera as one of the world's biggest slums. More than three-quarters of households in Kibera live below the poverty line (Gulyani and Talukdar 2010) and 85% of households across Nairobi slums experience mild to severe food insecurity during "normal" times, and this situation is worse during acute crises (Kimani-Murage et al. 2014).

Sack gardening involves farmers planting crops into large sacks of soil. The sacks are placed wherever space can be found within the slum, and this may be directly outside homes or in communal areas. Holes are pierced into sides of the sacks enabling plants to be grown from the sides of the sack, in addition to the tops. This allows farmers to grow 20–40 plants in a single sack, considerably more plants than would be possible to grow on an equivalent patch of land without vertical gardening (Gallaher 2015). This is important given that there is typically little space in slum environments to practise other forms of urban agriculture. Plants grown include kale, Swiss chard, green onions, coriander, tomatoes, and varieties of squashes and pumpkins harvested for their leaves (Gallaher 2015). This practice has become increasingly popular in Kibera due to support from Solidarites, a French humanitarian organisation, following post-election violence in 2008. Solidarites provided technical advice and free seedlings to farmers with the aim of improving food security between 2008 and 2012, and the practice has continued since the Solidarites programme ended. Several thousand households in Kibera are currently thought to practise some form of sack gardening (Gallaher 2015; Gallaher et al. 2013).

Interviews with residents of the Kibera slums suggest that sack gardening has directly contributed to household food security (Gallaher et al. 2013). Sack gardening is positively associated with the diversity of vegetables consumed by a household (Gallaher et al. 2013). 87% of (sack gardening) farmers stated that the practice meant they saved money for purchase of other types of foods, and 88% felt that their gardens provided them with extra food (Gallaher et al. 2013). Sack gardening has also resulted in an increase in social capital and therefore has an additional, indirect, impact on food security (Gallaher et al. 2013).

Despite sack gardening taking up less space than other forms of urban agriculture, finding adequate space remains a major challenge for Kibera sack farmers (Gallaher 2015). This lack of space has led to some sacks being placed in potentially unsanitary locations such as next to latrines or sewage drainage ditches (Gallaher 2015). Additional challenges noted by sack farmers were the difficulty and illegal nature of procuring soil (usually “stolen” from public land) and obtaining water for irrigation in the dry season. Whilst most of the initial seeds and seedlings for the sack gardens were provided by Solidarites, anecdotal evidence demonstrates that farmers have begun to plant offshoots from existing plants in addition to purchasing seeds from local markets (Gallaher 2015). This suggests that the intervention may be sustainable without external (humanitarian) funding, but long-term monitoring and evaluation is required for this to be established given the barriers outlines by current urban farmers. Urban sack gardening is unlikely to be sufficient to completely meet the food needs of Kibera from a calorie and micronutrient perspective. However, the Kibera sack gardening case study demonstrates that local strategies in slum environments do have the potential to improve food security for the urban poor in rapidly urbanising settings, given the right support.

Increased uptake of urban food production strategies may be required to ensure food security globally in a world with a declining ratio of food producers to food consumers. Cities will need to address food security for their citizens, but the impacts of urbanisation on the whole food system cannot be ignored. Food security is an issue facing the whole of humanity, and one where policies in urban centres have a major impact on the health and well-being of their citizens.

4 Conclusion

Encouraging healthy urban environments is crucial to improving human well-being, as a large and growing proportion of the global population now reside in cities. The health impacts (positive or negative) of urban environments can be arranged along a continuum: at one end, cities directly cause health problems and create opportunities for health; at the other, cities have no direct impact but are the key setting in which universal health needs must now be met.

The healthiness of a city is more than a sum of the health of its citizens. Healthy cities are those that promote and consider health in their policies, and that actively strive to improve the mental, physical and social health of their citizens. The healthiness of a city can be judged by the processes and strategies that a city uses to improve health, not just by measuring the health status of the population. The WHO Europe Healthy Cities Network provides a framework that allows member cities to share their experiences of interventions and collectively build best practice. Regional and national networks such as the WHO Europe Healthy Cities Network are valuable, but they need to be inclusive if they are to have sufficient reach and a noticeable and sustained positive health impact.

In this chapter, we have used physical inactivity and food security as examples of major health issues that lie at different points along the continuum of health impacts that cities can have. Low physical activity is the ninth leading risk factor for death worldwide and contributes to high body mass index which is ranked fifth (Institute for Health Metrics and Evaluation 2015). Dietary factors are ranked as the leading risk factor for deaths worldwide (Institute for Health Metrics and Evaluation 2015). The section on physical activity demonstrates that cities have direct impacts on health, and that city-level interventions can lead to positive health impacts that can counteract some of the negative impacts of urbanisation. In addition, the synergy between increasing physical activity and sustainable transport demonstrates that meeting health goals can have positive impacts beyond health, such as in promoting environmental sustainability and addressing inequalities. It is important to note that the urbanisation process can also have decidedly positive direct impacts on health. Many healthcare services are easier and more efficient to deliver in urban environments as a direct impact of large numbers of individuals living in close proximity to one another.

The section on food security illustrates a fundamental health issue that needs to be addressed in urban environments. Cities are the environment in which a growing majority of individuals interact with the most fundamental aspects of human existence, such as the need for food, water, and other resources. The fundamental nature of issues at this end of the continuum does not mean that solutions are universal or easily transferable. Context-specific knowledge of challenges and solutions needs to be gathered and used in improving well-being in different urban settings. The urbanisation process also has inevitable impacts on global networks, such as the food system, thus influencing the well-being of those outside the urban environment. The health impacts of cities are clearly not restricted merely to city dwellers and therefore the impacts of urbanisation cannot be addressed by cities alone; cultures and trade patterns will need to adapt to this global phenomenon.

Other chapters in this book also deal with issues relevant to health and well-being in urban settings. For example, 10% of global deaths have been attributed to air pollution (Institute for Health Metrics and Evaluation 2015) and improved sanitation is vital to continuing to address the burden of waterborne and other infectious diseases as highlighted in the Water in chapter. Policies for addressing these challenges, whilst considering health and well-being, offer the best mechanism for moving towards health cities.

Urbanisation presents both challenges and opportunities for human health and well-being. Cities should strive to understand their impacts and actively work towards improving them, regardless of whether they are specific to cities or more fundamental in nature. With an understanding of their impact, cities should consider health and well-being in planning and policy and promote the health of their populace, partly by building on good practice from similar contexts. However, cities cannot influence health alone, and national and international strategies that acknowledge the impact of urbanisation are necessary.

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A Place for Food Within Sustainable Urban Masterplanning

Bee Farrell

The production, transportation, consumption and waste of food has been a "puzzling omission" in urban masterplanning (American Planning Association, introduction, 2007). The need to provide enough food for a growing urban population, which safeguards finite resources and respects the environment, is an urgent challenge. This chapter considers past and present consequences of food security solutions and advocates reflective and critical planning which recognises the fusion of historical food and ecological know-how, locally based knowledge and contemporary technology. This approach offers "locally embedded *and* globally attuned" multi-scalar food practices for a sustainable urban future (Morgan 2009, 347). Urban masterplanners—working as part of interdisciplinary teams—can powerfully contribute creative and intelligent planning and design solutions for a sustainable and fair food future.

1 Why Food Matters to Sustainable Urban Masterplanning

Food is fundamental, a biological necessity which can give social and economic sustenance. Mention food and we all have something to say. As urban dwellers living in established industrial countries we can enthuse about a favourite restaurant

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and then maybe in the next conversation debate food shortages in Chad, Africa, or question the 2013 meat adulteration scandal.[1] This range of possible responses highlights the multi-layered relationship we have with food. Foodways consultant Millie Rahn believes, "we eat what we are" so what are we? (Rahn 2015, 374).

As of 2009, the Food and Agricultural Organization (FAO) of the United Nations (UN) confirmed we are all predominately urban dwellers (FAO 2009a, b, 8). We manage concurrent multi-scalar lives of local, regional, national and international, within a trans-global web of digital and transportation interconnectivity. Yet we live in closer proximity to our neighbours than ever before. It is a context destined to increase as we move towards the nine billion population projection of 2050. This urban existence presents challenges and also offers opportunities to live more sustainably—if it also supports responsible rural and urban[2] farming. Although possibly counter-intuitive, urban living is greener than rural living:

> New Yorkers individually drive, pollute, consume, and throw away much less than do the average residents of the surrounding suburbs, exurbs, small towns and farms, because the tightly circumscribed space in which they live creates efficiencies and reduces the possibility for reckless consumption. (Owen 2010, 8)

So, if urban places are more likely to sustainably meet our fundamental biological, social and economic necessities and needs and our environmental responsibilities, then our intake and output of food and food-related waste is entrenched in this "tightly circumscribed space". Healthy, affordable and environmentally responsible food is key to healthful and secure urban places and food security. The fact that it has been a "puzzling omission" within planning indicates that we have not seriously thought beyond our favourite restaurant conversation (American Planning Association 2016).

Until food is seen as an issue of sustainability rather than trade, it will remain a commodity which depletes resources and widens inequalities. And if it is the "end of cheap nature", we need to respect, replenish and wisely utilise finite resources (Moore 2015, 285). For over forty years, the environmental activist and farmer Wendell Berry has held a belief that "urban people have agricultural responsibilities that they should try to meet" (Berry 2002). Evidence of this responsibility is emerging, yet it needs to be developed further by the creative and lateral thinking of planners, architects, developers, mayors and urban dwellers. The commitment of these individuals and groups set within organisations, businesses and civic society can ensure that urban dwellers eat "good, clean and fair" food (Petrini 2005). An aim which is the key to quality of life and sustainability on a global scale.

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[1]Chad is one of the world's hungriest countries as measured on the International Food Policy Research Institute Global Hunger Map 2015. The 2013 meat adulteration scandal was a scandal in Europe; foods advertised as containing beef were found to contain undeclared or improperly declared horse meat and other meats such as pork.

[2]Urban farming relates to the new spatial geometry of urbanisation and sustainable settlements in which the city and the countryside are considered as one space.

Firstly I endeavour to present why food is central to sustainable urban planning. By considering sustainable urban masterplanning—which incorporates urban design, landscaping, infrastructure, service provision, circulation, land use and buildings—in terms of challenges and solutions, some equations can be considered. Challenges to economies, health and security are not only a modern concern. Throughout history, our relationship with food has been a constant juggle of finding solutions and making decisions to solve the challenges of food provision. As with many aspects of our modern lives, the consequences of past decisions and behaviour are what we are living with today. Solutions made today need to be reflective, forward thinking and ecologically biased. A happenstance attitude to sustainable urban food planning is not an option any more, it never should have been, but "food production evolved as a by-product of decisions made without awareness of their consequences" (Diamond 1997, 106). Contemporary challenges such as climate change, migration or a world of finite resources are extreme and complex. A reflective-predictive approach offers solutions which are based on comprehensive thinking and green ingenuity.

The second part of the chapter will describe a case study of applied anthropological research at Farrells, an international architectural masterplanners. The commissioned research had two phases. A cross disciplinary investigation into the internal and external influences on food in urban planning design, such as British governmental health objectives or the inclusion of interdisciplinary thinking in design formed the basis of the research. Subsequent research into exemplar global urban sustainability initiatives, such as the UN Sustainable Development Goals, was also referenced in the initial investigation.[3] The thoroughness of the two research phases enabled the design of a comprehensive sustainable food framework that assessed the role of food in planning and design within the company's 40-year portfolio of projects. The "Food and Water" framework links to their five additional and integrated "Adaptive Community" frameworks of Healthy Places, Heritage, Economy and Technology, Sustainable Places and Knowledge and Partnerships.[4]

The research recognised that food anthropology is increasingly valid in urban masterplanning. It considers the interplay and impact of the sociocultural effects on the built environment, the value of the natural environment and the complexities of sustainable urban food. I will present some of Farrells' exemplar projects and also some international examples from other masterplanners, architects, designers, policy makers and urban food producers to demonstrate that sustainable food—urban and rural—makes good sense for business, the environment and for our health.

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[3]http://www.un.org/sustainabledevelopment/sustainable-development-goals/.

[4]http://farrells.com/media/175132/key-principles-for-adaptive-communities.pdf.

2 Looking Back: Challenges, Solutions and Consequences

Some environmental scientists consider we were Anthropos from the moment we began farming for food over 5000 years ago. Others deem that the industrial food and farming systems of the mid-1800s marked the point in which the epoch of the Anthropocene[5] began:

> Triggering a range of profound impacts which include the rising global temperatures, a transformation of erosion and depositation patterns, acidification of the oceans and changes to the carbon cycle. (Crane 2010, 213)

Regardless who is right about when the Anthropocene epoch truly started, what is clear is that since we moved from hunter gatherer to farmer we have been consuming natural resources with little consideration of the free gift of nature or for the long-term health of the planet. The distancification of food and farming from the general populace has a very long history that has—amongst other features—enabled the creation of surplus food. This managed overabundance has contributed to the commodification of food and the long food chains characteristic of the transnational food systems of the past 60 years. For some of us, the benefits have been cheap, plentiful and a diverse range of food. But this system has also been full of nutritional and economic imbalances, social injustices, health scares and environmental costs. Anthropologist Robert B. Albitron recognises some of the consequences of a food system in which newly industrialised countries essentially overfeed established industrialised countries as he states that "we live in a world capable in principle of providing a diverse healthy diet for all, yet one quarter of its people suffer from frequent hunger and ill-health" (Albritton [2010] 2013, 342).

To counter the inequalities of transnational food systems and address the need for environmental stewardship, there has been stabilising work done by many including *Fairtrade International,* the organic food movement, *The Soil Association*, the *Slow Food Movement* and *Friends of the Earth.*[6] But their environmental and socially just work has been overshadowed by large-scale farming, mass food production and transnational food chains with unsustainable and illogical equations. Equations such as the "need to reduce agriculture's impact on the environment and natural resources" yet seemingly unstoppable industrial agriculture as it "continues to expand, and is the dominant driver of tropical deforestation, the conversion of carbon-rich peat lands, and associated impacts on biodiversity" (Searchinger et al. 2013, 1).

We are now at a time when the gifts of nature are no longer a given. Recognition of the need to live harmoniously with nature and respect its omnipotence was described as "If man walks in nature's midst, then he is nature's guest and must learn to behave as a well-brought up guest" (Hunderwasser cited in Restany 2001,

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[5]The proposed epoch which is defined by the impact that humans are having upon ecological systems.

[6]Third sector international organisations which work to address inequalities and environmental degradation.

270). It follows that a sustainable and socially just food future needs to actively respect the health of the environment. This needs to work on multiple scales—local to global—rural to city region and urban—newly industrialised country to industrially established country—and marine to coast and land. In the case of food and sustainable urban living:

> Where society and nature can interact and co-evolve in a truly ecological fashion, a vision that is indispensable to a food planning movement that aspires to be locally-embedded *and* globally attuned. (Morgan 2009, 347)

3 Garden Cities of Tomorrow and Urban Agriculture Today

Morgan describes our evolving multi-scalar ecological position as local *and* global thinking, endorsed by many as profoundly important to sustainable living:

> In studies of climate change issues, at least, it is clear that some of the driving forces operate on a global scale, while many of the phenomena that underlie environmental processes operate at a local scale. (Wilbanks 2013, 31)

Ebenezer Howard's vision advocated the need to make places which encouraged local social connectivity, value food chains *and* had potential as a national and international design model. His Garden City vision required 60% of the available land to be set aside for food production surrounding the planned new settlements, to be controlled by a trust as community land. This element of his visions was not achieved in the UK *Garden Cities,* and, therefore, he could not demonstrate whether the planned self-sufficiency in food could be achieved.

Young and Smart (2014) explain how new thinking on local food creates an opportunity for a call to action and a vision of future planning for local food. They re-evaluated the neglected importance, in Howard's original vision of the Garden City (Fig. 1), of the land which surrounds settlements that can be used for local food production. The Food and Agriculture Organization of the UN (FAO) and others also refer to this potential food-growing land in terms of "City Region Food Systems" (CRFS).[7]

At the Farrells Forum symposium "Shortening the Food Chain-Re-integrating Food into the City", Gary Young presented their idea and discussed some important questions.[8] How much land does it take to grow food for an individual? How can this be calibrated taking into account varied locations both urban and rural? Their design proposition looked at the achievability of urban food self-sufficiency, scaled up to a community level, when backed by socially sustainable groups such as food hubs (Fig. 2).

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[7]http://cityregionfoodsystems.org/partners/.

[8]A Farrells' Forum sustainable urban food symposium which was given to an interdisciplinary audience of industry partners.

