Mike Jenks · Colin Jones *Editors*

Dimensions of the Sustainable City

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Springer

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Cover illustrations: (front) Urban infill on brownfield land can intensify activity in the city and help towards a more sustainable environment (Oxford City centre, UK). Photo: Mike Jenks; (back) An efficient tram system can encourage people to use public transport and reduce traffic in the city (Sheffield City centre, UK). Photo: Mike Jenks.

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Preface

This book represents the overarching output from the *CityForm: Sustainable Urban Form Consortium* funded by the Engineering and Physical Sciences Research Council (EPSRC) under its Sustainable Urban Environments Programme (Grant number GR/520529/01). The consortium comprised a multi-disciplinary team based at the universities of De Montfort, Heriot-Watt, Oxford Brookes, Sheffield and Strathclyde. The consortium was supported by a large number of non-academic partners – Corus, the Environment Agency, Glasgow City Council, Groundwork UK, The Landscape Institute, Leicester City Council, Oxford City Council, The Prince's Foundation, Rogers Stirk Harbour + Partners, Scottish Executive, Sheffield City Council, Sheffield Wildlife Trust, Strathclyde Passenger Transport, and URBED.

The core of the research explored the relationship of five strands representing the environmental (energy and ecology), transport, and social and economic dimensions of urban sustainability to urban form. There were also three satellite projects that examined ways of adapting the city, whether sustainable developments lead to sustainable lifestyles and the ecological and psychological value of urban green space.

Many of the papers on which this book is based are to be found on the CityForm web page, www.cityform.org.uk. The editors of the book were the co-champions of the consortium.

Oxford, UK — Mike Jenks
Edinburgh, UK — Colin Jones

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Chapter 1
Issues and Concepts

Mike Jenks and Colin Jones

What is Meant by the Sustainable City?

There has been a considerable amount of research that defines and characterises the form of the sustainable city, and which urban forms may most affect sustainability. It is a complex issue. The physical dimensions of urban form may include its size, shape, land uses, configuration and distribution of open space – a composite of a multitude of characteristics, including a city's transportation system and urban design features (e.g. Handy, 1996; Llewelyn-Davies, 2000). However, its sustainability depends on more abstract issues – environmental (including transport), social and economic. Research suggests that, not one, but a number of urban forms may be sustainable (Williams et al., 2000). Yet much of the debate about the sustainability of cities and urban forms has focused on increasing the density of development, ensuring a mix of uses, containing urban 'sprawl' and achieving social and economic diversity and vitality – often characterised as the concept of a 'compact city' (see Jenks et al., 1996; Jenks and Dempsey, 2005).

In the UK, government policy embodies such principles through its Urban White Paper (DETR, 2000a; DCLG, 2006a), mostly based on the report of the Urban Task Force (1999). Thus in the UK, a dominant paradigm is being implemented in many towns and cities. It is for more compact, high-density and mixed use urban forms, and the belief is that they will be sustainable. This book will take this type of urban form as its starting point and will test the claims made for it.

Urban Form and Claims to Sustainability

With the implementation of policy, practice has, to an extent, overtaken the knowledge and evidence needed to assure the success of sustainable urban forms. Notwithstanding examples of good practice, advocacy rather than research has often

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characterised the debate, and has led to many positive claims for the influence and benefits of different urban forms.

The European Commission was an early and influential advocate of urban containment and more compact forms (CEC, 1990). The hypothesis was that compact urban forms would reduce urban sprawl, protect agricultural and amenity land, and lead to more efficient use of existing, previously developed urban land. With a mixture of uses in much closer proximity, alternative modes of travel would be encouraged, such as walking and cycling, and public transport use would also increase. This in turn would lead to environmental, social and economic benefits. Such ideas were taken up in UK government strategy (HM Government, 1994), strongly advocated as a basis for policy and implementation (Urban Task Force, 1999; DETR, 2000a) and in numerous government publications giving planning guidance (e.g. ODPM, 2004a, b, DCLG, 2006a, b), and policy guidance (e.g. CABE, 2005). Similar urban form concepts to achieve urban sustainability can also be found in, for example, the USA with New Urbanism and Smart Growth initiatives (Katz, 1994; Smart Growth, 2008). All tend to advocate urban forms that are higher than previous densities, with mixed use, which are contained in order to reduce travel distances and dependence on private transport, as well as being socially diverse and economically viable.

The effect of some of these proposed policies and 'solutions' has become evident. In the UK over the past five years there has been an increased take up of brownfield land, fuelled by government targets for building 60% of new homes on re-used urban land (DETR, 2000a, 2001). However, the intensive use of existing land means there is a potential loss of open space and amenity. Environmentally, less open space is likely to have adverse effects on biodiversity and the provision of environmental/ecosystem services (e.g. water and drainage), the consequences of which are largely unexplored. Socially, the impact of 'intensification' or compaction may affect the quality of life of users, and the effects may in some respects fall unevenly on the poor (Burton, 2000a).

Higher densities are strongly advocated, and on the ground there are examples of schemes built and being proposed at higher densities than recommended in guidance (CABE, 2005), of over 100 dwellings/ha (Owers and Oliver, 2001; Dawson, 2004). Theoretical studies have been undertaken on physical capacity, showing how reducing parking provision can increase density (Llewelyn-Davies, 1997; Stubbs and Walters, 2001), and examples of 'car free' housing have been built (Canmore Housing Association, 2008). An active Millennium Communities Programme (English Partnerships, 2007), emerging from the government's Millennium Villages initiatives, has identified seven potential developments, two of which (Greenwich Millennium Village, and Allerton Bywater) are being built. More recently the UK government has announced a competition to build a number of 'eco-towns' comprising zero carbon development as a move to support the UK's carbon reduction targets, and has short listed 15 potential sites for these developments (DCLG, 2007). The 'eco-towns' have been contested in sustainability terms, and are controversial, particularly where they are to be situated on green field sites (Revill and Davies, 2008).

Table 1.1 Aspects of a sustainable built environment (Sources draw upon, inter alia: CABE, 2008; English Partnerships, 2007)

Land use and built form	Environmental – energy conservation	Environmental – recycling and re-use	Communication and transport
• **Intensive use of urban land** • **Networks of green corridors** • Community buildings, self-managed • **Mixture of land uses at relatively high density** • Affordable homes • **Local identity** • Sustainable building materials • Flexible design and good space standards • Improved noise insulation	• **Combined heat and power (CHP) – local power** generation • Micro power generation • Renewable energy • Reduced energy consumption and embodied energy • High levels of insulation • Intelligent lighting and integrated security, heating, and IT systems • 'A' rated white goods • Eco-rating e.g. BREEAM 'excellent'	• 'Grey' water systems • Recycle water for gardening and car washing • Reuse water and filter, to be directed to ecology parks or green spaces • Waste recycling, and use for production of biogas • Reduced domestic and construction waste • Carbon-neutral lifestyle	• **Light transit routes, eco-friendly buses and bikeways** • Car clubs and cycle facilities • **Pedestrian-friendly infrastructure** • **Restricted car parking** • Environmental advice – bus/transit times, energy and water monitoring • IT enabled

The common features of these many initiatives that are claimed to contribute to sustainability are based on a general consensus of opinion, as well as some evidence, and are outlined in Table 1.1, above. These are largely the physical and environmental aspects of sustainability, and are those aspects that are probably easiest to incorporate into developments - not all of them relate to urban form – those that do are highlighted in the table. Generally, only these relevant aspects have been included in the core research reported in this book. However, these have not all been tested to see if they work in practice, and little has been done to show how they interact or integrate as a whole. So while this more intense development may have benefits of providing a more viable model or public transport, it is not clear from experience to date that there has been the modal shift in transport use necessary to yield the claimed environmental benefits. And there are social sustainability arguments underlying these physical aspects, for example high densities and good public transport are linked to social benefits of ease of access to facilities. But more difficult to achieve are safe, inclusive and equitable environments – the link to urban form has received little empirical attention and may well be tenuous. Nor is there evidence to show a clear link between such forms and economic viability. These are therefore not included in Table 1.1: the social and economic aspects are a key to the research that follows and will be placed in context at the end of the book.

An issue of Global Significance

Despite the lack of empirical research to support such claims, it seems evident, at least in the UK, Europe and much of the western world, these policies and 'solutions' provide a useful model and are being implemented in practice. However they are untested, raising questions about their validity. For every positive claim there are also potentially negative impacts to consider. Higher densities may lead to overcrowding, more traffic, and may not be the favoured choice for residents wishing to purchase homes – populations trends still tend to favour rural or suburban locations (e.g. Breheny, 1995). Also, as indicated above, the social and economic impacts are hard to trace to the influence of urban form – many other factors are more important.

It is surprising, therefore, that similar ideas have resonated beyond the western world, and have been taken up by countries where the urban context is very different (e.g. Jenks and Burgess, 2000). Across the world there are some 60 metropolitan regions with populations of more than 5 million inhabitants. Of these regions 46% have populations in excess of 10 million, the largest being the Tokyo Metropolitan Region with more than 36 million people. Most of these large regions, some 62%, are to be found in Asia where the growth rate is fast (World Gazetteer, 2005). These vast urban regions, with either very large urban agglomerations or huge cities at their core, are a far cry from the comforting compact city model inspired by the historic cores of relatively small European cities. These cities often have not just one, but many centres, and these are frequently decentralised, disconnected and fragmented forms (e.g. Graham and Marvin, 2001; Kozak, 2008). In this global context it suggests that the idea of a 'traditional' compact city could be seen as a contradiction in terms.

Nevertheless, some policies and forms that could be appropriate in the world context where cities are experiencing rapid growth are beginning to emerge. In these contexts urban form needs to be considered at a larger and more strategic scale. For example, linking public transportation and development, which may take a number of different forms, including the intensification (or densification) of development around transport interchanges – what has been termed 'transit oriented development' (e.g. Boarnet and Crane, 2001; Calthorpe, 1993; Cervero, 1998; Low and Gleeson 2003). Major transport routes may also provide the opportunity for denser development along the routes, and this has been successfully undertaken in Curitiba in Brazil (Acioly, 2000; Curitiba websites) and in Bogota, Colombia with their 'Transmilenio' bus rapid transit system. When many transportation nodes at higher densities, linked by transportation routes combine into a city-wide strategy, a polycentric form may emerge. Such planned and controlled polycentric development may have the potential to achieve more sustainable forms, provided all the 'nodes' are linked with efficient public transport, although again, these forms have not been rigorously tested (e.g. Jenks, et al., 2008; Lambregts and Zonneveld, 2003; Urban Task Force, 1999).

Within these large urban contexts, fast-growing cities and mega-cities, there are also smaller scale attempts at creating the sustainable city. Indeed the claims for such developments, similar in concept but larger in scale, are often loud and assertive. In the Shanghai metropolitan region, the ‘world’s first sustainable city’ has been proposed – Dongtan (Arup, 2008; Dongtan Development Co., 2008). This ticks most, if not all the boxes in the table above, yet in effect it is a relatively low density (for China) suburb of Shanghai. Even more surprising, in the United Arab Emirates, two eco-city initiatives are underway – Masdar in Abu Dhabi designed by Foster and Parnters (Basantani, 2008; Foster and Partners, 2008) and an eco-city in Ras Al Khaima, designed by Rem Koolhaas and OMA (Trotter, 2008; OMA, 2008). These are ‘stand-alone’ models, again ticking all the boxes and edging towards zero carbon development. There is a danger that these ‘models’ will become eco-theme parks, functioning in a similar way to carbon offset schemes, salving the conscience, and freeing the neighbouring cities to continue business as usual development. Obviously these eco-cities (like the eco-towns in the UK) will be a help if all new development is zero carbon, but most places and most cities are already existing, and often very large. Sustainable development and sustainable urban forms need to pervade the whole environment, and not simply be exemplars that are separated from every day, messy reality.

Understanding the dimensions of the sustainable city is a complex issue. Care needs to be exercised over the context within which the cities exist, their cultural background and regional and national differences. There will be significant differences in different parts of the world of the interpretation of the sustainable city; however there are common underlying and enduring themes that appear to inform both the debate about and claims for urban forms that promote sustainability. Overall, research indicates that there are unlikely to be single spatial or physical solutions, rather that there may be many forms that can achieve sustainability, depending on the context in which they are applied (e.g. Guy and Marvin, 2000; Jenks and Dempsey, 2005).

The Aim of the Book

This book is about experience in the UK, but it picks up on many of the common themes and issues experienced in cities worldwide and presents research that assesses and measures them. Thus, in order to make progress, the research reported here measures and characterises urban form so it can be related to environmental, social and economic sustainability, and comparatively analyses different forms. The research concentrates on the physical design of urban form with respect to: physical configuration and layout, including links to the wider urban system; its land uses and functions; the typology and density of built form and presence of open space. The claims made that more compact, high-density and mixed use urban forms are environmentally sound, efficient for transport, socially beneficial and economically viable will then be tested. Each of these aspects is considered below, the current state of knowledge is briefly reviewed and gaps in knowledge identified.

Researching the Dimensions of the Sustainable City

The book explores the relationships between urban forms and environmental, social and economic sustainability. The major research question addressed is: *To what extent and in what ways does urban form contribute to sustainability?* This question is important to tackle and addresses several gaps in knowledge identified from analysis and review of research in the field. The sections below indicate some of the key problems that led to this research question.

Environmental Sustainability

Environmental benefits are claimed to accrue from more compact urban forms where concentration of uses means less need to travel and therefore lower emissions from vehicles (see Transport below). In addition, claims about higher densities suggest benefits in energy savings through combined heat and power (CHP) provision, but that benefits might be outweighed by the loss of open space. In assessing aspects of environmental sustainability the research focussed on the different patterns of provision of open, and especially green, space. The environmental benefits of open green spaces include: reduced surface and air temperatures, due to solar shading, free radiation to the night sky and evapotranspiration from trees leading to improved summertime thermal comfort (Vu et al., 1998); a haven from urban pollution and noise (Tyrväinen, 1997); and, buffering against wind reducing wind chills (Lacy, 1977). Benefits extend to the surrounding buildings, e.g.: heightened market value (Savard et al., 2000); improved access to natural light, reducing lighting loads in non-domestic buildings (Crisp et al., 1988); provision of passive solar heat to dwellings (Yannis, 1994); and, a low-noise and low-pollution source of fresh air allowing natural, rather than mechanical ventilation. Finally, green spaces can ameliorate the urban heat island effect and provide ‘free’ cooling to buildings (Watkins et al., 2002) – thus reducing the use of air conditioning systems thereby lowering energy consumption and CO_2 emissions, running costs and further anthropogenic heat release into the city.

The ecological benefits suggested for open green space include: the provision of ecosystem/environmental services with consequences for such diverse issues as flood control, waste management, and pest control (Bolund and Hunhammar, 1999; Attwell, 2000; Pauleit and Duhme, 2000); the provision of habitat for biodiversity (Gilbert, 1989; Savard et al., 2000; Kinzig and Grove, 2001); and, heightened awareness of environmental issues among users (Cannon, 1999; Savard et al., 2000).

Claimed social benefits of access to green space encompass a range of quality of life dimensions, including: improved human health and well-being (Ulrich, 1981; Ulrich et al., 1991; Parsons et al., 1998); opportunities for social interaction and group activities and a possible reduction in crime (Whyte, 1980; Skjaeveland and Garling, 1997; Tinsley et al., 2002); strengthened feelings of neighbourhood attachment and local community (Bonaiuto et al., 1999; Langdon, 1994) and the promotion of civic pride and sense of place (Duany and Plater-Zyberk, 1992) and providing opportunities for contact with nature (Burgess et al., 1988).

Despite this plethora of perceived benefits, there has been relatively little work done in UK cities to assess whether they materialise in practice. Little empirical research quantifies the magnitude of the benefit or determines who are the beneficiaries. There is little work on the effect which urban form has on the thermal comfort in open spaces and the energy and environmental implications for UK cities (except Regents Park, London (Watkins et al., 2002)). Neither have all the energy and emissions implications been studied simultaneously (i.e. heating of dwellings, cooling and lighting of non-domestic buildings) for particular combinations of building types, urban forms and open spaces.

While there is an extensive literature focusing on the social benefits, and usage, of managed urban green spaces (e.g. Tinsley et al., 2002; Faber et al., 1998; Payne et al., 2002; Burgess et al., 1988), there has been relatively little empirical investigation of the social benefits of non-managed public spaces and private gardens. Furthermore, very little is known about whether or how the perceived social benefits and usage of urban green spaces varies with the density of the built environment (investigated by only one empirical study by Syme et al., 2001), nor how frequently local green spaces are used and what benefits are perceived to be associated with them.

Transport

Key policy (DETR, 2000a) and planning guidelines in the UK (DTLR, 2001) suggest that planning can reduce both the need to travel and length of journeys, and give safer and easier access to facilities through more compact, higher density and mixed use forms. The benefit of these forms is inter alia claimed to reduce car use, and encourage a shift towards more sustainable modes of travel, such as walking, cycling, and through increased use of public transport. However, such transport benefits crucially depend on people changing their travel behaviour.

Links between urban form and travel behaviour were identified, for example, by Handy (1996) and Badoe and Miller (2000). Handy (1996) found that residents in traditional neighbourhoods, characterised by higher densities, better accessibility and pedestrian- friendly design exhibited more sustainable travel behaviour than residents of neighbourhoods with lower densities, poor accessibility and pedestrian unfriendly design. Urban form, as measured by density, diversity (i.e. mix) and design, exerted a *modest to moderate* influence on travel demand, and that compact, mixed-use, pedestrian friendly designs were associated with more sustainable travel patterns (e.g. Cervero, 1998). In the UK, Stead et al. (2000) found that socioeconomic characteristics typically explained around half of the variation in travel distance per person across different study areas, whilst land use characteristics explained around one third of the variation.

However, finding a significant association of this kind between urban form and travel demand does not in itself mean that urban form per se will bring about more sustainable travel behaviour. The potential for the 'compact city' to bring about this result was questioned by Simmonds and Coombe (2000). In a study using a transport model of the Bristol area, a number of urban form scenarios were tested and found to make little impact on both total travel and car travel when viewed against the trend of increasing car ownership and the low cost of travel by car. These factors have greatly weakened the influence of spatial segregation on travel behaviour, and have presented many individuals with a far wider choice of residential location, job opportunities, services and other activities than ever before. Thus, the policies of densification and mixed-use development are likely to have little effect on travel behaviour without appropriate supporting transport policies.

The gaps in research suggest the need to seek a better understanding of the impact of urban form on travel behaviour to enable more accurate predictions of the travel patterns resulting from changes in urban form to be made. Many previous studies that sought to do this can be criticised on either methodological or theoretical grounds (see Badoe and Miller (2000) for recent critiques).

A common failing is to give inadequate consideration (or none at all) to the effects of factors representing the availability and quality of transport options, such as travel times and journey costs. Many previous studies have used data aggregated at the local level which serves to mask the effect of within-area variability. Disaggregated analyses, which use individual and household personal and travel/activity data and urban form measured at the local or the household level, are better suited to reveal the underlying complexities of the relationship between urban form and travel behaviour. Ultimately, the development of the most appropriate balance of urban form policies for the delivery of more sustainable travel patterns in a given context requires the application of sound theory derived from causal inferences. The research reported here addresses how (and why) individual, or sets of interrelated, elements of urban form influence travel behaviour and in what way socioeconomic characteristics interact with urban form to influence travel behaviour.

Social Benefits

The claims about the influence of urban form on social sustainability are complex and embrace issues of both quality of life and social equity. Higher densities and mixed use urban forms will, it has been argued, lead a better quality of life due to more social interaction, community spirit and cultural vitality (e.g. Rudlin and Falk, 1999), in part due to 'proximity to work, shops and basic social, educational and leisure facilities' (Urban Task Force, 1999: 64). Having a variety of uses and the means to access them nearby is also seen as a key to achieving social equity (ibid: 45), especially for the more disadvantaged in society who may not have the resources (and for those who do not wish) to own a car. Burton (2000b) identifies a number of claims that positively link compact urban form to social equity. These claimed benefits include better access to facilities and jobs, better public transport and opportunities for walking and cycling, lower levels of social segregation and less crime. But alongside the benefits, there are claims that compaction leads to negative impacts such as poorer access to green spaces, poorer health, reduced living space and less affordable housing (ibid).

The evidence about these many claims raises a number of key questions for the research reported here. One clear message is that there is no single answer, as benefits (or costs) depend on the type of urban form and its social context. For example, while inner city mixed use areas might achieve benefits of more social interaction and vitality, and better access to facilities, they also could suffer from social tensions, crime or fear of crime and bad neighbour effects (Williams, 2000). In more suburban residential areas, quality of life may be enhanced by access to greenery, stronger social contacts and better safety and security, but poorer access to facilities (Masnavi, 2000). Questions are also raised about the acceptability of living in such urban forms (Jenks, 2000) and whether there is a social capacity beyond which environments begin to be unsustainable (Williams et al., 1999). Given the continuing counter-urbanisation trends (Breheny, 1995) and a powerful anti-urban ethos in the UK (Crookston et al., 1996), further questions are raised about peoples' attitudes to, and the extent to which they may wish to live in more 'compact' environments (notwithstanding the claimed benefits). When people do choose to live in more 'sustainable' urban forms (e.g. flagship or demonstration projects such as BedZed in the UK or Bo01 in Malmo, Sweden), the question remains whether or not they change to follow more sustainable lifestyles. Although the sustainability of certain physical aspects of the built environment such as density, compactness and design have been the subject of research (van Diepen, 2000; Williams, 2000; Williams et al., 2000; Carmona et al., 2001), in places these studies cast doubts on the link between built form and end user behaviour. However, so far no comprehensive studies have concentrated on behaviour or lifestyles associated with sustainable urban developments.

Economic Viability

It has been suggested that higher density forms support more diverse local service provision, by making local businesses and units more viable, while strengthening local supply chains. Higher density mixed used central areas are claimed to encourage more interaction and networking which promote innovation and creativity and hence greater endogenous growth including the formation of economic 'clusters'. Urban consolidation reduces infrastructure costs through scale and network economies and the re-use of existing capacity, whilst raising land values and so making (re-)development more viable, so reinforcing the spatial strategy.

Research has shown that range and quality of local services tends to be greater in high density areas, especially central/nodal places, but trends in the economics and technology of some sectors is still leading to rationalisation into larger units, which may seek non-central locations. Service viability depends on income as well as density, and deprived urban neighbourhoods may lack services even when densities are high. Local supply chains are weak in many sectors, and may be weakening over time (Simmie et al., 2000; Simmie, 2001; Bramley et al., 2001). While some knowledge-based and cultural sectors are attracted to central cities, the evidence for clustering is weak in many cases and relevant networks may be more regional, national or international (Begg, 2001; Simmie, 2001). Many businesses are still attracted to low-density developments with ample car-parking in edge city locations accessible to motorways. Urban containment raises housing costs and reduces space consumption (Cheshire and Sheppard, 1989; Evans, 1991; Bramley, 1999, 2002; Bramley et al., 1995; Bramley and Watkins, 1996; Bramley, 2002), while high land values may militate against diversity of local services. Higher demand renders brownfield development viable but this is problematic for 'low demand' city regions (Monk and Whitehead, 2000; Bramley, 2002).

There were many gaps in economic research for this book to fill. There is a lack of systematic data on trends in the range and quality of local services and its relationship with urban form, and similarly with respect to supply chains and their key determinants. Systematic data on infrastructure costs of new or re-provision, and on their incidence, are conspicuously absent in the UK, unlike some other countries (US, Australia), although there is some literature on qualitative changes in provision (Guy et al., 1997). Data on property market performance is improving but has not been linked to urban form, and there are issues about the perceptions held by key property investors of different locations and forms of development including issues of risk (Heneberry and Guy, 1999). How susceptible such perceptions are to change based on experience and demonstration effects is important, and the same comment applies to business location preferences relating to congestion, access, parking and space constraints on expansion. Detailed urban form and design options, within a general high density framework, may significantly impact on the viability of residential developments, via values, costs, risks or timing.

Researching the Sustainable City

It is apparent that few of the claimed benefits of sustainable cities and features of these new 'sustainable' urban forms have been tested systematically, and the evidence to date is inconclusive. While it is possible to identify particular gaps in knowledge, there exists a deeper issue that needs to be addressed. Even where successes have been identified, and positive claims made, there is a considerable lack of evidence-based explanation, prediction and theory about the extent to which urban form as a whole contributes to sustainability. Many of the issues in this complex field interact and conflict. There may be many trade-offs and compromises to achieve advances in sustainability and to satisfy users and residents. In order to address these issues, and fill some of the gaps in knowledge, the research needed to deploy a range of robust and sophisticated methodologies.

Methodology

The methodology aimed to consider and integrate the range of aspects of urban form identified as influencing sustainability. It involves the measurement of urban forms, including building typologies, digital map footprints and configurations which are mapped on GIS, and analysed using methods including SPSS, measures of accessibility and spatial measures through Multiple Centrality Analysis (MCA). At the core of the research, three case study areas in each of five UK cities – Edinburgh, Glasgow, Leicester, Oxford and Sheffield - were selected. These areas represented a central, suburban, and 'in between' location in each city, representing a virtual 'slice' through a city. The research was carried out at a number of scales, including the city, the case study area (or neighbourhood), sub areas, the street and individual dwellings. Figure 1.1 below indicates the range of methods used at the city and neighbourhood scales of the investigation.

The methodologies employed to measure sustainability include:

- *Environmental*: environmental modelling, site surveys, biodiversity, mapped on GIS
- *Social*: questionnaires, focus groups, neighbourhood statistics
- *Economic*: interviews, land and property market data and models
- *Transport*: activity diaries, field surveys, accessibility assessments, transportation mode

These complex sets of data are analysed to find the urban forms which are beneficial, those which are problematic and those where conflicts between and within the sustainability impacts arise. The research was carried out by a number

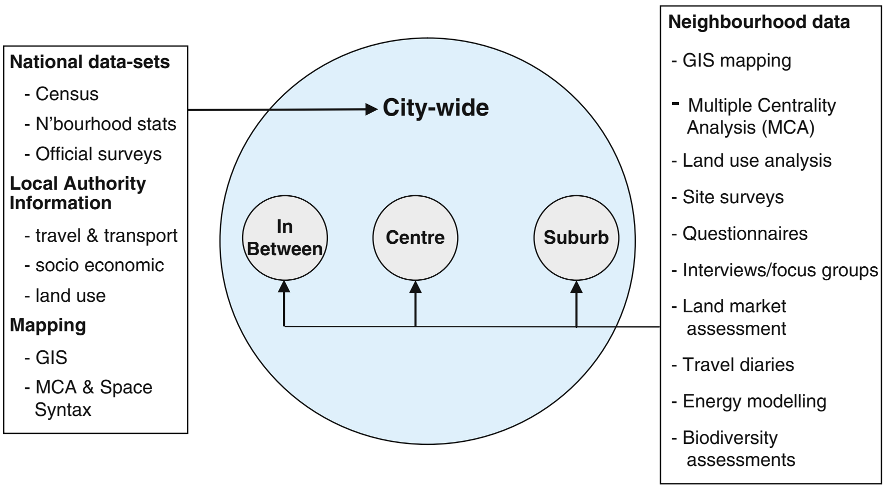
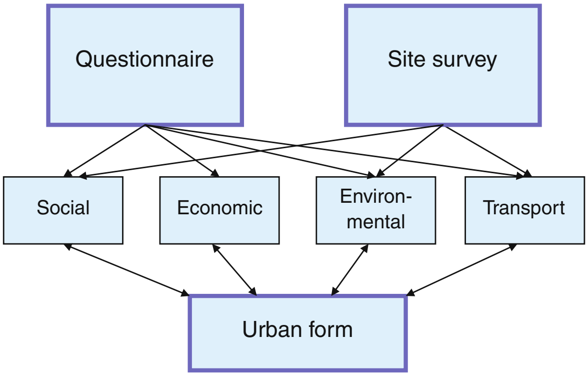


Fig. 1.1 Research methods used at city and neighbourhood scales

Fig. 1.2 Common research methodologies used



of specialist groups within the consortium. Two common methods were used by all in order to provide a basis for the specialist research carried out in each aspect of sustainability (Fig. 1.2). These overall measurements and the specialist ones, were related to the measurements of the urban form of the 15 case studies.