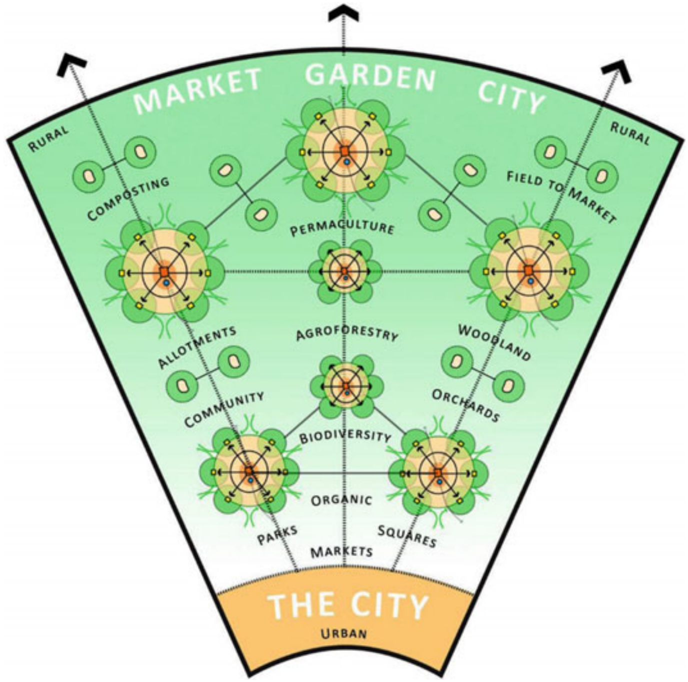

Fig. 1 Market Garden City, Young and Smart (2014)

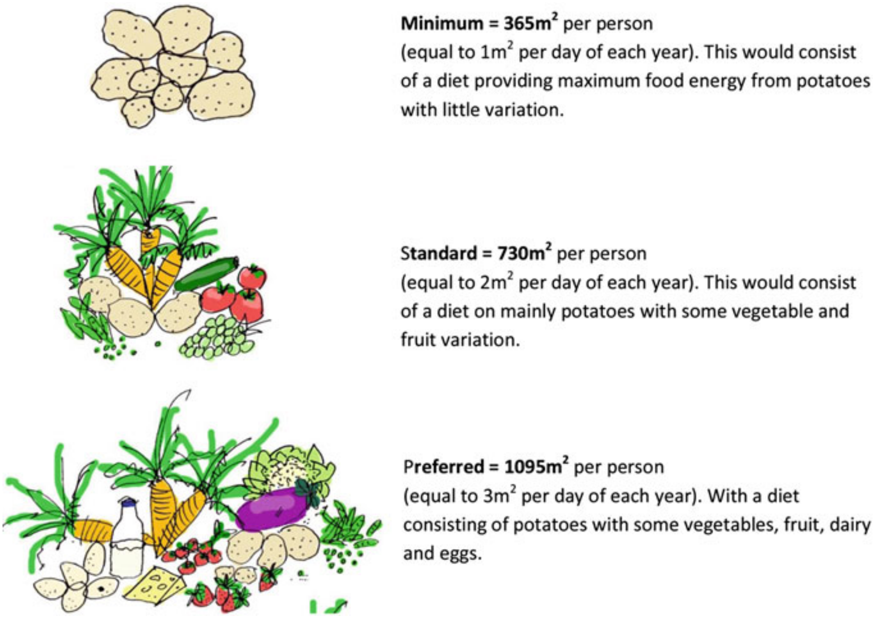

Fig. 2 How much land does it take? Young and Smart (2014)

The recent history of the urban agriculture movement echoes Howard's design work and is a practical and creative way of bringing the countryside to the city. Opportunistic projects that use "meanwhile" or unused land and empty spaces—including walls and roofs—have shown that growing food in cities has many benefits for the urban dweller. Socially and economically, it is acknowledged that there are advantages to growing, cooking and eating together. A food value chain rather than a long food chain increases the amount and quality of available fresh urban food, promotes healthy activity and social cohesion and decreases urban temperatures—reduces urban heat islands—by greening rooftops, walls and unused spaces.

> We are now talking about urban agriculture in new terms, as something strategic and infrastructural: the question is how a significant amount of urban agriculture can be reintegrated into cities. (Viljoen 2011, 9)

The important vision of cities and towns providing food for their inhabitants is exciting and echoes the Transition Initiative,[9] an environmental charity that promotes "food feet, not food miles" and advocates replacing urban ornamental plants with food-producing bushes and trees and encouraging community gardens (Lim 2014, 365). However, there are insistent challenges to urban food self-sufficiency. These relate to physical, cultural and economic urban contexts. Is there enough land, time, skills and motivation for urban dwellers to eat and thrive on their edible landscape? Gary Young believes that:

> Even with most optimistic expectations using aquaculture, vertical growing and rooftop farms an almost implausibly large part of London's land area would be needed for food self-sufficiency. This would require a major shift in emphasis of city planning. For some this is an exciting prospect, however the challenges of capital city planning are extensive and need a balanced and holistic approach including re-establishing links for local food production from the wider surrounding areas. (Young 2016)

Land tenure in cities is a major challenge to urban agriculture, culturally and spatially. Some may believe that land for homes is more important than urban land for growing fruit and vegetables, but there are some inspiring and effective solutions which creatively give city dwellers both homes and urban agriculture—and a multitude of other benefits such as greening the city to lower temperatures—challenging heat islands—or rejuvenating "meanwhile" land before it is developed or supporting local enterprise. Sometimes, these can be long-term activity such as the Edible Campus at McGill University in Montreal, Canada (Fig. 3) or short term such as guerrilla gardening (Fig. 4) or interventions such as "Pavements for the People".[10]

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[9]A UK-based project which works towards resilience against peak oil, economic instability and climate change.

[10]http://popupcity.net/pavements-for-the-people.

Fig. 3 McGill Edible Campus, Montreal, Canada, Sarah (2016)

Fig. 4 Guerrilla gardening with sunflowers, Rue Lesbroussart, Brussels, Brusselsfarmer2 (2016)

4 The "Tangled Bank" of Sustainable Urban Food Solutions

Terry Farrell's city-making approach endorses Darwin's ecological philosophy of biodiversity ensuring health to the environment. Farrell believes that nature's web of patterns and rhythms are a valuable model for creative and pragmatic urban design. Urban agriculture models are a vital element of sustainable urban food planning. The tangled web of elements that contribute to sustainable urban food model (Fig. 5) chimes with Farrell's interwoven and holistic city-making design.

A "locally aware *and* globally attuned" model of food production, transportation and consumption challenges the presently dominant transnational transport systems of air and road to feed urban dwellers (Morgan 2009, 347). And if closed-loop systems are embedded in all aspects of the production and waste of food systems, urban sustainability becomes an exciting and creative design and technological opportunity. One example of closed-loop food and waste thinking is exemplified by the Kenyan *biocentres* which are fulfilling two major urban challenges (Fig. 6). They are cleaning up the open sewers of the streets in Kibera, a suburb of Nairobi, Kenya, and the methane from their human faeces is converted into biogas, which can be used for cooking and lighting.[11]

Another example is an innovation proposal in the Netherlands called *Agroparks* which "cluster agricultural functions, including plant and animal production and processing, with other activities to create closed-loop systems that conserve resources and water flows" (Gorgolewski et al. 2011, 54). However, this solution could be problematic as scaling up to meet needs would always be omnipresent, such a solution may continue the disconnection of urban dweller from their food and food responsibilities and large-scale transportation, storage and distribution systems are still required (Donkers 2016, 26).

London, Paris, Berlin and Rome give an insight into how food shaped cities through trade routes, street food, market places and the valuable use of human faecal waste or "night soil". Many of these urban practices worked well, not as distinct food systems but as city systems embedded into the interconnected ways and means of living with how we eat, and the food and human waste we produce. Food and waste existing, entering and exiting cities and towns very visibly, acknowledged as a part of life. A past life in which "The presence of food in cities once caused chaos, but it was a necessary chaos, as much part of life as sleeping and breathing" (Steel 2008, 120). There are twenty-first century global examples of vibrant city food market halls which have fused a city's historical food identity with modern metanarratives of tourism, transport and multiculturalism—such as Borough Market in London, UK, Mercardo de la Esperanza, Santander, Spain or Markthalle Neun, Berlin, Germany. Food market halls are models of city regional food being made available to city dwellers promoting community and individual

[11]Practical partnership action by Kenyan Trust *Umande* with British charity *Practical Action*.

Fig. 5 Multidimensional sustainable urban food proposal (sketch), Bee Farrell (2015)

Fig. 6 Biogas plant construction, Gachoire Girls' High School, Kenya, Secretariat (2016)

benefits to health and economy—providing a blueprint for contemporary urban planning and design.

5 There is No Such Thing as a Free Lunch

The ancient use of human faecal waste as part of a closed-loop system was re-invigorated in the eighteenth century in Paris and Berlin "reintegrating man with his waste" (Reid 1991, 65). Sewage farming was felt to have great potential to a city, enabling the "basis of a society of independent communities of peasant farmers living in a symbiotic relationship with the city" (Reid 1991, 68). However, this developed into the late eighteenth century unsustainable model—the sewage works—wasteful and unsustainable because "1% of wastewater is human waste. The rest is wasted water" (Dring 2015). There are some promising contemporary global examples of the sustainable thinking and action related to food and human waste using biogas and aerobic digesters as the previously mentioned example in Kenya. Many other cities such as Munich, Philadelphia, New York and Toronto are also closing the loop for human and animal faecal matter (from urban farms and zoos) and waste food to successfully produce methane from anaerobic digesters and develop biogas production systems.[12]

Environmental and health experts such as Friends of The Earth and the UN are strongly urging us to eat less meat. Although some heed this urgent recommendation, many more carry on eating the most unsustainable part of our diet. The consequences of the world predominately eating industrially farmed meat and dairy products are that the grazing land which is needed equates to 26% of global ice-free land. Livestock producing our protein in this way also produces 18% of global greenhouse emissions—measured in CO_2 equivalent. Ultimately a meat and dairy-filled diet needs more crops and water than we can sustainably provide (Steinfeld et al. 2006).

> The environmental impact per unit of livestock production must be cut in half, just to avoid increasing the level of damage beyond its present level. (Steinfeld et al. 2006, 22)

Do we all need to become vegetarians to save the planet? Many believe so—but many more are advocating that we eat less meat and what we do eat has ethical and environmental credentials. Alternative forms of protein are being promoted by the United Nations in the "International Year of Pulses",[13] and there is also a rethinking of how meat can be more sustainably grown—such as a return to using food waste to feed animals—a practice now actively happening in Japan and USA and strongly

[12] http://cleantechnica.com/?s=bio+gas.

[13] http://www.fao.org/pulses-2016/en/.

Fig. 7 Backyard aquaponics, Silicon Valley, California, Boullosa (2016)

advocated by the UK environmental charity Sustain and *The Pig Idea.*[14] It makes so much more sense to use food waste to feed animals rather than grow crops to feed animals to then feed us. There are other approaches and new technology which can also provide healthy and environmentally responsible animal protein. Some of these solutions are actively emerging as predominately urban-based farms that use aquaponics (Fig. 7) to produce edible greens and fish, vertical farms for pork and/or edible greens and protein-supplying insect or guinea pig farms. The fusion of technological know-how and traditional small-scale urban farming offers a food value chain to urban dwellers with a smaller carbon footprint—and benefits for the local economy, more sustainable protein sources and community activity—than large-scale industrial farming. Lim describes the closed-loop food-production technology of aquaponics as:

[14]https://www.sustainweb.org/foodwaste/the_pig_idea/.
"The most efficient thing to do with food waste is to feed it directly to pigs. Instead we have a hugely inefficient system where pigs are being fed food that humans could otherwise eat.

> Eliminating the need for soil and using fish to feed the plants, aquaponics farming also eliminates the need for chemical fertilisers, agrochemicals and pesticides. (Lim 2014, 109)

There are many successful case studies of sustainable food production and consumption within urban food initiatives throughout the world. Each ingenious and successful example is place and climate specific, yet can also offer far-reaching relevant inspiration for urban planning, design and practice. Place specificity relates to climatic and cultural characteristics. Rainfall, irrigation, temperature and soil type all require a different approach, as does the deep-rooted range of cultural food behaviours of different places.

6 Urban Food Waste

Supermarkets are a worldwide phenomenon with each country operating its unique dualism of supermarkets *and* independent food producers/traders. Global annual food waste from supermarkets is unsustainable and illogical. The FAO believe that "The food currently wasted in Europe could feed 200 million people" (FAO 2016a, b). If we did not waste so much food, we would not need to grow so much now and or in the future. Many argue that we actually grow enough food to feed everyone, but we waste it and—the finite resources that went into growing it—water, land and labour. The food thrown away from supermarkets, homes and public-eating places totals a global 1.3 billion tonnes of discarded *edible food* every year.[15] This unsustainable practice demands many changes including interdisciplinary design and planning solutions which support food value chains, sustainable land use and environmental stewardship.

> If only a quarter of the foods that are currently lost or wasted can be saved it will be enough to feed the 870 million people that are hungry in the world at this moment. (FAO, van Otterdijk 2016)

Supermarkets, strengthened by increasing worldwide legislation to challenge food waste, are beginning to take responsible action. Guided by organisations such as Wrap and individuals such as Parisian councillor Arash Derambarsh, this change is increasingly endorsed by consumers.[16] What has food waste got to do with urban planning? Two distinct things are the following: land use and climate change. Annual wasted and rotting food takes up 30% of agricultural land and produces 3.3G tonnes of carbon emissions, making it into the top third of carbon emission producers after America and China (FAO 2013).

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[15]United Nation's Save-Food programme www.save-food.org.

[16]WRAP is a UK-based non-profit team working to challenge circular economies and resource efficiency. Derambarsh is a Parisian councillor who activated new legislation to stop French supermarket food waste in 2015.

Urban masterplanners working in multidisciplinary teams—which include supermarkets, non-governmental organisations, global organisations, local government councillors, academia, businesses and consumers—can embed holistic sustainable design and infrastructure which supports environmentally responsible and fairer food, and a cleaner environment.

7 Knowledge Exchange for Sustainable Urban Food

In the twenty-first century knowledge exchange is enabling global and local goals to be discussed, understood and met. The digital information age is providing a platform for green and empowering opportunities to address issues of climate change, food equality, health and sustainable urban living on a grand and small scale. There are many global examples of integrated work which incorporates green infrastructure planning and green technology to ensure greater sustainability and security for food. The co-joining of sustainability with development may be questionable because formalised sustainability linked with development work may be a reflection of the values of industrially established countries. But if sustainable planning is place and culturally specific—it has sovereignty—then it can offer home-grown development to support healthier and more prosperous lives. Architects and designers *Snøhetta* are based in Norway and America. Projects are led by their philosophy which recognises and values the importance of place and cultural specificity:

> We know that with well-conceived design we can help things run more fluidly, improve people's well-being, and make life more enjoyable. Every project is a unique expression of the ethos of its users, climate, and context. (Snøhetta 2016)

Some of these numerous global cross-disciplinary examples of sustainable food development and knowledge are shared on the FAO digital platform "Food-For-Cities".[17] One example of the many daily connections being made is from an architectural student who is "researching [on] the city's urban agriculture for a mass housing design project… aimed to accommodate recent immigrants from rural areas of Peru, offering them the possibility of farming within a metropolitan context to create a self-sustained community" (Food-For-Cities member, 2016). Members of the platform reveal and share local and global knowledge—like the example of Lima, Peru—with new initiatives to use wastewater to irrigate city trees, tax benefits for food producers and the re-establishment of urban Lima farms.

Another example of holistic, effective and sustainable thinking and structuring is the holistic and environmental approach of the 2012 UK Town and Country Planning and Wildlife Trust (2012) which echoes the view that "Landscape as the first infrastructure" which makes healthier and more sustainable places

[17] http://www.fao.org/fcit/fcit-home/en/.

(Farrell 2004). This is coupled with a commitment to "place-making", in which the people and the history of a place and its community are valued and are instrumental to their creative and sustainable design.

> The many challenges that we now face to make our cities, where the majority of the population live, safe and healthy places mean that we will have to re-think the future of urban design to include more vegetation. (Farrell 1 2015)

In 2013, Farrells commissioned a two-year applied research project to update their sustainability work. This project began with a food and greening audit of all their UK-based projects. This led to an exhibition, panel presentation and a ten-point design initial framework, "Food and Greening" which was later adapted to "Food and Water". The framework was informed by The "Continual Productive Urban Landscape" framework by architects Viljoen and Bohn (2014) and other international resources including New York's *Food Works*,[18] Milan's *Nutrire Milano*[19] and London's *Capital Growth*[20] that each focus on sustainable agriculture and the provision of fair, clean and just food. The 10 determinants of the "Food and Greening" framework (below) are flexible enough for architects and masterplanners to interpret according to their specific projects, but also structured enough to give consistent and meaningful responses. Initially, they were predominantly used to review and assess past projects, but were incorporated into present and future design discussions and planning. The "Food and Greening" framework instigated a revision of Farrells' sustainability principles which developed into further research and design of Adaptive Communities (AC) framework. The AC review used its 60 determinants of six integrated strands of urban sustainability: Healthy Places, Heritage, Economy and Technology, Knowledge and Partnerships, Sustainable Places and Food and Water.

8 Food and Greening Framework

Places which give opportunities for healthy and sustainable diets;
Biodiverse planting;
Local food production;
Short food chains;
Incorporation of community food projects;
Promotion of sustainable food or farming knowledge and skills;
Support for food enterprises;
Closed-loop solutions for food and water waste;

[18] http://council.nyc.gov/downloads/pdf/foodworks1.pdf.
[19] http://imagislab.it/nutrire-milano-en.
[20] http://www.capitalgrowth.org/.

A future of sustained food supplies;
Rain and grey water harvesting.

The approach and framework is enmeshed with Farrells' urbiculture approach, and place-specific masterplanning to foster sustainability within their projects. Although food planning in design had played a strong philosophical and aesthetic role, Farrells felt that much of this work was not explicit internally within the practice or externally with clients, stakeholders or the public. The initial application of the "Food and Greening" framework to fourteen selected projects enabled a dialogue with the company's architects and planners that provided a catalyst for recognising sustainable urban food design in additional projects in their UK and HK offices.

There is existing research and planning activity in the distinct areas of food and greening, for example, local food production, shortening of food chains and bio-diverse planting, however this activity and approach was not always defined and made explicit beyond the realms of the project. The Farrells Forum exhibition brought together a significant selection of exemplar Farrells' projects—two of which are described and illustrated below—to showcase the work that is being done by the practice in this field. These projects highlight the importance of considering food—in all its contexts—urban greening and closed-loop water systems in how sustainable urban places are planned, designed and managed.

9 Farrells' Sustainable Urban Food Projects

Bicester is a historical market town with a long established relationship to the surrounding countryside. The NW Bicester site has been in continuous use for farming, from strip fields—evident in the archaeology survey of the earliest settlements—to the later enclosure of large fields for commercial arable and dairy pasture. Farrells felt it was important in their approach and design that the development retained and enhanced linkages to its past use for food production. The NW Bicester site aims to provide a community orchard, allotments with communal composting, community streets with herb boxes, barbecue areas and fruit trees in all private gardens for the residents of the first completed homes.

The consumption of local, fresh and seasonal sustainable food will be inspired by online cookery demonstrations using the "shimmy"—a smart broadband tablet in each home—and through local classes, food fairs and via the site's shops, eco pub and cafés with food from local, organic or Fairtrade sources. NW Bicester is a master plan for 6000 homes which is part of the Bicester Garden City planned urban extension for 13,000 new homes promoted by the Local Plan (Fig. 8). The green design by Farrells encompassed partnership work with BioRegional who created One Planet Living.[21] One of BioRegional manifesto goals is Sustainable

[21]http://nwbicester.co.uk/2012/11/north-west-bicester-awarded-one-planet-living-status/.

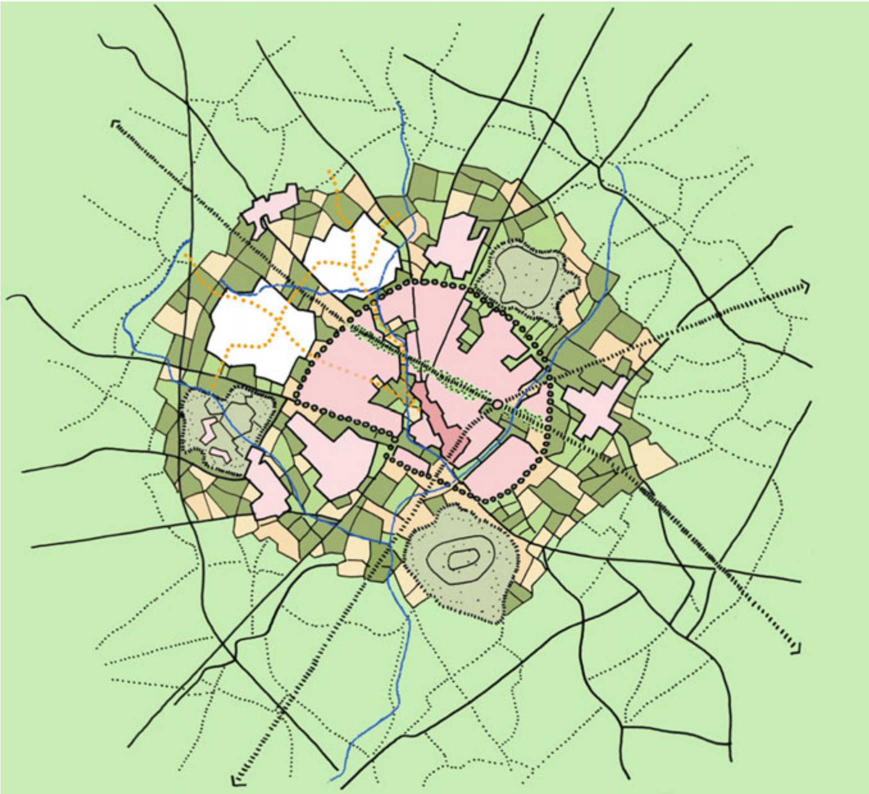

Fig. 8 NW Bicester fuses historical food patterns with Farrells' contemporary masterplanning design, Farrells (2009–2016)

Food, and they have endorsed NW Bicester with this status, one of only six projects in the world to achieve this at the time. It is an urban exemplar of green design and sustainable and healthy food, assessed using Farrells' initial "Food and Greening" determinants; it demonstrated that all of them were included in the design.

Over 40% of the NW Bicester site area is green infrastructure and so it will provide potential for wild fruit foraging in 25 km of existing hedgerows that are accessible within residential public open space and along a ten-kilometre green loop of leisure walks. The green infrastructure will also provide new natural habitats through a nature reserve, wetlands and country park to achieve net biodiversity gain and habitats supporting plants and insects, such as bees, which are crucial to the food chain.

London's St. Ermins Hotel is a refurbishment and additional wing and link building project with a load-bearing green roof for beehives—affectionately known as their B&B (Fig. 9). It has biodiverse planting and is a local food enterprise producing jars of local honey and employing a member of staff who collects and prepares the honey to be served in the hotel restaurant and who also runs

Fig. 9 St Ermin's Hotel beehives, Farrells' Focus exhibition panel (2010–2012)

bee-keeping workshops. St. Ermin's honey contributes to the local economy and also develops sustainable food knowledge and the skills needed to foster a food value chain. Using the "Food and Greening" framework, it achieved the following within design and build:

- Biodiverse planting;
- Local food production;
- Support for food enterprise;
- Promotion of sustainable food knowledge and skills.

The visibility and role of food in masterplanning and design is increasing on a worldwide basis, but there is still a tendency for it to be placed only under the umbrella of sustainability; it could logically also be part of urban design briefs of economic revitalisation, quality of life places to live and work, sustainable land use or transport infrastructure. There are many architects and masterplanners who are working in holistic and multidisciplinary ways designing places which are innovative and food biased, but there is still the traditional mind-set that it is not an approach which makes for good business or that it relates to the cities and megacities of the future. Many may view food planning in cities as designing a restaurant or food outlets as part of a master plan and that the ever-industrious and resourceful urban food "meanwhile" work will cater for the food production in

Fig. 10 Home Farm deck level, Spark Architects (2015)

cities. But this is not the case anymore—to feed a city needs a food bias in planning and design which looks at its production, transportation, storage, consumption and waste as a whole.

Examples of food embedded into design practice can be seen in architectural practices such as *Snøhetta* and their plans for a public food market hall in Portland Oregon, the *James Beard Public Market* in honour of the American chef and food educator. Their master plan includes multiple pedestrian access routes to the river, bridges and market, a teaching kitchen, a hydroponic roof, permanent and flexible food trade stands and eateries—an exemplar for embedding food into planning and design meeting all 10 of the "Food and Water" determinants. Another exemplar by Spark Architects and masterplanners recognises the interconnectedness of Green technology, health (mental and physical), community well-being, quality of life, the aging global population and provision of sustainable and secure food. Their conceptual proposal *Home Farm* won the 2015 World Architectural Festival "Future Experimental Project" prize, and its design has now been developed into exciting reality Home Farm Cyberjaya, Malaysia (Fig. 10):

> Home Farm brings together the normally siloed activities of commercial farming and aged care living. The commercial farming activity of Home Farm in part supports its resident community Residents are offered part-time employment on the farm, planting, harvesting, packing and selling farm produce.
>
> (Spark Architects 2015)

City design and urban living needs to be part of food and [rural] agriculture planning—these essential cross-disciplinary partnership collaborations can move food provision away from intensive and unsustainable industrial agriculture, and its long food chains and the distancification of the city dweller with their daily food. The UN—as well as many other environmental, health and education non-governmental organisations—believes that:

> There is an urgent need to ensure that cities are included on the agenda of food and agriculture policy makers, planners and institutions. Likewise, it is equally urgent to integrate food security and agriculture into the agenda of city planners and local urban authorities. (FAO 2016)

The impressive (opportunistic) work to date of urban food champions is a vital part of a sustainable (urban) food future in which masterplanners and architects who work as part of multidisciplinary teams—supported financially by stakeholders and/or governments—can reach the global and local UN food security goals.[22] The Chicago Metropolitan Agency for Planning (CMAP) is an example of integrated and coordinated city region planning which encompasses the culture, character and people of a place, the commitment from local government, infrastructural design by masterplanners, engineers, landscape architects and architects and the community-based activities which support quality of life for residents:

> A sustainable food system incorporates practices, policies, and operations that are beneficial to the three pillars of sustainability: the local, regional, and global economy; our land, water, and living resources; and our communities, including public health and our social connections to one another. (CMAP 2016)

Coordinated and multidisciplinary sustainable urban food planning and masterplanning design work responds to and relies on initiatives, resources, policy, community projects and place-specific thinking. Planning and policy strategies in American and Canadian city regions such as Vancouver, Baltimore, Seattle, Toronto and Marin county have developed resources and strategies which inform and influence the city planning and liveability. Baltimore sustainability plan[23] has resources such as food desert maps while Vancouver has developed a basis analysis of the city's food system.[24] Holistic planning which is food biased is happening all

[22]The steps in delivering safe nutritious food from the field to the urban consumer, the production, processing and marketing, are all interlinked and should mutually strengthen each other.

[23]Baltimore City, in collaboration with Johns Hopkins Center for a Livable Future (CLF), produced the 2015 Food Environment Map and Report to draw attention to food access patterns in Baltimore City's neighbourhoods and to assist with policy development and implementation.

[24]"By mapping Vancouver's select physical food assets and correlating them with population density, we can begin to gain a better picture of how access to food assets may vary across different parts of the city."

over the world—and there are increasing numbers of exciting and creative theoretical projects, but it has to be reality, the norm and not the exception with more commitment given—in terms of finance, training and time—to drive an urgent need to address our food security.

10 Conclusion

The challenging spectre of a Malthusian equation of a predicted 9.6 billion global population needing a 70% increase in food production but with a scarcity of land to grow upon is overshadowing creative and resource-efficient solutions (FAO 2009a, b). If the contemporary solution to complex challenges to sustainable and secure food is the intensification of farming and the continuing disconnection of urban dwellers from food production and waste, it will result in an increasingly unsustainable and unjust way of feeding ourselves. There are so many alternatives which, although obvious, are not mainstream because they demand a new way of believing and behaving like a well-brought up "guest of the nature." A well-fed guest at a global table will need to be ecologically and socially responsible as the UK champion for UK food security Benton (2016) states:

> How we change the food system for the better is the elephant in the room. Until we find a way, as a society, to value food, value our planet, and value ourselves better, business as usual will continue and the costs will grow.

Urban masterplanners can offer design solutions that create opportunities to support food value chains and healthy urban food—and challenge the "elephant in the room". Food in masterplanning includes design for planned urban agriculture *and* urban infrastructure which encompasses green technology with food and closed-loop waste-biased city living. The future of sustainable urban food is challenging but "to be an architect you have to be an optimist-to believe in a future that can be better" (Pimbley 2016). The solutions will have to be new, creative and ingenious, not a replicated enlargement of aforementioned unsustainable and wasteful food and farming systems. Enlightened and creative architects and urban masterplanners such as, Ameller, Dubois & Associés, Du Toit All Hillier, Farrells, Mithun Arhitects,[25] Producktif Studio,[26] Snøhetta, Spark and Young are all working in interdisciplinary teams with food planning embedded in city region design. This enlightened and exciting approach is key to urban—and rural—sustainability. Young believes that "food is a resource" and thus consequently it needs to be respected and replenished through green thinking, food planning, holistic design and urban living which is both reflective and far-reaching.

[25] http://mithun.com/.

[26] http://produktif.com/.

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Infrastructure, Equity and Urban Planning: A Just Process for the Allocation of Benefits and Burdens

Daniel Durrant

This chapter asks first what is infrastructure or more importantly infrastructures as the physical artefacts and technologies are inextricably intertwined with complex economic, social and ecological systems. This is central to the first dimension of equity considered, *distributional equity*. Infrastructures allocate different 'goods' spatially, and to population groups therefore to understand the impacts of infrastructures upon distributional equity it is important to understand what exactly they are and what goods they produce. Second, planning and the planning of infrastructures highlight the importance of *procedural equity* and equality of input into the process. The next section examines definitions of equity and their application to urban planning and urban infrastructure. This draws upon three philosophical analyses of the concept and ways in which it has been recently applied to develop principles that could reshape the way infrastructure is planned and provided. A framework is developed to illustrate the ways in which the planning of urban infrastructure might be used to establish more equitable outcomes. This is based upon a vertical axis along which procedural inputs influence the way the planning process allocates distributional outputs. These are distributed along a horizontal axis of *benefits* and *burdens* with the planning process used as a means of establishing minimum and maximum permissible thresholds. As the examples of infrastructure that has been planned and delivered specifically to address issues of social equity are few and far between, the chapter is interspersed with examples of where some dimensions have been addressed either explicitly or indirectly.

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1 Introduction

As a dimension of sustainability social equity is something of a hydra. Achieving equity in one area can see multiple inequalities rear their heads in others as urban infrastructure produces a multitude of potential inequalities planners must account for (Beatley 1988; Thomopoulos and Tight 2009). Furthermore, concepts of sustainability introduce additional dimensions with the need for equity between generations and even species. There is no one comprehensive solution, and different infrastructures affect equity in different ways, indeed no single definition works in all circumstances. Definitions are dependent upon the ethical framework adopted (Beatley 1988). This chapter considers four different ethical frameworks most relevant to equity in infrastructure critiquing the dominant utilitarian framework and then exploring the potential of Rawlsian, egalitarian and the Aristotelian capabilities theory. Appraising the consequences for social equity in government programs such as the funding of infrastructure projects is increasingly a legal duty (Legislation.gov.uk 2010) in the UK, with the need to identify and measure the impact on specific groups within society (Transport for London 2004) or upon different income groups (HM Treasury 2011). Yet as is often the case, it is the economic arguments and justifications that push their way to the fore. However, for some time now a paradigm shift has been underway. The modernist assumptions that the comprehensive, universal provision as the route to technological progress have 'splintered', in part due to the privatisation of, formally public infrastructure providers (Graham and Marvin 2001). Since the 1980s, the global trend in public policy has been towards infrastructure as an opportunity for private investment, often at the expense of its role in public provision, Britain's first Private Finance Initiative (PFI) funded infrastructure project, the controversial Skye Bridge, being a good example (see Monbiot 2004). However, new concepts are in the process of forming and new forms of infrastructure are called for (Brown 2014). The challenge in this case is in the first instance a conceptual shift that is far from complete. The overarching aim of this chapter is to illustrate the inadequacies of current conceptions of equity still influential in urban planning and the planning of urban infrastructure and to introduce the reader to alternatives. Much of this work cites developments in transport planning as this is one infrastructural system where the issues are visibly played out; however, concern with issues such as the 'digital divide' (van Dijk 2016) indicates concerns across a range of infrastructures. It is not taken as given that a low carbon future is also an equitable one. Consequently, what is called for is a clearly understood and expressed set of principles governing the planning and provision of urban infrastructure.

2 What is Infrastructure?

Most definitions of infrastructure take in the organisational as well as the physical nature of the concept. The term has been traced back to its origins in French railway planning first entering English usage via the military (Marshall 2015). Its etymology as the basis or underlying structure of a system points towards a dual role as something that both shapes and directs yet at the same time lacks complete visibility: 'something grey behind a chain-link fence' (Brand 2010). Yet in the transmission of goods, people, power and information over increasingly vast distances, it has formed the basis of an industrial and information revolution. It underpins a model of development supported by a financial ecosystem from the World Bank and the various development banks through to states and private investors seeking to capitalise on the benefits infrastructure investment has historically generated. It is a model that has produced huge aggregate benefits although the distribution of these benefits has been far from equal. Furthermore, the burdens have often fallen upon groups and environments least able to resist urbanisation and the extraction of resources (such as urban land) and, it appears increasingly, upon future generations.

At the extreme, the burdens imposed by infrastructure include the sequestration of land and the health consequences of externalities such as noise and air pollution. The former in contemporary societies is governed by some legal protections for landowners although historically it has not always been the case and groups such as tenants will often have fewer rights. Even today, where land use or rights are not protected or overridden by powerful interests, large infrastructure projects such as the Three Gorges Dam in China can be the cause of significant displacement of populations (Gellert and Lynch 2003). More immediate, albeit temporary, burdens such as noise, pollution, community severance can be imposed during the construction, operation and decommissioning of urban infrastructure (Fig. 1).

If the pressing issue of the inequality between generations and species is to be meaningfully addressed, then infrastructures and the planning of infrastructure must play a part in directing a shift from high to low carbon emissions and reducing resource consumption (Giddens 2011). It is beyond the scope of this chapter to comment on the feasibility of such a challenge; instead, it focuses on the question of whether it can be achieved in an equitable way. This is particularly relevant as people are lifted out of poverty and given access to basic infrastructure questions of equity become more rather than less important. The role played by the hard infrastructures that provide sanitation, power, transport and communication and the soft infrastructure that provide health, education and law and order has all been massively successful in raising the standards of living for the least well off in many parts of the world, China being the prime example. It has seen the most rapid rise in economic and social development of any major economy, lifting more than 800 million people out of poverty and achieving the Millennium Development Goals by 2015 (World Bank 2016). In some ways, China has followed a similar, albeit

Fig. 1 Acoustic barriers on the Tullamarine Freeway, Melbourne, Australia [*photograph* Atlantica, used under license (CC-BY-SA 3.0)]. For some burdens such as noise, there are engineering solutions available assuming sufficient mitigation costs are included in the initial project appraisal. Others such as the impact of automobile emissions and the particulate matter they produce on air quality may require policy action to limit certain vehicles and to encourage modal shift to less polluting forms of transport

accelerated, path to countries in the Global North. High levels of investment in infrastructure combine with economic development to produce widespread increases in the standard of living: a pattern common to other rapidly growing East Asian Economies such as Thailand and Vietnam (Asian Development Bank 2005). Whilst there is still much to do with infrastructure deficits plaguing the Global South, this model has been largely successful, up to a point. The 'environmental story' of East Asian infrastructure development, for example, is far less positive (ibid).

Arguably, this vision of technological progress, a vision underpinned by infrastructure, has reached its zenith as citizens are increasingly sceptical of the benefits (Beck 1992) and averse to the burdens imposed. As the consequences of a resource intensive, fossil fuel-based model of development are widely acknowledged to be unacceptable, the existing forms of infrastructure that underpin this model will have to adapt, adjust and, in some cases, switch to something new. In parallel to this shift is the rise of democracy, civil society and human rights, often enshrined in international law. This gives citizens who are asked to bear the costs of infrastructure increased opportunity to challenge that imposition. Furthermore, it affects the appetite of funders and investors to become involved in projects that may have demonstrable and unjustifiable consequences for social equity: just as they would for infrastructure that is environmentally destructive or fails to meet its economic or technical performance criteria.

Understanding the urban dimension of infrastructure is both revealing of what exactly infrastructure is and problematic as it confines the issues to a particular place. On the one hand, cities contain concentrations of wealth and poverty and so are ideal locations for attempts to narrow the gap between the two. Infrastructure can define cities with infrastructures providing power, heat and gas often originally provided at the municipal level, and in some of the Nordic countries, for example, municipal ownership is still common (Fig. 2). In the UK at least, many rural areas are not connected to either networks providing natural gas and waste water treatment; likewise, it is common for rural homes to rely on local water sources rather than being incorporated into the networks that serve urban areas. However, infrastructural networks also link rural and urban areas. Polluting and higher-risk coal and nuclear power generation have traditionally been sited away from cities but connected by transmission infrastructure to those areas where the power is required. Food and its provision through transport infrastructure have visibly shaped a city like London's urban form with wide roads enabling the flow of fresh meat 'on the hoof' into the city centre (Steel 2008). The way that infrastructure reflects this relationship between rural and urban helps to underline some of the challenges when this relationship is understood through the lens of social equity as, by definition, rural areas are where deficits, such as high speed broadband, persist even in the Global North.