The Structure of the Book

The book attempts to determine the relationships between different urban forms in a range of urban contexts, and: environmental sustainability; transport; social sustainability; and, economic sustainability. It provides guidance on sustainable urban forms, which are acceptable to users, and appropriate for the future. The book follows the structure of the research which was organised into a large, integrated, core project, with three related but separate projects feeding into it (Fig. 1.3).

Thus the book is organised in chapters that relate to the key claims about urban sustainability, and report on the research undertaken.[1] It addresses each major set of claims in separate chapters, and concludes at the end with an initial integration of the research findings that provides some answer to the key question as noted earlier – *to what extent and in what ways does urban form contribute to sustainability*, thus illuminating the dimensions to the sustainable city.

The first chapter presents an introduction to and justification for the book. In doing so it offers an overview of different urban forms and their claims to sustainability, assesses the state of the debate and introduces the key pillars of sustainability – environmental, transport, social benefits, and economic viability.

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[1]This forms part of the output from the *CityForm: Sustainable Urban Form Consortium* funded by the Engineering and Physical Sciences Research Council (EPSRC) under its Sustainable Urban Environments Programme (Grant number GR/520529/01). Further details of the research and publications can be found at http://www.city-form.org/

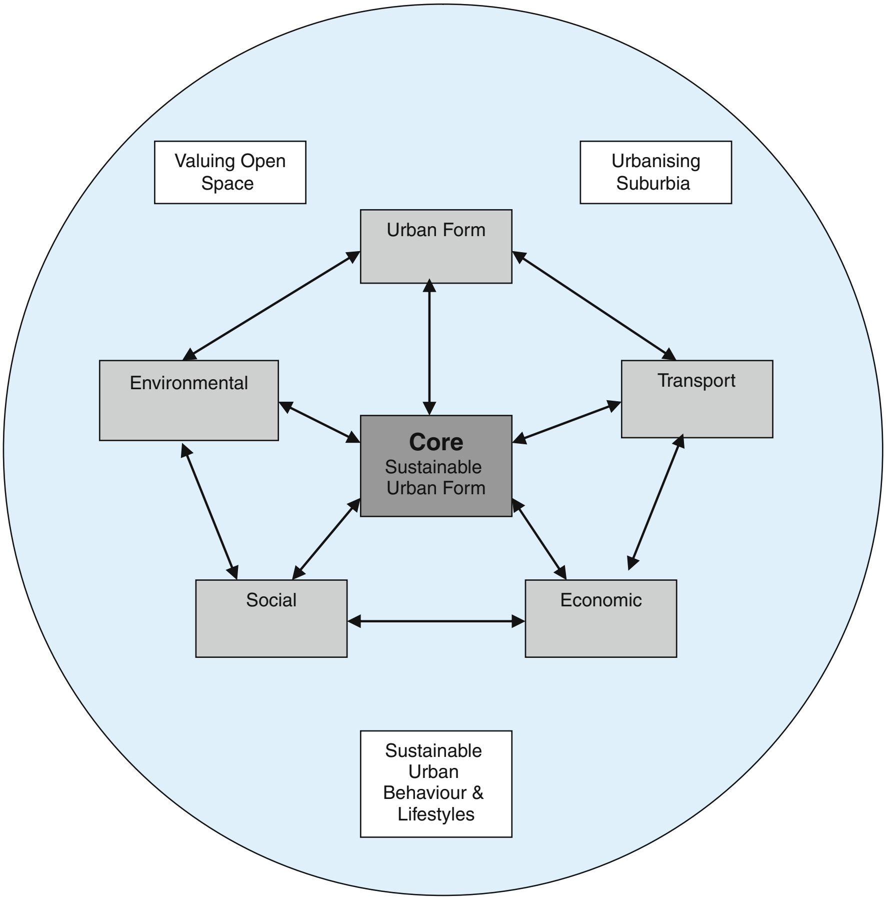

Fig. 1.3 Structure of the CityForm research

A platform for the research is presented in the second chapter. It begins with a review of measures of urban form recognising the role of different scales and outlines the methods of measurement used in the project. It profiles the five cities and fifteen case study areas within these cities that are examined in detail in later chapters. Case study areas represent a ‘slice’ through each city – a suburban area, a central area and an area ‘in between’. These profiles encompass the urban physical form and the socio-economic characteristics by reference to Census statistics. The chapter concludes with a clear exposition of the elements that make up urban form and how they might integrate together.

The effect of urban form on mobility and activity, focusing particularly on the role of neighbourhood is assessed in the third chapter which reviews the underlying issues and current planning policy in the UK that aims to promote more sustainable mobility within cities. Multivariate analysis is used to explore the relationships between residential neighbourhood characteristics, travel behaviour and the type, duration and frequency of activity participation, whilst taking into account the effects of employment location, the wider urban structure and personal characteristics. This empirical research is based on a combination of national data sets and in-depth travel surveys. The chapter concludes with an appraisal of these relationships.

Increasing densities is a key aspect of contemporary urban development, but the ecological consequences of denser urban forms, which Chapter Four examines, are poorly understood. It is suggested that the major determinant of ecosystem performance in urban areas is the amount of available green space. While both green space availability and ecosystem performance are negatively related to urban density, there is considerable complexity within these relationships. This suggests that at any given density, there is substantial scope for maximising ecological performance. For example, in residential areas, the amount, quality and subdivision of green space are strongly influenced by housing morphology. Nevertheless, different aspects of ecosystem performance have different optima with respect to the configuration of urban green space. The implications for ecological optimisation of urban form are discussed alongside the empirical evidence derived from the study.

The social dimension of sustainability is widely accepted but exactly what this means has not been clearly defined and agreed. Similarly, claims about the social sustainability of certain urban forms, such as the 'compact city', have not been adequately tested. Chapter Five addresses both of these challenges. It begins with a discussion of social sustainability, identifying two main dimensions to the concept, related to equity of access and the sustainability/quality of community. The second part of the chapter concentrates on the relationships between social sustainability and urban form, presenting new evidence about the relationships between these two sets of measures based on quantitative measures and taking account of other socio-demographic influences. Finally qualitative evidence is drawn together to gain further insight into the relationships found.

In strictly physical terms the influence of urban form, and particularly built form on building energy use is well understood. At certain levels of description however there remain gaps to be filled if our understanding of these factors is to be well related to other aspects of energy use, particularly those determined by behaviour to improve building energy efficiency. Chapter Six describes work based on recently available UK energy consumption data that aims to improve knowledge in these areas, with the goal of improving energy models that underlie UK home energy rating schemes. Results are presented from the statistical analysis of consumption and questionnaire survey data from respondents living in different built form types in the study areas.

Chapter Seven initially focuses on the nature of the economic debate surrounding sustainable urban forms. From this base it considers the underlying forces that shape the elements of urban form and their impact in turn on a sustainable urban economy. The roles of transport infrastructure and spatial real estate markets in particular are highlighted in the examination of urban form. The chapter suggests an alternative formulation of the approach to urban sustainability that requires, as a necessary condition, viable real estate sectors with sustainable markets. The implications of this viability condition are considered alongside the empirical evidence of individual intra-urban land use patterns in the five cities including ‘viability’ maps of the housing market and retailing.

Chapter Eight describes the development and application of a tool that allows the systematic comparison of the physical, social and economic characteristics of urban areas with commonly agreed indicators and target or threshold values of sustainable development. Establishing the difference between existing and target values allows the objective assessment of adaptation in urban areas in order to make them work in a more socially and economically balanced way. The applicability of the tool for the planning and the programming of urban areas is illustrated in a number of case studies in Glasgow.

Chapter Nine presents the results of research investigating the question: Do sustainable urban environments engender sustainable behaviour and lifestyles, and if not why not? The research findings review the behavioural impacts on households living in sustainable housing developments. The research tests the lifestyle impacts of 13 housing schemes built according to sustainability principles. These schemes include a number of design features associated with sustainability, such as energy-efficient homes and infrastructure which promotes walking and cycling. The chapter presents findings on the extent to which elements of neighbourhood design (drawn from a checklist of over 100 features) support eight key sustainable behaviours. The chapter concludes with comments on the relevance of the findings for designers and policy makers.

Urban green spaces are valuable resources in cities. There is a growing realisation that urban areas form significant components of regional and national biodiversity conservation networks, and the importance of urban nature for the well-being of human urban residents has been the focus of distinct bodies of research. With half of the world’s human population living in urban areas and a continued decline of biodiversity in the wider landscape, urban green space plays an increasingly important role in creating sustainable cities. Chapter Ten considers the links between the distribution of people and biodiversity in the city, the relationship between biodiversity and human well-being, and the potential trade-offs between management of urban green space for people and nature based on empirical research undertaken.

The final chapter addresses the key question: to what extent and in what ways does urban form affect sustainability? It challenges theories about the sustainability of urban form and the oft repeated mantras so prevalent in policy. It summarises the relationships between urban form elements and the dimensions – social acceptability, energy use, travel and mobility, ecology and biodiversity and economic viability – set out in earlier chapters. Some key results that integrate the various components on the research are presented, thus going some way towards answering the key research question raised. The chapter aims to provide policy guidance based on the evidence presented and the key urban form trade offs are identified. The chapter also examines the potential impact of building individual sustainable developments, the use of open space and adapting the city.

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Chapter 2
Elements of Urban Form

Nicola Dempsey, Caroline Brown, Shibu Raman, Sergio Porta, Mike Jenks, Colin Jones and Glen Bramley

Introduction

This chapter provides a common platform for the research presented in this book and is divided into two parts. The first section examines the elements of urban form identified for the purposes of the research and explains how they were measured. The second section profiles the five case study cities and fifteen case neighbourhoods which were the focus for the empirical research discussed in later chapters. These profiles provide an outline of both the urban form and socio-economic characteristics of the areas studied. The chapter concludes with a review of the urban form features of the case study cities and neighbourhoods, and shows how the different physical elements integrate together with socio-economic characteristics.

Elements of Urban Form

The term 'urban form' can be used simply to describe a city's physical characteristics. At the broad city or regional scale, urban form has been defined as the spatial configuration of fixed elements (Anderson et al., 1996). Features of urban form at this scale would include urban settlement type, such as a market town, central business district or suburbs. However, urban form is closely related to scale and has been described as the 'morphological attributes of an urban area at all scales' (Williams et al., 2000). Characteristics therefore range from, at a very localized scale, features such as building materials, façades and fenestration, to, at a broader scale, housing type, street type and their spatial arrangement, or layout.

It should be noted that urban form does not simply relate to physical features, but also encompasses non-physical aspects. One can see this in the example of density. Simply put, density is used as a measure of the number of people living in a

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given area: it is not just a physical, tangible element. Density is also closely linked with the configuration of the social environment and interaction within residential neighbourhoods: flats and apartments are examples of high-density housing whereas detached and semi-detached properties tend to be of lower densities. There are therefore non-physical economic, social and political processes in place which are physically manifested in housing, schools, parks and other services and facilities.

The scales at which urban form can be considered or measured include the individual building, street, urban block, neighbourhood and city. These levels of spatial disaggregation influence how urban form is measured, analyzed and ultimately understood. The issue of scale is discussed throughout this chapter (and the book) as it constitutes an underlying dimension of any examination of urban form.

Urban form generally encompasses a number of physical features and non-physical characteristics including size, shape, scale, density, land uses, building types, urban block layout and distribution of green space. These are categorised here as five broad and inter-related elements that make up urban form in a given city (Fig. 2.1).

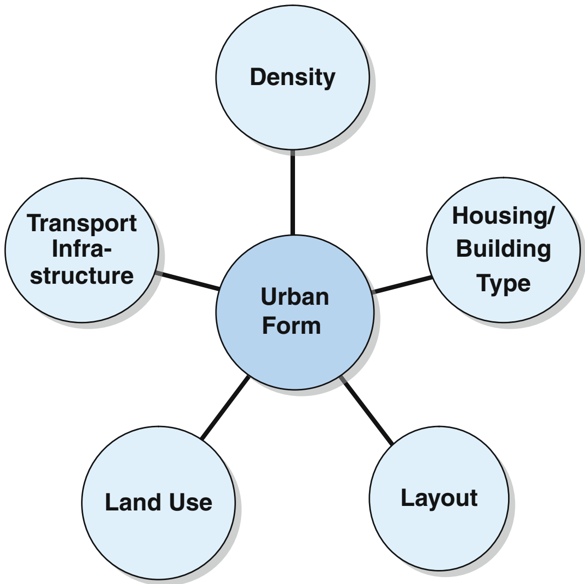

Fig. 2.1 Elements of urban form

These elements of urban form have been identified on the basis that they are claimed to influence sustainability and human behaviour. They are considered in more detail below. These elements relate to developed, and not developing, countries. For this reason, infrastructure (e.g. water, roads, gas etc.) is not discussed here as an element of urban form; however, it is acknowledged that infrastructure would form an important part of examinations of urban form in developing countries.

Density

Density is a deceptively complex concept with a number of inter-related dimensions. While it may provide an objective, spatially-based, measure of the number of people (living) in a given area, it is also assessed subjectively; it is a social interpretation dependent on individual characteristics and so may differ from resident to resident (Churchman, 1999). For example, while the density of Trafalgar Square in London may be reported as low (density usually being a measure of residential occupancy), the perceived density, and extent of crowding, may be very high (after Rapoport, 1975).

Density entered the consciousness of UK policy makers in the nineteenth century when urban areas were growing rapidly and overcrowding and appalling living conditions were prevalent among the poor (Jenks and Dempsey, 2005). There is also a more cultural dimension to density, where the densities at which people live may be considered as relative. Current English housing policy states that new residential building should be at a minimum of 30 dwellings/ha which for some may be an unacceptably high density (DCLG, 2006). In Hong Kong however, a minimum of ten times that density would be considered low (after Jenks, 2000; Breheny, 1997; Jenks and Dempsey, 2005).

Density is also closely associated with other elements of urban form, such as land use and access to services – for example, for a service or facility to be viable, it needs to serve a population of a particular size. Density on the one hand can be seen as an outcome of the competition between land uses within a given urban transport infrastructure and its associated pattern of accessibility. On the other hand it is a policy goal as it is also an input into the quality of urban life through the viability of services provision and availability of public and private space. Density has therefore been used as a tool to measure the viability of public transport infrastructure and other service provision, the feasibility of certain land uses, particularly commercial and service, in urban design and construction. At what point density becomes high (or too high) is unclear, but in recent years planning policy and practices in many countries have been attempting to increase the average density of new development.

Land Use

Broadly speaking, the term land use is used to describe the different functions of the environment. Within the urban context, the dominant land use tends to be residential but a functional urban area requires industrial, retail, offices, infrastructure and other uses. The spatial (micro) pattern of land uses is crucial to the arguments about the efficiency of a city and potential ‘sustainable’ urban forms in influencing urban travel patterns and the quality of life, for example through the existence of green space. There are also certain ‘locally-unwanted land uses’ such as prisons (Grant, 2002), airports, or landfill sites claimed to be undesirable in residential mixed-use areas (Healey, 1997). Planners have traditionally attempted to separate land uses because of potential undesirable externalities but are now in favour of mixed use developments. For example current UK policy promotes easily accessible services and facilities for residents (DCLG, 2006); both ‘horizontally’ – at ground floor level – and, increasingly in new city centre developments, ‘vertically’ – within the same building (DETR, 2000). However, land use patterns are dynamic rather than static phenomena and are subject to real estate market forces.

A key component of local land use is the availability of local neighbourhood services. The provision of services and facilities is dependent on the resident population’s requirements so a particular land use mix therefore differs from neighbourhood to neighbourhood (Urban Task Force, 1999). The local urban context and the requirements of the population are therefore important in this matter. It is not however clear which services and facilities can and should be provided at which spatial scale. An ‘everyday eight’ local neighbourhood services and facilities identified by Winter and Farthing in the UK context includes post office, supermarket, primary school, newsagent and open space (1997, p. 127). Other services to which residents need local access, albeit on a less frequent basis, include a doctor’s surgery (Barton et al., 2003; Urban Task Force, 1999), chemist; bank (Burton, 1997); and community centre (Aldous, 1992). There is extensive prescriptive UK guidance on what those land uses should be for a given neighbourhood however there is no consensus (Dempsey, 2008).

Accessibility and Transport Infrastructure

Transport infrastructure is closely associated with accessibility as it determines the ease with which buildings, spaces and places can be reached. The level of accessibility describes the area residents and users are able to reach, as well as the extent to which they have the means to access places, services and facilities that are outside their local area (after Talen, 2003).

Accessibility is actually a layered concept and is not simply proximity as distance is just one contributor. It is dependent on a number of factors including the location of potential destinations relative to an individual’s starting point, how well the transport system connects to spatially distributed locations, how the individual uses the transport system, and the characteristics of, for example, the services and facilities that the individual plans to use (Liu and Zhu, 2004). A key accessibility relationship is between home and the city centre. Different aspects of the concept encompass access in terms of what is available within walking distance of home (sometimes referred to as ‘pedshed’), or access in terms of the means to get to, for example, services and facilities which are located further afield (Barton et al., 2003; Schoon, 2001). It is therefore closely linked to land use and layout: the services, facilities, open space, how they are arranged within a city or neighbourhood and the means of getting to them all contribute to how accessible a place or service might be described.

Urban Layout

Layout describes the spatial arrangement and configuration of elements of streets, blocks and buildings, often referred to at the street scale, such as grid or tree-like (cul-de-sac) street patterns. Layout has an important influence on pedestrian movement and the way in which different places and spaces are connected to each other (ODPM, 2005; CABE and DETR, 2000). The layout, whether or not it is ‘permeable’ and easy to find the way, controls access and movement for pedestrians, and could influence other aspects of urban form such as land use or density (Hillier and Hanson, 1984; Hillier, 1996).

The layouts of today’s cities are largely artifacts of their historical development and planning and building regulations. The configuration of the street network, in terms of its urban block sizes, their overall location within the city, pedestrian and vehicular connectivity, can affect the functioning of a city by, for example, influencing the location intensity of activities (Penn et al., 1998; Porta et al., 2008).

The connectedness and permeability of urban layouts are claimed to determine the nature and extent of routes between and through spaces which in turn has an influence on how lively and well-used a space is (Cowan, 1997). Streets which are well-connected to services, facilities etc. and/or the means for the pedestrian of reaching them, are argued to be more frequently used than deserted or quiet options (Gehl, 2001; Gehl et al., 2004).

Housing and Building Characteristics

The characteristics of housing and other buildings in urban settlements can have an important bearing on everyday living: it has already been noted that residents living in low-density detached dwellings with large gardens will have a distinct experience of the urban environment from high-rise city centre apartment dwellers. However, the influence of building characteristics extends beyond the density of urban living. Factors such as building type, height and age may have an effect on a number of issues. These might include a building’s orientation and exposure to sunlight and daylight (Mardaljevic, 2005) and the potential for modifications, such as changes to living space to work space or individual room conversion to continue accommodating an ageing resident as in the ‘lifetime homes’ model (Holmes, 2007).

Other factors such as the amount of living space in dwellings, number and types of particular rooms and lowest level of living space may also have significant influences on the efficiency of buildings in terms of its embodied, operating and life cycle energy (Newton et al., 2000).

Integrated Elements

While it is useful to examine these elements separately, it is also clear that they are inter-connected and interdependent. For example, the accessibility within an urban settlement is very closely linked to its density and the layout of, and extent of mixed uses within. A neighbourhood is not accessible without viable services and facilities available for residents to use. Neither is it accessible without pedestrian, cycling and public transport networks through which the neighbourhood is connected both to its own services and to services outside. When planning and constructing new residential areas, housing type and size may be dictated by the proposed density of a site, which for example, in line with recent UK policy, will also provide a range of land uses (including different services and facilities and open space) and a connected and permeable urban layout. This message is endorsed by a series of US studies that have sought to develop measures of urban sprawl (Ewing et al., 2002; Cutsinger et al., 2004).

The interrelated associations between these elements have wide-reaching implications for the research. Firstly, there is a need for compatibility in how the different elements of urban form are measured. This is to ensure that, secondly, the statistical (and other) analyses conducted can account for the individual effect that each element may have on a particular aspect of sustainability, as well as the collective influence of the elements of urban form. In this way, the main research question which looks to explain how urban form affects sustainability can be answered in as robust and reliable a manner possible. The next section examines outlines the methodological approach used in the research to measure these elements of urban form.

Measuring Urban Form

A largely quantitative approach was adopted in this research, although qualitative methods were used in parts of the project and are detailed in the relevant chapters. To measure robustly the features of urban form outlined above, a two-pronged process of data collection was followed. Firstly, existing datasets such as the 2001 Census, the Valuation Roll and Ordnance Survey data were examined to provide information on, for example, initial density measures, non-domestic properties and their location. Secondly, after ascertaining gaps in the data, e.g. building heights and information on transport infrastructure (e.g. bus stop location and type of car parking), a site survey was conducted in the study neighbourhoods on a street-by-street basis.

The site surveys were undertaken by researchers using an innovative method employing PDAs (personal digital assistants) with GPS (global positioning system) modules which allowed geocoded survey data to be directly downloaded into a GIS (geographic information system) platform. A useful innovation was the production of prototype software to automatically link separately sourced data tables from Ordnance Survey and Valuation Data. This allowed site surveyors easily to identify, locate and check business and mixed use premises. The data collected in this way included details about: buildings such as condition and height; land uses; the presence of litter and graffiti; position of bus stops and shelters.

The research design was a cross-sectional one, where data are collected at one point in time providing a ‘snapshot’ approach (Gray, 2004). While the project did not detail the extent to which a changing urban form can contribute to sustainability over time, it offers new and valuable data on how and to what extent current urban forms in UK cities can be described as sustainable. The following sections outline how each element of urban form was measured in the research.

Measuring Density

A wide range of different measurements have been used to calculate the density of a given area, such as persons per hectare (pph), dwellings per hectare (dph), bed spaces per hectare and habitable rooms per hectare (Woodford et al., 1976). Employing a number of density measures has been argued to be more robust than using one single density indicator which cannot accurately measure the density of a given area (Jenks and Dempsey, 2005).

A range of density indicators was selected to provide as complete a picture as possible of the overall density of the case studies, while accounting for the different scales of urban form (the city, neighbourhood, ‘sub-area’ and street). Examples of these indicators are presented in Table 2.1. It should be noted that the indicators of net residential density used here are based on a definition of residential which includes outdoor space such as gardens, but *excludes* streets and footpaths. This method of calculation results in density figures which are higher than those usually reported.

It is clear from the table that the indicators measure physical density and not perceived density. Aspects of perceived density are measured in Chapters 9.

Measuring Land Use

In order to measure the extent of mixed land uses in the case study neighbourhoods, a number of appropriate land uses were selected, excluding land uses which are not relevant for the purposes of the research, e.g. telecommunications, energy and waste infrastructure. Data on a number of particular services and facilities are not always specified in secondary data sources (e.g. name of supermarket, newsagent and children’s nursery), indicating a need to conduct primary data collection.

It is necessary to account for any ‘edge effects’, where residents may be using local services and facilities outside the case study boundaries identified for the research purposes. A ‘buffer zone’ of approximately 400m (approx. 5 min walking distance) is applied around each case study area to account for any ‘edge effect’. Households living on the edge of a chosen case study area might be closer to facilities just outside the boundary and therefore may choose to use those rather than the ones initially identified in the research. By applying a buffer zone around the neighbourhood, the researchers are able to capture and investigate usage of particular services and facilities including food shops, post office and GP surgeries. This land use information is then mapped using a GIS-based platform (Fig. 2.2). Examples of these land use indicators used in the research are presented in Table 2.2. The categories used are based on the National Land Use Database (NLUD) developed by the then ODPM (2003).

Table 2.1 Indicators of density

Measurement	Description	Examples of aspects/features measured	Sources of information
Gross Density (City)	The ratio of persons, households, or dwelling units to the entire area of the city regardless of land use.	– Total city population – No. of households – No. of dwellings – City area	– Census data – Local authorities
Gross Density (Neighbourhood)	Number of persons, households, or dwelling units per hectare of the total neighbourhood area.	– Total population – No. of households – No. of dwellings – Case study area	– Census data – Local authorities – Valuation Roll – Ordnance Survey
Gross Residential Density (Sub-area)	Number of persons, households, or dwelling units per hectare of the total sub-area area.	– Total population – No. of households – No. of dwellings – Sub-area	– Census data – Valuation Roll – Ordnance Survey
Net Residential Density (Neighbourhood)	Number of persons, households or dwellings per hectare of the total land area devoted to residential land use.	– Total population – No. of households – No. of dwellings – Total residential land area	– Census data – Ordnance Survey
Net Residential Density (Sub-area)	Number of persons, households or dwellings per hectare of the total land area devoted to residential land use within the sub-area.	– Total population – No. of households – No. of dwellings – Total residential land area	– Census data – Ordnance Survey – Valuation Roll
Net Residential Density (Street & Plot)	Number of dwellings per plot.	– No. of dwellings per plot – Plot area	– Ordnance Survey
Floor Area Ratio (Neighbourhood & Sub-area)	Ratio of floor area to site area.	– Floor area (of each building) – No. of storeys – Site area (of each plot)	– Ordnance Survey – Site survey
Coverage Ratio (Neighbourhood & Sub-area)	Ratio of building footprint to site area.	– Building footprint (each building) – Site area (of each plot)	– Ordnance Survey

Measuring Accessibility and Transport Infrastructure

As indicated earlier, measures of accessibility can refer to different aspects of the concept. The indicators used to measure accessibility here cover transport infrastructure for pedestrians and cyclists as well as public and private transport. Table 2.3 shows some of the indicators used to measure accessibility which include

Fig. 2.2 Example of GIS-generated land use map (Oxford) (© Ordnance Survey)

characteristics of public transport infrastructure and journey times and distances. These indicators (and others such as socio-economic characteristics of residents and employment location) were included in a transport model (discussed in detail in Chapter 3) to provide as accurate a picture of accessibility in the case study neighbourhoods.

Measuring Housing/Building Characteristics

It is not possible or desirable to measure the characteristics of every building in the case study neighbourhoods. An efficient method of measuring the characteristics involves the identification of predominant housing types per street, and highlighting where there were exceptions to this. It is also useful to make use of the household questionnaire in measuring these characteristics. While the focus of the questionnaire is to measure aspects of sustainability, it proved to be a useful tool to collect urban form indicators, such as housing type, lowest level of living accommodation and a household's access to a garden/residential outdoor space.

The characteristics of non-domestic buildings are collected which understandably overlap with the indicators measuring land use. Indicators of maintenance are included in this category of indicators, such as the condition of buildings (where considered to be poor relative to other buildings in the street) and levels of litter and instances of graffiti and vandalism (Table 2.4).

Table 2.2 Indicators of land use

Measurement	Description	Examples of aspects/features measured	Sources of information
Residential land use (Individual dwellings)	Residential, institutional and communal accommodation	– Sheltered accommodation – Care homes – University halls of residence	– Ordnance Survey – Site survey
Commercial and retail land use (Individual buildings)	Properties housing all commercial uses	– Retails & Supermarkets – Shops – Storage & Warehouses – Restaurants/cafés	– Ordnance Survey – Valuation Roll – Site survey
Offices (Individual buildings)	Office space	– Business parks – Banks and building societies – Other offices	– Ordnance Survey – Valuation Roll – Site survey
Industrial (Individual buildings)	Industrial properties including industrial storage and warehouses	– Factories/Workshops – Industrial storage facilities (depots etc.)	– Ordnance Survey – Valuation Roll – Site survey
Community Buildings (Individual buildings)	Buildings used for community purposes including: – educational – health – community services	– Primary schools – Health centres and GPs – Hospitals – Community centres – Places of worship – Police stations	– Ordnance Survey – Site survey
Leisure and recreational Buildings (Individual buildings)	Buildings used for leisure and recreational purposes	– Museums – Libraries – Cinemas – Indoor sports facilities	– Ordnance Survey – Valuation Roll – Site survey
Outdoor Recreation (Individual spaces)	Outdoor amenity and open spaces	– Football pitches – Golf courses – Sports grounds – Allotments	– Ordnance Survey – Site survey
Other public green space (Individual spaces)	Spaces of grassland, woodland etc.	– Woodland – Heathland	– Ordnance Survey – Site survey
Previously developed land (Individual spaces)	Previously developed land which is or was occupied by a building or other permanent structure	– Derelict land – Vacant land	– Ordnance Survey – Valuation Roll – Site survey
Mixed use (Individual buildings)	Buildings with multiple land uses	– Vertical mixed uses (flats above shops/offices above commercial etc.)	– Ordnance Survey – Valuation Roll – Site survey

Table 2.3 Indicators of accessibility

Measurement	Description	Examples of aspects/features measured	Sources of information
Public transport infrastructure (Street)	Location of public transport features	– Location of bus/tram stops – Bus/tram routes – Frequency of services	– Ordnance Survey maps – Site survey – Public transport companies – Local authorities
Private transport infrastructure (Street)	Location of private transport features (i.e. parking)	– Location of off-street parking and types – Location of on-street parking and types	– Ordnance Survey maps – Site survey
Pedestrian/cycling infrastructure (Street)	Location of (cycle) paths/alleyways/ underpasses etc.	– Location of routes inaccessible to motorized transport	– Ordnance Survey maps – Site survey
Road management (Street)	Route management	– One-way systems – Traffic management – Speed restrictions	– Ordnance Survey maps – Site survey
Journey time/distance (Individual buildings)	Journey to work/other services etc. in terms of time and distance	– Trip origin – Trip destination	– Ordnance Survey maps – Site survey – Transport modelling

Table 2.4 Indicators of housing/building characteristics

Measurement	Description	Examples of aspects/features measured	Sources of information
Housing type (Individual buildings)	Predominant housing type per street with exceptions marked	– Detached housing – Semi-detached housing – Terraced housing – Tenements – Flats/apartments	– Ordnance Survey – Site survey – Questionnaire
Housing characteristics (Individual buildings)	Characteristics of individual dwellings	– Lowest level of living accommodation – Access to garden – Number of bedrooms – Condition of building	– Questionnaire
Building type (Individual buildings)	Building type according to land use categories	– Commercial buildings – Offices – Community buildings	– Ordnance Survey – Site survey
Street characteristics (Street)	Level of maintenance	– Extent of litter – Instances of graffiti – Instances of vandalism – Instances of no street lighting	– Site survey

Measuring Layout

Urban layouts are difficult to quantify. Spatial network analysis is one of the ways in which spatial layouts can be objectively described and quantified to identify similarities or differences. Typically in a spatial network analysis, relationships between spaces in a city/settlement/building are represented as relational graphs similar to social network graphs. These graphs can then be analyzed to identify patterns and to quantify the relationships between spaces.

For this research, Multiple Centrality Assessment (MCA) is employed to measure layout (see Porta et al., 2006). MCA operates on a standard (or primal) graph representation based on street network systems which accounts for metric distances while analyzing the relationship between spaces. The final output provides a set of simple and compound measures of centrality numerically expressing the relative importance of a space in relationship to other spaces in the city. The output also includes a network map that shows the location and clustering patterns of spatial centrality (Fig. 2.3). A more detailed description of MCA and a table of the indicators employed to measure urban layout can be found in Appendix 1.

Measuring Overview

The elements of urban form link the constituent and distinct parts of this research together. This is the first time empirical research has examined the effect that urban form has on sustainability in a holistic manner. Indicators employed to measure urban form include both simple and complex measures collected or derived from secondary sources, primary data collection or detailed computer modelling. The range of indicators described above allows us to determine the relative influence that differing elements of urban form – land use, density, accessibility, housing/building characteristics and layout – have on economic, environmental and social sustainability.

The relationships that the elements of urban form, both individually and as a whole, have on the different aspects of sustainability are analyzed and outlined later in the book. The next section describes the case studies in detail and outlines the features of urban form in each area.

Case Study Areas: Profiles

The research in this book is based on empirical analysis in five British cities and a small number of neighbourhoods within each of these cities chosen for more in depth study. This part of the chapter describes these places in some detail, providing information about their urban form, housing, socio-demographic characteristics, history and economic profile. The case study cities are described first, followed by the profiles of the case study neighbourhoods.

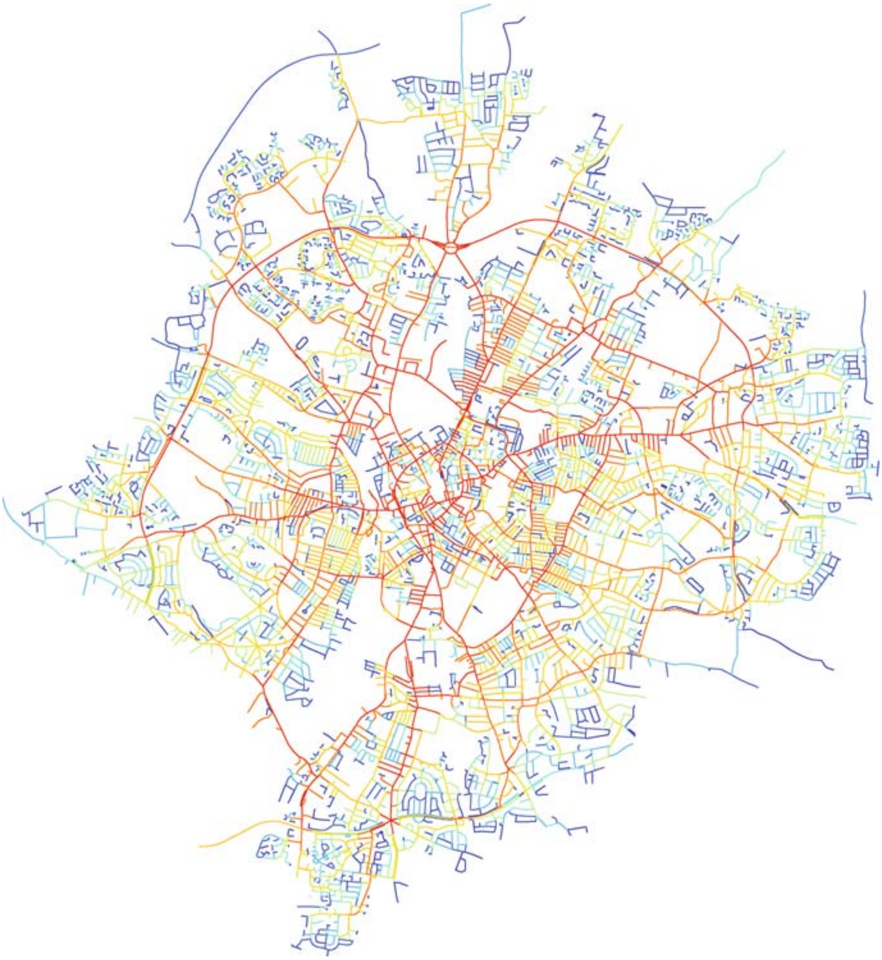

Fig. 2.3 Example of an MCA-generated map of Leicester

Case Study Cities

Five provincial British cities provide the focus for the CityForm research: Leicester, Oxford and Sheffield in England and Glasgow and Edinburgh in Scotland (Fig. 2.4). The cities are all university towns and cover a variety of geographical and economic situations. It is important to note, that while the cities are varied in their economic, demographic and physical make-up, they cannot be claimed to represent UK cities as a whole. As a result, care must be taken when interpreting the results of this research.

Fig. 2.4 Location of the case study cities

General Characteristics of the Five Cities

Glasgow and Sheffield are the largest of the cities, with populations of more than 500,000. They are both traditional industrial cities that grew dramatically in the nineteenth century and now have important commercial roles. Edinburgh is the next largest with a total population of approximately 450,000 and is one of the few large provincial cities in the UK whose population is growing. It is the capital of Scotland and an important administrative and financial services centre. Both Leicester and Oxford are significantly smaller; Leicester with a population of 280,000 and Oxford with a population of 134,000. Leicester has quite a diverse economic structure and a thriving ethnic minority community that accounts for more than a third of its population. Oxford is most well-known as a university city, but is also a thriving tourist and business centre.

Demographically, the five cities tend to have a younger than average population with a high proportion of people in their twenties. This may be linked to their status as university towns, with the effects most noticeable in Oxford where one quarter of local people are aged between 20 and 29 and the average age of Oxford residents is 35 years 4 months. The most affluent of the five cities are Edinburgh and Oxford and they also have the highest proportion of young adults. Glasgow and Sheffield residents tend to be slightly older (38 and 39 years respectively), while Leicester has the youngest population profile with an average age of 35 years – more than 3 years younger than the UK average.

All of the case study cities – with the exception of Edinburgh – have a lower proportion of owner occupiers than the UK average (70%). Sheffield has the lowest proportion of private renters (10%), while in Oxford almost a quarter of households are private renters. Social renting on the other hand is most prevalent in Glasgow, where 40% of households have a social landlord, while just over one in six households in Edinburgh are in this situation.

Driving to work by car or van is the most popular mode of travel in all five cities with more than half of commuters using a car in Leicester and Sheffield. Glasgow is the only one to have an underground system and 4% use it while Sheffield has a tram network which attracts 3% of commuters. More than a quarter use the bus in Edinburgh but the city with the highest proportion of commuters using (all types of) public transport is Glasgow. Another notable difference is the high percentage, 15%, of people who travel to work on bicycle in Oxford, which is much higher than the other four cities (3% in Edinburgh).

Some Physical Characteristics of the Five Cities

Density provides a standard international indicator of urban form and enables both a simple comparison of individual cities and a worldwide perspective on the five case study cities. The figures presented in Table 2.5 reveal a significant variation in population density and dwellings per hectare. Sheffield is the least densely

Table 2.5 Density and housing types: case study cities

City	Density		Housing types (%)			
	People per hectare	Dwellings per hectare	Detached	Semi-detached	Terraced	Flats/ apartments
Edinburgh	17.1	8.2	11	14	15	60
Glasgow	33.1	16.1	3	13	13	70
Leicester	38.3	15.8	10	37	36	17
Oxford	29.5	11.5	10	32	31	27
Sheffield	14.0	6.1	14	37	30	18

Source: Census 2001

populated city of the five, both in persons per hectare and dwellings per hectare. Leicester has the greatest number of persons per hectare and Glasgow has the greatest number of dwellings per hectare. Edinburgh has a comparably low density, similar to that of Sheffield. These statistics also show that there is no clear divide between England and Scotland despite the distinctive tenemented housing stock prevalent in both Scottish cities. Edinburgh and Glasgow both have much higher numbers of flats than the English cities with around 60% and 70% of households living in flats in these two cities. However, there are differences between the English and Scottish cities studied in the number of rooms per dwelling. The English cities all had an average of more than 5 compared with 4 in Glasgow and 4.6 in Edinburgh.

As Table 2.5 shows the densities of these cities range from 29 to 38 persons per hectare which places them at the lower end of the international spectrum of urban densities but much higher than most North American cities. The densities are at the low end of the range of densities of European cities and substantially below the densities of Asian cities that are typically over 200 people per hectare (Bertaud, 2003).

Case Study Neighbourhoods

The starting point for the empirical research is the neighbourhood and fifteen case studies were chosen to represent inner, between and outer neighbourhoods within the five cities. The case study neighbourhoods are chosen to provide a slice through each of the cities and to represent a wide range of neighbourhoods. The overview of these neighbourhood characteristics also provides a useful insight into the spatial socio/demographic and housing stock structure of (British) cities.

Each case study neighbourhood includes at least 2000 households, a mixture of land uses, a range of housing types and street patterns, nearby public transport and households with a range of socio-economic backgrounds. These neighbourhoods are used as the principal spatial unit of study and where appropriate are also split into sub-areas. Sub-areas are defined using maps and local knowledge, to identify natural physical sub-divisions respecting obvious major boundary features and to reflect relative homogeneity of urban form within their boundaries. Each case study neighbourhood is divided into 6–7 sub-neighbourhoods, giving a set of 97 in total (a few of which contain only a small number of households, because they are dominated by non-residential land uses).

Characteristics of Neighbourhoods

A range of information was collected about the case study neighbourhoods. This includes a site survey capturing information about the built environment and a questionnaire survey providing information about household characteristics, behaviour, feelings about the neighbourhood and use of local facilities (e.g. parks, shops, public transport). An overview of the 15 neighbourhoods is profiled at the end of this chapter (Table 2.6), and more details on individual localities are included in Appendix 2.

At one level these areas represent a set of diverse neighbourhoods but a number of regularities can also be discerned. Gross population densities follow a negative gradient spatial structure from inner to outer neighbourhood. There are also consistent spatial demographic patterns: younger people with few children living in inner areas and older households and families predominating in outer areas. Between areas are more diverse. Private rented housing is focused in the inner areas and outer areas are almost exclusively owner occupied. Social housing in British cities is spatially concentrated, and this is reflected in our case study areas, being located mainly in a few inner areas. These findings show the spatial structure of the five cities, as given by the characteristics of the case study areas, conform to an urban system diffusing from a central core, and that the different physical urban form elements integrate together with socio-economic characteristics.

Layouts of Neighbourhoods

The spatial analysis is carried out at the city level, neighbourhood, sub-area and street level. Most of the comparative analysis to determine the performance of various types of urban form is at the neighbourhood and sub-area level. The spatial characteristics of the neighbourhoods reveal a range of layout types ranging from the predominantly gridded to those that are largely culs-de-sac. The characteristics are quantified using MCA analysis as it permits the calculation of many indices that measure street networks and allow systematic comparison of the case study neighbourhoods (see Appendix 1 for details). There are measurable differences between the neighbourhoods and none can be said to represent one layout type or another, as all have a complex mixture of layout forms (Fig. 2.5).

The MCA analysis also identified the density of street intersections, the relative degree of complexity of the street networks, their interconnectedness, and how efficient the networks are – related to actual distances between intersections. In addition, the degree of compactness or sprawl is measured by considering the ‘fractal’ dimension of street patterns in the case study neighbourhoods. The fractal

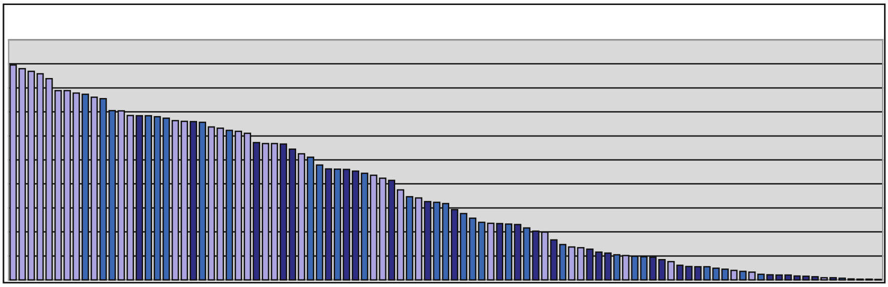

Fig. 2.5 Shows the spectrum of complexity index scores across the fifteen neighbourhoods. Lower values indicate higher choice-grid like pattern that are predominantly in inner neighbourhoods and higher values indicate low choice-tree like pattern in the suburbs. (*light blue* = suburban; *medium blue* = between; *dark blue* = inner city)

dimension index ranges from 1 to 2 – a score of 1 would be a perfect linear system where intersections lie on a straight line, while a score of 2 would be a system where intersections are distributed evenly throughout the space covering the whole neighbourhood. The range in the neighbourhoods from a more compact form in Sheffield inner area to the sprawling layout of Glasgow outer has a relatively narrow spread of values is again due to the fact that many case study areas have both compact and spread areas within them (Fig. 2.6).

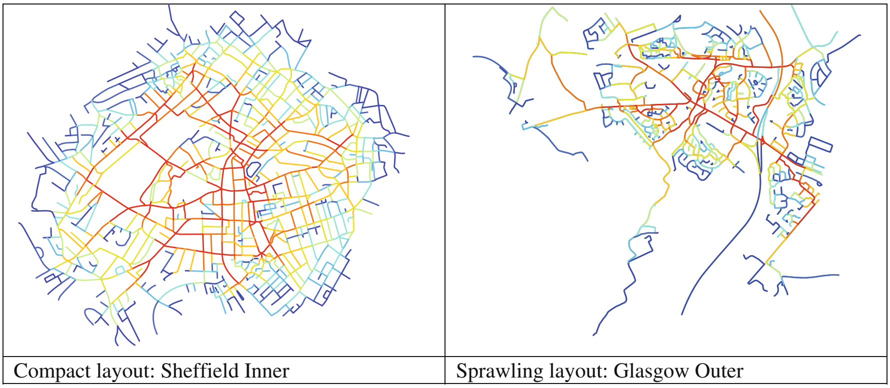

Fig. 2.6 Examples of compact and sprawling neighbourhoods

Summary and Conclusions

At one level the elements of urban form are relatively simple – land use, density, accessibility defined by transport infrastructure, characteristics of the built environment and layout. Although there is an expanding literature that seeks to quantify urban form using complicated measures and advanced statistical techniques the findings of these studies have emphasised the overlapping nature of the elements and the results have not justified the complexity. The study has chosen in general to apply as simple measures as possible as the best way to elucidate the issues on sustainability. The analysis reported in this book is based on five cities in the UK. The urban form characteristics of these cities in terms of population density are very similar within the spectrum of world cities. These densities are at the low end of the range of densities of European cities and substantially below the densities of Asian cities.

The fifteen case study neighbourhoods selected for deeper study and located at inner, middle and outer points to represent slices through each of the five cities. There are a number of pointers that arise from the various measures of the elements of urban form of these neighbourhoods:

- The inner neighbourhoods tend to be well connected and complex, with predominately grid-like structures;
- The inner neighbourhoods tend to have more compact layouts in comparison with suburban neighbourhoods;
- The suburban neighbourhoods have tree-like structures with a single or limited number of main roads acting as a spine or trunk with culs-de-sac;
- The gross population densities also follow a similar spatial structure; a broadly consistent negative gradient from the city centre;
- There are consistent spatial demographic patterns: younger people with few children living in inner neighbourhoods and older households and families predominating in outer neighbourhoods. Between neighbourhoods are more diverse.
- Private rented housing is focused in the inner neighbourhoods and outer neighbourhoods are almost exclusively owner occupied.
- Social housing in British cities is spatially concentrated, and this is reflected in our case study areas, being located mainly in a few inner neighbourhoods.

These findings show the spatial structure of the five cities, as given by the characteristics of the case study neighbourhoods, conform to an urban area diffusing from a central core, and that the different physical urban form elements integrate together with socio-economic characteristics. The following chapters investigate the sustainability of different dimensions of this urban system drawing on more detailed study of these case study neighbourhoods.

Table 2.6 Profile of the case study neighbourhoods

CASE STUDY CITY: EDINBURGH

INNER


MIDDLE


OUTER


Table 2.6 (continued)

INNER	
General description	Social characteristics and housing
A high density neighbourhood dominated by traditional tenements and modern flats. The area has very little green space and few residential gardens. There is a busy high street with shops and cafes. The area also includes a large hotel, multiplex cinema and associated leisure uses.	The area is home to many single person households, young couples and homes in multiple-occupation (together about 75% of households). Around one-fifth of residents are retired, and there are relatively few families in the area. More than 90% of households live in flats.
Layout is compact with grid and cul-de-sac form.	Just over half of homes here are owner occupied and one quarter privately rented. 20% of local stock is social rented.
MIDDLE	
General description	Social characteristics and housing
Much of the area is characterized by post-war housing: detached and semi-detached homes with gardens. Flats, some of them built recently, occur in parts of the neighbourhood. The area lies to the north of the city centre and is bisected by a major road and railway line. A large supermarket, car park, cemetery and school dominate one part of the area.	Almost 40% of residents in this area are retired, and around 15% of households include children. Half of homes in this area are flats, and the other half are a fairly even mixture of detached, semi-detached and terraced houses.Two-thirds of these homes are owner occupied and less than one-tenth are privately rented. Social renting accounts for around 17% of the stock.
Layout is predominantly gridded, not orthogonal.	
OUTER	
General description	Social characteristics and housing
A largely residential area, dominated by detached and semi-detached houses with private gardens. The area includes part of a university campus and is bisected by a major arterial road. This road functions as a local high street with a variety of shops and services. It is extremely busy with vehicular traffic, but provides easy access to bus services.	A large proportion of residents in this area are retired (40%) and almost one-quarter of households include children. Around one-third of homes are detached and one-third are semi-detached. Flats account for 17% of stock and terraced houses 11% of local homes. Almost all homes in this area are owner-occupied (97%).
Layout is a compact super grid.	

Table 2.6 (continued)

CASE STUDY CITY: GLASGOW

INNER


MIDDLE


OUTER


Table 2.6 (continued)

INNER General description A very diverse area, including city centre shops, bar, restaurants, cultural facilities and a least one large open space. Residential uses are spread unevenly across the area, with pockets of high density flats – including student accommodation – in some parts. Not all parts of the area are doing well, and there are derelict buildings and underused sites. Residents here have very little private green space. Layout is deformed compact grid.	Social characteristics and housing The area is home to many single person households, young couples and homes in multiple-occupation (together about 87% of households). Very few families live in this part of the city, and one-tenth of residents are retired. More than 90% of households live in flats. Almost 60% of homes here are owner occupied and one quarter privately rented. 16% of local stock is social rented.
MIDDLE General description The area has two distinct parts. One part is very low density, with large houses (some subdivided into flats) set in large gardens and leafy streets. The other part has tenement flats, shops and a greater mix of uses. A local park contributes to the leafy feel. Layout is a deformed grid with some compact grids.	Social characteristics and housing Around one third of residents in this area are retired and almost one-quarter of households include children. Around 80% of households are living in flats. Most of the other homes in the area are terraced or semi-detached. 86% of homes here are owner occupied and only a very small proportion of housing is privately rented. Social renting accounts for around 6% of the stock.
OUTER General description Close to the edge of the city, this area is bordered by farmland and has a river running through it. Many of the houses are semi-detached with private gardens and many families live in this area. Part of the area includes an industrial estate and a school. Layout is clustered dispersed culs-de-sac.	Social characteristics and housing Just over one quarter of residents in this area are retired and around one-third of households include children. Around 40% of homes are semi-detached and the rest are evenly divided between flats, terraced houses and detached homes. Around 70% of homes in this area are owner-occupied with the remainder let through social landlords. There is no private rented accommodation here.

Table 2.6 (continued)

CASE STUDY CITY: LEICESTER

INNER

MIDDLE

OUTER

Table 2.6 (continued)

INNER General description A very diverse area, including the city hospital, museum, art gallery and university campus. Residential uses are unevenly spread, with pockets of high-density flats and student accommodation. There is little private green space here, although there are some public open spaces. A significant proportion of residents are non-white; and there is a high number of single person households. In terms of layout, the area has a deformed wheel, radial pattern.	Social characteristics and housing The area is home to many single person households, young couples and homes in multiple occupation (together about 80% of households). There are relatively few families in the area and around 15% of residents are retired. This area is notable for its high level of unemployment (13%). Just under 90% of households live in flats. Only one-fifth of homes here are owner occupied and one quarter privately rented. More than half of homes in this area are social rented.
MIDDLE General description This part of the city is dominated by terraced housing. It is close to the university and has a significant proportion of private rented properties. Some parts of the area are slightly lower density with semi-detached houses, and there are some flats. A significant proportion of local residents are non-white. In terms of layout, the area has a deformed grid.	Social characteristics and housing Around two thirds of homes in this area are terraced, and just over 10% are flats. 74% of homes here are owner-occupied and one quarter are privately rented.
OUTER General description Residential density is low in this part of the city. Detached and semi-detached houses with gardens dominate, although there are a few flats in places. There is some public open space, but most residents have access to private gardens. In terms of layout, the area has a very deformed grid with culs-de-sac	Social characteristics and housing In this area around one third of households are older (one or more adults aged 60+), but only 20% of residents are retired. In most other case study areas the proportion of retired and older households are roughly equal. A quarter of households in this area include children. This area is dominated by semi-detached homes, which account for more than 60% of local housing stock. There are few flats or terraced houses here and almost all the other homes in the area are detached houses. Owner-occupation rates are very high, and there is very little rented accommodation (around 5%).

Table 2.6 (continued)

CASE STUDY CITY: OXFORD

INNER

MIDDLE

OUTER

Table 2.6 (continued)

INNER	
General description	Social characteristics and housing
The area includes a high number of non-residential buildings including university colleges, a library and museum. A significant proportion of residents are single and young, although some families and older people live in the southern part of the area. The proportion of private and public open space varies enormously, with very little private open space in the most central parts.	Around one quarter of residents are retired, and 15% of households include children. Around one half of homes are flats, and most of the remaining housing stock is terraced, with a very small proportion of detached and semi-detached homes.
Layout is in crucifix form, with small blocks at the centre	Around half of homes here are owner-occupied and one-third are privately rented.
MIDDLE	
General description	Social characteristics and housing
The area includes a mixture of housing types. Open spaces include allotments, a cricket ground, a river and private gardens. It is bound to the west by the railway line and a canal runs through the area. A number of non-residential uses include a community centre, hospital and numerous cafes and restaurants. A number of the residential properties are owned by the university.	Around one third of residents in this area are retired and almost one-fifth of households include children. Just under half of homes are terraced and one quarter of households live in flats. Semi-detached homes account for almost all the other houses in the area. Roughly 60% of homes are owner-occupied and one third are privately rented. Social renting accounts for less than 10% of stock.
Layout is an elongated deformed grid with compact grid within.	
OUTER	
General description	Social characteristics and housing
This area is a large housing estate, laid out with culs-de- sac and a mixture of detached, semi-detached and terraced houses. Density is high for an outer case study area. The area includes a number of public buildings, e.g. school, stadium and business park. There is a mixture of public and private open space, with many of the houses having access to private gardens.	In this area one-fifth of residents are older, and more than one-third of residents are retired. In most other case study areas the proportion of retired and older households are roughly equal. One third of households in this area include children. Just under half of homes in this area are terraced, and the rest are split equally between semi-detached homes and flats.
Layout is predominantly culs-de-sac.	Around 40% of homes here are owner-occupied and a similar proportion is social rented. Around 10% of homes in this area are in shared ownership.