It is important, however, to get beyond conceptions of infrastructures as purely physical artefacts. Given the focus of urban planning is on the allocation and

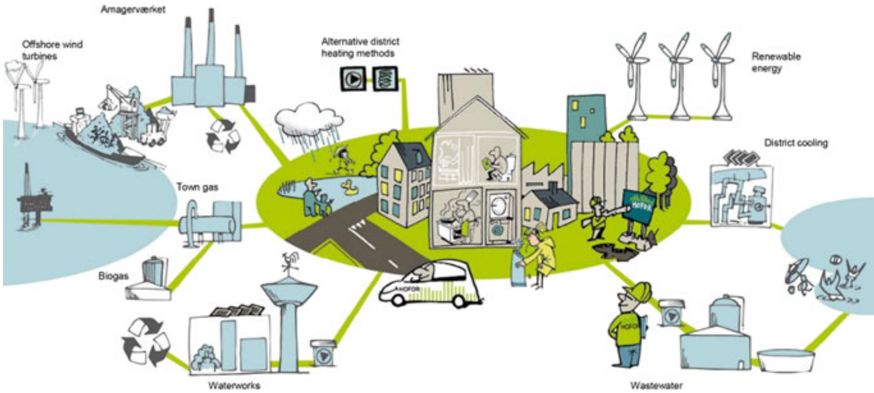

Fig. 2 Copenhagen's HOFOR utility company, an example of how municipal ownership is still common in the Nordic countries. Reproduced from HOFOR (2016)

governance of urban space, it is hardly surprising that the focus tends to be on the spatial manifestation of infrastructure. This is where it competes with other urban land uses and has an impact on the lives of urban citizens. Since Ebenezer Howard's vision of a planned community supported by its infrastructure, there has always been a utopian strand in urban planning that sees the organisation of space as the pursuit of some greater good. In Howard's plans, infrastructure was always hard (waterways and rail links) and soft (care homes and educational facilities). In a resource constrained world, there is increasing expectation that infrastructure is also multi-purpose. An example of this is the integration of transport and communications infrastructure or waste water and community facilities (Brown 2014) that has always occurred to an extent; however, the expectations of this are increasing given the resources new infrastructure consumes. As with physical functions, the integration of social infrastructures into the design of the physical artefacts adds to the overall value of the whole infrastructural system. Beyond this, in our information society infrastructures sit within infrastructures. Take, for example, micro-payment and trading systems that sit within and depend upon mobile telephony and Internet infrastructure. Furthermore, as the infrastructural dimensions of environmental systems are being acknowledged this broadens the definition of infrastructure further still.

There are good reasons for including social systems in any definition of infrastructure. They may be more flexible and adaptable, and in terms of equity they can go some way towards overcoming the limitations imposed by the physical structures. The way that the rail operators in the UK have systems to support disabled access to trains through ramps and human support may not be a perfect solution. It is second best when compared to the full disabled accessibility that is required for new infrastructure; however, it does enable some access to a system where the resources available for upgrading facilities are limited and progress is slow. Finally, what is in many ways more significant is the way that technologies, such as those employed in infrastructural systems sit within relatively stable socio-technical systems. These are known as 'regimes' (Rip and Kemp 1998) made up of structures and actors, legislation, public and private sector institutions, the skills and knowledge necessary to produce different technologies and crucially social norms and values. Rather than something that is external to social systems, infrastructural technologies can be seen to coevolve mutually shaping and being shaped by the socio-technical regimes of which they are a part. Technological transitions of the type required to shift to lower carbon forms of infrastructure can be brought about by internal or external pressures on these wider socio-technical regimes (Geels 2002). Pressure to change technologies can come from a wide variety of sources such as economic or demographic shifts and crucially, shifts in the norms and values of societies (Smith et al. 2005). Understanding infrastructures as more than just transport, communications or energy technologies are central to understanding how new infrastructural technologies coevolve to both produce and reflect societal shifts.

2.1 What Kind of Goods are Infrastructures?

There are three important generalisations that can be made in defining what infrastructures are and the type of benefits and burdens they distribute (Frischmann 2012). First, government is still heavily involved either funding, granting consent and regulation; often all three. Second, infrastructures tend to be, at least theoretically, open to everyone albeit often above a certain cost threshold. Third, there are considerable beneficial 'spillovers' that go beyond the individual users. It is these benefits that suggest the definition of merit goods in that they are deemed by society to be of sufficient value that they should be provided to all. The market alone is in many cases insufficient (this can be due to high levels of risk and sunk capital for large transport infrastructure or poor returns on high installation costs for broadband in rural and hard to serve urban areas such as older tower blocks); therefore, they may require some form of public provision or subsidy. This is particularly true of the infrastructures necessary to shift from high to lower carbon emitting forms of energy and transport in circumstances where markets favour the former. The concept of merit goods draws the allocation of resources into the equation as, if certain goods are to be actively provided rather than passively enabled, then the resources must be found and (re)distributed to ensure the desired level is achieved.

When considering distributional equity in relation to infrastructure, one should consider what is it that infrastructure provides or even what are the infrastructures that should be distributed equitably? For some, it may be a question of resources whilst for others it is the opportunities enabled by infrastructure that ought to be the focus of measures to increase equity. With infrastructure, the question of resources is ever present. Resources are required to construct new infrastructure, maintain the systems that enable existing infrastructures to function and also decommission or repurpose those that have become obsolete. The decision to allocate resources to one piece of infrastructure incurs opportunity costs as it may be at the expense of another infrastructural choice. Where the burdens of providing those resources (be that finance, land or human capital) fall is considered in some detail below. One final, often neglected, resource is trust. Given the allocation of resources is often 'up front' based on projected returns in the future, there is a need to maintain the trust of those who provide them, the public. This is trust that the projections are accurate that mitigation will be delivered and of a sufficient standard that the claimed benefits will actually materialise (Fig. 3). Given the depressing history of, particularly the larger (Flyvbjerg et al. 2003), infrastructure projects trust is a key resource that is often depleted.

What must also be considered is the benefits of infrastructure. These can be actual benefits such as rising land values or new transport links, and with basic infrastructures freedom from the risks of waterborne diseases and intermittent power supply. However, they can also be potential benefits such as those derived from mobility or access to communication technologies. Finally, it is also important to consider *when* the burdens of infrastructure are distributed. As technologies such as acoustic barriers and tunnel boring improve, even large infrastructures can

Fig. 3 Zakim Bridge, the 'Big Dig' [*photograph* Leigh Housholder, used under license (CC-BY 2.0)]. Altschuler and Luberoff (2003) describe the practice of inaccurate cost estimates for major infrastructure projects as a 'tragedy of the commons' that undermines faith in the project and government as a whole. An example of the type of project they cite is Boston's Central Artery Tunnel the 'Big Dig'. The project was highly controversial and marred by an overspend of 155% of the original cost estimate, a delay of three years combined with allegations of corruption, prosecutions for fraud and poor workmanship that saw a section of the ceiling collapse in 2006 killing a motorist (OMEGA Centre 2016)

almost disappear in terms of the burdens they impose upon the urban environment (Fig. 4). However, there are parts of the lifecycle, such as the construction phase, when there is still considerable potential for disruption even if in the long run the infrastructure improves equity overall. Ten years of construction may appear a small price to pay for a project with national benefits and a sixty-year projected lifespan. However, from an individual perspective this could mean the formative years of a child's life, primary through to tertiary education spent with increased noise and atmospheric pollution, reduced access to green space and elevated risks due to high volumes of construction traffic (Fig. 5).

Fig. 4 Some infrastructure can almost disappear or provide a colourful addition to the urban environment. Recycling and waste shoots in Hammarby Sjöstad (*Image* author's own)

Fig. 5 In contrast the renovation of Dutch mainline stations such as Rotterdam Station shown here causes major disruption for travellers and local residents (*Image* author's own)

Fig. 6 Landschaftspark Duisburg Nord an example of where planning visions and the reuse of the former industrial infrastructure of the Ruhr Valley has aligned [*photograph* Carsten, used under license (CC-BY-SA 3.0)]. See also Hall (2014)

2.2 *Planning and Infrastructure*

The term planning is used in its broadest sense here. Many infrastructures and infrastructure projects have their own, distinct planning and appraisal processes that both construct a justification for projects and concern the timing and allocation of resources necessary to move a specific piece of infrastructure from inception to operation. If a 'cradle to cradle' (Braungart and McDonough 2009) approach is taken, then also the decommissioning and reuse of this physical component of the infrastructural system (see Fig. 6). Ideally this should fit with plans concerning the allocation of urban space although unfortunately this is not always the case. Planning, like infrastructures, allocates burdens and benefits, and within this *process* there is considerable scope for inequalities. If the ultimate outputs are to be considered legitimate then there are good grounds for arguing that all those who stand to lose or gain have equal input into the process (Dewey 1927). This is more than a theoretical issue as failure to consult properly is an area where there is considerable scope for legal challenge. In a democracy, the requirement is generally for the opportunities to participate to be distributed equally or at the very least not closed off to some groups. For such a principle to be maintained, it is often the case that considerable additional effort must be made to ensure that excluded groups are given equal opportunity to participate (Planning Aid 2012).

One issue that is particularly acute in planning, and even more so in infrastructure planning, is the inequalities in the status allocated to different forms of information. The type of knowledge required such as planning, engineering and economics is all the product of years of specialist education and often professional accreditation. It is possible for those lacking such knowledge to purchase the skills of expert consultants, but often at a high price. The special status given to these forms of knowledge is often understandable, indeed necessary to protect public safety, yet it also poses problems when this form of expert knowledge, such as those used in the appraisal of infrastructure projects discussed in the following subsection, provides the *justification* for decision making. It can squeeze out or fail to acknowledge the value of 'local knowledge'[1] (Yanow 2003) about the consequences of infrastructure projects for those that must live with them. In addition to this, the risks of siloed approaches and individual disciplines defining problems and solutions from a single perspective are well known (Brown 2014) yet still persistent.

Opening up the 'black box' of infrastructure decision making is difficult to achieve in practice and may still be uncomfortable for some professionals. Access to information is an important issue with confidentiality and commercial sensitivity used to restrict the important knowledge generated by infrastructure projects (OMEGA Centre 2013). On the other hand, the Internet and freedom of information legislation can, in some respects, equalise access to information. There is still one area where the problems of unequal weighting applied to different forms of knowledge within the planning process, and particularly the process of infrastructure planning is much harder to address. The black box remains firmly closed with respect to the values and assumptions contained with it. They go unacknowledged and are presented as facts. Furthermore, these facts can constrain the options considered and shape the solutions from a limited pallet creating 'narratives of necessity' (Owens and Cowell 2011) that both the wider political decisions and shape the process of planning and infrastructure appraisal. This not only poses problems from the perspective of equal participation but can also create considerable risks of 'path dependency' (Curtis and Low 2012) locking in pathways to high carbon emitting forms of infrastructure. This is as the values that tend to be entrenched are the ones that shape conventional approaches such as the appraisal techniques discussed below.

2.3 Maximising Utility

There is a certain irony that one of the key mechanisms for the appraisal of infrastructure that is increasingly seen as a barrier to more equitable, less environmentally damaging forms of infrastructure was initially perceived as an alternative to pork-barrel infrastructure projects (Shapiro and Schroeder 2008). The belief was that cost–benefit analysis (CBA) provides a rational means of ensuring the benefits of infrastructure were distributed to society as a whole, rather than to a small group of (sometimes corrupt) individuals. CBA is based on utilitarian principles that assume that the maximisation of individual utility will ultimately

[1]The attachment to certain places and landscapes identified by Patrick Devine-Wright (2013) and often dismissed by (in this case renewable energy infrastructure) project promoters as NIMBYism (Not in My Back Yard) is an example of the type of local knowledge which if ignored can generate opposition and resulting costs and delays for project promoters. In contrast the Berger Inquiry into the Mackenzie Valley Pipeline in Canada's Northwest Territories is often cited (Torgeson 2003) as a positive example of the inclusion of local and indigenous knowledge.

produce equality. With CBA, this is achieved by aggregation of total benefits, the solution that produces the most benefits for the least cost being the ideal one.

Utilitarian assumptions have long influenced urban planning (Moroni 2006), and as an appraisal methodology, CBA exerts considerable power in shaping the planning and implementation of urban infrastructure. Whilst in many situations the general principle that the benefits of infrastructure should exceed the costs is hard to argue with, the practice of CBA has been widely criticised for the inequalities it produces. As a facet of the 'modernist infrastructural ideal' (Graham and Marvin 2001), the practice was at least underpinned by some notion of public benefit. However, under neoliberal governance regimes, the aggregate economic benefits are increasingly seen as public benefits regardless, of who the actual recipients are.

Three practices, in particular, monetisation of costs and benefits, discounting and (for transport projects) the emphasis on travel time savings, produce considerable inequalities in the way the benefits and burdens of infrastructures are distributed. First, the calculation of the financial costs of some elements of infrastructure projects is not always problematic. Materials, labour and the purchase of land can all be estimated with a sufficient degree of certainty to ensure it is simply a matter of good sense. Where monetisation becomes more problematic is when it is attached to projected benefits and costs, often some time into an uncertain future. There are problems of validity when such calculations are based upon a further set of assumptions about willingness to pay for a resource (Naess 2006). A problem that is particularly acute for environmental resources which are often resistant to translation into monetary values. Monetisation of values can, furthermore, reinforce existing inequalities as money itself is not evenly distributed and so a significant cost to one group may be barely noticed by another.

Alongside the monetisation of values, there is the practice of discounting which assumes a cost incurred today is greater than one of the same monetary value incurred sometime in the future. This can militate against intergenerational equity in the way it legitimises the passing on of costs to future generations. For this reason, a much lower discount rate was adopted in the influential Stern Report (Stern 2006) into the costs of climate change mitigation. The assumptions embedded within the practice of discounting are also those of increasing prosperity and rising incomes.

Finally, the valuation of travel time savings in transport infrastructure is another example of the way that the benefits of infrastructure are often unequally distributed. A contemporary example of this can be found in plans for a high speed rail connection between London and Birmingham (HS2) in the UK. Benefits are unequally allocated due to a higher estimated value of business user's time. This is despite the majority of predicted users of the railway being non-business travellers with 70% travelling for leisure trips and non-business related reasons (HS2Ltd/DfT 2011). The consequences of this have been the design of the infrastructure has been shaped by the need to facilitate rapid travel. This has been at the expense of the urban environment as the design requires a large amount of demolition surrounding Euston station. This particular case illustrates a further questionable practice used in CBA. It is certainly the true that with increasingly complex and interconnected infrastructures, the calculation of *all* costs and benefits is problematic. However, it is also highly political *which* costs are calculated. In addition to the demolition of what is largely social and low-cost housing as a result of HS2, construction will cause years of disruption for local businesses. The problem is particularly acute on Drummond Street, an area characterised by predominantly Bengali owned shops and restaurants. These are costs excluded from the CBA of what has already proved to be a contentious project. Opponents also argue that the compensation costs to property owners are inadequate, an indication that even when the methodology itself is not challenged the selection of inputs into the analysis is never value free.

3 What is Equity

A further challenge when seeking to deliver more equitable forms of urban infrastructure is to be clear about what form of equity is desired. As the application of CBA shows, an assumption of equity (or more precisely the assumption that a single conception of equity is sufficient) can lead to unjust and unequal outcomes. In the following section, alternatives to the utilitarian calculations of equity are identified. Each has in one way or another been applied to the planning and development of urban infrastructures, and each is likely to skew that development towards different ends.

3.1 Meeting the Needs of the Least Well Off: Rawls' Difference Principle

It is first useful to consider why equity ought to be an important dimension and, as is argued here, an explicit aim of any attempt to deliver more sustainable urban infrastructures. There is sound empirical evidence that more equal societies are better in terms of physical and mental health, educational attainment and trust in others (Wilkinson and Pickett 2011). This is in the face of growing inequality (Dorling 2010) and the increasing redistribution of wealth upwards (Piketty 2014). The evidence points to equality, or at least reduced inequality, as a better state of affairs for all concerned. This is the argument that equality is a rational choice as seen in Rawls' (1971) arguments for greater equality and better outcomes for the least well off. Rawls' argues that a rational individual would choose a more equal society if they were unaware of their own likely position in that society, operating behind what he called a 'veil of ignorance'. This provides an argument for the reduction in inequalities yet Rawls also acknowledges the reality, indeed the desirability of some inequality the level of which is limited by Rawls' 'difference principle'. This states that

> the higher expectations of those better situated are just if and only if they work as part of a scheme which improves the expectations of the least advantaged members of society. (Rawls 1971)

This may appear abstract yet it has been influential on public policy making and has been effectively applied as a principle for restricting the use of the private car beyond the point it impinges upon pedestrian accessibility (Tyler 2004). Not all believe Rawls' basic principles can be applied *directly* as they relate to the basic institutions of society rather than specific policy or infrastructural decisions (Martens 2017). Others, however, argue that they can guide actions, such as efforts to minimise disruption or linking the provision of affordable housing to infrastructure provision, whilst acknowledging their limitations in mandating action that directly or exclusively, benefits the least well off (Beatley 1988). What the application of Rawlsian principles achieves is the establishment of threshold levels in the distribution of the burdens of infrastructure below which it is not permissible to fall.

3.2 Establishing Minimum Thresholds: Capabilities

Beyond the rationalist approach adopted by Rawls, there is another, essentialist view that is important to acknowledge. This is the argument that equality in some areas is important in itself. Important here is the work of Martha Nussbaum and Amatya Sen on basic capabilities. These are a set of essential features human life that have a special claim to political support and protection. These include bodily health, friendship, control of one's environment and the ability to live with other species (Nussbaum 1997) to select those most clearly related to the provision of infrastructure. These capabilities are indivisible; their essential nature means that it is not acceptable to trade them off against each other or against other desirable ends. A clear example of the type of policy this prohibits would be support for infrastructure that trades health against wealth, even assuming the economic gain is equally distributed.[2] A key feature of the capabilities approach is the way that it establishes basic threshold levels of capabilities below which a 'good human life' (Nussbaum 1992) is not possible.

Whilst Rawls provides limits below which actions should not fall, the capabilities approach provides thresholds that *compel* action. They have been used as a basis for arguments about gender inequalities in the design of pedestrian and public transport infrastructure (Robeyns 2003) inequalities facing those with disabilities (Tyler 2006) and can contribute to accessibility appraisal (van Wee and Roeser 2013). Such an

[2]Whilst in practice such calculations are rarely overt and can be masked behind practices such as CBA one can find examples, particularly in the Global South where little weight is given to the health impacts of new road infrastructure (Klopp 2012). However, in the Global North, where arguably the need for basic economic development is less pressing there is still considerable spending on road infrastructure despite the known health and environmental costs (see Metz 2008) with action on air quality particularly slow in the UK.

approach is potentially costly, particularly in retrofitting older infrastructure designed and built in an era when little consideration was given to people with disabilities. However, for Nussbaum this is the area where resources ought to be directed before any alternatives that may increase other forms of utility, such as wealth (Nussbaum 1992). The lifting of all citizens above the threshold level is the key criteria against which policies are measured.