Table 2.6 (continued)

CASE STUDY CITY: SHEFFIELD

INNER

MIDDLE

OUTER

Table 2.6 (continued)

INNER	
General description	Social characteristics and housing
This part of the city includes a number of non-residential buildings including: a sports stadium, university buildings, a school, cafes and restaurants. Residential buildings include student accommodation and both high and low-rise blocks of flats. There are also a number of open spaces, including parks and sports fields. Layout is a deformed compact grid.	Around one quarter of residents are retired and about 15% of households include children. Unemployment is slightly higher here than in other areas (5%). This area is dominated by flats - around 80% of households living in flats. Most of the other homes in the area are terraced or semi-detached. Just over one-quarter of homes here are owner occupied and almost one-fifth are privately rented. More than half of homes in this area are social rented
MIDDLE	
General description	Social characteristics and housing
A largely residential area with the majority of residents living in terraced houses. Public open space is concentrated in specific areas, although most houses have some form of private garden. Sheffield's topography is particularly relevant in this area, with the main road from the city centre lying at the top of a steep hill. Layout is a deformed compact grid.	Just over one-fifth of residents are retired and 15% of households include children. Around 60% of homes in this area are terraced and the rest are a fairly even mixture of detached, semi-detached and terraced houses. Three-quarters of homes here are owner-occupied and just under 20% are privately rented. Social renting accounts for around 12% of housing stock.
OUTER	
General description	Social characteristics and housing
This area is on the edge of the city close to farmland and open countryside. Residential density is fairly low, with many detached and semi-detached houses with large gardens. Non-residential uses are limited and concentrated in specific areas along the bus route. There is a housing estate to the north of the area made up of flats and houses which has access to shared open space. Layout is curvilinear with culs-de-sac.	Just over 40% of households in this area are older, and one-quarter include children. Just over half of homes in this area are semi-detached and around 30% are detached. The rest of the housing stock is almost all made up of flats. A large proportion of homes (86%) are owner-occupied, and 11% are social rented.

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Chapter 3
Travel and Mobility

Neil Ferguson and Lee Woods

Introduction

Combating the undesirable effects of mobility in cities caused by the use of the private car has become a key issue in the development of sustainable urban policy. Associated with car use are a number of well-documented problems including rising levels of energy consumption, road congestion, greenhouse gas emissions and pollution as well as road safety, health and severance effects (European Commission, 2007a). Underlying these problems is a complex process which involves interaction between rising levels of car ownership, the development of road transport provision and the location decisions of individuals and businesses in and around cities. The process has resulted in the emergence of new urban forms typified by the decentralisation of activities and the unstructured expansion of urban areas into the surrounding countryside otherwise known as urban sprawl (European Environment Agency, 2006). New suburban residential neighbourhoods, characterised by low density, single-use development, reinforce the dominance of the car as the principal, or sometimes sole, form of transport to access everyday activities.

The dominant role of car travel is exemplified by the fact that in the European Union (EU), passenger car use rose by 18% between 1995 and 2004 (European Environment Agency, 2008). In 2004, travel by car was responsible for 74% of all passenger transport, including air and sea transport, and constituted an average of around 27 km/EU inhabitant per day (European Commission, 2007b). In the future, worldwide travel is forecast to increase by 48% between 2000 and 2050. Whilst the largest increases are forecast in China, India and non-EU Europe, significant increases are also forecast in the EU and North America (European Environment Agency, 2007).

Around 75% of the population of the EU currently live in urban areas (European Environment Agency, 2006). It is therefore clear that the transport undertaken

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by those living in urban areas constitutes a significant proportion of all personal travel. Moreover, the average number of car trips per person per day in urban areas increased by 10% in the EU in the 1990s, principally at the expense of public transport, walking and cycling. During the same time period, the length of the average car journey increased by 20% (European Commission, 2006).

In recent years, a return to traditional urban forms has been advocated by New Urbanists in the United States (Duany et al., 2001) and the Urban Villages Campaign (Thompson-Fawcett, 2000) and the Urban Task Force (DETR, 1999) in the United Kingdom. Although some differences in approach can be detected at the strategic level reflecting the distinctive planning contexts in the two countries, strong parallels can be detected at the neighbourhood level (Hall, 2000). The neighbourhood urban forms promoted by these groups are characterised by moderately high densities of housing, mixed land-uses, proximity to public transport and grid-pattern road layouts based around the traditional block (Panerai et al., 2004) with provision for walking and cycling. It is claimed that these urban forms will reduce travel by car by encouraging walking and cycling to local amenities and the use of public transport for longer journeys. In so doing, these urban forms will address, at least in part, the economic, environmental and social problems referred to above.

At the heart of these traditional urban forms lies the aim of providing a good level of local accessibility which meets the needs and wishes of the neighbourhood population and thereby supports more sustainable mobility patterns. However, the success of traditional urban forms in reducing car use can be questioned on four grounds.

First, for households with access to a car, the flexibility offered and the ease with which spatial separation can be overcome by car can provide a strong incentive to use a car even when viable transport alternatives exist. This has two potential implications (a) the car may remain the favoured mode to undertake a journey even when it would be possible to walk, cycle or use public transport, particularly in the absence of any measures of car restraint and (b) the car offers a more extensive set of potential destinations than the restricted set open to those without access to a car. In a comparison of the relative costs and benefits of travelling to potential destinations, a destination which realistically can only be reached by car may be favoured over a destination which can be reached by other means. For example, it may be the case that driving to an edge-of-city shopping centre might prove more attractive than walking a short distance to local shops.

Second, as discussed by Boarnet and Crane (2001), any time and cost savings gained by using locally available amenities may simply lead to the generation of additional travel for other purposes. Thus, all travel (local and non-local) must be taken into account when comparing the travel patterns of residents of more than one type of neighbourhood.

Third, when it is argued that traditional urban forms will reduce travel by car it is implied that travel, and the activities this travel serves, are organised with reference to the residential location. While this may be true of a certain proportion of travel, it is also the case that constraints which require an individual to be at a specific location at a particular time can reduce the influence of local neighbourhood design on travel choices. For example, the requirement to be at work for a large part of the day may lead to an individual organising some activities with reference to the work location or the journey to/from work. This requires a more complex perspective of accessibility (also known as constraints-based accessibility) which relates to how easily urban form affords access to activity locations given the characteristics of individuals, the activities in which they participate and the constraints which these activities place upon them (Pirie, 1979; Kwan, 1998; Miller and Shaw, 2001).

Fourth, implicit in the vast majority of studies undertaken to date is the assumption that the direction of causality runs from urban form to travel behaviour. That is, a change in urban form is assumed to engender a change in travel behaviour. However, this assumption overlooks how longer term decisions relating to residential location and employment may be influenced by the travel preferences of decision-makers. For example, individuals who have strong preference towards car use may be more likely to favour low density residential locations that support this preference. Thus, the observed relationship between urban form and travel behaviour may be attributable, at least in part, to underlying travel preferences that influence residential location choices. This is known as self-selection bias and has been addressed in a handful of studies undertaken in the United States (Boarnet and Crane, 2001; Krizek, 2003; Handy et al., 2005; Bhat and Gio, 2007). To date, there have been no studies in Europe which have examined this specific issue.

Given the potential limitations outlined above, this chapter seeks to investigate the effectiveness of urban form as a policy tool which can be utilised to induce more sustainable travel patterns. There is already a large body of empirical research which has explored the relationship between urban form and travel behaviour. Various dimensions of urban form (e.g. density, mix of uses, road layout and location) and travel behaviour (e.g. trip frequency, trip length, choice of mode and travel time) have been examined. This, in turn, has generated a number of syntheses of recent work (Crane, 2000; Ewing and Cervero, 2001; Badoe and Miller, 2000; Banister, 2005). In seeking to build upon this previous work, this chapter contributes to our understanding of the influence of urban form and travel in the following ways. First of all, it explores the extent to which the availability of cars in a household is influenced by urban form. As argued above, car availability may undermine any potential reductions in car use attributable to urban form. Understanding this relationship is therefore of central importance to the development of a fuller understanding of the causal relationship between urban form and travel behaviour. Following this, the trip-making behaviour of individuals in different urban settings is examined. This includes analyses of the influence of urban form on the number of trips undertaken by car and the frequency of using local amenities. Finally, the relationship between urban form and the total distance travelled by individuals in the course of their daily activities is investigated. Clearly, this measure of travel behaviour takes into account any additional travel generated from savings gained by using local amenities in traditional urban neighbourhoods.

Research Approach

Data

The research is based on evidence from Glasgow and Edinburgh. The Scottish Household Survey (SHS) was the principal dataset used. Households interviewed between 2003 and 2006 were selected for this research (Hope, 2007). A travel questionnaire survey was also carried out in the six case study areas located in the two cities based on self completion. This questionnaire combined questions about travel behaviour and transport resources. One of the objectives of this travel survey was to examine changes in travel behaviour before and after moving home, especially home owners.

Measures of Urban Form

With reference to Chapter 2, measures of the following elements of urban form – density, land use mix, accessibility of place of residence in relation to the city centre and access to public transport – are selected. Population density was chosen to represent intensity of development. Various options were explored to represent land use mix using workplace employment data. The ratio of retail jobs to population was selected as it has relatively low correlations with other urban form measures. The accessibility of place of residence in relation to the city centre was represented by the road network distance from home to city centre. Finally, a dummy variable was created which reflected the quality of access to public transport. If a SHS respondent lived within 6 min of a bus stop and the frequency of service was at least one bus every 10 min then the respondent was categorised as having access to a high quality bus service.

A prime consideration in the selection of scale was the geographical resolution of the SHS dataset. A specialised SHS dataset was obtained which contained the home zone of respondents. Each home zone has a population of between 2,500 and 6,000 people and there are 133 and 101 such Intermediate Geography zones in Glasgow and Edinburgh respectively (Scottish Government, 2005). In consequence, the urban form measures assigned to each respondent were those based on the Intermediate Geography zone system, with the exception of the access to public transport measure which was determined directly from variables within the SHS. The home postal address of respondents to the travel and household questionnaires was known and so the selection of geographical scale on which urban form was measured was not constrained in the same way as the SHS dataset. Where appropriate, urban form measures are determined at the Intermediate Geography level and also using a zoning system with smaller geographical units known as Datazones (Scottish Government, 2005) which have residential populations of between 500 and 1,000.

Analysis

The following sections report the results of the research undertaken. In the next section the influence of urban form on household car availability is examined. This analysis considers both cross-sectional data (that is, data which relates to household car availability at a single point in time) and longitudinal data which incorporates the change in household car availability following a change in residential location. The principle advantage offered by longitudinal data is that it allows greater insight into the causal relationship between urban form and car availability than that offered by cross-sectional data which is limited to providing evidence of co-variation (Finkel, 1995). This is followed by sections that investigate the relationship between trip-making and urban form and travel distance and urban form, with the latter section considering both cross-sectional and longitudinal datasets.

Multivariate statistical models were estimated in order to examine the influence of the various elements of urban form on car availability and travel behaviour. The effects of socio-economic characteristics were taken into account by including variables such as age, gender and income as explanatory variables alongside urban form variables. For the analysis of travel behaviour the effect of urban form on workdays was distinguished from travel on non-workdays. In so doing, the effect of work-related constraints on travel behaviour was taken into account. In general, explanatory variables were taken to be statistically significant if there was found to be less than a 5% chance that they had no effect on the measure of travel behaviour under consideration.

Household Car Availability

The availability of cars in a household is a key factor in determining the level of accessibility enjoyed by household members. Between 1996/1998 and 2006, car ownership in urban areas of Great Britain with a population of more than 250,000 grew from 0.97 to 1.15 cars per household (DfT, 2002; DfT, 2007b). As discussed above car availability can also be regarded as an intervening variable which indirectly links urban form and travel behaviour. Although most multivariate analyses of travel behaviour have used car ownership as an explanatory variable alongside urban form and other socio-economic factors, this approach ignores the effect of urban form on car ownership itself. In so doing, the causal link between urban form and travel behaviour is overlooked and the overall effect of urban form on travel behaviour may be underestimated.

A few studies have specifically examined the relationship between urban form and car ownership. In the UK, Stead (1999, cited in Stead, Williams and Titheridge, 2000) found that car ownership was lower in areas close to good quality public transport. Research in the United States has found car ownership levels to be lower in mixed land use developments (Chu, 2002; Hess and Ong, 2002), in neo-traditional developments (Shay and Khattak, 2005) and in areas with higher household and employment densities and transit availability (Bhat and Gio, 2007).

The number of cars normally available for use by households is predicted using an ordered logit model. This is an appropriate model to use in situations where the outcome variable – the number of available cars – is both discrete and ordered (Borooah, 2002). The estimated model predicts the probability of a household having zero, one, two or three or more available cars for a given set of urban form attributes and socio-economic characteristics.

The results of the model are shown in Table 3.1 where the unit of analysis is the intermediate geography zones in Edinburgh and Glasgow. The size and direction of influence of explanatory variables are indicated by the parameter estimates shown in this table. As might be expected, the strongest effect on available cars is household income – for example, households with an income greater than £40,000 per annum have a greater probability of having available three or more cars than a household with an annual income of between £20,000 and £30,000. With regard to the urban form variables tested, car ownership was found to increase with decreasing population density and land use mix and increasing distance from the city centre.

In addition to the cross-sectional model estimated from the SHS, the effect of a change in urban form was examined by constructing a longitudinal model of the effect of moving home on household car availability. This approach is useful because it allows us to study one of the mechanisms by which the development

Table 3.1 Ordered logit model for cars available to households

	Parameter estimate
Small adult	0.70**
Single parent	−0.28*
Small family	0.83**
Large family	1.22**
Large adult	1.83**
Older smaller	0.85**
Single pensioner	−0.35**
Single adult (Reference)	
Glasgow resident	−0.54**
Edinburgh resident (Reference)	
No access to high quality bus service	0.16**
Access to high quality bus service (Reference)	
Income £0–£10 k	−2.14**
Income £10–£20 k	−1.40**
Income £20–£30 k (Reference)	
Income £40 k plus	0.92**
Distance from city centre (km)	0.07**
Retail employment to population ratio	−0.72*
Population density	−0.05**
Number of observations	8254
Log likelihood at 0	14198.66
Log likelihood at convergence	10344.86
McFadden pseudo R-square	0.23

* indicates statistically significant at the 5% level
** statistically significant at the 1% level

of neighbourhoods which follow more traditional urban forms may influence car availability. (The other mechanism is to re-engineer existing neighbourhoods and explore the effect on the behaviour of inhabitants which lies outside the scope of this study). The number of cars available after moving house was estimated using an ordered logit model in which change in population density, the ratio of retail employment to population and change in the distance to the city centre were included as explanatory variables. Table 3.2 shows the model results where the unit of analysis this time is data zones, representing 500 to 1000 people. It can be seen that the estimated parameters for change in population density and change in retail employment: population ratio are both negative. Change in network distance to the city centre is not statistically significant and neither is change in distance to work. This suggests that, after controlling for change in household income and change in distance to work, moving to a neighbourhood with higher density and greater degree of land use mix will result in a reduction in the number of available cars.

The results of the analysis described in this section demonstrate that the number of cars available to a household is lower when the characteristics of the residential neighbourhood conform to a traditional urban form typology. This is an important finding in the sense that it follows that households in more traditional neighbourhoods have lower levels of car accessibility and thus may be more likely to walk or cycle to local amenities or use public transport for longer journeys. However, in order to find out if this is the case the direct effect of urban form on travel behaviour must be examined alongside the indirect effect of urban form on travel behaviour through car availability. This is undertaken in the following two sections.

Table 3.2 Ordered logit model for change in available cars on moving house

	Parameter estimate
Change in population density	–0.06
Change in distance to work (kilometres)	0.003
Change in distance to city centre (kilometres) × 1000	0.01
Change in retail employment to population ratio	–2.36*
Change in income – a lot less	–4.70**
Change in income – a little less	–0.28
Change in income – about the same	–0.08
Change in income – a little more	–0.56
Change in income – a lot more (Reference)	
0 cars before move	–7.30**
1 car before move	–1.41
2 cars before move	1.90
3 or more cars before move (Reference)	
Number of observations	111
Log likelihood at 0	226.70
Log likelihood at convergence	112.20
McFadden pseudo R-square	0.51

* indicates statistically significant at the 5% level
** statistically significant at the 1% level

Trip Generation

Drawing on transport planning terminology, a trip can be defined as a one-way journey from an origin to a destination in order to undertake some activity at the destination; the type of activity undertaken is used to assign a purpose to the trip. The process by which an individual elects to undertake a trip is known as trip generation and the number of trips provides some indication of the amount of out-of-home activity in which an individual participates.

All other things being equal, and given the claims made in support of traditional urban forms, we would expect the number of trips made by car by those living in traditional neighbourhoods to be lower than those living in lower density, single-use neighbourhoods. We would also expect greater use to be made of local amenities. Previous studies give some supporting evidence. Næss (2006) observed higher weekday trip frequencies for residents in peripheral areas of the Copenhagen metropolitan area than in central areas. At the weekend, trip frequency was found to increase with proximity to the centre of the city after controlling for the effects of density (which itself was found to be to be inversely related to trip frequency). Drawing on a number of studies undertaken in the UK Banister (2005) concluded that trip frequency by car reduces as residential density increases. On the other hand, in a study conducted in the United States Boarnet and Sarmiento (1998) found no evidence that population density or functional mix influenced the number of non-work car trips.

In order to test the aforesaid claims, trip-making in different urban settings was examined and the results are given below. The analysis is divided into two parts. In the first part, the effect of urban form on trip frequency is examined. The second part examines the extent to which proximity to certain classes of local amenity influences the frequency of use of that class of amenity.

Trip Frequency

The SHS Travel Diary which forms part of the SHS was used to examine the effect of urban form on trip frequency. This diary records the travel behaviour of a randomly selected adult in each surveyed household over the course of a single day. All trips which are over a quarter of a mile or more than five minutes on foot are recorded. Again surveyed adults living in households residing within Glasgow and Edinburgh are selected for analysis and the spatial unit of analysis is intermediate geography zones of 2,500 to 6,000 people. Respondents for whom no travel was reported on the day in question are included in the dataset.

Ordered logit models are used to predict the total number of trips, the number of car trips and the number of single occupant car trips and the results are shown in Table 3.3. Factors representing urban form and socio-economics were included in these models as well as a dummy variable to indicate day type; that is, whether or not the day on which travel was recorded was a work day. Over and above the simple

Table 3.3 Ordered logit model for trip frequency

	Parameter estimates Total trips	Car trips	Car trips – Single occupancy
Male	–0.07	–0.10	0.24**
Female (Reference)			
Age 16–24 years	0.07	–0.24*	–0.64**
Age 25–34 years	0.03	0.04	–0.19
Age 35–44 years (Reference)			
Age 45–59 years	0.05	0.17*	0.18
Age 60–75 years	0.10	–0.04	–0.16
Age 75 years plus	–0.31*	–0.17	–0.66*
Income £0–£10 k	–0.28**	–0.47**	–0.20
Income £10–£20 k	–0.09	–0.16*	–0.06
Income £20–£30 k (Reference)			
Income £40 k plus	0.15*	–0.07	–0.12
Cars available = 0	–0.37**	–2.07**	–4.65**
Cars available = 1 (Reference)			
Cars available = 2	0.25**	0.68**	1.07**
Cars available = 3 plus	0.13	0.49**	1.00**
Small adult	–0.24**	–0.32**	–1.00**
Single parent	0.22*	0.15	–0.57**
Small family	–0.18*	–0.13	–1.06**
Large family	–0.27**	–0.25*	–1.18**
Large adult	–0.34**	–0.57**	–1.37**
Older smaller	–0.23*	–0.18	–0.90**
Single pensioner	0.05	0.22	0.51*
Single adult (Reference)			
Non-workday	–2.26**	–1.00**	–1.18**
Workday (Reference)			
Edinburgh resident	0.30**	0.11*	0.04
Glasgow resident (Reference)			
No access to high quality bus service	–0.82**	0.17**	0.20**
Access to high quality bus service (Reference)			
Employed or full time study	–0.01	–0.09	0.50
Not employed or full time study (Reference)	–0.70**		
Population density (persons per hectare) ♦	–0.01	–0.06**	–0.05**
Retail employment to population ratio ♦	0.80**	–0.95**	–0.93
Distance to centre (kilometres)		0.02	–0.01
Non-workday * Employed or full time study		0.10	–0.55
Non-workday * Not employed or full time study (Reference)			
Workday * Employed or full time study (Reference)			

Table 3.3 (continued)

	Parameter estimates Total trips	Car trips	Car trips – Single occupancy
Workday * Not employed or full time study (Reference)			
Nonworkday * Population density (× 1000)	–0.04**	–	–
Workday * Population density (Reference)		–	–
Number of observations	9657	8254	8254
Log likelihood at 0	26115.30	17211.64	10737.64
Log likelihood at convergence	23814.80	14560.42	7803.55
McFadden pseudo R-square	0.09	0.15	0.27

* indicates statistically significant at the 5% level
** statistically significant at the 1% level

additive effects of each factor on the number of trips, the question as to whether socio-economic influences and/or day type moderate the effect of urban form factors was also explored by including interaction terms in the models. For example, it might be the case that the influence of density on trip frequency varies according to household income. A number of interaction terms were examined, but the only one which was found to be statistically significant was the interaction between day type and population density for the model of the total number of trips.

The overall model fit for total number of trips is quite low (as indicated by a McFadden pseudo R-squared value of less than 0.1) which suggests that trip frequency is not influenced to any great extent by the explanatory variables in the model. Nonetheless, the parameter estimate for the ratio of retail jobs to residential population is negative and statistically significant indicating that the total number of trips decreases as land use mix increases. On work days population density and distance from home to city centre are not found to be statistically significant. On the other hand, the total number of trips is found to decrease with increasing population density on non work days. This suggests that the residential neighbourhood context exerts a greater influence on trip making when the effect of travel to work is absent and is consistent with the finding of Næss (2006).

With regard to car trips only population density and the ratio of retail employment to population are both found to be statistically significant predictors of the number of such trips and the number of single occupant trips. In both cases the models suggest that the number of trips decreases with increasing values of these attributes of urban form. Home to city centre distance is not found to be statistically significant in either model.

Household income is found to have a statistically significant effect on trip-making behaviour. Households with an income of less than £10,000 are found to make fewer trips overall and trips by car than households with an income of between £20,000 and £30,000. High income households (more than £40,000) are found to make more trips overall but no more car trips than households with an income between £20,000 and £30,000. This suggests that the number of car trips increases with income up to a certain point after which increasing income has no discernible effect.

The effect of the number of available cars on trip making is also investigated. It will be recalled from earlier that population density, land use mix and distance to city centre are found to be associated with the number of cars available to a household. It can also be seen from Table 3.3 that the parameter estimates for two or more cars is positive and statistically significant. This indicates that, relative to a household with only one car, the number of trips is higher for those living in households with two or more cars. Overall, this analysis highlights both the direct effects of urban form on trip frequency and also the indirect effect that elements of urban form have on trip making through car availability.

Use of Local Amenities

A complementary perspective on local trip-making can be obtained by examining the use of neighbourhood amenities. More specifically, the distance between home and a particular class of amenity can be thought of as a proxy for mixed use development. This section examines whether distance to an amenity and any constraints placed by work influence the frequency of use of that amenity.

The data used in this analysis is drawn from three sources. First, the household survey of case study neighbourhoods collected information on respondents' use of specified local amenities. Permissible responses are (1) most days, (2) at least once a week, (3) at least once a month, (4) occasionally, (5) don't use. Second, the locations of the following classes of amenity are mapped within a Geographical Information System (GIS): post office, library, bars, restaurants/cafes and convenience store. Third, the road network distance from each respondent's home address to specified categories of services and facilities is determined using GIS. This enables the distance to the nearest amenity in each class and the number of amenities in a class which were located within 500 m of each respondent's home to be determined.

Respondents are further categorised according to work status and those who are categorised as full-time workers, retired and looking after family/home were selected for analysis. This enabled the effect of employment on the frequency of use of local amenities to be tested. Full-time workers are sub-divided into those working locally (defined as those working within the same postcode sector as their place of residence) and those not.

The frequency of use of each class of amenity was estimated using an ordered logit model and the results are presented in Table 3.4. Positive parameter estimates indicate an increase in the likelihood of the "don't use" response whilst negative parameter estimates indicate an increase in the "most days" response. The distance to the nearest amenity is found to be a statistically significant predictor of the frequency of use of post office, library and convenience store after controlling for socio-economic and demographic factors. The parameter estimates are positive

Table 3.4 Frequency of use of various classes of local amenity

		Post office	Restaurant/ café	Bar/pub	Library	Convenience store
Access	Distance to centre (km)	–0.03	0.03	–0.001	–0.03	0.05
	Nearest Service/Facility (km)	0.76**	–	–	0.58**	2.05**
	Number of Service/Facility	–	–0.02**	–0.05**	–	–
	Population Density	–0.39	1.15	0.07	0.63	–2.00*
	Min Distance to Supermarket (km)	–	–	–	–	–1.08**
City	Edinburgh	0.22	–0.01	0.31	–0.32	0.15
	Glasgow	0.07	–0.67**	0.15	–0.41*	(Reference)
	Leicester	–0.10	–0.34	–0.68**	–0.82**	–
	Oxford	0.06	–0.62**	–0.18	–0.32	–
	Sheffield (Reference)					
Gender	Male	–0.04	–0.004	–0.56**	0.06	–0.20
	Female (Reference)					
Age	16–24 years	0.96**	–1.53**	–2.54**	0.36	–0.74
	25–34 years	1.11**	–1.28**	–1.87**	0.50	–0.27
	35–44 years	1.01**	–1.24**	–1.54**	0.04	–0.65
	45–54 years	0.79**	–0.97**	–1.34**	–0.05	–0.37
	55–64 years	0.40*	–0.64**	–1.11**	0.06	–0.38
	65 years + (Reference)					
Status	Employed full-time – work locally	1.02**	–0.33	–0.84**	0.72*	–0.29
	Employed full-time – not work locally	1.19**	–0.17	–0.80**	1.02**	0.06
	Retired	0.96**	–0.15	–0.81**	0.62*	–0.32
	Looking after family/home (Reference)					
Income	<£10 k	–0.51*	1.45**	0.13	–0.12	–0.50
	£10–£20 k	–0.19	1.19**	0.05	–0.27	0.39
	£20–£30 k	–0.13	1.01**	–0.04	–0.28	–0.04
	£30–£40 k	–0.13	0.59**	–0.03	–0.25	–0.16
	£50–£80 k	–0.19	0.31	–0.28	–0.20	–0.12
	>£80 k (Reference)					
Cars	No cars	0.08	–0.11	0.09	–0.24	–0.42
	1 car	0.11	–0.27	0.19	–0.08	–0.13
	2 or more cars (Reference)					
	Number of observations	2049	1642	1675	1856	858
	Log likelihood at 0	5434.52	4733.09	4757.46	3957.90	2387.32
	Log likelihood at convergence	5184.88	4292.37	4295.52	3834.95	2288.91
	McFadden pseudo R-Square	0.05	0.09	0.10	0.03	0.04

* indicates statistically significant at the 5% level
** statistically significant at the 1% level

which indicate that frequency of use decreases as proximity to the specific local service/facility increases. For convenience shops, the effect of competition with supermarkets is also revealed – the greater the distance to the nearest supermarket the more frequent the use of a local convenience shop. Likewise, the number of restaurants/cafes and pubs within 500 m of a respondent's home are statistically significant predictors of frequency of use. The parameter estimates are negative indicating that an increase in the provision of this amenity class is associated with an increase in the frequency of use.