3.3 Equal Distribution of Resources: Transport Justice

The final conception of equity considered moves the discussion on from the establishment of thresholds that either forbid certain patterns in the distribution of the burdens of infrastructure or mandate infrastructure designed to facilitate a certain level of activity. Recent work in the field of transport planning (Martens 2017) calls for principles of equality to guide the process to ensure the benefits (in this case of the accessibility generated by transport infrastructure) are distributed equally to all. Based upon the work of the egalitarian philosopher Ronald Dworkin, the argument is that the key merit good distributed by a transport system is accessibility. The concept refers to a person's potential to interact and the actual amount of their interactions that are enabled by transport infrastructure of all types. It is also dependent upon personal attributes such as wealth, ability and ownership of a vehicle, and finally it includes a contextual or spatial dimension as different locations have different levels of accessibility.

In contrast to traditional approaches to transport planning that place demand, and meeting demand, at the centre of the planning process, this approach places people at the centre. Traditional focus on demand (reflected in the path dependency discussed above) ensures more resources are devoted to establishing a vicious circle in which the infrastructure reflects increased demand and expands, thereby creating yet more demand. Transport justice explicitly limits the public resources that can be devoted towards the expansion to transport infrastructure and also the private resources that can be appropriated through compulsory purchase. This is through a planning process in which population groups are identified by their spatial location, their accessibility is defined, alongside an acceptable minimum threshold for accessibility. This minimum threshold or 'domain of sufficiency' is acknowledged as political and something that should be established by democratic deliberations. Albeit deliberations informed by a knowledge base, utilising data on the actual benefits currently allocated such as levels of employment, degree of social isolation and access to health care. Where this approach differs from the other two described is that it explicitly inhibits public expenditure on infrastructure that benefits the most well off. It is not prohibited: it is simply that such infrastructure should be self-financing. Take, for example, an airport express link, the cost of construction and maintenance would be funded by the ticket price possibly in combination with a subsidy from the airport operator. No public subsidy, use of compulsory purchase powers or grant of land would be available. In practice, it may result in such infrastructure becoming unviable or at least much conservative in their aspirations with the potential to limit excessive resource consumption.

4 Inputs and Outputs

Part of the challenge of more equitable infrastructure provision is a shift to what are arguably more just conceptions of equity than the utility-based approach embodied within CBA, the modernist paradigm and the neoliberal approach that has replaced it. The solutions above provide a conceptual and normative framework that justifies a reallocation of resources towards more equitable forms of infrastructure provision. Based upon this framework, this penultimate section sketches out and illustrates a model of the way in which the planning process might enable these conceptions of equity to shape the provision of future infrastructures.

4.1 More Equitable Planning

If, as is argued here, infrastructures are reflective of the values of the societies that produce them, then it is the planning process, through which many of those inputs are made. Some of those values may be hidden in the assumptions of the experts managing the process, whilst others may leak in from the political milieu in which decisions are made. Equity is a critical principle at this stage in the process if the voices of all those who are likely to bear the burdens are to be given equal weight. This does not mean that all burdens are to be treated equally. Acceptable limits to the burdens imposed and benefits allocated by the construction and operation of infrastructure is something that needs to be established by an open democratic process to ensure that the voices of the most vocal or most powerful do not exclude others. An open process[3] ought also to be able to tease out some of the assumptions implicit in the methodologies employed in project appraisal. It should also be remembered that the process itself is a burden to some and a benefit to others. The professionals that manage the process, public bureaucrats and particularly the private sector consultants sometimes have a vested interest in extending the planning process. The same is true of groups seeking to delay outputs that they may wish to avoid. Again, equity as a principle ought to go some way to ensuring that such strategic behaviour is exposed for what it is.

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[3]There is insufficient space to go into detail on what such a process might look like although in many cases it goes beyond a simple series of public meetings or an instrumental ‘consultation’ exercise. These may well form part of the process however in areas such as appraisal where the details are technical in nature what may be called for are citizens juries or ‘mini-publics’ (Mackenzie and Warren 2012) where a smaller group of citizens is given an opportunity to interrogate the assumptions and practices in more detail.

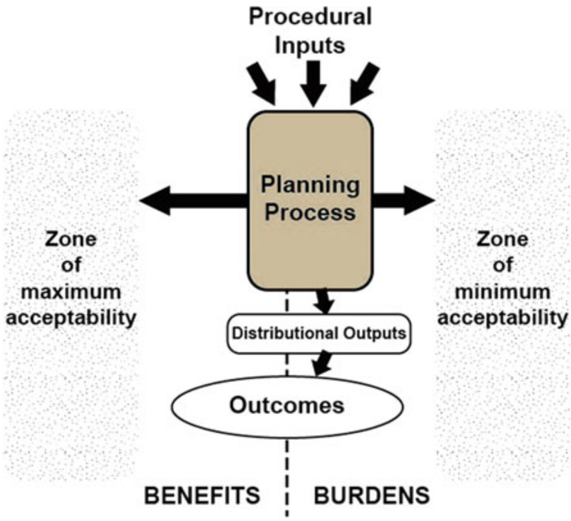

Fig. 7 How a planning process might deliver a more equal allocation of benefits and burdens

Planning as a process ultimately allocates benefits and burdens, and there is a broad literature on fairness in decision making and planning (Dryzek 1995; Healey 1995; Forester 1999; Innes and Booher 2004) as well as practical examples of attempts to achieve it (Just Space 2016). In the early stages of planning, where the problems infrastructure is conceived to resolve are defined, unequal can become iniquitous if the voices of those who bear the burdens are excluded or marginalised through tokenistic consultation. What is added here is an explicit role in establishing the boundaries of acceptability, both minimum and maximum levels (Fig. 7). Where these are and whether or not they have been exceeded may not always be immediately apparent. Consequently, what is called for is a more tentative process of implementation, one that allows for a periodic opening up of the processes of implementation to ensure an equitable distribution is maintained. The outputs may in themselves not distribute burdens and benefits equally, with good reason. The expressed purpose of some piece of urban infrastructure may be to address an existing inequality or identified deficit. Overall, though, the outcomes ought to be an equal distribution of the benefits and burdens, something that calls for a strong clearly expressed concept of equity to shape the process.

4.2 Equity in the Distribution of Burdens

Given the complexities it is perhaps unsurprising the limited progress that has been made in the production of infrastructures that explicitly address issues of equity. This is not to discount significant achievements such as the ongoing work to provide basic infrastructure to parts of cities in the Global South, such as the informal settlements where it is often lacking, or the widespread improvements in disabled access. Important work on social exclusion in transport in the UK has seen the concept operationalised and applied by regional transport providers, only to see schemes designed to address social exclusion fall foul of the current climate of fiscal austerity due to loss of subsidy (Lucas 2012). Community ownership of energy infrastructure offers possibilities; however, this tends to be at the margins and often a rural phenomenon in the UK, albeit with the picture somewhat brighter in countries such as Denmark, Germany and Austria (Walker 2008). Once energy infrastructure such as gas pipelines reverts to the national level, the problems of technocratic styles of governance and economic imperatives tend to reassert themselves (Groves et al. 2013). Adaptations to the methodologies such as CBA that govern the process suggest that it may be possible to retain, albeit within a further layer of ethical consideration, one that is more sensitive to context and issues such as equity and fairness (van Wee and Roeser 2013). Further adaptations have also sought to include social and environmental values within CBA, see for example the work of Fujiwara and Campbell (2011); whereas others argue the solution lies in alternatives such as Multi Criteria Analysis (Thomopoulos and Tight 2009) that have proved successful in selecting locations for urban green infrastructure (Gül et al. 2006).

There are some examples cited of infrastructure that does achieve some benefit in terms of social equity. Amsterdam Metro, a costly and controversial project, does improve transport accessibility for neighbourhoods to the North of the city addressing existing shortfalls (Martens 2017). As an example of a 'disruptive technology' (Flores Dewey 2016) from the field of transport planning, Bus Rapid Transit (BRT, Fig. 8) appears to offer a shift away from the car-dominated urban infrastructure reflective of an earlier epoch. Developed in its current form in Latin America, it is a clear example of a socio-technical system. It represents a hybrid of different transport, ticketing technologies and legislation to achieve segregated bus lanes; and of human capital in the form of the skills to maintain and drive the low emissions vehicles required for these high-frequency bus services. Its advocates see this technology as facilitating a shift away from the private car and embedding

Fig. 8 Curitiba's BRT system [*photograph* Morio, used under license (CC-BY-SA 3.0)]

sustainable transport within the urban form (Munoz and Paget Seekins 2016). In contrast to more costly fixed transport links, it is more flexible, based on re-using the road network, its network of high quality stations can provide complementarity with other forms of infrastructure such as public conveniences. Furthermore, it has the potential, if not always realised (Flores Dewey 2016), to interact with the informal paratransit networks often used by the poor (Sagaris 2016). Yet even here the tendency towards a conflictual, paternalistic approach to consultation and implementation has been noted and contrasted with the more coproductive strategies of civil society initiatives to promote cycling infrastructure (ibid).

5 Conclusion

If there is something to be salvaged from the modernist ideal of infrastructure (Graham and Marvin 2001), then perhaps it is the concept of comprehensiveness or, put another way, equality. In the Global North, we have come to accept the fact that infrastructural technologies are in place to ensure basic services such as power, clean water and sanitation are provided almost equally to all areas and individuals. The problems of equality here are less in the physical systems than in the management and institutional systems that still, too often, exclude or penalise the most vulnerable. Ensuring the parts of the world where such systems are not in place are brought up to a minimum threshold is still a noble aim. Yet with other infrastructures we have come to accept a level of inequality which is ultimately unjustifiable (Martens 2017). An indication that in the Global North there is still a way to go and even, as infrastructures such as BRT show, lessons that can be learnt from the Global South. The focus on urban planning in this chapter has meant the examples drawn upon Tend to focus upon transport infrastructures as these are the ones that most concern urban planning given the way they consume and also open up urban space for development. Nevertheless, the gap between digital and transport infrastructures is rapidly closing with the development of self-driving cars and the increasing interest of technology companies in the management of public transport (Harris 2016). The need for guiding principles is, if anything, increasing given that the emerging forms of infrastructure contain a plethora of assumptions that shape the way the benefits they provide and the burdens they ask the public as a whole to bear are allocated. If infrastructure underpins the form of development adopted by modern societies, then through the processes of planning it also reflects the values of the societies that produce it. In turn these values are embedded within the physical structures. They are projected into and shape the societies of the future. Equity, between genders, groups and those of different sexual orientations, is an increasingly significant principle of contemporary societies. Therefore, if equality of access is already established for some infrastructures and is theoretically possible for others (Martens 2017), then why should this principle not shape the infrastructure and societies of the future?

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Sustainable Places: Delivering Adaptive Communities

Laura Mazzeo, Nick James, Gary Young and Bee Farrell

1 Introduction

Delivering sustainable places as architects, urban planners and urban designers is quite a different matter from defining theoretically what constitutes sustainable urbanism.

Delivering sustainable places has led us to reflect upon the very definition of sustainability and conclude that sustainable urbanism is first and foremost a process, rather than an outcome in and of itself. The process is, however, still driven and directed by outcome, namely the creation of adaptive communities, but it is within the process that sustainable urbanism truly emerges.

Born of this understanding and the attempt to offer solutions to the challenges urban planners and architects face in practicing 'sustainable urbanism', is what we describe as the PLACE methodology. The PLACE methodology, refined over decades of practice, is what allows us to deliver adaptive communities. It started with a reflection on 'buffer thinking'—that buildings must respond to the climate and physical conditions they are built in—and has since evolved, focusing on three main principles:

- 'Place' is the client;
- Proactive planning is essential to creating places for the greater good of all;
- Building consensus needs to shape the process.

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Looking at a number of case studies in the UK of adaptive communities that our practice has delivered through the PLACE methodology, we will focus on the following six pillars: economy and technology, healthy places, food and water, heritage, knowledge and partnerships and sustainable places. Lastly, we turn to Asia where adaptive communities have taken on different urban forms of high and even hyper-density models capitalising on transport hubs, truly mixed-use environments, building tall or creating three-dimensional public spaces under the pressure of delivering rapid growth.

2 Part 1—Confronting Practice with Theory—Sustainable Urbanism: A Process

Sustainable urbanism is a growing concept within the built environment profession, often defined as a set of solutions to be applied to a blank canvas, or a desired outcome to be achieved through development. The concept has repeatedly been associated with the latest fashionable name of the moment such as 'smart' or 'resilient' cities, resulting in uncertainty as to its definition, purpose and ultimate goals. However, with more than 50 years of practice committed to advocating and delivering sustainable places, our experience has shown us that sustainable urbanism is first and foremost a process.

Sustainable interventions were first recognised within Germany's forestry industry through the work of Hans Carl von Carlowitz. In his seminal book 'Sylvicultura Oeconomica' (1713), Carlowitz advocates the practice of 'nachhaltende Nutzung' (sustainable use) of forest resources, which implied maintaining a balance between harvesting old trees and ensuring that there were enough young trees to replace them (Van Zon 2002).

It was not until 1987 that the concept of sustainability was publically applied to the built environment through the publication of the infamous 'Our Common Future' report. Lead by the Norwegian politician Gro Harlem Brundtland, the report defines a simple and oft-quoted definition of sustainable development as:

> …development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Despite a near universal recognition that sustainable cities are now a desirable policy goal, there is now even less certainty about what this might mean in practice (Bulkeley and Betsill 2005). It is further recognised that while environmentally sensitive design approaches are being widely adopted at the building scale, there has been little progression in their application at the wider urban scale (Oktay 2011).

However, with renewed interest in the world's urban development, timely explorations into the roles of urban planning and urban design (Adhya 2015) have allowed sustainable urbanism to emerge as the focus of several current debates. These include the topics of metropolitan growth versus inner-city decline, urban desirability versus suburban liveability and, importantly, the exercise of defining sustainability versus practicing sustainability (Adhya 2015).

As such, various definitions of sustainable urbanism have emerged, including Farr's (2008) definition as 'walkable and transit-served urbanism integrated with high-performance buildings and infrastructure' (Adhya 2015; Adhya et al. 2010). Reflecting on this design-driven definition, we observe with Adhya (2015) that within this and other form-based and outcome-driven definitions of sustainable urbanism, a number of important elements of key urban processes, such as social diversity, economic equity and environmental justice, are ignored.

Conversely, we advocate that sustainable urbanism should instead be defined in terms of three fundamental elements; health, place specificity and social ethics (Adhya et al. 2010). Health addresses two core values of sustainability; the sustenance of human well-being as individuals, communities and society; and the human capacity to trust, cooperate and work together so as to improve the future. Place specificity and the process of placemaking refer to the manner in which people transform the places they find themselves through a diversely creative process (Schneekloth and Shibley 1998). Social ethics additionally relate to the recent rise towards social improvement and hope within the urban environment.

A process-oriented and profoundly human connection to sustainability is, therefore, critical to restoring the role of responsive urban design and in defining sustainable urbanism (Adhya et al. 2010). This framework and definition of sustainable urbanism has shaped our practice of urbanism and architecture, aiming to deliver a process-driven approach to urbanism, shaped by consensus building and human cooperation, place specificity and social ethics.

2.1 Desired Outcome: Adaptive Communities

Having defined our understanding of sustainable urbanism as an inherently human-focused process to developing the built environment, it is equally important to explore how we define its desired outcome. By understanding the goals and physical aspirations of sustainable urbanism, we aim to further shape our understanding of the process and indeed what we are looking for from sustainability.

During the interwar period, modernist planners and architects developed influential ideas of highly planned greener cities that would alleviate the mistakes of industrialisation. These included Le Corbusier's 'The City of Tomorrow and Its Planning' (1929) and Eliel Saarinen's 'The City: Its Growth, Its Decay, Its Future'

(1943), both of which had a lasting impact on the design of European and North American cities. Later, in the aftermath of the Second World War, the future cities discourse was geared towards remedying cities destroyed by aerial bombing and ground warfare (Mooir et al. 2014).

A plethora of terms and ideas has subsequently emerged within the 'future city' debate. Due to the increasing urgencies of the environmental challenge experienced globally, the most common term to emerge has been that of the 'sustainable city'. The model of the sustainable city focuses on the development of cities designed to minimise their environmental impact and significantly reduce their carbon consumption.

'Smart City' has alternatively taken on the more digital dimensions of the built environment. The term responds to the rise of new Internet technology interfaces and uses geographic information and communication technology to build cognitive frameworks in city planning and management (Murgante and Borruso 2013).

'Resilient City' is a concept which is also growing in use. The term takes on a dual meaning and is used in reference to both a community's capacity to withstand external environmental and social shocks, as well as its economic adaptability and agility when faced with financial change. As references to resilience continued to increase, so too have criticisms that the concept may be inappropriate (Norris et al. 2008).

Reflecting on the definitions and applications of each of these models for the future city, we advocate that a transition must be made from the structurally static view of resilient communities to a structurally dynamic view of adaptive communities (Hollings and Gunderson 2002). We argue that rather than preserving a community in stasis, the challenge and ultimate design goal is to conserve the ability to adapt to change and to be able to respond in a flexible way to uncertainty and surprise. Adaptable communities should instead present the opportunity to maintain options and variety in their design, in order to buffer disturbance while also creating novelty and interest (Hollings and Gunderson 2002). As Tompkins and Adger (2004) observe, 'all social and natural systems evolve and, in some instances, co-evolve with each other over time'.

Adaptive communities, therefore, offer a strong and viable opportunity for our communities to evolve and develop together, with the ultimate goal of creating enduring and sustainable cities.

3 Part 2—A Methodology Born of Practice

> A new era of professional, intellectual and cultural exchange between cities is emerging and our world-renowned institutions and agencies should be at the forefront of this, whilst recognising we have much to learn from others. P. 181 Farrell Review

Throughout our 50 years of experience in the built environment, we have been able to develop and refine our understanding of sustainable urbanism, establishing what it means to us and our work, defining what its desired outcomes are and reflectively exploring how best to deliver it. By defining sustainable urbanism as a practical process through which to deliver the future city, we have been able to establish the concept of adaptive communities as the physical embodiment of these ideals.

Using a series of project case studies drawn from our practical experience in the UK, China and further afield, we aim to illustrate the key concepts behind, and practical application of, the process of designing adaptive communities.

3.1 'Buffer Thinking'

Our experience with developing adaptive communities started in the 1980s with the concept of 'buffer thinking', a term coined by Sir Terry Farrell and Ralph Lebens (Building Design June 6, 1980). This term describes a 'conscious attitude to design because […] it implies application of awareness and intelligent design skill rather than heavy handed technology. It is an energy solution which involves the participation of the user individually and collectively'. This original thinking is very similar to that of today's Passivhaus[1] and more design driven sustainable concepts. The main principle behind the 'buffer thinking' approach was to adapt building and development forms to allow them to respond to the pressures of their climate and surrounding environment. By adopting a highly informed and climate-driven approach to design, 'buffer thinking' allows us to create buildings and communities which have the ability to respond and adapt to local, and global climate change. It is this future thinking which has allowed us to build our understanding of adaptive communities and explore the building blocks with which they may be formed. The illustrations below show how the 'buffer thinking' approach was applicable to different building types, for housing, commercial and industrial uses and recreational facilities (Fig. 1).

[1]The Passivhaus standard was developed in Germany in the early 1990s by Professors Bo Adamson of Sweden and Wolfgang Feist of Germany and the first dwellings to be completed to the Passivhaus Standard were constructed in Darmstadt in 1991: 'A Passivhaus is a building, for which thermal comfort can be achieved solely by post-heating or post-cooling of the fresh air mass, which is required to achieve sufficient indoor air quality conditions—without the need for additional recirculation of air' (http://www.passivhaus.org.uk/, 27 July 2016).

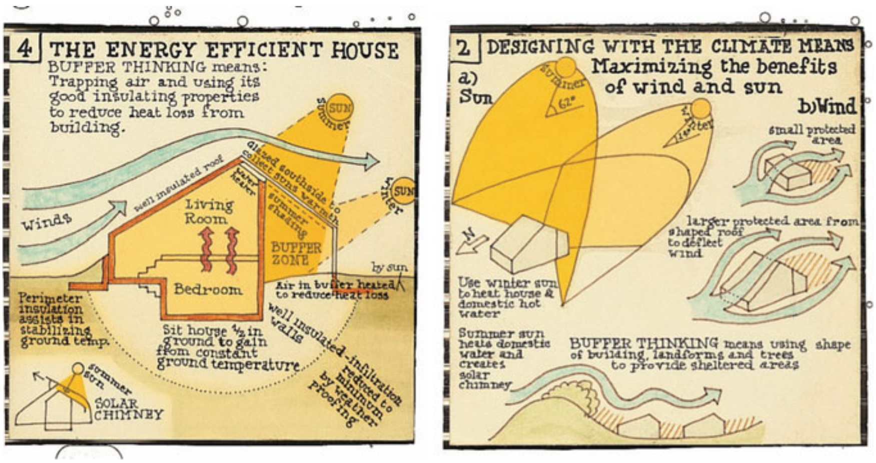

Fig. 1 ‘Buffer thinking’ © Farrells

3.2 *‘Place is the Client’*

This innovative philosophy later evolved into the concept of the 'Place is the client'. Within our understanding of sustainable urbanism as a process, one must first understand the importance of 'place' as a holistic way of viewing the built environment. This includes the geology, history, urban morphology, demographics, economics and politics of an area. Beyond this, it is vital to also understand the social setting and key aspirations of residents for today and the potential opportunities for tomorrow.

Therefore, believing that successful sustainable urbanism is a process that starts with a 'new understanding of place', the Farrell Review (2014) proposes that the concept of 'place' should be driven by its real meaning, as well as being used to structure a methodological approach to masterplanning and design. The review suggests that the acronym PLACE should be used to embody the core skill sets of planning, landscape, architecture, conservation and engineering.

A wider concept of 'place' could also be described as the key public activities of politics, life, advocacy, community and the environment, again using the acronym to help as an organisational concept in driving the vision of sustainable urbanism.

The PLACE approach is a set of five cross-cutting principles, each of which is integral to the process of sustainable urbanism:

1. A new understanding of place-based planning and design;
2. A new level of connectedness between government departments, institutions, agencies, professions and the public;
3. A new level of public engagement through education and outreach in every village, town and city, and volunteering enabled by information and communications technology;
4. A commitment to making the ordinary better and to improving the everyday built environment;
5. A sustainable and low-carbon future.

This innovative approach to 'place' was particularly evident throughout our work on the former Earls Court Exhibition Centre site. Indeed, our highly informed approach to masterplanning focused on the core concept of growing from the area's existing four 'urban villages', namely; North End Road, Earls Court, West Brompton and West Kensington. The proposed masterplan offers 10,000 new homes, a wide variety of community and commercial facilities, a new high street and a new 'Lost River' community park. This will bring to the fore the 'lost' history of the 'place', respond to its contextual setting and allow the masterplan to better integrate with its surrounding communities (Fig. 2).

Building on this appreciative and respectful approach to 'place', we are developing a masterplan for the historic Royal Docks at Convoys Wharf, Deptford. Responding to the 16.6 ha site's rich and significant heritage, the masterplan incorporates the remaining archaeology and interprets the history of the site into contemporary design. The proposals seek to reconnect Deptford, and its people, to the river. By improving connectivity and delivering a wide range of animated uses along the water's edge, the masterplan nearly doubles the London Borough of

Four villages and a high street

Your guide to how the various areas of the new Earls Court district might look and feel in 2030

Earls Court already has established neighbourhoods and communities, which is why plans for its future include four distinctive new villages that build on the character of the area. The Broadway, from north to south, and the High Street, from east to west, would stitch together an expanse of land that has been largely under-used and impenetrable for decades. Lost River Park, new squares and tree-lined streets would create green, tranquil alternatives to the vibrant thoroughfares offering shops, entertainment and culture. Sustainability and long-term prosperity are at the heart of these plans, which strive to create an area that thousands would be proud to call home.

1 Earls Court Village
Smart, elegant and genteel, Earls Court Village is a haven of civilised tranquillity, framed by graceful new buildings and the grand, sweeping terraces of Warwick Crescent and Empress Crescent, which complement the neighbouring Victorian architecture. Cobbled courtyards, garden squares and quiet mews create a feeling of intimacy.

2 The High Street
It's packed with quirky, high-quality independent shops, but the high street offers more than just retail. The bars, cafés and restaurants make it a meeting place, while cultural and community centres encourage learning and enterprise. The character of the high street changes from the relaxed, homely bustle of North End Village through the creative buzz of Whitley Square and its exhibitions and events to the refined elegance of Exhibition Square.

3 Lost River Park
The character of this innovative park changes from formal landscaping with seasonal planting and sculpture in the north and south to a wilder and more natural feel in the centre. As the park skirts along the side of the Seagrave Road neighbourhood it becomes a haven for plant life and animals, and there are spaces for cycle routes, allotments, picnic spots and areas for children to play in and adults to practise yoga and aerobics.

4 West Brompton Village and Seagrave
This area is leafy, tranquil and popular with families, thanks to the green open spaces of the nearby Lost River Park and the family housing on Seagrave Road, which is walking distance to the new primary school in Thaxton Square.

5 The Broadway
This grand tree-lined boulevard gradually changes in character from the dramatic office blocks of West Kensington Village in the north to the more intimate, residential feel of West Brompton Village in the south. With mansion flats and apartments mixed in with work and retail spaces, its energy doesn't simply disappear after office hours.

6 North End Village
Inspired by the thriving North End Road market, this vibrant, multicultural urban village surrounds the more cosmopolitan end of the high street. Tree-lined landscaping along North End Road and street performers in Whitley Square will inspire a lively café culture by day. Open-air cinema screenings and a string of bars and restaurants will create a vivacious atmosphere by night.

7 West Kensington Village
This new front door to central London is to be a dynamic commercial hub defined by cutting-edge office blocks and loft-style apartments. Striking architecture, street art and sculpture will attract an international crowd, but Cromwell Place, Mathias Square and wide pedestrian pavements help soften the urban buzz.

Fig. 2 MyEarlsCourt, Time Out 2011 © Farrells

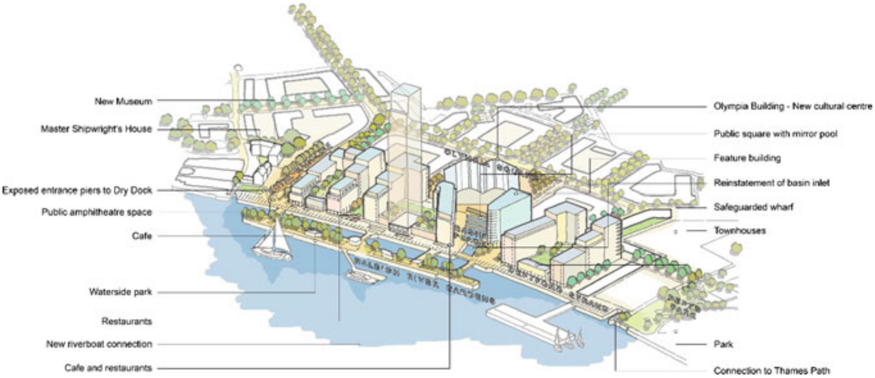

Fig. 3 Convoys Wharf © Farrells

Lewisham's accessible waterfront. After over 12 months of engagement with the local community, the masterplan has taken into account comments from local residents and groups. Through this broad appreciation of the 'place as the client', we have been able to provide a masterplan which supports extensive cultural and recreational opportunities, along with many new jobs and homes for the growing community (Fig. 3).

3.2.1 Proactive Planning

Along with this holistic approach to 'place', we must be more proactive when planning the future shape and form of our villages, towns and cities. Our planning system has become too reactive and relies on development control, which forces local authority planners to spend their time firefighting rather than thinking creatively about the future shape and form of villages, towns and cities. Everything is open to negotiation for every planning application, and as a result huge amounts of time and resources are spent on issues that could have been predetermined by a collective vision shaped in collaboration with local communities, neighbourhood forums and PLACE Review Panels. Proactive planning would free up valuable time for local authority planners to develop masterplans and design codes which are supported by local communities, while reinvigorating the planning profession and its public perception. Proactive planning does not set rules in stone but rather seeks to bring all stakeholders to the table to identify opportunities so that they can be realised over the longer term.

Proactive planning looks to the bigger picture and seeks to create a spatial framework that is both strong in the present and flexible enough to accommodate the needs of future generations. This forward-looking and highly advocative approach to planning and architecture can be seen in our study of the Marylebone-Euston Road. This explorative study looked at the potential for this iconic road to be transformed into one of London's greatest assets, boasting vibrant street life, attractive landscaping, seminal buildings and developments and major squares and green spaces.

This proactive approach to masterplanning presented a series of innovative visions for the future development of the Marylebone-Euston Road. The broad principles behind our work were to develop an encompassing strategy aimed at resolving the road's prominent traffic/pedestrian conflicts, while additionally reclaiming the road's numerous communities which have been lost to destructive traffic engineering over the years. By far, the most successful aspect of our approach was seeing the road as a series of linked, linear projects, each one a bite-sized piece of urban design. By establishing these links between projects, we were able to show a creative vision for the future evolution and adaptation of this prominent part of London, with the bonus of releasing an acre of land (Fig. 4).

At a far larger scale, we have adopted a similarly proactive approach to creating a vision for over 500 ha of West London. The aim of this work was to explore the wider potential of the proposed Crossrail and High Speed 2 stations at Old Oak Common and to look at the economic benefits that could ensue from their co-location. The resulting vision could generate an estimated 12,000 new homes, 115,000 new jobs, a new waterside park along the Grand Union Canal and a revolutionary rapid transit system (Fig. 5).

It must be noted that proactive planning at the urban scale requires a significant amount of foresight and creativity. For example, we recognise that London is set to reach 10 million by 2030, making it Europe's only 'super-metropolis' or megacity. There are currently 35 cities in the world that have a population of over 10 million and can be called megacities. As a result of its success, London needs significantly

Fig. 4 Marylebone-Euston Road Vision © Farrells

Fig. 5 Old Oak Common Vision © Farrells

more housing, better public transport, adequate power and water supply and a stricter monitoring of pollution sources including noise, light and air.

The Greater London Authority (GLA) has responded to this challenge by investing in a number of bold infrastructure projects focused on opening up areas for potential growth across the capital. Unlike the rest of the city, large areas of East

London have seen little or no distinctive growth. A lack of transport accessibility has held back housing delivery in East London and that which has been delivered has too often consisted of low-density sprawl in featureless dormitory suburbs.

Indeed, whilst there are 34 bridges across the River Thames, there is only one to the east of Tower Bridge and it is this lack of river crossings that in part impedes growth in this area. With this in mind, we have made proposals to introduce a series of additional low-level river crossings to support the capital's strategic economic objectives. Unlike Dartford's high-level bridge, lower, more local crossings, will help support high-quality urban growth and a far greater sense of community connectivity. The vast scale of high-level bridges often causes long approach ramps to stretch a mile back from the river bank, creating a highly fragmented and sterile riverside environment. In contrast, low-level bridges will have less of a physical impact at the water's edge and enable safe and pleasant walking and cycling, conveniently connecting people to communities with transport and service nodes on either side of the river.

The vision is, therefore, to create a series of 'mini-cities' along the Thames, each interacting with each other as well as the rest of London. These 'cities in the east' could enable the delivery of over 50,000 new homes and 40,000 new jobs, allowing London to comfortably provide for its expected growth. This will only be made possible through an extensive investment in transport and infrastructure.

Fig. 6 Bridging East London; Low-level Bridges © Farrells

Another core consideration of 'proactive planning' is the basic need to supply sustainable cities and megacities with food. The very essence of sustainability is place-specific thinking and living, set within access to global opportunities; to be 'locally embedded and globally attuned' (Morgan 2009). Sustainably grown food cannot be transported, stored, cooked, eaten and the waste recycled within a homogenous megacity approach. Sustainable cities and megacities will increasingly need food value chains to provide environmental, cultural, economic and health prosperity to a city and its residents. This shift in thinking from long food chains to innovative food value webs, sustainable small developments, innovation and community activity will require multidisciplinary teams to plan, design and coordinate cities using food as the locus for all their work.

By adopting a more proactive approach to planning and design across the built environment industry, there is a distinct opportunity to design the future city to be highly conscious of its setting and to be able to instinctively plan for challenges and change. Through this approach, we aim to create communities which are able to adapt to their ever changing environments and offer a more promising, optimistic and sustainable urban future.

3.2.2 Building Consensus

In the present political culture, big ideas such as those we promote in our practice often fail to get support. From an economic point of view, there is a fear that large-scale, ambitious public ventures are unpopular. It is, therefore, widely recognised throughout the built environment profession that the largest challenge is not in the design or practical implementation of sustainable solutions but rather in the process of obtaining community and stakeholder buy-in (Fig. 6).

Community engagement is, therefore, at the heart of this place-orientated and proactive approach to planning and design. By engaging with the community and local stakeholders as early as possible in projects such as Earls Court and Old Oak Common, we can begin the highly integrated process of delivering sustainable urbanism. A sustained and intuitive approach to building consensus is core to creating adaptive communities which are designed for the people and by the people. This conscious sense of involvement and ownership over the development of 'their' community empowers local people, helps build strong community cohesion and enlivens their determination to be involved in the continuing transformation of the surrounding neighbourhood and its future success.

The process of building consensus has always been a core feature of our work. Our ground-breaking work on the Thames Estuary Parklands, started in 2000 and still ongoing, was the first time an architectural practice had consulted with such a vast number of communities and interest groups throughout an area.

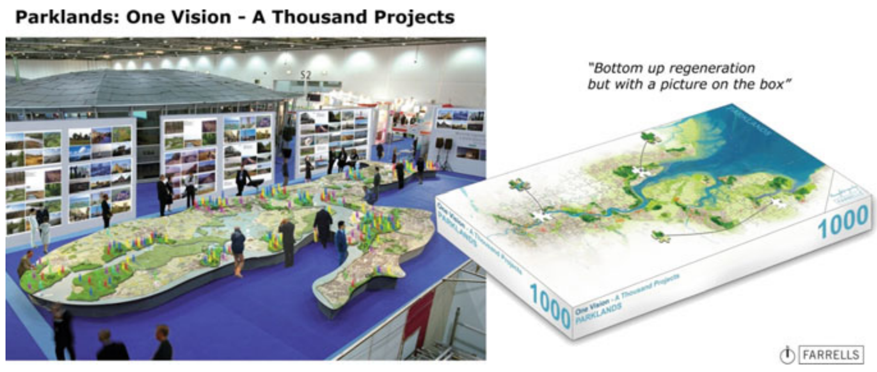

Fig. 7 Thames Gateway Parklands Vision © Farrells

The Parklands vision is to regenerate and develop urban and rural open spaces, connecting them together to create an accessible and coherent landscape. The aim is to improve the quality of life for people who live throughout the Thames Gateway, improve the experience for visitors and increase the opportunities for those who work across this large area of eastern England. The focus of the study, and our engagement process, was to promote the Estuary's Parklands to help ensure that they are sustainably managed. The work contributed towards the development of the Thames Gateway as an eco-region, defined by the WWF as being a 'large unit of land or water containing a geographically distinct assemblage of species, natural communities and environmental conditions'. The Parklands project aimed to help make the Thames Gateway a special place that draws on the Thames Estuary's unique landscape, its rich history and its vibrant mix of cultures and communities. A vision masterplan has subsequently been created that connects both new and existing communities back to the river, its tributaries and the landscape of the Estuary (Fig. 7).

This growing movement towards more proactive models of community engagement is being supported by a number of government-driven decentralisation schemes. Of particular, significance is the UK Localism Act (2011b), which acknowledged the role of communities in the design and delivery of local public services and aimed to facilitate the devolution of decision-making powers from central government. It puts forward Neighbourhood Planning as a proactive planning approach that introduces a new right for local communities to draw up Neighbourhood Development Plans, allowing them to express their aspirations for the future of their localities (DCLG 2011a, b). Neighbourhood Planning embodies a shift from reactive planning (appeasement and consultation) to proactive planning (delegated power and partnership).

However, despite this changing environment throughout the industry, the process of consensus building continues to experience problems and striking contradictions. The widely heterogeneous nature of inner-city communities inevitably leads to conflicts of interest. Furthermore, third party management of the engagement strategy can become a ‘tickbox’ exercise, focused far too often on the act of engagement rather than its outcomes (Lopes de Souza 2006). The result is the evolution of a process hampered by inconsistency and opposition, which offers no real means by which the community can influence change (Nuijten et al. 2012).