Distance from home to the city centre is found to be a statistically significant predictor of the frequency of use of local restaurants and pubs but not for the other categories of services/facilities considered. The analysis suggests that the further a person lives from the city centre, the less frequent his or her use will be of local restaurants and pubs. This result probably reflects the preponderance of opportunities for eating and drinking within city centres in comparison with other locations within the city and the fact that a threshold of 500 m was used to determine the number of local eating and drinking opportunities. For residents located in or near to city centres there are likely to be a significant number of eating and drinking opportunities which are located just beyond this threshold. Since this effect on frequency of use is not captured in the model by the local access variable it may be captured instead by the distance to the city centre variable.

To test the hypothesis that respondents with formal commitments outside their residential neighbourhood make less frequent use of amenities within their neighbourhood, respondents were divided into four work status categories as described above. The reference category is those looking after family and home. Relative to this group, employed respondents were estimated to use the local post office and library less frequently. The magnitude of the estimated parameters also suggests that those employed locally use local amenities more frequently than those employed outside the local area. No statistically significant differences are found between the employment categories for the frequency of use of restaurants or convenience stores. On the other hand, the frequency of use of local pubs is found to be higher for employed and retired respondents in comparison with those looking after family and home. The link between employment location and the use of local amenity is again evident on inspection of the magnitude of the parameter estimates for use of pubs – those working locally are more likely to use a local pub than those working outside the local area.

Trip Generation: Summary

The principal conclusion that can be reached from the analysis of trip frequency is that increasing land use mix and density reduces the frequency of car trips and single occupancy car trips. No difference was detected between work days and non-work days. Increasing car availability was also found to increase trip frequency by car which, recalling the earlier results, indicates an indirect pathway linking urban form and trip frequency.

It will be remembered that only car trips which were over a quarter of a mile in length were recorded in the SHS Travel Diary and so it is possible that car trips undertaken by residents in neighbourhoods which have good local access to people and amenities (that is, high density, mixed-use neighbourhoods) are underestimated. However, it does not seem likely that the number of car trips that fall below this threshold would be sufficiently high to have a large influence on the results.

The frequency of use of a number of key local amenities is found to decline with distance from home. Economic status and employment location are also found to influence the frequency of use of some amenities which is consistent with a constraints-based accessibility perspective. A key limitation of this work is the extent to which frequency of use is correlated with local access. It is possible that demand is uniform across a neighbourhood, all other things being equal, and those with lower levels of access organise their use of amenities more efficiently than those living in close proximity to local services and thus undertake fewer trips to satisfy demand. This may provide an explanation for the use of essential services such as post offices, but does not satisfactorily explain the use of discretionary amenities such as restaurants and bars. Assuming uniform demand, it may also be the case that those living further from local services are more likely to use non-local services, such as those located close to the workplace. Even if demand is non-uniform and is influenced by proximity/intensity, the direction of causality may not be straightforward. It is possible that those with a propensity to use certain types of local services (such as bars and restaurants) may choose to live in locations with good access to these services.

Trip frequency is only one measure of travel behaviour and reflects the number of spatially separated activities carried out in the course of a day. It does not however capture the total amount of travel undertaken which has particular relevance to the question of the efficiency of resource use in transportation and urban form. This question is examined in the following section.

Distance Travelled

The total amount of travel undertaken is an appropriate measure to assess the overall effects of urban form on travel behaviour. It encompasses any variations in the pattern of trips which may exist between residents of different neighbourhood urban form typologies. This includes substitution effects whereby travel time savings made when undertaking an activity close to home may be used for additional travel. It also takes into account all travel that may be associated with specific activities such as work which are fixed in time and space. Previous work has noted that population density is negatively associated with travel distance (Stead, 2001) and positively associated with distance from home to the city centre (Næss, 2006: 104). Travel distance by car on weekdays is also found to be positively associated with distance to the city centre (Næss, 2006).

The analysis presented in this section commences with an examination of the effect of urban form on the distance travelled by all modes and the distance travelled by car using the SHS. The Travel Diary records an origin and a destination for each recorded trip. The network distance travelled for each trip was estimated using GIS and then aggregated for each respondent living within the cities of Glasgow and Edinburgh to give two measures of travel behaviour – total distance travelled by all modes and total distance travelled by car. As before, respondents for whom no travel was reported were included in the analysis. The areal unit of analysis is the Intermediate Geography zone.

Multiple linear regression analyses were undertaken in which total distance travelled and total car distance travelled were regressed on to number of explanatory variables reflecting urban form, socio-economic characteristics and day type (that is, work day or non work day). Interaction terms between day type and the urban form variables are tested, but only the interaction term between day type and distance to city centre is found to be statistically significant in both models. This suggests that, with this exception, the influence of urban form on distance travelled is the same for work and non-work days.

To avoid endogeneity bias in the estimation of distance travelled, a two-stage estimation procedure was used (Train, 1986). The expected number of cars available to a household was first estimated from the SHS for each respondent using the car ownership model described above. The estimated number of cars available to each household was then included as a predictor of distance travelled.

With reference to Table 3.5, total distance travelled decreases with increasing population density and increasing ratio of retail employment to population. Proximity to a high quality bus route is found to reduce the amount of car travel whereas household income is not shown to have a statistically significant effect. For work days, distance between home and the city centre is positively associated with total distance travelled. However, non-work days reduce the effect of this factor; that is, the location of home relative to the city centre is found to have a greater effect on total distance travelled on work days than it has on non-work days. This is consistent with the work of Næss (2006) who found the effect of distance between home and city centre on total distance travelled to be lower at the weekend than on weekdays.

A similar picture emerges for total distance travelled by car. The principal difference is that the ratio of retail employment to population is not statistically significant. This suggests that, all other things being equal, living in a mixed use neighbourhood does not reduce the amount of travel undertaken by car. Also, no difference is detected in the amount of travel undertaken on work days and non-work days.

Both total travel distance and travel distance by car are found to increase with increasing car availability, which highlights the indirect influence that urban form has on these measures of travel behaviour. Maps showing the model results applied to Glasgow and Edinburgh for workdays and non-workdays are shown in Figures 3.1, 3.2, 3.3, and 3.4. It can be seen that distance travelled by car tends to increase with distance from the centres of the two cities reflecting the predominately

Table 3.5 Multiple regression models of distance travelled

	Parameter estimates	
	Distance Travelled Total	Distance Travelled by Car
Constant	2.00**	0.47*
Population density (persons per hectare) ♦	−0.02**	−0.03**
Distance to centre (km)	0.05**	0.08**
Retail jobs to population ratio ♦	−0.39	−0.22
City – Edinburgh	0.12**	0.06
High Quality Bus Route	−0.09*	−0.07*
Car ownership	0.35**	0.87**
Gender – female	−0.02	−0.04
Age – 16–24	0.02	−0.19**
Age – 25–34	0.02	−0.02
Age – 45–59	−0.07	0.01
Age – 60–74	0.05	0.04
Age – 75 plus	−0.15	−0.09
Income – £0–£10 k	−0.10	−0.10
Income – £10–£20 k	−0.02	−0.03
Income £30 k plus	0.05	−0.07
Household – small adult	−0.09	−0.12
Household – single parent	−0.05	0.07
Household – small family	−0.13	−0.11
Household – large family	−0.26**	−0.24*
Household – large adult	−0.38**	−0.52**
Household – older smaller	−0.17	−0.05
Household – single pensioner	0.04	0.12
Employed	0.30	0.24
Day type – non-work	−0.86**	−0.15
Non-work * Employed	−0.24	−0.01
Non-work * Distance to centre	−0.03	−0.07**
Number of observations	5240	5240
Adjusted R-square	0.213	0.184

* indicates statistically significant at the 5% level
** statistically significant at the 1% level

mono-centric structure of both cities and the decline in population density from the middle to the outer city. From a statistical perspective, this also serves to highlight the correlation between these two measures of urban form and the difficulty in completely separating the effects of density and location in an observational study of this kind.

Further evidence of the influence of urban form on car use is available from the longitudinal data set collected amongst home-movers. Respondents were asked to compare their current total amount of car travel as a driver and passenger with their car use before moving home. Permissible responses were (a) a lot less, (b) a little less, (c) about the same, (d) a little more and (e) a lot more. The determinants of the change in car use is estimated using an ordered logit model in which changes

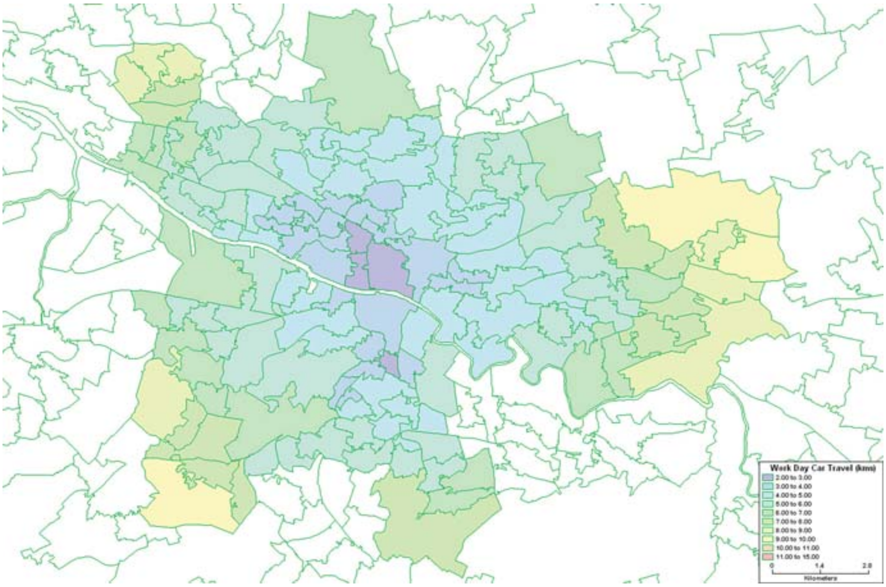

Fig. 3.1 Distance travelled by car in Glasgow (work day)

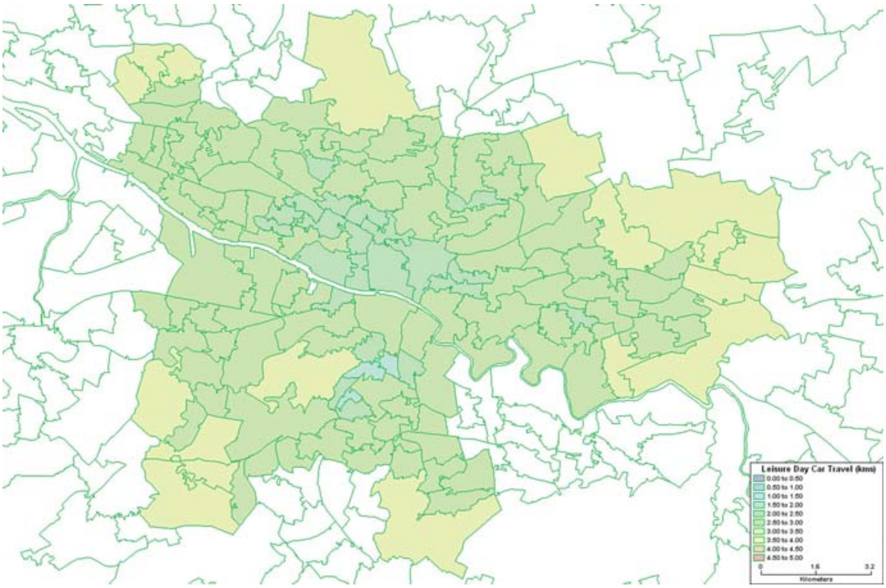

Fig. 3.2 Distance travelled by car in Glasgow (non-work day)

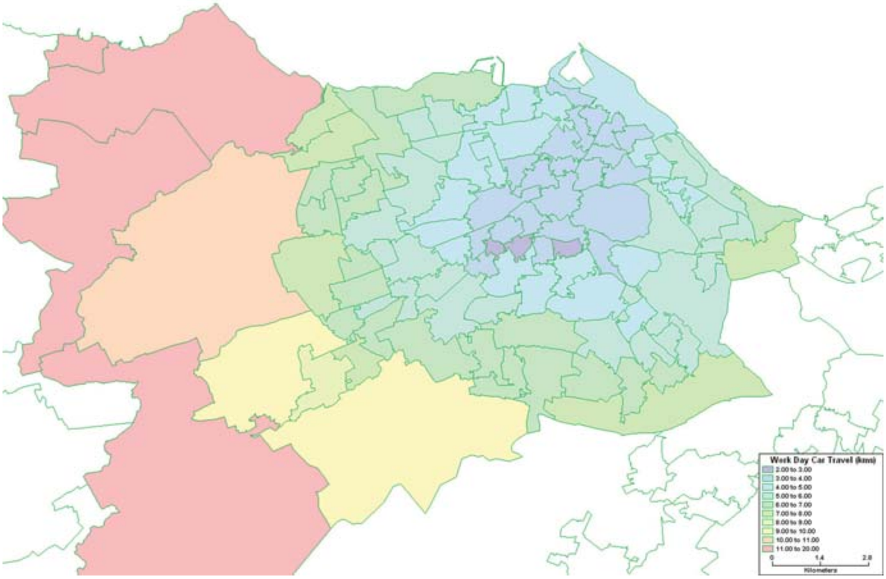

Fig. 3.3 Distance travelled by car in Edinburgh (work day)

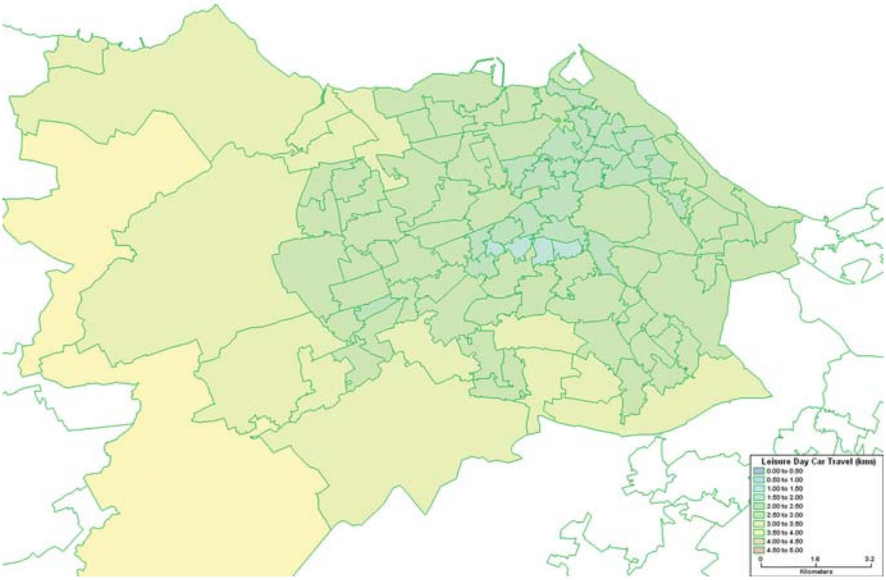

Fig. 3.4 Distance travelled by car in Edinburgh (non-work day)

in population density, the ratio of retail employment to population and distance to the city centre are included as explanatory variables. The results are presented in Table 3.6 based on datazones. It can be seen that a change in population density brought about by moving home is negatively associated with a change in car use. The other urban form attributes are not found to be statistically significant, although this may be partly attributable to the relatively small sample size used in this analysis.

It should also be noted that a change in the number of cars available to a household after moving home is found to be positively associated with the amount of car travel. This specific result should be read in conjunction with the longitudinal model of household car availability described above in which changes in population density and retail employment: population mix following household re-location are found to be negatively associated with car availability. This highlights the indirect effect that urban form has on car travel through car availability which can

Table 3.6 Ordered logit model for change in car travel

	Parameter estimate
Change in population density (persons per hectare) × 1000	–0.07**
Change in distance to work (kilometres)	0.02
Change in distance to city centre (kilometres) × 1000	0.05
Change in retail employment to population ratio	–0.77
Change in available cars	0.72*
Age 16–24 years	0.77
Age 25–34 years	1.02
Age 35–44 years	–0.13
Age 45–54 years	–0.09
Age 55–64 years	–0.15
Age 65 years plus (Reference)	
Male	0.59
Female (Reference)	
Change in income – a lot less	0.28
Change in income – a little less	0.45
Change in income – about the same	–0.25
Change in income – a little more	0.87
Change in income – a lot more (Reference)	
Attitudinal cluster 1 – non-car driver	–0.54
Attitudinal cluster 2 – non-car driver	–1.30
Attitudinal cluster 3 – car driver	–0.70
Attitudinal cluster 4 – car driver	0.01
Attitudinal cluster 5 – car driver	0.01
Attitudinal cluster 6 – car driver	
Number of observations	96
Log likelihood at 0	286.7
Log likelihood at convergence	244.2
McFadden pseudo R-square	0.15

* indicates statistically significant at the 5% level
** statistically significant at the 1% level

be regarded as additional to the direct effect of urban form factors on car travel discussed in the previous paragraph.

The extent to which residential self-selection explains change in car travel is also explored. The travel questionnaire asked respondents the degree to which they agreed with a number of statements on car travel. Cluster analysis was undertaken and respondents were then assigned to one of six groups reflecting attitude towards car travel. Four of these groups related to car drivers and two related to those who either did not have access to a car or did not have a driving licence. Dummy variables are included in the model to represent group membership. Following Handy et al. (2005), evidence of self selection would be detected if the attitudinal dummy variables that are statistically significant predictors of change in car travel remain constant over the period of residential re-location. With reference to Table 3.6 it can be seen that none of the attitudinal dummy variables is statistically significant. This suggests that self-selection of residential location on the basis of travel preferences is not a major influence on car travel. Several caveats must however be added. First, the sample is relatively small. Second, the sample of home-movers is itself self-selected and hence subject to potential bias. Finally, in many households, the choice of residential location is a joint decision whereas the dataset analysed here uses attitudinal data relating to only a single respondent from each household.

In summary, this section has shown that neighbourhoods corresponding to traditional urban form typologies are associated with lower levels of distance travelled by all modes and distance travelled by car. Urban form is shown to influence distance travelled directly and also indirectly through household car availability. The possibility that this association between urban form and car travel arises from households choosing neighbourhoods that support inherent travel preferences is also explored but no evidence is established in support of this premise.

Conclusions

This chapter has sought to examine the extent to which urban form, in particular the residential neighbourhood context, influences certain key aspects of travel-related behaviour. In recent years arguments have been advanced in support of traditional urban forms, partly on the basis that they will induce more sustainable travel patterns. Three measures of travel-related behaviour are explored, namely car availability, trip generation and distance travelled, and the effects of population density, functional mix and distance from the city centre on these measures are tested using multivariate statistical models which allows socio-economic effects to be controlled.

From the work presented in this chapter several conclusions can be drawn that are reinforced by the broad agreement between the results of the cross-sectional analyses of car ownership and car use and the outcomes of elective urban form change brought about by moving home. First, traditional urban forms are associated with lower levels of car availability which in turn are associated with lower trip frequencies and shorter travel distances. The indirect influence of urban form on travel behaviour through the intermediate variable of car availability is in addition to the direct effect of urban form on travel behaviour. Second, traditional urban forms are associated with lower car trip frequencies, total distance travelled and distance travelled by car. There are a number of reasons why this may be the case. Areas of higher population density areas are able to support a greater number and variety of local services and facilities and have good public transport connectivity which leads to a lower household demand for access to cars. In the highest density areas, limited parking supply and regulatory control can also be expected to play a role in reducing car demand. Third, household income has a strong influence on car ownership and also influences trip making behaviour but has no measurable effect on distance travelled.

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Chapter 4
Environment and Biodiversity

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Introduction

Research over many decades has documented numerous environmental effects of urbanization, ranging from the loss and reconfiguration of green space to dramatic changes in ecosystems and biodiversity. Rather less is known about how urban form, in particular the density of urban development, alters environmental patterns and processes *within* cities. Investigation of the relationships between urban form and environmental structure and performance is an important issue in the urban sustainability debate and here we use that work to illustrate some of the key ideas in this newly emerging field. After outlining the general effects of urbanization on environment and biodiversity, we then consider in turn the relationships between urban form and patterns of green space, the degree to which urban environments can provide useful ecosystem services to human populations, and finally the responses of biodiversity to urban development.

Urbanization transforms the ecology of an area. Such transformation can include: (i) the alteration of habitat, such as the loss and fragmentation of natural vegetation, and the creation of novel habitat types (Niemelä, 1999; Pickett et al., 2001; McKinney, 2002; Johnson and Klemens, 2005); (ii) the alteration of ecosystem services (e.g. air, water and climate regulation, pollination), and other resource flows, including reduction in net primary production, increase in regional temperature, and degradation of air and water quality (Henry and Dicks, 1987; Rebele, 1994); (iii) the alteration of disturbance regimes, typically an increase in disturbance frequencies (Rebele, 1994); and (iv) disruption of species occurrence and abundance patterns, commonly including the local extinction of many species that are habitat specialists, require large habitat patches, utilise the interiors rather than the edges of patches, or are associated with complex vegetation structures (Pickett et al., 2001; McKinney, 2002; Chace and Walsh, 2006). The extent and intensity of these effects depend largely on the extent, composition and management

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of green spaces in urban areas. However, both variation in these characteristics and the details of their interactions particularly with ecosystem services and biodiversity remain rather poorly understood. This is perhaps surprising, given that both the characteristics of green space and its ecological correlates also bear on a number of other important issues. In particular, the extent, composition and management of green space has been shown to have significant effects on urban economies, through a diverse array of impacts, including on house prices, the costs of heating and cooling buildings, and the ease of attracting businesses and employees to areas (e.g. CABE Space, 2004), and on human physical, mental and social well-being (Dunnett and Quasim, 2000; Kuo and Sullivan, 2001; de Vries et al., 2003; Fuller et al., 2007a).

A useful step in developing an improved understanding of the structure of green space and some of the benefits that it brings within urban areas is to determine how these depend on urban form (the structure of the built environment). At the most simplistic level, the structure of urban green space might be viewed as the converse of urban form. Indeed, both measures of green space and of the built environment have been identified as key environmental indicators in urban areas (e.g. Pauleit and Duhme, 2000; Whitford et al., 2001). However, for a given ratio of green space to coverage by impervious surface, the nature and density of the built form can vary widely, such that there is a great deal of scatter in the relationship between measures of green space cover and urban density (Tratalos et al., 2007a). Further, the spatial configuration of habitat patches, rather than simply the degree of coverage by green space, can be important in determining biological processes for certain groups of organisms and types of ecosystem function (Bastin and Thomas, 1999). Links between coverage by green space and the nature of urban form have not been well explored (Pickett and Cadenasso, 2006).

There is considerable variation in the structure of cities, with local and regional factors heavily influencing urban form. For example, Sheffield, one of the case study cities, has a long history as a market town with a distinctly urban character (Hey, 2005). The population grew from 10,000 inhabitants in 1736–83,000 in 1851, and 90,000 by 1901. In the second half of the nineteenth century steel manufacture became the major industry and remained so for nearly one hundred years. Access to water for this industry dictated much of the pattern of early urbanization, and prevailing winds from the west meant that affluent residential areas were typically sited in the western suburbs with cleaner air, leading to a westward sprawl of the city boundary and increased population growth (currently 513,000). During the 1970s and 1980s, manufacturing industry began to shrink drastically, the economy diversified, and by the mid-1990s two-thirds of jobs were in the service sector. Substantial areas were redeveloped under regeneration programmes that replaced many industrial sites with housing or office blocks (Hey, 2005). This history has, in part, shaped the configuration of urban Sheffield today, with the most heavily developed areas in the river valleys, forming a y-shaped pattern. Large green spaces are restricted to the zones of intermediate and low levels of urban development, and a band of high density housing is noticeable between the centre and the outer suburbs (Fig. 4.1). In the context of the environment and biodiversity, urban form is perhaps best measured in terms of the density of various elements of urbanization,

Fig. 4.1 Satellite image of Sheffield. Image of Sheffield acquired June 2005, 17° off nadir angle, cloud cover 1%. The area shown is all Ordnance Survey 1 km^2 national grid squares, inside the administrative boundary which comprise 10% or more impervious surface (buildings, roads or other sealed surface)

the patterns of coverage of different land use types, and the degree to which different patches of land cover are connected to each other. Insofar as the road network alters the configuration of green spaces by dividing them into smaller fragments, and might form a barrier (or a conduit) for dispersal of animals and plants, the physical structure of the road network is an important component of urban form as it impacts environmental performance. Although they may remain of interest, the effectiveness or efficiency of other measures of connectivity, as reflected for example in social cohesion and the ease with which people can move between areas using transport networks, are of less direct relevance, because they do not bear directly on the amount and configuration of patches of usable habitat.

In this chapter, we review aspects of the relationships between urban form and green space extent, ecosystem service provision and biodiversity. In so doing, we use examples drawn principally, although not exclusively from empirical studies of these issues conducted within the five case study cities.

Green Space and Urban Form

Broadly defined to include most soft rather than hard or impervious surfaces, local government statistics often indicate that green space covers a substantial proportion of most cities in the UK. However, values based on the administrative boundaries of cities are difficult to interpret as these often extend well beyond the actual limits of urbanization and may include substantial rural areas. For example, urban areas form only about one-third of the area within Sheffield's administrative boundary, while another third is agriculture, and the remaining area forms part of the Peak District National Park (Beer, 2005). To generate more comparable data, we define the urban area simply as all the 1 km^2 grid squares inside the administrative boundary that comprise 10% or more sealed surface (buildings, roads or other human-made surface). Within this urban area, green space covers 60–70% if gardens are included, and 30–45% if gardens are excluded (Table 4.1). The data in Table 4.1 make two interesting points. First, the figures are remarkably consistent across the five study cities, despite their very different histories and topographies. Secondly, the figures are perhaps surprisingly high; a substantial majority of the surface within urban areas comprises green space, if gardens are included (see also Pauleit and Duhme, 2000). In this context it is important to note that these analysis are based on high resolution vector mapping, which includes even very small areas of green space such as road verges and amenity plantings. Given that small patches of green space make a disproportionately large contribution to overall levels of urban green space (see below), analyses of green space coverage that use mapping at a coarser scale might substantially underestimate its extent. In addition, these figures treat gardens as purely green space, whereas a proportion of the coverage of most gardens comprises impervious surfaces (e.g. in Sheffield, about one-third of garden area comprises impervious surfaces such as paths, patios, etc.; Tratalos et al., 2007a).

Table 4.1 Total Green Space Coverage within the Five Case Study Cities

City	Total urban area (km^2)	Total green space (km^2)	Gardens (km^2)	Non garden green space (km^2)	% coverage by green space incl. gardens	% coverage by green space excl. gardens
Edinburgh	124.02	80.75	27.63	53.12	65.1	42.8
Glasgow	197.60	120.27	32.47	87.80	60.9	44.4
Leicester	70.09	41.84	18.88	22.96	59.7	32.8
Oxford	37.28	25.06	8.18	16.88	67.2	45.3
Sheffield	158.93	104.61	39.56	65.05	65.8	40.9

Green space is defined as any land parcel classified as "natural surface" by Ordnance Survey's MasterMap dataset (Ordnance Survey 2006), while gardens are those parcels classified as "multiple". The urban area is defined as that area inside the city's administrative boundary intersecting Ordnance Survey 1 km^2 national grid squares with 10% or more of their area comprising impervious surfaces (buildings, roads or human made surface).

A detailed grid-based analysis of green space across the five case study cities (Fig. 4.2) reveals that in each case coverage by green space is highly heterogeneous, with a long left tail of areas with very low levels of green space coverage, and a significant number of cells with almost complete coverage, representing large parks, well-wooded remnants and encapsulated patches of undeveloped land. The general pattern is remarkably consistent across the five cities, with the peak in proportional coverage generally occurring around 0.6. The frequency of cells with very high coverage varies markedly though, with Edinburgh and Oxford showing distinct peaks, indicating large patches of internal green space within those cities,

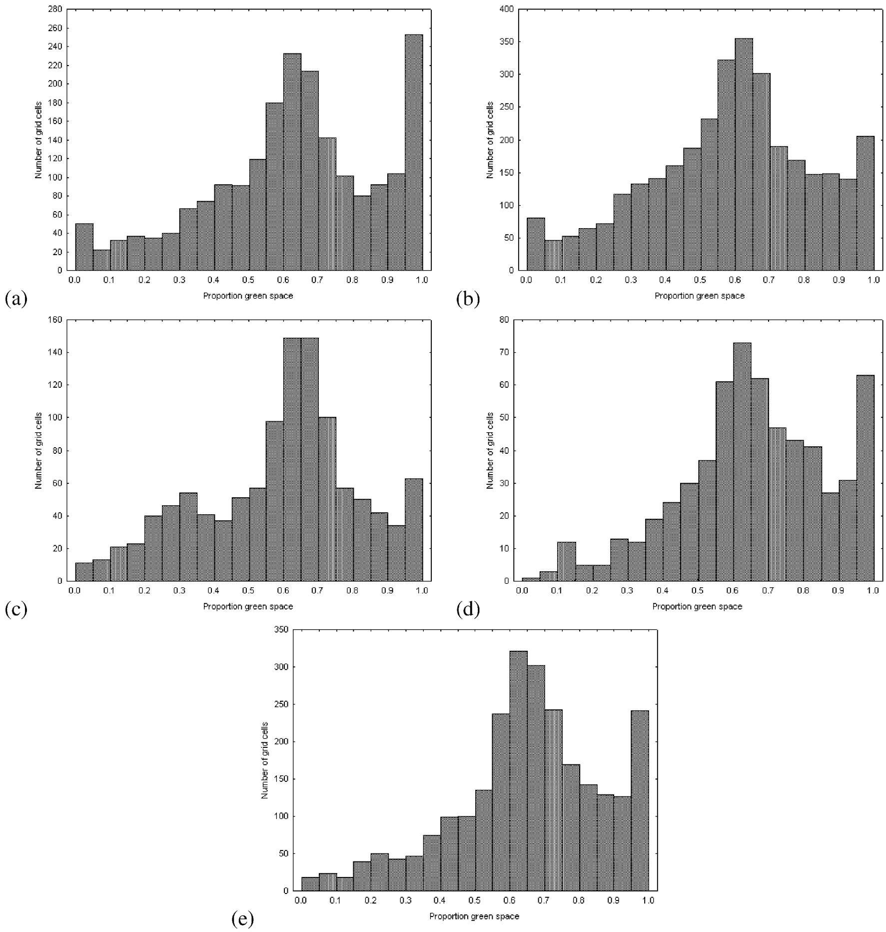

Fig. 4.2 Proportions of green space across case study cities at 250 × 250 m cell resolution (**a**) Edinburgh, (**b**) Glasgow, (**c**) Leicester, (**d**) Oxford and (**e**) Sheffield. Green Space is vegetated surface including domestic gardens

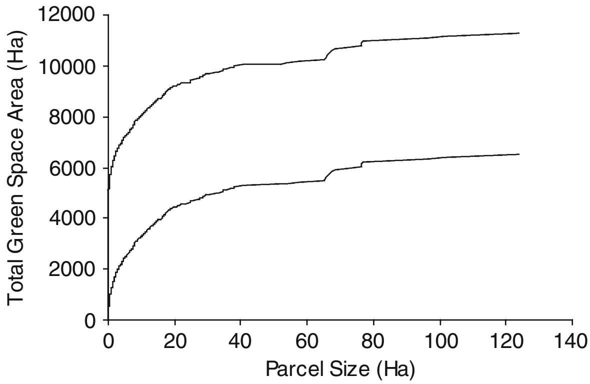

Fig. 4.3 Cumulative amount of green space in Sheffield as parcels are added beginning with the smallest. The lower line excludes garden parcels

and Glasgow and Leicester showing a much less pronounced peak indicating that few large patches of green space exist within the boundaries of those cities.

A high proportion of urban green space in UK cities is composed of small patches, such as domestic gardens and roadside verges, rather than large patches, such as public parks and playing fields. For example, there are 326,147 separate parcels of green space within the Sheffield urban area, of which 93% are front or rear garden. When arranged in rank order of increasing area, the contribution to overall cumulative area of green space decelerates strongly as parcel size increases, a pattern that persists even when gardens are excluded (Fig. 4.3). Across urban Sheffield, 50% of green space comprises the parcels with an area less than 0.59 ha. Excluding gardens, the equivalent figure is 9.9 ha. This is significant, as much strategic planning of urban green space is focussed on the large green spaces, and ignores the smaller ones. In practice, however, the vast network of small patches may make substantial contributions to the net environmental benefits provided by urban green space, and may be vital to maintaining the contributions of some of the larger patches (e.g. through influences on overall habitat availability and on the degree of connectivity among larger patches). Without the smaller patches the larger ones would genuinely resemble the isolated habitat islands that strategic planning often portrays them to be.

The size of a patch of green space is an important variable in ecological terms, because larger patches tend to support more species and individuals, buffer those populations from local extinctions, and allow the organisms within them to disperse across the landscape (Bastin and Thomas, 1999). As well as overall green space, average patch size tends to decline with increasing building/housing density, with some evidence that the relationship is markedly non-linear, being steeper at lower densities (Tratalos et al., 2007a). This effect may be exacerbated by the larger numbers of land parcels in areas of higher density. Crucially though, the ecological impact of changes in habitat patch sizes depends on whether habitat characteristics of patches also vary with their size, the minimum patch areas that particular species can tolerate, and the ability of species to disperse across the landscape to other patches (Watson et al., 2005; Bierwagen, 2007).

Green space is not distributed evenly within cities (Fig. 4.4a, b). Yet, despite variation in geographic settings, socio-economic and developmental histories, topographies and sizes, there are often marked similarities between cities in this distribution, and some common correlates with key measures of urban form. For example, across the five case study cities the overall extent of green space tends to increase with elevation and topographic slope, and decline with number of road nodes, length of roads, and the density and area of housing and other buildings (Davies et al., unpublished data). The slopes of these relationships are often broadly similar between these cities. The relationships between overall green space and building/housing density result in large part from the net trade-off between two processes, the decline and the increase respectively of non-garden and garden green space with increasing housing density. Indeed, this is arguably a key driver of patterns of green space in urban areas. This is particularly apparent for relationships between green space coverage and the density of given housing types (flats, terraced, semi-detached, detached; Fig. 4.4i–l), with the net balance between the two processes shifting, such that for flats it is dominated by the loss of non-garden green space whilst for detached houses it is dominated by the gain of garden green space.

Whilst interesting patterns are evident in the distribution of green space treated as a whole, it is also clearly the case that all green space is not the same. One marked difference is in the occurrence of trees. Trees can contribute to some, though not all, of the key advantages of green space disproportionately to the area they occupy on the ground because of their complex structure that includes a canopy. This may be important in urban areas where ground space is at a premium. Therefore the numbers and distribution of trees are potentially important aspects of greenspace provision in urban areas. In what seems likely to be a general pattern, across Sheffield there is an approximately triangular relationship between tree cover and extent of green space, such that whilst the maximum amount of tree cover increases with the extent of green space, below this limit the full range of variation in tree cover is exhibited (Davies et al., 2008). There are also marked declines in tree cover with increasing housing density (Iverson and Cook, 2000). This is a particular concern at the present time given that the occurrence of trees in individual private gardens declines as those gardens become smaller (Smith et al., 2005), and that decreases in garden size are occurring in urban areas of the UK as a consequence of increased densification both in the form of high density new developments and infilling development.

Such densification, both in the UK and elsewhere, also results in general reductions of green space (e.g. Pauleit and Duhme, 2000; Pauleit et al., 2005; Yli-Pelkonen and Niemelä, 2005). This occurs both as a consequence of infill development in areas which historically have had lower densities of buildings, and through development in those areas which recently have had higher levels of brownfield land. For Sheffield, a trend of increasing urban density is apparent from a generally positive relationship between the date of urbanization and current levels of green space (Fig. 4.5a). However, a flattening of the relationship since the

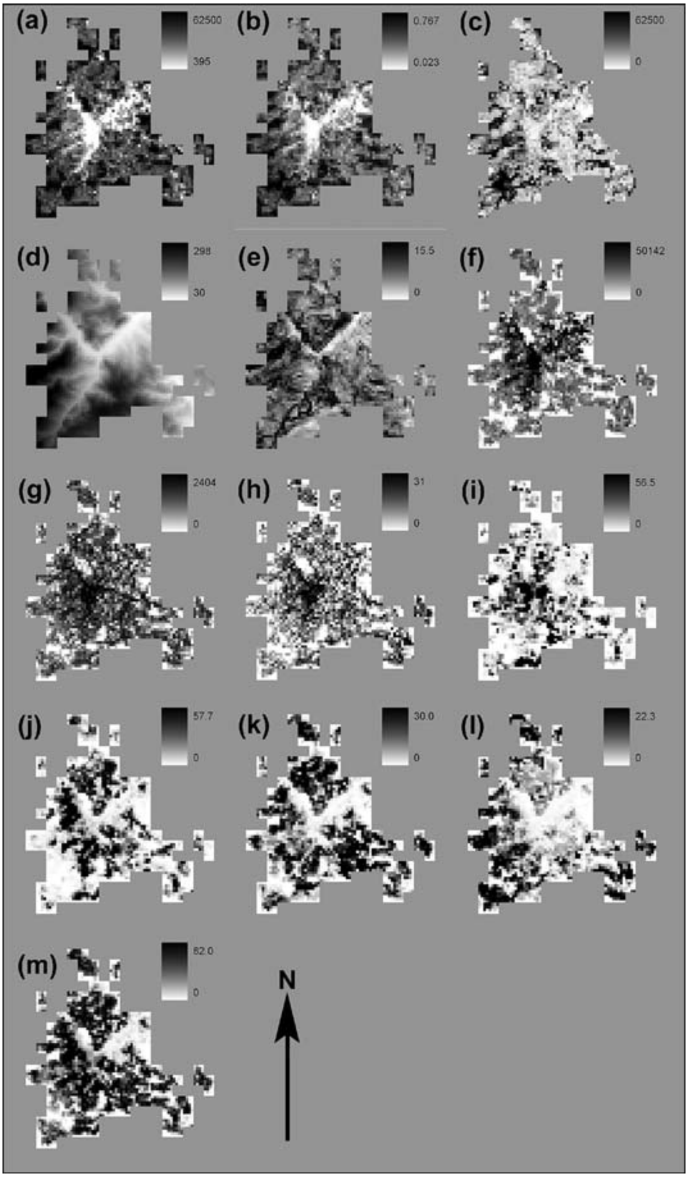

Fig. 4.4 Environmental Surfaces for Sheffield at 250 × 250 m cell resolution: (**a**) extent of green space (m^2); (**b**) vegetation cover (Normalized Difference Vegtation Index: NDVI); (**c**) tree-cover (m^2); (**d**) elevation (m); (**e**) degree angle of slope; (**f**) buildings area (m^2); (**g**) road length (m); (**h**) road nodes (junctions); (**i**) density of households in blocks of flats; (**j**) terraced housing density; (**k**) semi-detached housing density; (**l**) detached housing density; and (**m**) total housing density. All housing densities were measured as households ha^{-1}

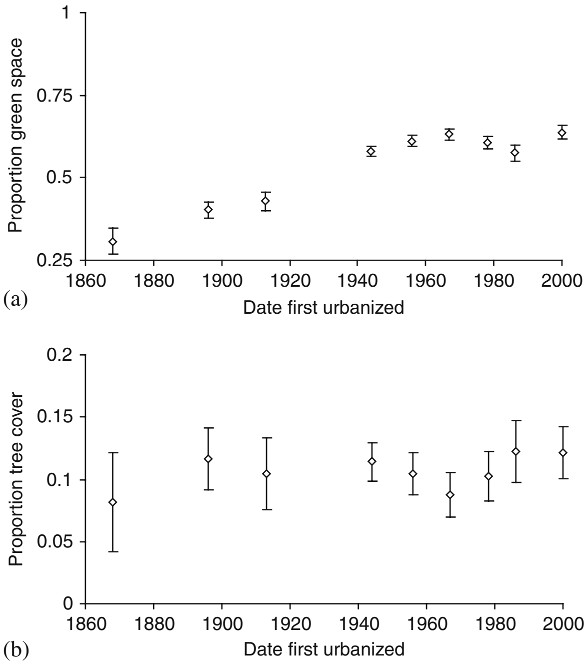

Fig. 4.5 The Relationship between Date of first Urbanization and the Proportion of each 250 × 250 m cell in Sheffield that currently comprises (**a**) Green Space and (**b**) Tree Cover. Date first urbanized is the date of the first Ordnance Survey map series for which each grid cell became dominated (>50% coverage) by urban built form, and as such represents the latest date at which urbanization was known to have occurred. Grid cells not yet urbanized are excluded from the plot. Green space is vegetated surface including domestic gardens. Tree cover is derived from digitising tree cover from aerial photographs taken in 1998

1960s could indicate that recently developed areas have suffered a disproportionate loss of green space. An alternative explanation for this pattern is that urbanization of an area results initially in the loss of a certain proportion of green space, which is then gradually further eroded over time. Tree cover shows a much less pronounced, and more variable relationship with date urbanized (Fig. 4.5b). This suggests that, while more recently developed areas have similar levels of tree cover, a greater proportion of it is over impervious surface. In Sheffield, a tendency for larger trees in the western part of the city partly results from their being planted in the nineteenth century during planting initiatives associated with creation of parks and avenues. Tree cover as seen in aerial imagery is therefore probably associated with age of urbanisation, since a mature species will have a large crown area.

Ecosystem Services and Urban Form

Recent emphasis on assessing the value of the environment in terms of the benefits that ecosystems provide to humans (ecosystem services), has resulted in increasing interest in evaluating the role of urban areas in providing ecosystem services (e.g. Bolund and Hunhammar, 1999; Pataki et al., 2006; Tratalos et al., 2007a). This is partly because local provision of some of these services is valuable to human communities in those areas, for example services such as temperature and water regulation, pest control, pollination, and recreation, all have implications for urban economies and human well-being. It is also partly because although urban systems have traditionally been accorded rather low value where environmental metrics focus on naturalness and lack of human influence, this does not necessarily mean their contribution to other types of ecosystem service such as carbon sequestration, is also low.

In order to examine the relationship between ecosystem service provision and urban form within and between cities we largely take an approach based on simple general models of the relationships between variables on the ground that can be measured across entire cities, and specific services. This allows patterns to be explored, but may not pick up all the local, and city-specific, detail that direct measurement of the services themselves would allow. However the data demands of the latter at the scales of comparison we are interested in here make the general approach the only one practical at the present time for most services.

Temperature Regulation

Urban areas experience heat island effects, in which temperatures are elevated compared with surrounding landscapes, particularly at night and in cold weather (Pickett et al., 2001; Baker et al., 2002). Although they are a function of several factors, across urban areas both air and land surface temperatures tend to increase with proportional coverage by impervious surfaces and to decrease as proportional coverage of green surfaces increases (Chen and Wong 2006; Jenerette et al., 2007). Levels of tree cover in particular can have a marked influence on temperatures, in major part by generating energy loss, and therefore cooling, through water loss to the atmosphere (Stone and Rodgers, 2001).

As well as wholesale changes in temperature regimes wrought by urbanization, variation in urban form within a built up area can have significant thermal impacts. Data from an array of temperature loggers placed across urban Sheffield revealed that elevated temperatures in both summer and winter were associated largely with the city centre, declining toward the less built up suburbs (Fig. 4.6a, b). This effect was still apparent at a local scale in the environs around each temperature logger; there was a positive relationship between temperature and impervious surface coverage within 100 m of a location, in both summer and winter (Fig. 4.7a, b).

Diurnal temperature range also varied markedly, with areas near the city centre showing a smaller difference between minimum and maximum daily temperature (Fig. 4.6c, d), although local coverage by impervious surface was not related to daily temperature range (Fig. 4.7c, d). These general patterns demonstrate marked buffering of temperatures in heavily developed areas, and show that the effect persists throughout the year. It is crucial to note, however, that while the amount of heat energy emitted per unit area might be higher in places dominated by impervious surfaces, the per household contribution to these emissions depends

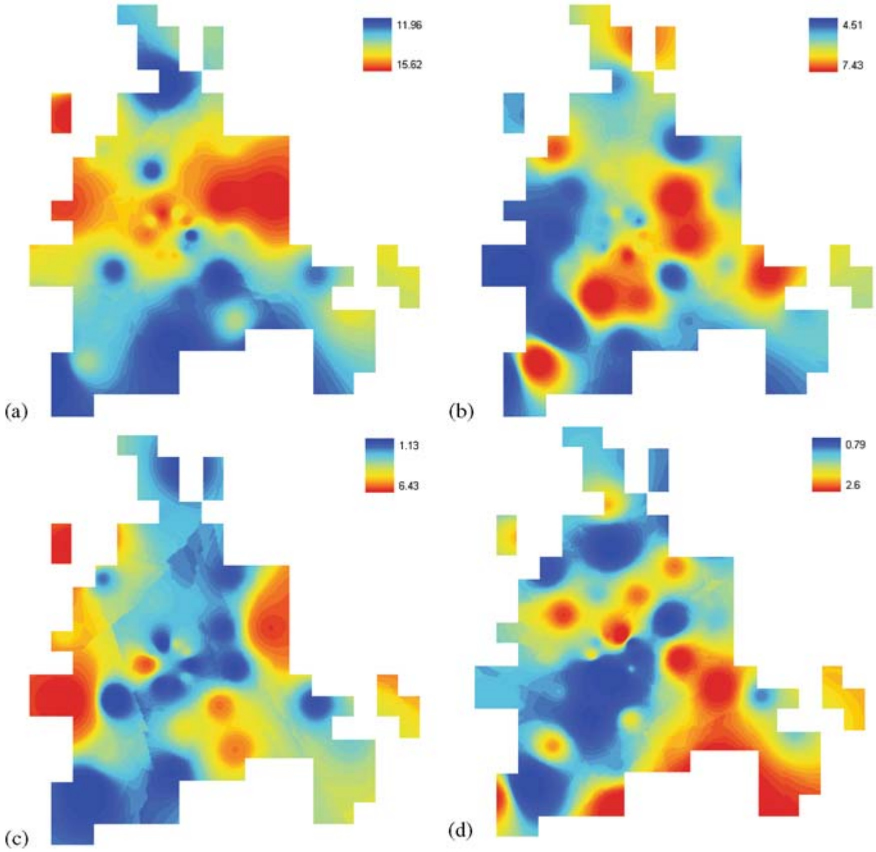

Fig. 4.6 Temperature surfaces across Sheffield (**a**) Mean summer temperature, (**b**) mean winter temperature, and mean diurnal temperature range in (**c**) summer and (**d**) winter. °C interpolated from hourly data collected by an array of 50 temperature loggers arranged in five concentric rings of 10 loggers each centred on the city centre. Loggers were buried in soil at a depth of 20 mm, and data were downloaded every three months

on the absolute coverage by impervious surface within the housing parcel (Stone and Rodgers, 2001). Although smaller housing parcels tend to have a higher proportional coverage by impervious surface (Smith et al., 2005), this is unlikely to cancel out the reduction in absolute coverage by impervious surface as housing parcel size declines. Multi-dwelling buildings will further reduce the per household contribution to urban heating. Consequently, although higher density residential urban forms might generate higher levels of heating per unit area, the total amount of heat energy released from such developments is likely to be less than that produced by a low density neighbourhood comprising the same number of households.

Temperature changes through urbanization can have a variety of ecological consequences, some of which extend beyond the urban area itself, including changes

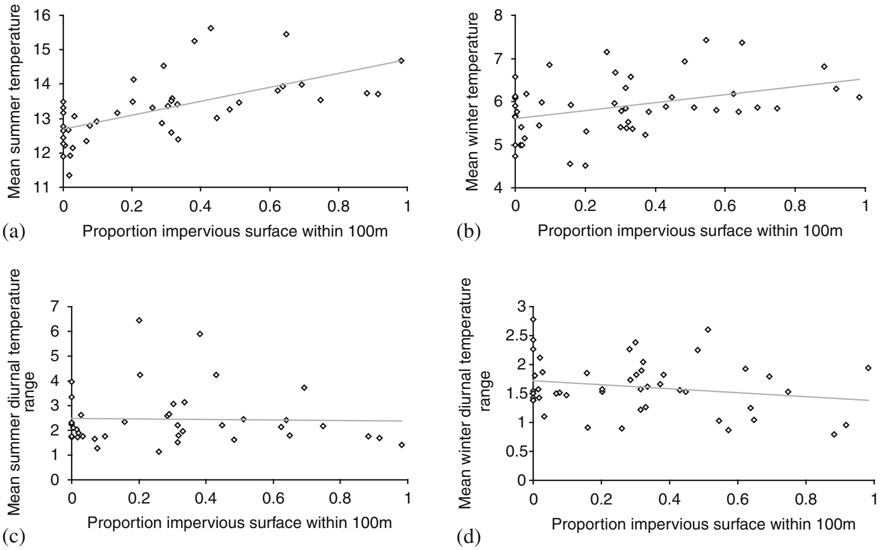

Fig. 4.7 Relationships between Cover by Impervious Surface within a 100 m radius of each Temperature Logger and (**a**) Mean Summer Temperature (**b**) Mean Winter Temperature, and Mean Diurnal Temperature Range in (**c**) Summer (**d**) Winter. Based on linear regressions

relative to rural areas in the timing of germination, leaf flush, leaf drop, and flowering of plants, and in the breeding and survival of animals (Zhang et al., 2004a, 2004b; Partecke et al., 2005; Neil and Wu, 2006). It seems likely that similar changes may also occur within the boundaries of urban areas, and be particularly influenced by variation in coverage by green space, although disentangling the effects of green space per se and its influences on temperature may not be straightforward.

Water Regulation

Cities in the UK almost invariably draw the bulk of their water supplies from outside the urban area, and have rather low coverage by standing water. However, urban areas have to deal with water influx, either directly on the area, or in rivers and streams that pass through it. Flood control and reduction of storm-water runoff are therefore key components in the ecosystem service of water regulation. Water runs directly over impervious surfaces, increasing the frequency and severity of urban flooding. In recognition of this, much research has focussed on the relationship between impervious surface coverage and water regulation (Arnold and Gibbons, 1996). However, the converse of this is that increasing the extent of green spaces enhances water regulation, providing that soil surfaces within those green spaces are not heavily compacted. Green spaces also increase water loss from the ground through evapotranspiration (the transfer by soil and plants of water to the atmosphere as water vapour), with additional beneficial effects on climatic conditions in urban areas.

The distribution of green space within cities therefore becomes crucial for explaining variation in water regulation across the urban landscape. Although urbanization dramatically reduces green space coverage, significant levels (60–70%) remain in many typical urban areas (Table 4.1). It has been estimated that 59% of the surface of urban Manchester is evapotranspiring (Gill et al., 2007). For the case study neighbourhoods across the five cities these reveal non-linear relationships with the extent of green space: runoff increases as greenspace declines, but at low levels of greenspace changes in the remaining greenspace have little effect (Tratalos et al., 2007a). This is a consequence of the relatively low infiltration rates of even many of the non-sealed surfaces when building densities become high.

As well as problems associated with the quantity of run-off generated in urban environments, transport of pollutants can occur as storm water washes over impervious surfaces such that suspended particulate matter within the run-off might include anthropogenically derived materials. Such contaminants can represent a significant non-point source of pollution in urban areas (Characklis and Wiesner 1997; Bibby and Webster-Brown, 2005).

Carbon Sequestration

It is becomingly increasingly apparent that, at least in some regions, carbon sequestration in urban areas may not be as trivial a consideration as some have suggested (Jo and McPherson 1995, Golubiewski 2006; Pataki et al., 2006). Indeed, whilst obviously small compared with carbon emissions the per unit area and the gross sizes of urban carbon pools (reservoirs of stored carbon) can nonetheless be substantial (Nowak and Crane 2002; Kaye et al., 2005; Lorenz et al., 2006). There are two major natural carbon pools in urban green spaces, comprising respectively vegetation and soils.

The levels of carbon sequestration by trees in urban areas, resulting from the fixation of carbon during photosynthesis and its storage as biomass, tend to be estimated using simple functions of tree cover (e.g. Rowntree and Nowak, 1991; Whitford et al., 2001; Tratalos et al., 2007a). Detailed mapping in Sheffield has shown that the surface of the city is about 15% tree-covered (see also Fig. 4.4c). This is notably lower than in some other cities in the northern hemisphere (e.g. Nowak and Crane, 2002). An analysis of carbon sequestration across the five case study cities indicated that more densely urbanized areas are associated with a lower predicted rate of carbon sequestration (Tratalos et al., 2007a). Because calculations for carbon sequestration were based on a linear relationship with tree cover (see Rowntree and Nowak, 1991), results for carbon sequestration can typically be interpreted as matching those for tree cover. However, while carbon sequestration will generally increase with tree cover, in practice the relationship will depend, among other things, on the demographic structure and species composition of the urban forest. This problem is compounded by the fact that tree cover will itself vary with the age of the properties which make up the urban form, and tree growth rates will vary according to soil compaction, pollution, impervious surface area under tree crown and water potential (Quigley, 2004).