Our work on the redevelopment of Earls Court aimed to develop an open, honest and transparent approach to consultation and consensus building, both at the strategic and community levels, before a design was even drawn. Over the project’s first two years, the team engaged with thousands of local people, along with organisations and action groups. The consultation process consisted of five key stages, starting with a series of drop-in sessions prior to the design team even being appointed. These exploratory avenues of communication allowed the client team to listen to the community’s issues and aspirations and start to identify and record recurring themes. These initial episodes were followed by a second series of more detailed workshops, where the community met the appointed design team and were introduced to the initial design concept. The principles of this concept reflected many of the concerns raised by residents and businesses at the initial drop-in sessions, and particularly focused on reinforcing the existing communities.

The project’s third stage of consultation came through the launch of www.myearlscourt.com. This open and highly engaging means of communication provided up-to-date information on the project, as well as a live blog which enabled local residents and businesses to comment on the evolving plans and ask questions of the client and project team. Through this welcoming and accessible avenue, the project team were able to gather a large amount of information which was actively interpreted and fed into the evolving scheme.

Following a further round of workshops, the Earls Court masterplan was presented to the community at a heavily publicised, and well-attended, exhibition event. Along with an extensive programme of meetings with local authority offices and key political and technical consultants, this detailed and encompassing process of engagement was comprehensive in its approach. The principle goals were to engage with as broad a spectrum of the community as possible, energise discussion through a range of mediums and actively build towards a masterplan based on consensus. Fundamentally, it was not a ‘box-ticking’ exercise; instead it seeks to actively engage for the broader purpose of public inclusion within the masterplanning process.

Building consensus to support a proactive planning approach based on an understanding of ‘place’ is at the heart of our practice in sustainable urbanism, and essential to the process which we believe is capable of delivering adaptive communities (Fig. 8).

Building on these conventional and well-tested avenues of consultation, The Farrell Review of Architecture and the Built Environment, commissioned by the UK Government, concluded that:

> Every town and city without an architecture and built environment centre should have an ‘urban room’ where the past, present and future of that place can be inspected. Virtually

Fig. 8 Earls Court Public Consultation © Farrells

> every city in China has one while in Japan, they are a mix of display and meeting places. Closer to home there are successful examples such as the Cork Vision Centre in Ireland. These 'Place Spaces' should have physical or virtual models, produced in collaboration with local technical colleges or universities, and they should be funded jointly by the public and private sectors, not owned exclusively by one or the other.

We were recently involved in helping to set up a pop-up urban room in Church Street, Westminster, near our offices. This highly exploratory and experimental venture saw the practice team up with the local Church Street Ward Neighbourhood Forum to organise a seven-week programme of events and activities. Rather than being a council-operated, corporate-funded, or technically driven consultation event, the urban room instead represented a community-run venture, creating a place for community members to meet and share ideas, concerns and aspirations for the community's future.

With little structure or definitive agenda, the Church Street Urban Room welcomed over a thousand visitors through its doors to participate in a wide selection of sessions and activities. The ideas from the community were fluid and wide ranging, and people felt comfortable to express themselves within this free and public space. The success of this, and other urban rooms, has led to the Urban Room Network being established, to promote and facilitate urban rooms throughout the country (Fig. 9).

We believe that the urban room is the ultimate means by which to build consensus. By facilitating a welcoming, open and highly familiar place for local people that offers an opportunity for self-expression and community growth, there is a

Fig. 9 Church Street Urban Room, London, NW8 © Farrells

distinct opportunity to extend the existing scope of community engagement and create a continuing stream of democratic and representational discussion.

4 Part 3—Adaptive Communities: Models and Case Studies

Since the days of 'buffer thinking', our practice of sustainable urbanism has evolved into a finer understanding of what constitutes a successful 'adaptive community'. The diagram below illustrates the six core principles we believe form the foundations of an adaptive community (Fig. 10).

Building on these six pillars of 'adaptive communities', we have developed an encompassing approach to masterplanning and design. Among others, Bicester Eco-Town stands out as prominent example of our holistic application of 'adaptive communities' thinking (Fig. 11).

An eco-town may be defined as a small new town of at least 5–20,000 homes, creating a completely new settlement to achieve zero-carbon development and more sustainable living. This advanced eco-development forms part of a long-lasting and holistic plan for the whole of Bicester Town. It signposts a new sustainable future, where the historic town centre once again becomes the focus of civic, cultural and economic life.

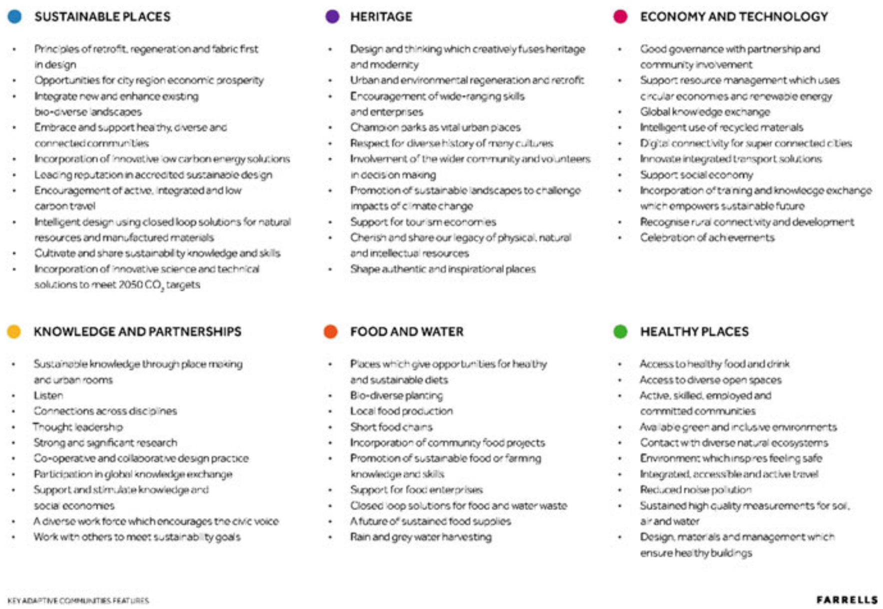

Fig. 10 The Six Pillars of an Adaptive Community © Farrells

Fig. 11 Bicester Eco-town © Farrells

Our project at Bicester is a 35,000,000 sq ft site in Oxfordshire begun in 2009 and is ongoing with the first phase completed in 2016. The residential masterplan aims to integrate housing, care and communities to keep people independent and in their own homes. For those who do need support, more innovative residential care facilities may be combined with flexible housing options and step-up or respite care. The masterplan's liveability aspects include walkable neighbourhoods, radically improved infrastructure for safe active travel and more accessible public transport, access to healthy and affordable food in the local area and high access to green space. Connected neighbourhoods and inclusive public spaces enable people of all ages and from all backgrounds to mix, laying the foundations for durable, strong communities. Examples include 'dementia-friendly' design or ensuring that public spaces include features such as public toilets or benches. This eco-town will also be a digitally enabled 'smart' town supported by integrated and effective public services, making it an attractive place to live and work, as well as being attractive to businesses and entrepreneurs.

Our design concepts reveal the distinctive layers which together form this 'place', celebrating the character of the natural landscape as well as the imprint of human activity. In order to allow the eco-development to evolve gradually and organically over time, we proposed using the site's existing farmsteads as the nuclei around which the new community is grown. This incremental and highly localised approach to development allows the masterplan to build upon the existing settlement pattern and heritage. Through this appreciative and place-driven approach to design, the new eco-development will be capable of delivering local employment, accommodate climate change, consciously contribute to the area's ecological balance and enable, and encourage, more sustainable lifestyles (Fig. 12).

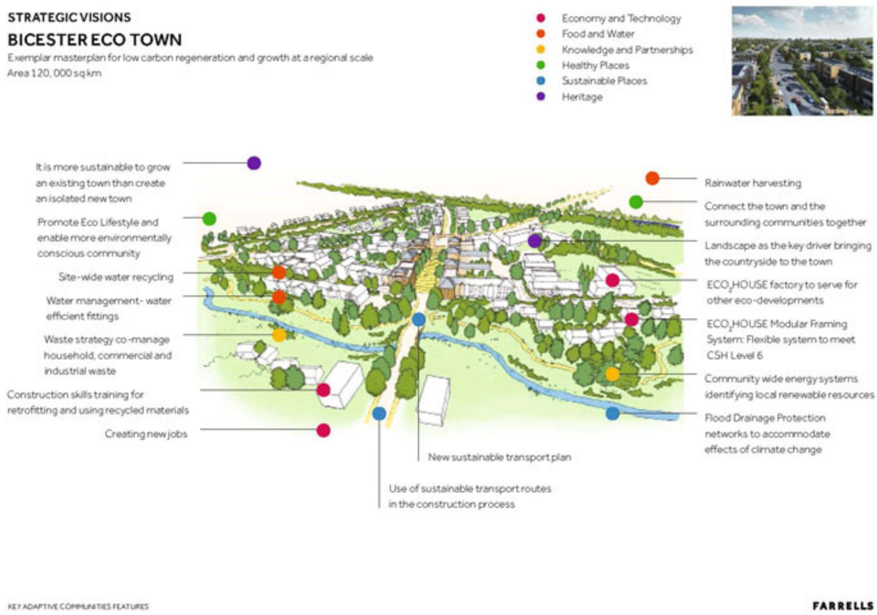

Fig. 12 Bicester Eco-town Sustainability Audit © Farrells

As we continue to develop our thinking on ‘adaptive communities’, we have been able to apply its core principles to a diverse range of projects throughout the practice. The Regent’s Place masterplan was one such project. Now complete, this commercially-led, mixed-use development represents the culmination of several years of planning, consultation, development and construction, successfully enhancing and transforming the urban fabric of a key area of London.

The brief demanded that this previously disconnected commercial enclave become a diverse community offering a highly integrated place to live, work and play. This was achieved by creating high-quality public spaces between the buildings and a network of new streets enabling and encouraging linkages to the surrounding area.

The most radical intervention was the creation of Triton Street, a completely new east-west route through Regent’s Place, forming an important pedestrian link between Regent’s Park and Drummond Street. Just one block north of the Euston Road, this new route creates a highly attractive, calm and engaging pedestrian route which is protected from traffic noise and pollution. Regent’s Place has since become a destination within Central London and the development consists of a broad variety of uses, both commercial and residential. The inclusion of these homes, 60% of which are affordable, helps reduce reliance on cars, and instead promotes greater use of nearby public transport, as well as a far more sustainable community mix (Fig. 13).

Building on these principle projects, our application of ‘adaptive communities’ in practice was most holistically applied to the masterplanning of London’s

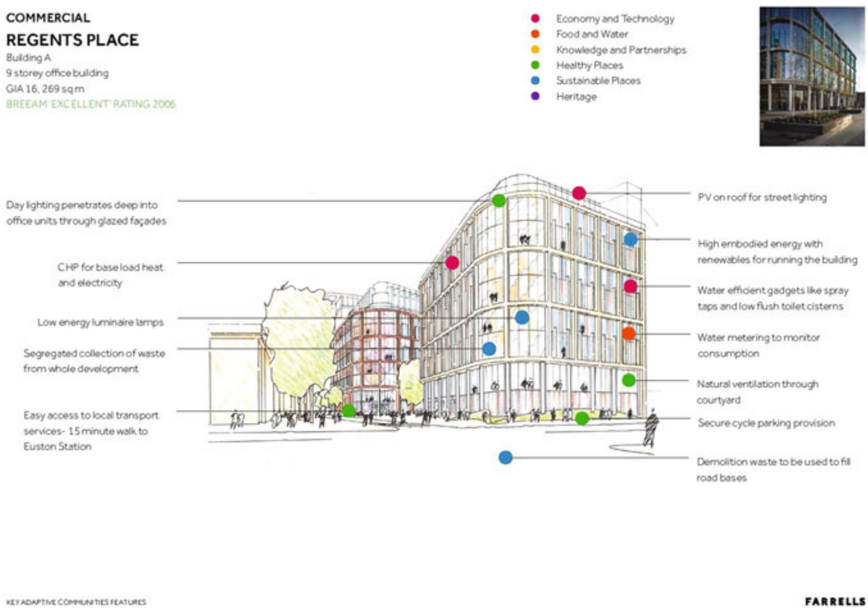

Fig. 13 Regent’s Place Sustainability Audit © Farrells

Greenwich Peninsula. At the heart of this project was the need to create an urban quarter for London, which embodied the concept of growth, renewal and rebirth, while also embracing the existing infrastructure. Our approach to the site was to create an urban grid which responded to the geometry of the river and the Millennium Dome. This created a network of streets, squares and parks, ensuring clear lines of connection throughout.

The immense scale of the project envisages 10,000 new homes, 27,000 new jobs, a state-of-the-art leisure and entertainment destination and enhanced community and transport facilities. By creating a series of neighbourhood quarters, each with a distinctive character and focused around key transport nodes, the masterplan creates a highly active, self-sustaining and varied new district which kick-starts London's expansion to the east (Fig. 14).

The visionary approach to masterplanning adopted within each of these standout projects demonstrates a comprehensive and sustainable approach to the planned development of an eco-town, a mixed-use commercial quarter and a whole new urban district.

By incorporating the six pillars of 'adaptive communities' throughout our practice, we strive to create developments which not only bring new life to formally under-optimised areas of our towns and cities, but also celebrate and build upon their heritage and locational assets. Each of these seminal projects encapsulates the core principles of 'place', proactive planning and building consensus, while also implementing these core principles. As we continue to grow and develop through

Fig. 14 Greenwich Peninsula Sustainability Audit © Farrells

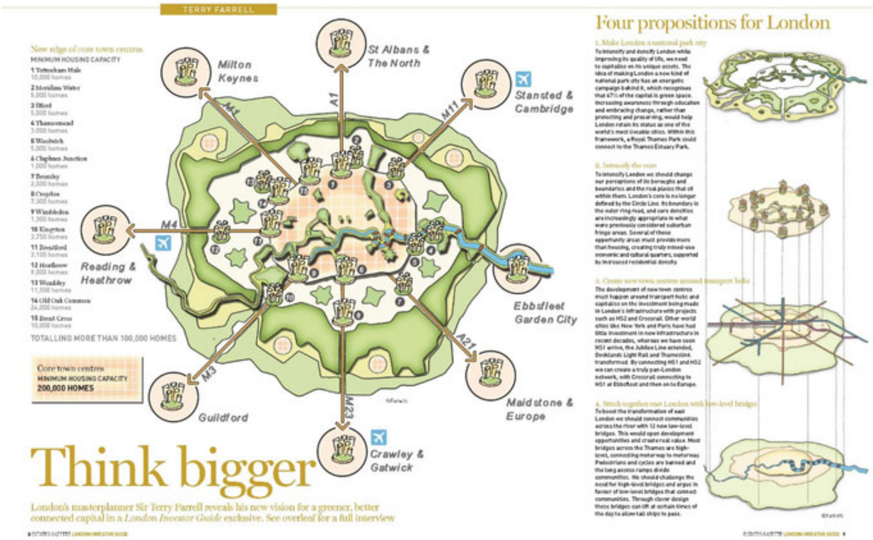

Fig. 15 Four Propositions for London, Estates Gazette © Farrells

our expansive work, we hope to further develop our understanding of sustainable urbanism in practice, and continue to create great places, 'adaptive communities' and future cities which will grow, evolve and prosper throughout their lifetime (Fig. 15).

4.1 Adaptive Communities in the Asian Context: Delivering Rapid Growth and Hyper-Density

With almost 70% of the world's population estimated to be living in urban areas by 2050 (Burdett and Taylor 2011), there has never been a more pressing time to consider how we will accommodate such large and rapid growth in urban populations, while also progressing towards a sustainable future.

Nowhere more so have such patterns of growth been seen than in the rapidly developing nations of Asia. Glaeser (2011) observes that just a generation ago, both China and India were predominantly poorer, rural nations. However, over a fifty-year period, they are achieving the same industrial and urban transformation that took centuries in the West (Glaeser 2011). The result is an inevitable explosion in the consumption of land, energy and natural resources, which may, in time, lead to concerns of global sustainability (Glaeser 2011).

There is, however, a middle ground that combines rapid growth with fewer environmental risks. This path involves high-density urban living (Glaeser 2011). This final section explores our international experience in Hong Kong where highly innovative and progressive approaches to urban planning and design are changing the model of sustainable development and questioning established design ideals. Reflecting on the contrasts between European and Asian approaches to design, this section analyses the principle concepts of transport-orientated development, three-dimensional public realm design and tall buildings. It concludes by advocating the rise of the hyper-density model, presenting a new image of 'adaptive communities' and a potential vision for the future city, not just relevant in Asia but with a wider global applicability.

4.2 *Transport-Oriented Development*

In the 1960s, Jacobs (1961) argued that we could minimise our damage to the environment by clustering together in high rises and walking to work. This notion has since been developed to support the concept of transport-orientated developments (TOD). As the name suggests, TODs orientate dense urban development around efficient public transport nodes and along linear network corridors (Floater and Rode 2012). Floater and Rode (2012) observe that, in rapidly developing cities such as London and Hong Kong, this integrated approach to transport and land-use planning has created a highly accessible city core, with a very high percentage of jobs located within 1 km of a rail station, and the vast majority of motorised trips using public transport. Not only has this been observed to bring social and economic benefits to cities, but this model also allows for very low per capita transport-related carbon emissions and extremely low car ownership (Floater and Rode 2012).

This close relationship between transport, social and economic mobility is key to accommodating rapid urban growth and developing a sustainable future for our cities: 'the technology of transport leads to contingent human habits being formed around significant hubs of movement, and the types of spaces (homes, workplaces, warehousing, shops, places of worship and even educational spaces) that are the very DNA of habitat start to accumulate around these new locations' (Farrell 2013).

Such TOD has formed the focus of development at London locations such as Kings Cross and our emerging proposals for Old Oak Common, as well as a number of principal projects in Hong Kong, including our comprehensive redevelopment of Kowloon Station.

When Hong Kong resolved to close its congested airport at Kai Tak, the construction of its replacement broke all records for scale, speed and innovation. Part of the largest infrastructure project in Hong Kong's history, the Lantau Airport Railway, was conceived to provide a high-speed link between the city and the new airport at the remote island of Chek Lap Kok. We won a design competition for the largest station on the line, Kowloon Station, which serves both the Tung Chung Line and the Airport Express. It resembles an airport terminal more than a conventional metro station, incorporating in-town check-in counters, baggage handling and screening systems, as well as complex facilities for interchange to franchised buses, minibuses, taxis and private coaches (Fig. 16).