A sample of 2170 trees from Sheffield indicates clear systematic patterns in tree species richness and size (Fig. 4.8). Broadly speaking, tree richness increased with distance from the city centre, along with an associated increase in tree size. The sample comprised 96 tree species, although the ten most abundant species accounted for 64% of all individuals recorded. Trees nearer the city centre tended to be taller relative to their girth than those on the margins of the city, although there was substantial variation in this (Fig. 4.8d). While some very mature trees were present in the sample, with girths of 3–4 m, the size distribution of the trees was strongly right-skewed (Fig. 4.9), with 50% of individuals having a girth <0.5 m. Continual

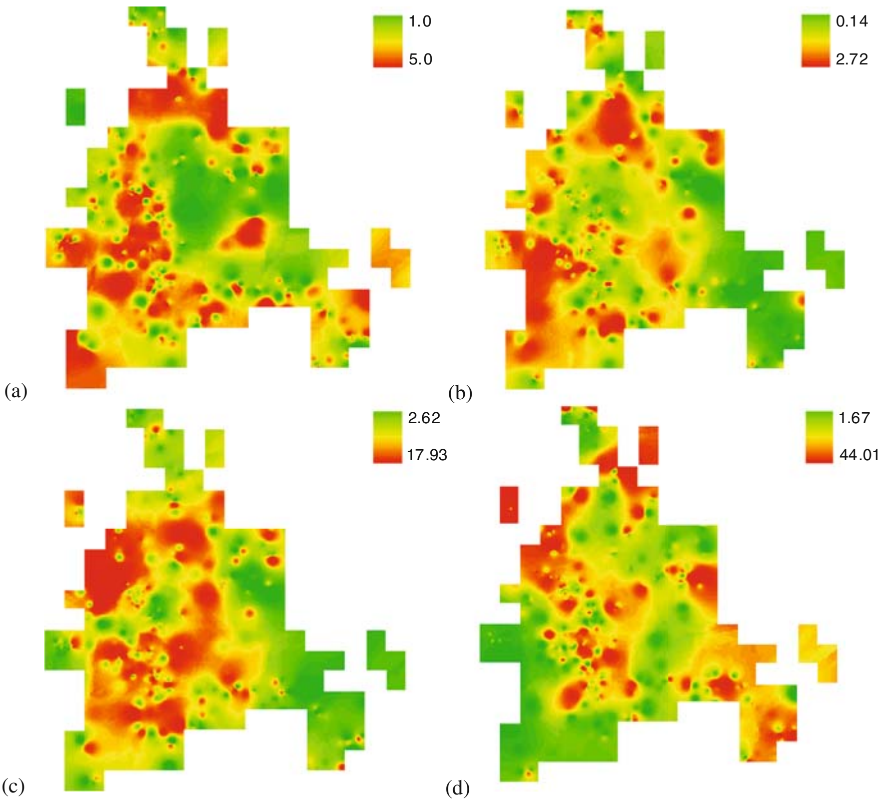

Fig. 4.8 Surfaces for Sheffield of (**a**) Tree Species Richness, (**b**) Average Tree Circumference (m), (**c**) Average Tree Height (m) and (**d**) Height/Circumference. Data are derived from field measurements of 2170 trees (the five trees nearest to 434 randomly-chosen locations across the city)

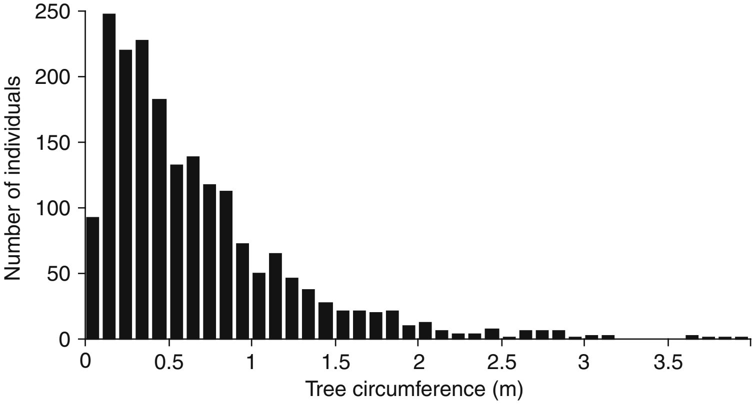

Fig. 4.9 Distribution of Circumferences of Trees across Urban Sheffield. Data are derived from field measurements of 1924 trees selected as the five trees nearest to 434 randomly-chosen locations across the city (circumference could not be measured for 246 individuals because of access difficulties)

replacement of mature urban trees with smaller species that are more manageable, and less prone to cause damage through deadfall, windthrow and root intrusion has recently been documented in London (London Assembly Environment Committee, 2007).

Management of the urban forest is further complicated by the influence of land ownership. Recent data from Sheffield indicate that, within a 13 km^2 study area, approximately 69% of tree cover occurred on privately owned land (Dennis, unpublished data). About 73% of the land was privately owned, indicating that proportional levels of tree cover on private and public lands were broadly similar. These data highlight the very limited extent to which adequate management of the urban forest can emerge simply from policies focusing on land under direct public control. There is a need to recognise that much urban land is under dispersed ownership, with small private parcels representing domestic gardens being managed in markedly different ways (Gaston et al., 2005). Furthermore, smaller private gardens are less likely to contain trees, and there are concerns that continuing densification of urban areas through infilling development might lead indirectly to further reductions in tree cover through this route (Smith et al., 2005). In public lands, street trees may be removed for public safety reasons, or as a result of subsidence claims by insurance companies. Despite no change in overall tree numbers in a five year study period, data from London indicate a rapid turnover of street trees for these reasons, and an ongoing disproportionate loss of mature native trees (London Assembly Environment Committee, 2007).

The other significant carbon pool in urban areas is that contained within soils. The sizes of such carbon pools have been surprisingly little explored, in large part because urban soils (i) are typically extremely heterogeneous both spatially and temporally, comprising a mix of islands of apparently natural soils within a matrix of highly human-altered soils; (ii) have almost invariably been poorly mapped; and

(iii) often have altered processes of decomposition and nutrient cycling, for a range of reasons including the urban heat island effect (Effland and Pouyat, 1997; Pouyat et al., 1997; Carreiro et al., 1999; Pickett et al., 2001). Where soil carbon pools have been estimated in urban areas, this has typically involved extrapolation from data collated from just a handful of cores and tiny quantities of soil (e.g. Pouyat et al., 2006). Nonetheless, such work suggests that these pools may be substantial. Legal protection of the ecological functions of urban soils in Germany attests to this importance, despite the rather rudimentary current understanding of the properties of urban soil (Lorenz et al., 2006).

The significance of carbon sequestration in urban areas depends fundamentally on how vegetation and soils are managed. Carbon emissions associated with management (e.g. from chain saws, chippers, lawn mowers and transport of cut vegetation) could, for example, negate any positive sequestration effects, although the extent to which this is a problem can be influenced by the choice of management approaches and the fate of vegetation that is removed (e.g. landfill, bio-fuels). However, even where this is the case, urban trees in particular may typically bring a number of other advantages (e.g. control of storm water, reducing energy use in buildings and human health benefits), and a decided net benefit (Akbari, 2002; McPherson et al., 2005).

Pollination

Many plant species are pollinated by insects, which transfer pollen from one plant to another. Some plant species cannot produce fertile seeds without pollination by insects, and the yield of most plants is improved where insect pollination occurs. Concern has been expressed about regional and local reductions in the numbers of pollinators in a variety of areas of the world (Biesmeijer et al., 2006; Klein et al., 2007). As well as impacting on agricultural crop production (Allen-Wardell et al., 1998), declines in pollinators adversely affect the functioning of natural and anthropogenically-perturbed ecosystems (Kearns et al., 1998; Cheptou and Avendaño, 2006; but see Ghazoul, 2005). Additionally, some people with private domestic gardens rely on, and derive economic benefit from, pollination of garden plants (Nabhan and Buchmann, 1997). Although several studies have documented declines in insect pollinators in response to urbanization, others have found elevated bee species richness in urban conditions, attributed to increased temperatures, reduced exposure to agricultural chemicals, and a wider variety of microhabitats being present in urban landscapes (Eremeeva and Sushchev, 2005 and references therein).

Pollinator faunas can also change systematically within urban areas. Across private gardens in Sheffield, the number of species of an important group of pollinators, bumblebees, is influenced both by immediate local and larger scale factors, increasing with the habitat diversity within the gardens and with the area of green space in the environs of the gardens (Smith et al., 2006a). However, no such relationships were apparent for the abundance of this group (Smith et al., 2006b).

As well as changes to pollinator faunas, impacts of urbanization on the distribution and population dynamics of plant species can affect plant-pollinator relationships. Fragmentation of the natural environment through urbanization frequently leads to small, isolated populations of plants, and diminished population densities, which can result in few pollinators finding a particular patch of plants. Cheptou and Avendaño (2006) studied an urban plant (*Crepis sancta*: Asteraceae), showing that the number of pollinating insects visiting a patch of plants increased as the number of plants in the patch increased. This suggests that where urbanization leads to a plant becoming rarer, visits by pollinators might also decline, potentially compounding the effect of urbanization. This will be particularly important for those plant species that are wholly dependent on insects for pollination, and cannot reproduce unless they are visited by pollinators. *Crepis sancta* is able to self-fertilize, but it was not able to increase its levels of selfing in response to a low number of visits by pollinators. More research is needed on the adaptations of plants to urbanization.

Provision of Pest Control

Effective functioning of ecosystems depends on the maintenance of interactions between species, including competition, predation, parasitism and mutualism. By differentially altering the abundance of particular species as areas are progressively developed, urbanization often results in new combinations of species that have not previously interacted. There is little information on how species interact in such new combinations, and how these interactions vary across urban landscapes. In one well studied example, urbanization of Phoenix, Arizona, led to a dramatic increase in available water, a limiting resource in the surrounding desert landscape. This has resulted in a shift in species interactions, including a greater top-down influence of predators on the system (Faeth et al., 2005). Urbanization can also lead to asymmetric changes in the abundances of particular species, such as rapid increases in species that might be regarded as “pests” (Alberti et al., 2003).

To assess the potential for such changes in response to increases in urban density, recent work in Sheffield examined rates of mortiality in a widespread herbivorous insect, the holly leaf-miner *Phytomyza ilicis* Curtis (Diptera, Agromyzidae). The holly leaf-miner is the most common insect herbivore of European holly *Ilex aquifolium*, feeding inside the leaves with the large blotch mines visible on the upper surface of occupied leaves. A pest population of holly leaf-miners was successfully controlled by introducing a parasitic wasp in Canada (Clausen, 1978), highlighting the potential economic importance of understanding such species interactions. While in the leaf, the larva is subject to a number of potential mortalities, including miscellaneous death during the larval or pupal stages, e.g. starvation caused by low plant quality, parasitism (always fatal) by various species of wasp, and bird predation (Cameron, 1939).

Sampling across Sheffield indicated only rather weak effects of impervious surface cover, housing and tree cover on the abundance and mortality of the holly

Table 4.2 Holly Leaf-Miner Demographics in relation to Urban Form in Sheffield

Urban form variable	Prop. mined leaves	Misc. larval death	Larval parasitism	Bird predation	Pupal parasitism	Misc. pupal death	Successful emergence
Impervious surface cover	–0.1	0.04	0.20**	–0.12	–0.06	–0.19*	–0.12
Housing density	0.14*	–0.11	0.01	–0.19**	0.14*	–0.04	0.09
Tree cover	–0.15*	0.21**	–0.002	0.23***	–0.20**	–0.10	–0.22**

Of 460 sampling locations across the city, holly plants were found within the survey area (approx 1 ha) at 276. The proportion of mined leaves on each plant was estimated by haphazardly sampling The table reports Spearman rank correlation coefficients of the relationships of these demographic outcomes with three urban form variables, measured within a 100 m radius from the holly plant location.

* indicates statistically significant at the 5% level ** statistically significant at the 1% level
*** statistically significant at 0.01% level

leaf-miner (Table 4.2). The strongest relationships ($r_s > 0.2$) were those with tree cover. Both miscellaneous larval death and bird predation increased with tree cover, while pupal parasitism declined. This translated into an overall decline in successful emergence with increasing urban tree cover. The other measures of urban form (impervious surface cover and housing density) were only weakly related to rates of mortality and parasitism, and were not associated with any overall change in successful emergence. These results show that at least some complex interactions among species can remain apparently largely intact even within highly developed sites.

Recreation

For many people, green spaces in urban areas provide their primary contact with biodiversity and the "natural" environment (Jorgensen et al., 2002), may influence their physical and mental well-being (Ulrich et al., 1991; Jackson, 2003), and, in the case of public green space, can offer broader social benefits as meeting places that give a shared focus to diverse communities and neighbourhoods (Germann-Chiari and Seeland, 2004; Martin et al., 2004). In consequence, regulatory and advisory agencies have made various recommendations for the minimum provision of urban green space, usually expressed as the walking distance or time to access the resource (e.g. Stanners and Bourdeau, 1995).

Across Sheffield, there is enormous variation in the distances through the road network that separate households from their nearest accessible public green space (Barbosa et al., 2007). Many households do not enjoy the levels of access recommended by governmental agencies, with the distribution of distances being strongly right-skewed such that for some households these distances are particularly large. The mean level of access varies significantly across different sectors of society. As these sectors tend to occupy areas characterised by different urban form, levels of access are also likely to vary systematically with urban form, although this has not explicitly been tested. These distance-based measures of access could usefully be refined to include travel constraints, such as physical and psychological barriers to pedestrian movement (Handy, 1996).

Even if green space is locally accessible, its quality is extremely variable. Work in Sheffield has demonstrated that benefits to psychological well-being of visitors to urban parks are positively correlated with the species richness of those spaces, suggesting that the biological complexity of urban green space is important in enhancing human well-being, as well as for the conservation of biodiversity itself (Fuller et al., 2007a; see Chapter 10).

The private domestic garden has long been considered an important part of human health and well-being (see e.g. Gerlach-Spriggs et al., 1998). Access to a garden reduced self-reported sensitivity to stress (Stigsdotter and Grahn, 2004), while lack of access has been associated with increased self-reported levels of depression and anxiety (Macintyre et al., 2003). When asked to identify the contribution of spending time in the garden to overall well-being, 57% of householders in Perth, Australia indicated it was very important or the most important factor (ARCWIS, 2002). Interactions between people and nature frequently happen in private gardens, with wildlife-friendly gardening practices now receiving greater attention, and a large proportion of the population specifically providing food and shelter for birds (Lepczyk et al., 2004; Fuller et al., in press). Because of the diverse array of benefits to human well-being of gardens on the one hand, and public green spaces on the other, it is unclear to what extent they are substitutable in urban planning (Barbosa et al., 2007). This is especially important given that increasing housing density reduces non-garden green space and expands overall coverage by gardens, although individual gardens become smaller.

Biodiversity and Urban Form

Biodiversity can be thought of as the variety of life, at all levels of organisation from genetic through species diversity to ecolosystem diversity. Biodiversity has variously been considered to be a contributor to some ecosystem services, to be an ecosystem service itself, and to be a product of some ecosystem services (Gaston and Spicer, 2004; Millennium Ecosystem Assessment, 2000). Doubtless, in some senses it is all three. However, in the context of urban systems, biodiversity has typically been considered in its own right, and largely with respect to how it relates to the physical level of urbanization, with little consideration of its relevance to ecosystem services or how it is influenced by variation in human activity across the urban landscape.

A large number of studies has now been conducted examining the relationships between the species richness of selected taxonomic groups (species richness is a key measure of biodiversity) and levels of urban development, usually along a rural-urban gradient. Generally, studies have shown declines in overall species richness at very high levels of urbanization, but a mixed response at low and intermediate levels of urban development, where the observed pattern depends strongly on taxonomic group (Marzluff, 2001; Chace and Walsh, 2006; McKinney, 2008). Some studies have shown no simple pattern with increased urban development (e.g. Roy et al., 1999; Niemelä et al., 2002; Mason, 2006). A decline in richness as urbanization intensifies is usually attributed to the loss of suitable habitat and resources. A peak in richness at intermediate levels is often associated with a greater number of land use types in areas of intermediate levels of development, intermediate levels of disturbance, and the multiple private ownership of land that leads to variation in management styles. Increases in richness with urban development seem usually, at least in part, to occur because of the relatively high numbers of alien/introduced species in more heavily developed areas (e.g. Kowarik, 1990; Roy et al., 1999; Marzluff, 2001; Wittig, 2004).

Across Sheffield, both plant and bird diversity shows strong heterogeneity (Fig. 4.10). Species richness of breeding birds is concentrated around the edges of the city, with generally low values in the centre (Fig. 4.10a). Breeding bird density shows a superficially similar pattern (Fig. 4.10b), although values appear to peak inside the margin of the city, an effect particularly evident along the south-eastern and northern fringes of the city. This pattern suggests that breeding bird densities peak some distance inside the edge of the city. Patterns of plant species richness are less clear. There are high values of native plant richness near the edge of city, particularly in the south and east (Fig. 4.10c), although there is substantial heterogeneity in the distribution. Alien plants show very low species richness around the edge of the city, peaking at intermediate levels of urban development, and declining again toward the city centre (Fig. 4.10d).

Despite the large number of studies documenting the responses of biodiversity to urbanization, understanding of the relationship between biodiversity and urban form per se remains poor. The different components of the rural-urban gradient are often not well differentiated in analyses, and comparison tends to be focussed on the difference between rural and urban areas rather than between urban areas of differing structure. This is particularly significant at the present time, when on the one hand urban areas in the UK are becoming havens for some species that have undergone marked declines in the wider countryside (e.g. blackbird *Turdus merula*, song thrush *T. philomelos*; Gregory and Baillie, 1998; Mason, 2000), largely as a consequence of intensive agriculture, and on the other hand some previously common and widespread species are undergoing marked declines in urban areas (e.g. starling *Sturnus vulgaris*, house sparrow *Passer domesticus*; Cannon et al., 2005). There are strong suggestions that both of these trends are more apparent in some urban forms than in others, but empirical evidence remains scant.

In Sheffield, housing density was strongly negatively associated with breeding bird richness (Fig. 4.11a), while the relationship with breeding bird abundance appeared hump-shaped, with bird abundance peaking at intermediate levels of housing density (Fig. 4.11b). This is presumably related to the overall loss of green space with increasing urban development, as well as a reduction in the range

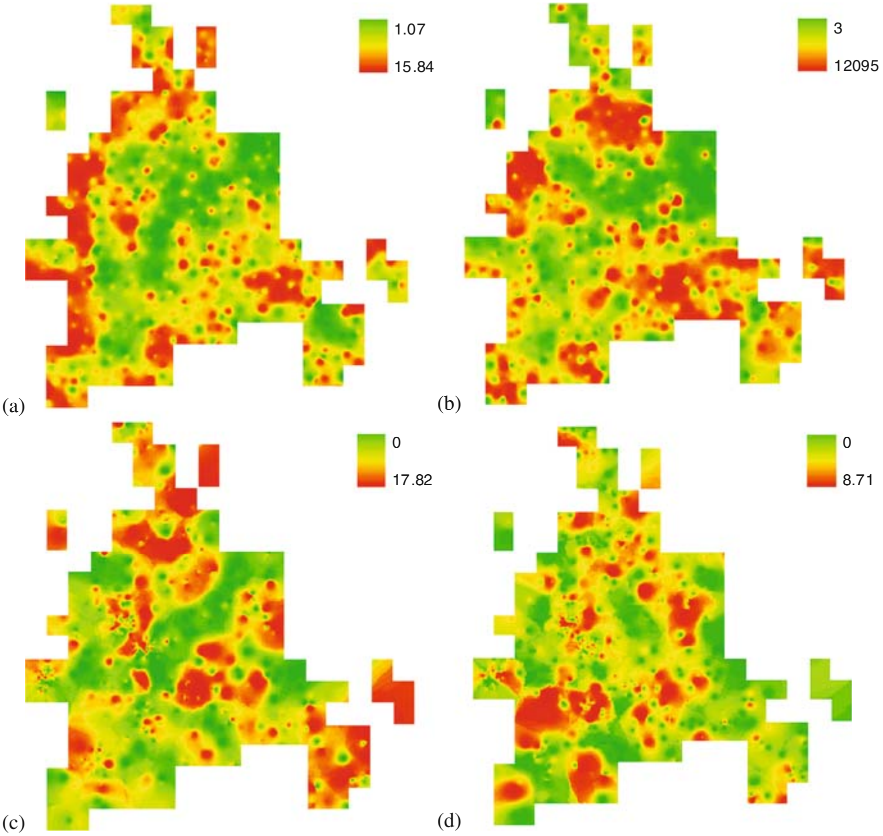

Fig. 4.10 Surfaces for Sheffield of (**a**) Breeding Bird Species Richness, (**b**) Breeding Bird Density (individuals km^{-2}), (**c**) Native Plant Species Richness and (**d**) Non-native Plant Species richness. Bird data are derived from 5-minute point transects carried out at 640 locations across Sheffield (a point randomly located within each 500×500 m grid cell across the city). Plant data are derived from 1000 quadrats (1 m^2) placed across the city

of available habitat types. A range of processes may contribute to such changes in abundance, including natural food availability, the availability of artificially-provided supplementary food, nest site availability and quality, predation pressure and interspecific competition (Clergeau et al., 1998; Thorington and Bowman, 2003; Shochat, 2004; Faeth et al., 2005). The ratios of different types of habitat available are likely to change systematically with increasing urban development. For example, as its overall coverage declines, green space changes markedly in composition, with a greater proportion being made up of gardens rather than other forms of vegetated surface.

The diversity of plants was more weakly related to housing density (as measured by the number of addresses per unit area). Raw plots show a negative relationship between housing density and native plant species richness (Fig. 4.11c), and a

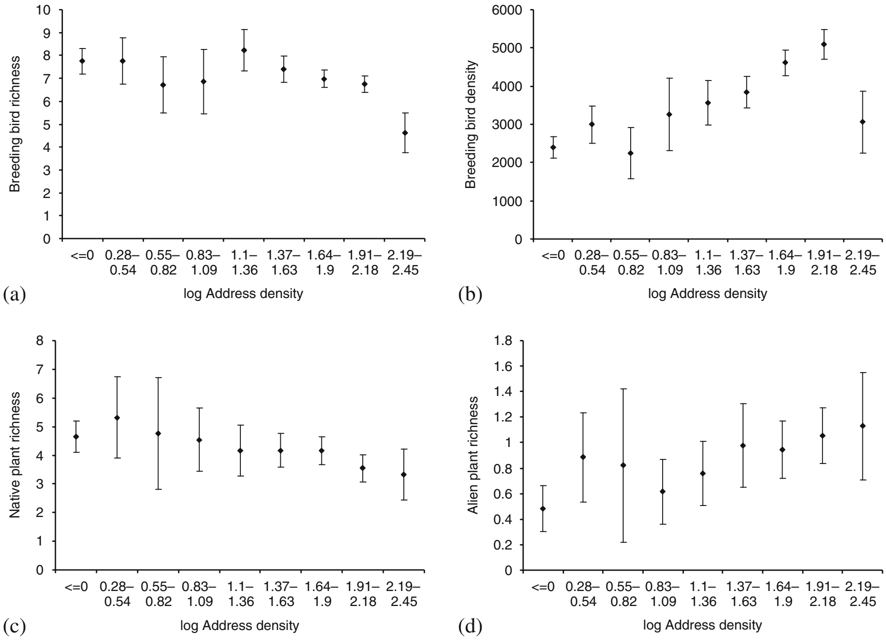

Fig. 4.11 Relationships between Housing Density and (**a**) Breeding Bird Species Richness, (**b**) Breeding Bird Density, (**c**) Native Plant Species Richness and (**d**) Non-Native Plant Species Richness. Housing density is log address density within a 100 m buffer around each sampling location. Bird density is individuals km$^{-2.}$ Error bars are 95% confidence intervals

positive relationship between housing density and alien plant species richness (Fig. 4.11d). Many urban alien plants in northern Europe have natural ranges in regions with Mediterranean climates and dry soils, rather akin to those found within highly urbanized environments (Sukopp and Wurzel, 2002). Moreover, propagule pressure resulting from introductions and escapes of alien plants from gardens and amenity plantings is likely to be much higher in towns and cities than in rural areas, and disturbed urban habitats may promote the establishment of non-native weedy species (Smith et al., 2006c; Dehnen-Schmutz et al., 2007).

Work in Sheffield has also revealed an intriguing behavioural response to urban noise (arguably either a measure, or a close correlate, of urban form). Sites where European robins *Erithacus rubecula* sang nocturnally tended also to be those places with high noise levels during the day, suggesting that the birds were singing at night to avoid acoustic competition with daytime urban noise (Fuller et al., 2007b). As noise levels are closely related to certain components of urban form, such as where transport networks are located, the times at which birds choose to sing may in turn be affected by urban design. (Warren et al., 2006). Daytime noise at a particular urban location is strongly positively correlated with the proportion of impervious surface in the surrounding area (Fig. 4.12). Integrative studies that can disentangle these multiple ecological and behavioural effects at a city-wide scale are needed.

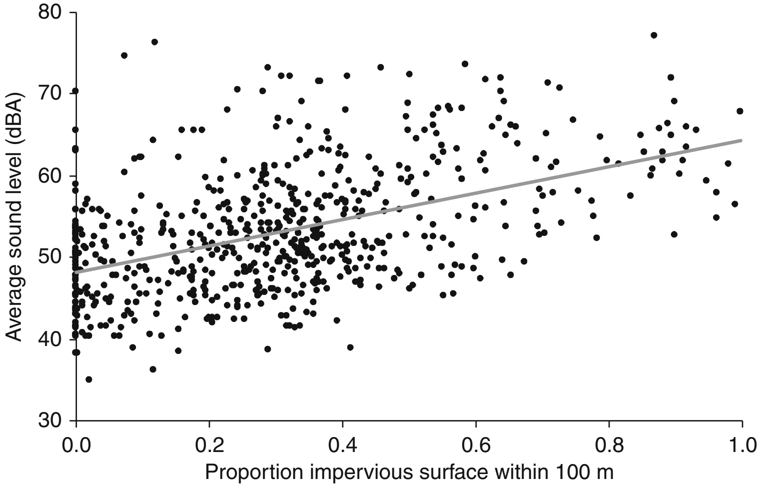

Fig. 4.12 Relationship between Noise Levels and Impervious Surfaces. Noise levels are the mean of 10 measurements taken with a handheld digital sound meter at 30 s intervals at 628 locations across Sheffield and the proportion of impervious surface within a 100 m radius around these points ($r = 0.48$, $n = 628$, $p < 0.001$)

Looking more widely across Britain as a whole, the species richness and abundance of breeding birds responds systematically to variation in housing density (Tratalos et al., 2007b). At a resolution of 1×1 km squares, avian species richness at first increases strongly with housing density, but then declines rapidly at higher housing densities. A similar pattern is seen in the richness of 27 urban specialist species used as urban health indicators by the UK government (DEFRA, 2002, 2003), suggesting that even those species best able to exploit urban environments are impacted at high urban densities. Standardised abundances of all species, including the urban indicator species, are positively associated with housing density, but decline at very high urban densities (Tratalos et al., 2007b).

Conclusions

The analysis has shown that the density of urban development, a key measure of urban form, is strongly associated with a reduction in total green space coverage, and changes to the connectivity of vegetated patches within the urban landscape. This has ramifications for the ecosystem services that are mediated by green space, including the regulation of water and temperature regimes, carbon sequestration and the provision of pest control and pollinators across the urban landscape. Moreover, changes to the amount and quality of green space will have significant consequences for recreation within urban areas, access to an experience of nature, and for human quality of life more generally. Levels of biodiversity generally increased initially with housing density, but then declined sharply at highly developed sites.