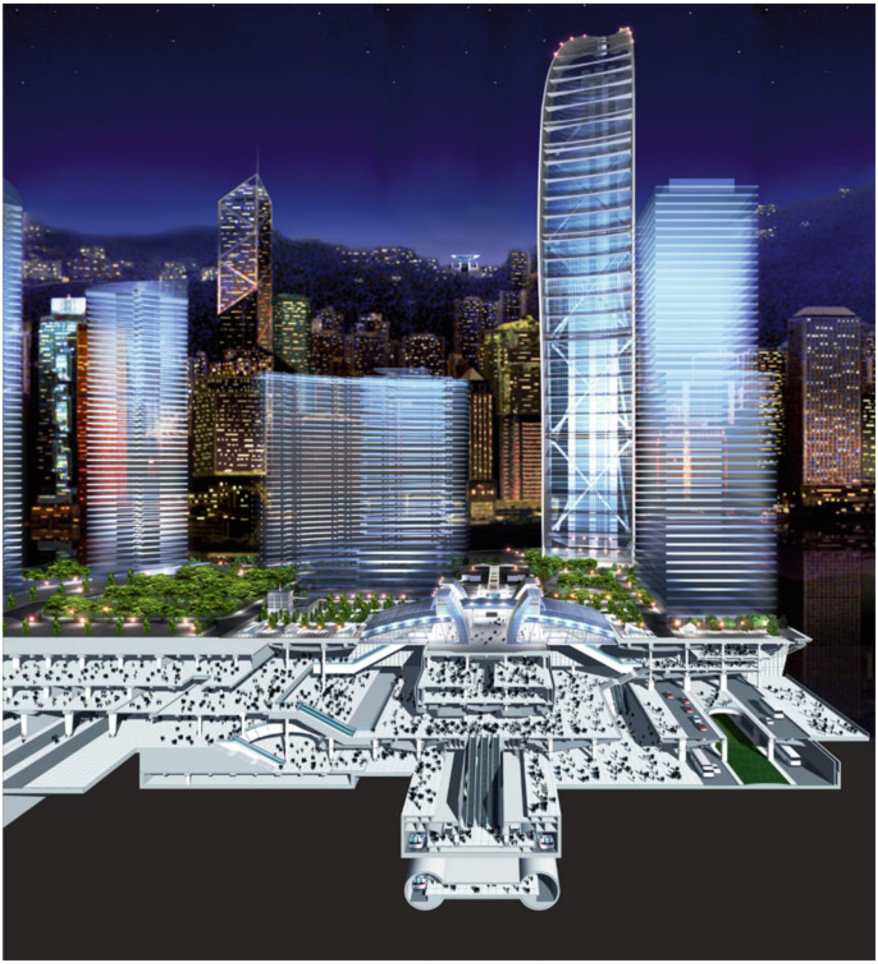

Fig. 16 Kowloon Station © Farrells

Above the station, we developed a masterplan for a high-density, three-dimensional transit-oriented urban quarter. The seven independent and sequentially phased development packages comprise one of the world's largest station air rights developments, grossing over one million square metres of space for hotel, office, retail and residential accommodation, all arranged around a central square with easy access to the station below. The final development is home to the 118-storey International Commerce Centre; Hong Kong's tallest building, accommodating a hotel at its top and millions of square feet of grade A office space.

With 90% of all trips made to and from the new Kowloon Station district being made via public transport, this large development project successfully represents the seminal importance of transit orientation within our developing approach to designing adaptive communities and shaping the future city. This large scale thinking considers a city's wider concerns and shows a distinct appreciation to more general types of habitat that grow out of the context of both social and technical change.

4.3 Three-Dimensional Public Realm

While it presents a highly convincing and compelling vision, the compact city development mode—growing from one dense centre serviced by an efficient transport network—has inevitable faced significant opposition. Indeed, public advocacy for high-density development is extraordinarily low, primarily because its merits are misunderstood (Books and Chakrabarti 2013). Yeh (2011) argues that there is a myth that high population density is undesirable and often associated with social problems but despite very high densities, rapidly growing cities are proven to still be very liveable. Yeh further advocates that the negative effects of density can be mitigated by the design, layout, open spaces, traffic and community facilities of both external and personal spaces within a 3D vertical city.

The Kowloon Station development further exemplifies this concept through its fundamental provision of pedestrian links at the first storey, supporting the prominent vision for the underutilised Kowloon Point. This forward thinking elevated public realm will eventually connect Kowloon Station with the West Kowloon Cultural District, one of the world's most ambitious cultural projects (Fig. 17).

Lau and Zhang (2015) advocate that a vertical city, with multifunctional land uses within a single plot or building, is the most viable solution for an urban condition characterised by increasing density due to population expansion, topographical limitation of buildable land, economic development and the pursuit for collective sustainable living. A hyper-dense city has an overall density that exceeds 5,000+ inhabitants/km^2 and often with city districts exceeding 30,000+ inhabitants/km^2. Cities that fall under this definition include Mumbai, Paris, Nairobi, Hong Kong, Macau, Dhaka, Dar Es Salaam, London, Manila, Stockholm and Shanghai. The hyper-dense city differs fundamentally from a megacity in that the 10 million plus population of a megacity could be spread across a large area with very low densities, though it is worth noting that many megacities are also hyper-dense.

By combining a multitude of varied land uses into the city's vertical dimension, the hyper-dense city can optimise the accessibility, vitality, amenity and efficiency of buildings, as well as the communities they serve (Lau and Zhang 2015). This is particularly important in regards to a city's invaluable public realm, which may be easily lost within the melee of rapid growth. The hyper-dense, vertical city, therefore, offers a new perspective to designing the public realm. Chen and Weijia (2009) note that there are a multitude of opportunities for improved urban greenery at multiple levels of elevation, from the ground through elevated walkways, on podium plinths and up to the rooftops.

Our work at Kennedy Town Station, the new western terminus of Hong Kong's MTR Island Line, exemplifies another type of multidimensional public space where

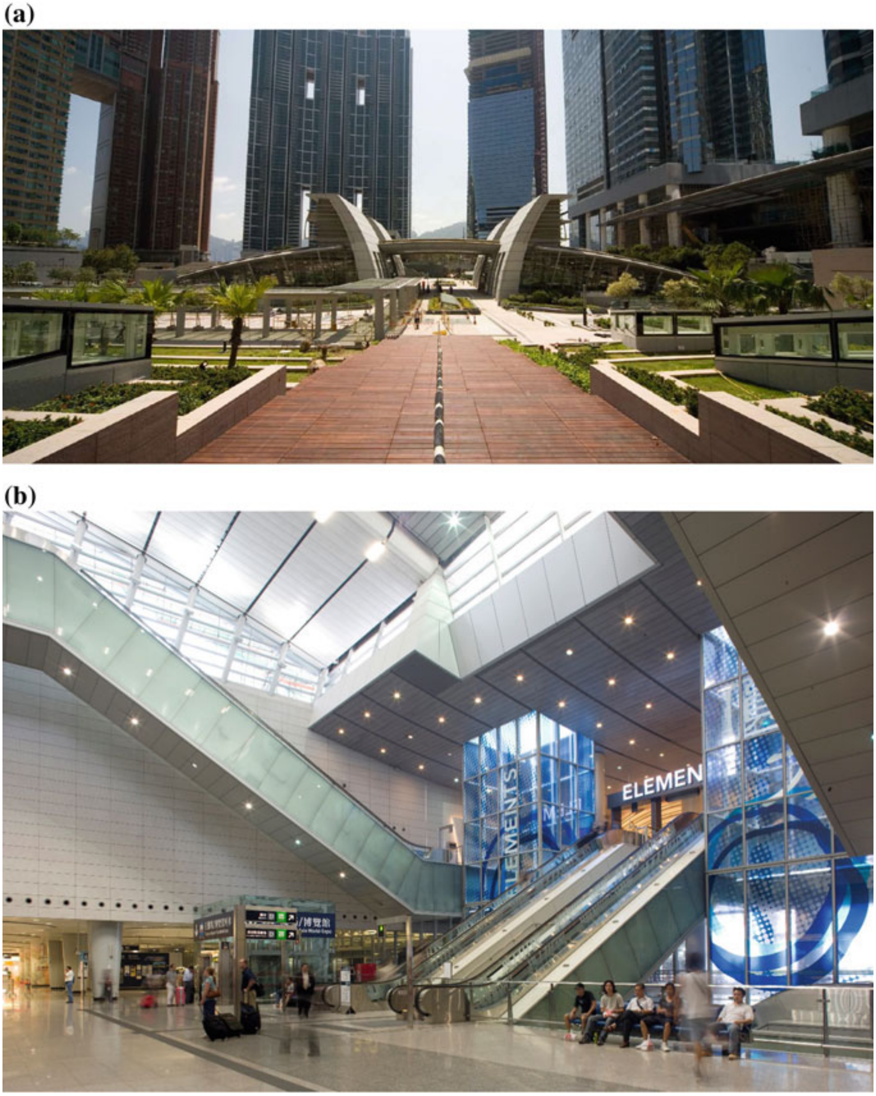

Fig. 17 **a** Kowloon Station Podium Garden and Square,**b** Kowloon Station Shopping Centre and Station Concourse Atrium © Farrells

the unpaid concourse, linking multiple ground levels, filled with natural light and lined with shops, is an extension of the external public spaces, themselves paid and maintained by the transport project.

Comprising two underground levels with entrance pavilions, a bus terminus and a children's playground above, the design of the station aims to sensitively blend its structure into the existing urban fabric. Natural materials and colours pay respect to adjacent historic stone walls, colonised by 120-year-old banyan trees, which were carefully preserved. The shallowness of the station afforded an opportunity to introduce natural light into the concourse areas. During the day, sunlight pours into the transparent entrance buildings as well as the glassed-in lift shafts. Community artworks adorn the concourse and reflect the unique characteristics of the Western District. Also, in the interest of improving access to the station, knitting the surrounding communities together and reducing reliance on polluting road-based transport, we designed two new lifts to connect Rock Hill Street with the upper section of Sands Street.

These aspirations for a multidimensional public space are widely accepted as being made possible through the introduction of the ‘podium/tower system’. This unique structural model separates a tower building into two parts: at the base is a podium, and above the podium is the tower (Lau and Zhang 2015). The podiums are used for mixed functions, offering a variety of community services and commercial enterprises, while the towers are reserved for residences (Lau and Zhang 2015). Through simple vertical segregation, the podium/tower is regarded as a unique example of vertical and multifunctional land-use practice, which creates an elevated or artificial ground floor, maximising the use of the podium roof area, and the efficiency of the building within the hyper-dense city core (Lau and Zhang 2015). These podium roofs present the distinct opportunity for multiple uses, importantly public amenity space (Fig. 18).

Fig. 18 Kennedy Town Station Public Realm © Farrells

4.4 Building Tall

High demand for commercial space combined with demand for housing and retail in central areas where land availability is highly constrained, or where co-location is made desirable by high land values, supports the exploration of mixed-use tall buildings in appropriate locations. It must be noted that what constitutes an appropriate location differs. In the practice of applying our 'PLACE' methodology and in the rigorous application of our aforementioned criteria for 'adaptive communities', we ascertain whether the tall building typology is appropriate for the development in question.

Appropriately located tall buildings, that are contextually sound, can play a positive role in the city by increasing its regeneration potential. When introduced as part of a large-scale regeneration/redevelopment scheme, tall buildings can achieve significant positive change for the local area, as well as creating significant positive city wide impacts, such as the need for services creating employment and by producing a safe environment round the clock by bringing a critical mass of residents and workers. They can change a site's land value and economic potential and subsequently increase the investment in the supporting infrastructure system. The tall building typology creates landmark elements which assist placemaking through legibility, while the focused intensification they offer helps to promote sustainable urbanism at the megacity level.

Within this framework of hyper-density, urban intensification is intended to achieve far broader objectives of sustainable development, relating to minimising the loss of countryside through urban sprawl, the reduction in traffic and carbon emissions and the focused regeneration of our city centres. In city centre locations or central clustered areas, land value, land use and efficient use of public infrastructure may increase intensification and vertical density. Intensification through an increase in scale can contribute to the city's overall provision of amenity space, as well as potentially increasing overall urban vitality. The intensification offered by tall buildings can create similar growth in population to that of small towns. This concentration of people and land use around satellites/focus points acts to focus functionality and placemaking and increase local activity and vitality, so as to create exciting and vibrant new places. Winner of an international design competition, our KK100 building held the title of tallest building in Shenzhen from 2011 to 2016 and is currently the tallest building ever designed by a British architect. It forms the centrepiece of an innovative high-density, eight-tower development that embodies a uniquely community-minded approach to urban regeneration.

The 3.6 ha site was previously home to Caiwuwei village, a dense cluster of tall, tightly packed village houses with restricted access to sunlight and fresh air. Inadequate municipal servicing contributed to urban decline. The developer included the existing residents as partners, forming a joint development company with them. Village homes were replaced in the form of spacious new flats overlooking Lizhi Park, and further benefitting from a communal garden space and swimming pool at podium level. Additional apartment buildings provided the villagers with second flats, ensuring their financial security through a steady source of rental income. The arrangement was a win-win for both the developer and the villagers.

The 100-storey, 441.8 m tower presents a truly mixed-use complex, containing grade A office space, a six-star hotel, trading areas, conference and business facilities and a fitness centre (Figs. 19 and 20).

Emphasis on sustainability was intrinsic to the tower's design. Major 'green' proposals included an environmentally friendly built form and envelope design. Its cladding is a sophisticated environmental skin that allows the tower to maintain an optimum interior environment while minimising potential solar heat gain and the modular approach of the system ensures that it is cost-effective. The use of natural light from the podium roof and an ample floor-to-floor height of 4 m allow daylight to penetrate deep into the floor plates. The tower has eight lift zones, four below and four above the sky lobby, which help to reduce the footprint of the core by stacking the lift shafts. The direct connection to the metro station reduces transit time and subsequently carbon emissions. This encompassing approach to 'building tall'

Fig. 19 KK100 Tower, Shenzhen, China © Farrells

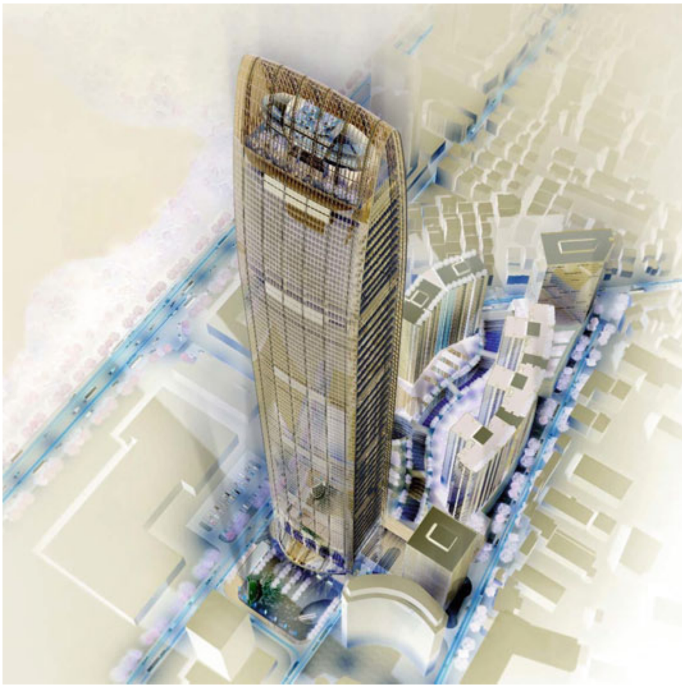

Fig. 20 KK100 Tower Conceptual Design © Farrells

presents a compelling and highly prominent precedent for how to deliver the hyper-dense city. While we of course do not advocate that this model is universally applicable, it does represent an enlightened view of the potential function and beneficial return from these vertical extensions to our city cores.

Place-based differences between UK and China developments are linked to the point in time in history where population density in city centres were maximised. Where London had the highest density levels in the late nineteenth century, the lack of construction methods and technology allowing taller buildings led to overcrowding and slums. In Hong Kong, and more widely across Asia, this phenomenon being relatively recent in comparison, typologies and technologies were already available to respond to a growing population. However, as urbanisation rates continue to increase worldwide and populations become more and more mobile, bringing renewed growth to western capitals, these hyper-dense models and associated environmental challenges become highly relevant globally.

Books and Chakrabarti (2013) reflect that these multifaceted approaches to design, including TOD, 3D public realm and building tall, form a prerequisite for making hyper-density not just liveable but enjoyable. There are, of course, a number of distinct questions which still surround the morphology and physical characteristics of the hyper-dense city, in particular the appropriate relationship between public infrastructure and the private realm (Books and Chakrabarti 2013). However, with rapid urbanisation continuing worldwide, experiments in hyper-dense morphology will continue, and questions surrounding the best formal qualities of intense, vertically dense, transport-orientated cities will remain very open-ended (Books and Chakrabarti 2013).

5 Conclusion

In conclusion, delivering sustainable places in the day-to-day practice of making and shaping the city confronts and questions its theoretical definition and the understanding of what constitutes sustainable urbanism.

Our extensive experience as practitioners has led us to understand and describe sustainable urbanism first and foremost as a process, as opposed to a set of fixed outcomes. We believe that the desired outcome of this continuous and self-reflective process is the creation of 'adaptive communities' that are designed to be flexible to weather ever-changing demographic, environmental, social and economic challenges. These 'adaptive communities' in turn offer a strong and viable opportunity for our communities to evolve and develop together in line with individual and community aspirations.

Over the years, in our pursuit of delivering 'adaptive communities', we have refined a PLACE methodology that advocates the following key principles:

- 'Place' is the client;
- Proactive planning is essential to creating places for the greater good of all;
- Building consensus needs to shape the process;
- Planning, landscape, architecture, conservation and engineering work together holistically, rather from isolated silos.

Using the PLACE methodology, we have delivered exemplar projects of 'adaptive communities' in the UK, such as Bicester Eco-Town and Regent's Place, that seek to understand historical and geographical context, build consensus, utilise technology to create healthy places, promote the considerate use and production of food and water, respect and enhance heritage and foster knowledge and partnerships. In Asia, 'adaptive communities', such as at KK100 or Kowloon Station, have taken on a different urban form: a hyper-dense model capitalising on the integration of transport hubs, mixed-use environments, high rise towers and three-dimensional public spaces to respond to the pressure of delivering rapid urban growth.

Ultimately, our experience as practitioners has proved time and time again how critical it is that sustainable urbanism is rooted in a comprehensive understanding of place which underpins the creation of 'adaptive communities' that provide for current and future residential and commercial needs, contribute to the positive management of rapid urban growth and where people enjoy living, playing and working.

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