An understanding of the distribution of ecosystem services and the associated pattern of biodiversity across the urban landscape is crucial for predicting the consequences of the increases in urban density required by current UK legislation. Although many of these responses point to a decline in ecosystem function and biodiversity potential with increasing urban density, there is substantial scatter around many of these relationships, suggesting scope for maximizing the environmental and ecological performance of urban areas for any given level of urban density. Perhaps rather more troubling are the observed declines in abundance at high urban densities even of those species most able to exploit urban environments. This suggests a difficult trade-off between on the one hand, minimizing the conversion of land for new development, and on the other maintaining meaningful levels of biodiversity and ecosystem function around the places where most of us live. There is a need for longitudinal studies documenting past changes in the spatial configuration of urban landscapes in response to urbanization, and using that information to predict the future consequences of alternative modes of development and regeneration at regional and even national scales. Spatially explicit area selection exercises, of the kind that have been used extensively in the conservation planning literature (e.g. Pressey et al., 1997; Cabeza and Moilanen, 2001) will help identify areas that are crucial to maintaining effective ecosystem function, and those that might efficiently be used for high density residential developments.

With more than half the world's population now living in urban areas, changes in how we plan, manage and develop such areas has potentially profound impacts. A better understanding of the best strategies for managing the trade-offs among environmental functions and urban form is urgently required if we are to ensure that increasing urban density and concomitant declines in green space and biodiversity are not to lead to impaired ecosystem function, reduced provision of ecosystem services and the degradation of human experiences of nature.

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Chapter 5
Social Acceptability

Glen Bramley, Caroline Brown, Nicola Dempsey, Sinead Power and David Watkins

Introduction

Urban forms cannot be considered ‘sustainable’ in the full sense if they are not acceptable to people as places to live, work and interact. This chapter focuses on the relationship between urban form and *social sustainability*, and has four main aims. First, drawing upon a wide-ranging literature we advance and clarify an understanding of social sustainability that allows us to explore possible links between social sustainability and urban form. There has hitherto been a lack of clear and agreed definitions for this concept and we hope our approach contributes to a better shared understanding. The second aim is to address ways of measuring social sustainability and testing/quantifying some of the hypothesized relationships between selected dimensions of social sustainability and urban form. The measures used draw primarily on the household survey of case study neighbourhoods, linked to urban form measures as described in Chapter 2. The third aim of the chapter is to examine the empirical relationships between aspects of social sustainability and different aspects of urban form, particularly density, housing type and location. This analysis highlights the importance of controlling for exogenous and intervening variables, such as housing tenure and the social composition of neighbourhoods, in testing and calibrating these relationships. The final aim is to offer some more insights into *how and why* some urban forms may provide more beneficial social outcomes for different groups of people, based on qualitative focus group evidence.

Defining Social Sustainability

Debates within the wider sustainable development literature have long moved beyond considering sustainability solely as an environmental concern, to

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include economic and social dimensions. A significant proportion of sustainable development rhetoric now stresses the importance of social equity (Burton, 2000a cites: CEC, 1990; Sherlock, 1990; Yiftachel and Hedgcock, 1993; Elkin et al., 1991; Selman 1996). The importance of a social dimension of sustainability has also been underlined at policy level. DETR (1997) stressed the need to empower all sections of the community to participate in decision making and to consider the social and community impacts of decisions, while DETR (2001) sought to give social progress the same emphasis as economic and environmental objectives. UK policy parallels international sustainability development agreements, with poverty eradication seen as an essential requirement (UN, 2002).

Whilst the sustainable development agenda emphasizes the importance of 'social' aspects of sustainability there has been little agreement as to what this constitutes. Polese and Stren (2000: 15–16) have put forward the following definition of social sustainability:

> Development (and/or growth) that is compatible with harmonious evolution of civil society, fostering an environment conducive to the compatible cohabitation of culturally and socially diverse groups while at the same time encouraging social integration, with improvements in the quality of life for all segments of the population.

The above definition discusses social sustainability in terms of the collective functioning of society as well as in terms of individual quality of life issues. Yiftachel and Hedgcock (1993:140) have further defined *urban* social sustainability as:

> the continuing ability of a city to function as a long-term, viable setting for human interaction, communication and cultural development.

Arguing that the sustainability debate has largely ignored social aspects, they propose an analytical framework that delineates between three key dimensions of 'urban' social sustainability: equity; (sense of) community; and urbanity. Again, within this definition we see the emphasis on the need for a city to function as an interactive unit as well as on equity issues. However, the concept of 'urbanity' is not clearly defined.

The UK Government has made efforts to link sustainability to quality of life, particularly through the indicators known as 'Quality of Life Counts' (DETR, 1999b, 2001). While it is not self-evident that sustainability and quality of life are synonymous, nevertheless, quality of life may provide the bridge between the 'urbanity' mentioned above and the 'liveability' agenda which has emerged in UK urban policy (ODPM 2003; DCLG 2006). In practice, the DETR (2001) document seeks to reconcile these obvious tensions by adopting an extended economic concept of 'capital'. This identifies three broad classes of 'capital' – economic, social and environmental – and defines sustainable development as a process of growth/development in which total capital (the combination of these three kinds) is 'non-decreasing' – i.e. we are not squandering the proverbial family silver. The notion of husbanding different kinds of 'capital' is one way of expressing the Brundtland (WCED, 1987) philosophy of inter-generational equity.

That sustainability, including its social dimension, is central to current planning and urban policies in the UK is evidenced by the title of the overarching policy document known as the *Sustainable Communities Plan* (ODPM, 2003). The most recent policy statement by HM Government (2005, Annex A), subsequently adopted by the EU as ‘The Bristol Accord’, set out its policy definition of ‘What is a Sustainable Community’ in terms of eight headings including: 1. active, inclusive and safe; 2. well served; 3. well designed and built; 4. well run; 5. environmentally sensitive; 6. well connected; 7. thriving; and 8. fair for everyone. We would regard this all-embracing definition as encompassing all three main ‘legs’ of the broader sustainability concept, including the environmental dimension (in 5.), the economic dimension (in 7.), transport (in 6.), and matters of governance (in 4.) and planning/design (in 3.) that go beyond the usual outcome focus into means rather than ends. The aspects of social sustainability with which we are concerned are located particularly within headings 1, 2, 3 and 8. The first heading includes ‘identity and belonging’, ‘tolerance of difference’, ‘friendly and cooperative communities’, leisure and cultural opportunities, crime/anti-social behaviour, and ‘a good quality of life’. The second heading identifies a range of accessible services including health, education and social care. The third reiterates issues around sense of place, friendliness, healthiness and safety of spaces, as well as accessibility by non-motorised transport and the issue of affordable housing. Although this appears as something of a long shopping list of desirables without a transparent logical coherence, if nothing else this document serves to underline the apparent policy priority given to the issues addressed in this chapter.

Social Capital, Social Cohesion and Social Inclusion

Whilst there is a relatively limited literature that focuses specifically on social sustainability, there is a much broader literature on the overlapping concepts of social capital, social cohesion and social exclusion. It is beyond the scope of this chapter to provide an adequate review of these concepts as they are discussed in this literature. We recognize that they are not very tightly or consistently defined and also that they are, in important respects, contested concepts. Table 5.1 simply identifies some of the key elements of each concept as exemplified in representative examples of recent literature reviewing them.

It may be argued that the underlying premise to all of these concepts is that individuals within society need to work together and interact in order for societies to be socially ‘sustained’. *Social networks* clearly provide a common thread between the three concepts as set out here. These concepts recognize the importance of people being involved and having a vested interest in society, as well as individuals having equal access to societal benefits. However, beyond this it may be observed that the third concept (social exclusion) is more distinct, focusing more on access to economic opportunities and services, whilst the first and second concepts have more areas of overlap. In addition to social networks and association, one can also

Table 5.1 Comparing Concepts of Social Capital, Social Cohesion and Social Exclusion

Social capital

'Social capital refers to features of social organisation such as networks, norms and trust that facilitate co-ordination, and co-operation for mutual benefit.' (Putnam, 1993: 35)

Suggested elements	
Empowerment	Participation
Associational activity	Common purpose
Supporting networks	Reciprocity
Collective norms and values	Trust
Safety	Belonging (Forrest and Kearns, 2001)

Social cohesion

'Social cohesion can emphasis the need for a shared sense of morality and common purpose; aspects of social control and social order; the threat to social solidarity of income and wealth inequalities between people, groups and places; the level of social interaction within communities or families; and a sense of belonging to place' (Forrest and Kearns, 2001: 2128).

Suggested elements
Common values and civic culture
Social order and social control
Social solidarity and reductions in wealth disparities
Social networks and social capital
Territorial belonging (Kearns and Forrest, 2000)

Social exclusion

'Social exclusion is a process that deprives individuals and families, groups and neighbours of the resources required for participation in the social, economic and political activity of society as a whole. This process is primarily a consequence of poverty and low income, but other factors such as discrimination, low educational attainment and depleted living environments also underpin it. Through this process people are cut off for a significant period in their lives from institutions and services, social networks and development opportunities that the great majority of a society enjoys' (Pierson, 2002: 7).

Suggested elements
Poverty and low income
Lack of access to jobs
Lack of social support and networks
Effect of the local area
Exclusion from services (Pierson, 2002)

discern common clusterings of concern with *norms, values and culture*, with *sense of belonging* (to place), and with *safety and trust* which may be seen as the positive side of social control and order.

A Working Definition of Social Sustainability

From the above review of the literature there are two recognisable, overarching concepts at the core of the notion of social sustainability within an area context. These are *social equity issues* (access to services, facilities and opportunities) and issues to do with the *sustainability of community itself*. Whilst social equity issues are powerful political and policy concerns, and centre upon a distributive notion of social justice – that is 'fairness in the apportionment of resources in society' (Burton, 2000a: 1970) – the more collective 'sustainability of community' dimension may be seen as more nebulous. However, we would argue that this clearly maps onto the concerns of both government and academic writers, particularly those addressing issues of social capital and cohesion. In exploring social sustainability at the neighbourhood level both of these dimensions need to be covered.

With regard to the first dimension, we are particularly interested in access to local services, while recognising that a fuller account of the equity dimension would also encompass access to jobs and affordable housing. In practice, we focus in this chapter on a limited representative selection of services (e.g. convenience shopping, primary healthcare) although in our wider study we will examine a broader range (see for example Fisher and Bramley (2006) analysis of poverty and local services).

Turning to the second dimension, and drawing on the above review of social sustainability and related concepts in both academic and policy literature, we argue that the following aspects are likely to be significant in helping to sustain communities at neighbourhood level:

- Interaction with other residents/social networks.
- Participation in collective community activities.
- Pride/sense of place
- Residential stability (versus turnover).
- Security (lack of crime and disorder)

Individually these dimensions tap into a number of interesting debates within urban policy. The variable 'interaction in the community' may be related to the social mix agenda. This emphasises that it is not just achieving a mix of characteristics of population within an area that matters, but whether people *actually* personally interact with their neighbours (Atkinson and Kintrea, 2001). Work in this area distinguishes 'strong' and 'weak' social ties, but suggests that both forms are of positive value. Informal social ties may be distinguished from active participation in formal community activities/organisations, frequently used as an indicator of local social capital; we would argue that both are potentially significant.

We are also interested in whether people use facilities within their neighbourhood, and their attitudes towards these facilities. The social premise is that if people participate in activities within their local community then they will have stronger ties to the community (this is distinct from the environmental benefit of reduced travel). A similar argument applies to the inclusion of the concept of pride/sense of place, the idea being that, if people feel attached to the neighbourhood, they will want to stay living in the area and contribute to its continued development (Woolever, 1992). The fourth aspect of sustainability of community is residential stability; within some of the literature, areas of high turnover are perceived to be unsettled and undesirable areas, although this is not always be the case (Bramley et al., 2000; Bramley and Morgan, 2003, Bailey and Livingstone, forthcoming). High outflows of residents combined with low or no inflows can mean that an urban community will be literally unsustainable over time (Power and Mumford, 1999; Bramley et al., 2000). Community stability is often associated with higher levels of social cohesion and associated benefits such as lower crime (Hirschfield and Bowers, 1997).

With regard to the final dimension UK government policy is increasingly stressing the need and ability of communities to combat crime for themselves (ODPM, 2004; Atkinson and Flint, 2003). This issue has long been connected to urban form (through the 'design and crime' literature). Shaftoe (2000: 230) argues that,

> community safety is an essential prerequisite for a stable and sustainable neighbourhood' with crime and fear of victimization being 'two of the top deleterious ingredients of urban living.

The Relationship Between Social Sustainability and Urban Form

Jenks et al. (1996, p.11) described the relationship between urban form and sustainability as *one of the most hotly debated issues on the international environmental agenda*. There has been a move away from focusing solely on environmental dimensions of sustainability to consider other dimensions including 'urban sustainability' and 'social sustainability' (CEC, 1990; Knight, 1996; Darlow, 1996; HM Government, 2005). What emerges from this review of the literature is that there are competing claims regarding the extent to which urban form influences social sustainability; claims and debates that have, to date, rarely been supported by empirical evidence (Jenks et al., 1996). Of the elements of urban form which might be considered, density is the one that has received the most attention in the literature with regard to its social impact. Much of this focus has been upon the policy question of whether we should contain the spatial extent of urban development by developing at higher densities or whether we should allow the spatial extension of urban areas and build at lower densities – the 'compact city' versus 'sprawl' debate (Breheny 1992a, 1992b; Ewing, 1997; DETR, 1999a; Barton 2000) and in the related 'new urbanism' literature (CNU, 2004; Katz, 1994; Calthorpe, 1993).

The density of urban development has the potential to impact upon all of the dimensions of social sustainability. For example, higher densities may make access to services and facilities both easier and more economically viable (Bunker, 1985; Collie, 1990; Haughton and Hunter, 1994; Burton, 2000b). Williams (2000) found that access may vary for different services. ODPM (2003) argues that particular densities are needed to support basic amenities in the neighbourhood and to minimize the use of resources such as land. Burton (2000a; 2000b) has produced (arguably) the most comprehensive work exploring the impact of urban form on social equity. Burton (2000b) found that nearly all of the 14 social equity effects that she identified are related in some way to urban compactness; job accessibility and wealth being the exceptions. For medium-sized English cities she found that higher urban densities may be positive for some aspects of social equity and negative for others. We revisit some of these equity-related issues of service access in the empirical work below.

Higher densities may also mean that people are more likely to meet each other on the street than in lower density areas (Talen, 1999; Duany and Plater-Zyberk, 2001). In contrast lower densities reduce the potential for spontaneous interaction and leads to an orientation towards car travel (TCRP, 1998). Glynn (1981) and Nasar and Julian (1995) both found ‘sense of community’ to be higher in neighbourhoods that facilitated face-to-face interaction. There are, however, alternative arguments that in higher density societies, people may withdraw from social contact. Wirth (1938) argued that high density living, along with the anonymity of city life, leads to an increase in stress and the severing of traditional ties that result in a decline in community or social ties. Bridge (2002:4) refers to Simmel’s (1995) discussion of the ‘psychic over-stimulation’ of the city’. In this way higher densities may lead to weaker social ties. There is an argument that, whilst very low densities may undermine social ties, at some point further up the scale higher densities may start to have the same effect (Freeman, 2001). We return later to this hint of non-linear relationships. It is argued that in a compact city, that is a city with high-density and mixed uses, communities are likely to be more mixed, and that as such there is likely to be a lower level of social segregation. Suburban sprawl in particular has come to be associated with high levels of segregation and inner city decay (CEC, 1990; Burton, 2000a; Bramley and Morgan, 2003). However, it is not axiomatic that social mix correlates with density or use mix in this way; in our empirical work below we distinguish these factors.

The density of development may also affect the appearance and aesthetics of places, and hence people’s sense of attachment to and pride in place. The TCRP (1998) review found that there is little evidence within the literature to suggest that Americans find sprawl less attractive than more compact forms of development, although they do cite work by Nelessen (1994), Shore (1995) and Diamond and Noonan (1996) which argues that lower density development is less aesthetically pleasing. There is also an argument that low density developments can be more attractive (Audirac and Zifou, 1989). Gordon and Richardson (1997) argue that given the choice people prefer low-density suburban living to high-density urban living. They note that many consumer preference surveys have shown a strong preference for suburban living (findings which are echoed, in some senses, in our own empirical findings reported below).

We can see from this brief review of the literature that the discussions on the relationship between density and social sustainability are quite complex, with at times contradictory hypotheses or findings. There are reasons to expect access to services to be better in denser urban forms, while quality of neighbourhood environment, community and social interaction may be less good in denser areas. The latter relationship is less clear-cut a priori from the literature, and could well vary contingent upon the social/demographic groups considered and interactions between urban form and social composition factors, including those associated with housing tenure. Further, there is a dearth of analysis at a small scale local level.

Measuring Social Sustainability

Our empirical investigation of social sustainability is mainly focused on the fifteen case study neighbourhoods described in Chapter 2, areas chosen to reflect a diversity of typical British urban forms with varying ages, types and tenures of housing and socio-demographic profiles. In our view the principal source of evidence on the social acceptability of different urban forms should be people themselves, particularly those living in the areas in question, and so the primary data source is the household survey in these neighbourhoods. The household survey responses are re-weighted to reflect the underlying demographic profile of the population of each neighbourhood based on the Census, so countering possible differences in response rates between demographic groups.

In general we do not rely on a single question within the survey to provide evidence on a given aspect of social sustainability, but rather draw on responses to a cluster of questions. In grouping responses together for the main composite social outcome measures reported below, both their logical/linguistic interpretation ('face validity') are considered but also the patterns of correlations between the responses across our sample.

The survey generates eight composite measures capturing the different aspects of social sustainability as defined above:

– Pride and attachment
– Interaction
– Safety
– Environment
– Satisfaction with home
– Stability vs mobility
– Participation in collective/group activity
– Use neighbourhood facilities/services

Although the emphasis in this listing appears to be primarily on the 'sustainability of community' aspect, the last heading clearly relates to equity of access and can be subdivided into types of service/facility, for example everyday utility services vs. cultural and recreational services. It can also be argued that satisfaction with home and quality of local environment are aspects of equity.

With our focus here on the big picture we concentrate on summary composite measures based on answers to multiple questions. These outcome measures have been expressed in an index form which is subject to commonsense interpretation. Taking the example of 'social interaction', this is based on responses to 13 questions, such as whether they have friends in neighbourhood, see them frequently, know neighbours by name, look out for each other, chat, borrow things, etc. For each question, negative responses reduce the score from a neutral value, while positive responses increase it (with neutral responses being possible in all cases). If someone gave all neutral responses across the 13 questions the score is 100 on the interaction index; all positive responses scores 200; if all responses were negative then the score is zero. The resulting index scores are numbers in the range 0–200, but are typically around or just above 100, for individuals. These are effectively continuous variables and we can therefore compare mean values and variations between and within groups, areas or area-types.

To establish relationships between these outcomes and urban form, we rely on linking the location of sample households (addresses) to information about those locations, particularly information about the small areas within which people reside. It should be noted at this point that the emphasis here is on urban form of the *residential neighbourhood* rather than, for example, the form of the place where people work, shop or carry out their recreation. We have a choice about the spatial *level* at which urban form characteristics might be attributed to individuals. For the analyses reported in this chapter we rely mainly on linkage at the level of the 'sub-area' (see Chapter 2).

Census and other neighbourhood data (including use of OS Mastermap) are apportioned to these spatial units. These data encompass a wide range of socio-demographic characteristics, physical urban form (density, dwelling type, storey height), proportions/ratios of land area attributable to different elements (e.g. residential buildings, gardens, greenspace, roads), other urban form and quality measures derived from the site survey, along with simple measures of access distance to city centres and more sophisticated network connectivity measures based on MCA. Other socio-economic data attached includes components from the Indices of Multiple Deprivation (IMD) and house prices.

In parallel with analyzing our own purpose-designed survey, we carried out analysis of certain large scale government surveys, which ask a more limited range of relevant questions, again linking sample locations to urban form and socio-demographic data for small neighbourhoods. This helps to benchmark our more selective case study results and check that these are not unrepresentative. We make brief reference below to results from this exercise based on the Survey of English Housing (see also Bramley and Power, 2005).

A key issue in interpreting evidence on the association between social outcomes and urban form is that of untangling 'real' and potentially 'causal' associations from what may be apparent, fortuitous or ambiguous relationships, given the complexities of urban life and the different kinds of relationships which may be at work. Simply showing that, in a two way table or correlation, there is an apparent (negative) relationship between, say, density and neighbourhood satisfaction/attachment, does not establish that there really is such a relationship, let alone that it is causal. It is essential to take account of ('control for') the influence of other relevant variables, i.e. other physical, social, economic or demographic factors which we have reason to believe may also influence neighbourhood satisfaction. For example, older people may tend to answer satisfaction surveys in more positive ways than younger people, and at the same time older people may be more likely to live in low density suburbs. To take another example, neighbourhoods with concentrations of poor people tend to exhibit a greater incidence of certain social problems which affect neighbourhood satisfaction; such neighbourhoods are also often higher density areas.

So although we do report simple descriptive tables showing patterns between different forms, we rely more in our main analysis and conclusions on statistical modeling. Multiple regression analysis provides a convenient and flexible tool for establishing the direction and strength of relationships while simultaneously taking account of the relationships with other variables.

Quantitative Relationships

Descriptive Patterns

Table 5.2 shows the simple pattern of scores on our eight composite outcome measures by broad location and density categories. For six of our eight outcomes there is a clear pattern of higher scores in outer areas and lower scores in inner areas. The exceptions are ‘safety’ where the between areas actually scored highest, and ‘use of neighbourhood services/facilities’ where inner areas scored highest.

The lower part of the table shows the pattern of scores by broad bands of gross residential density. For four of the outcome measures there is a clear pattern, whereby the highest score is for the lowest density band and the lowest score for the highest density band. This applies to pride/attachment, interaction, safety and home satisfaction. For environmental quality the highest score is for the second density band, and the same pattern applies to participation in groups. For the stability/mobility criterion, both the lower density bands have a similar higher score, while it is the medium-higher density band (40–70) which shows the lowest score. Not unexpectedly, use of neighbourhood services shows a different pattern with density, although this is not a simple reversal of the pattern shown for pride/attachment and the other social/community indicators. In fact the highest score is in the medium-higher density band, with lower scores in both the highest and the medium-low density.

Clearly, we could add further tables of this kind, looking at different aspects of urban form, for example house type, and subdividing our sample according to different demographic groups. However, this would take up a lot of space, and is in any case a less effective way of looking at the issue of different urban form effects and demographic effects than considering the results of multiple regression modeling.

Regression Modelling Results

As explained earlier, the key value of using statistical techniques such as multiple regression analysis is that they can identify relationships of outcomes with urban form factors, while taking account of other socio-demographic factors which also influence the measured outcomes and which may confound the apparent urban form effects. An additional advantage of the modelling is that it can also highlight the differential effect of different urban form features. Ordinary least squares regression is considered suitable for these data because the dependent variables (composite outcome scores) are continuous variables with approximately normal distributions.

The regression models typically ‘explain’ around 25% of the variance in individual scores, with a higher figure for ‘stability/mobility’ (36%) but a particularly low figure for participation in groups (8%). Relatively low proportions of variance explained are typical of models fitted to individual data such as these,

Table 5.2 Social Sustainability Outcome by Location and Density

Sub-area type location	Pride & attachment	Interaction	Safety	Environment	Satisfaction home	Stable/mobile	Participation groups	Use NH services
Inner	92.5	97.3	123.4	100.4	117.3	109.7	94.2	108.5
Middle	115.7	122.5	133.0	120.2	130.9	127.6	101.5	103.0
Outer	118.4	129.1	126.9	129.8	139.7	147.1	104.6	88.0
Total	108.5	115.9	127.6	116.4	129.0	127.7	100.0	100.0
Density								
<20 DPH	116.3	118.4	134.4	120.6	139.0	132.4	105.4	102.4
20–40 DPH	112.7	116.4	131.4	121.1	131.3	132.1	106.0	98.2
40–70 DPH	109.0	117.3	127.2	113.9	125.7	121.0	97.5	105.7
>70 DPH	97.3	111.7	119.1	111.2	123.6	128.1	92.5	92.7
Total	108.5	115.9	127.6	116.4	129.0	127.7	100.0	99.9

because there is a large element of unmeasured and random individual variation in preferences, behaviour and circumstances. Nevertheless, given the large samples the models capture general relationships reasonably well.

Table 5.3 shows the detailed pattern of impact of urban form and related variables on our eight outcomes. Individual socio-demographic control variables included in the models (typically between 12 and 20 such variables per model) are omitted from this table. These factors, including for example age, gender, ethnicity, household type, income and tenure, are expected to influence behaviour, experience and preferences, and we do not want these to confuse or confound the effects of urban form. The effects are shown by the regression coefficients, which show the impact of one unit increase in that particular variable on the outcome in question. Since our outcomes are all indexes centred on 100, most of these coefficients can be readily interpreted. For example, the first figure in the second column suggests that residents of terraced houses would have a 3.4 point higher interaction score, other things being equal. Figures shown in bold are coefficients which are statistically significant at the 10% level (ie they are 90% or more likely to be different from zero in the direction shown). Non-bold figures are coefficients which fall short of that level but where there are some signs, from a range of tests, of a relationship.

Urban form variables in the top half of the table are attributes of individual households/houses and generally take the dummy form (1 = yes, 0 = no). Variables below the line are attributes of our 97 sub-areas and are generally continuous measures, either percentages, logs of distances or density ratios.

We now comment briefly on some of the findings which this table reveals, starting with house types. Bungalows are good for home satisfaction but bad for use of local services. Detached houses are similarly good for home satisfaction but possibly less good for safety. Terraced homes appear better for interaction but less good for home satisfaction and environmental quality. Flats are associated with less stability/more mobility, unsurprisingly; slightly more surprising is the finding that people living above the fifth floor are more attached to their neighbourhood and feel safer.

'IMD Geog Access' basically measures more rural and isolated locations (within an essentially urban sample), and this is associated with more attachment and environmental quality but less use of local services. Living further from a major city centre is associated with lower scores on attachment, interaction, environment and service use. Net dwelling density has generally negative relationships with social outcomes and this is significant in four cases: attachment, safety, stability and local services (the last is slightly surprising, but perhaps suggests that location is more important for services than net density). The squared term in the model for stability indicates a non-linear relationship. The proportion of dwellings over 4 storeys is positively associated with interaction and participation, but negatively with environmental quality.

Having an individual private garden or yard is quite strongly positive across most outcomes including pride, interaction, environment and home satisfaction. This is somewhat reinforced by the positive effect of gardens as a percentage of land area on safety and of average garden size on pride and home satisfaction. At the same time other forms of greenspace are also positive for pride, interaction and participation.

Table 5.3 Individual impacts of Urban form variables on social sustainability outcomes

Regression Coeffic's (signif 10% level)	Pride and attachment	Interaction	Safety (crime)	Environ quality	Home satisfaction	Stability	Group participation	Local services
Individual Level								
Bungalow					**6.12**			**–7.28**
Detached house			**–5.27**	–3.80	**7.06**	–4.39		
Terrace	2.03	**3.41**		**–4.67**	**–6.46**			–3.23
Flat						**–7.50**		
floor5	**10.77**		**8.27**				–18.08	6.25
Garden	**4.28**	2.27		**3.02**	**5.91**			
no garden/yard/terrace	**–8.85**	**–14.11**	2.32	**–5.05**	**–9.84**	–3.71	**–12.36**	–2.94
above ground floor		**–3.53**			2.09		**–7.23**	–2.28
Sub-area level								
IMD geog access -	**4.16**			**7.14**			–1.86	**–3.17**
Log dist major centre	**–5.27**	**–3.35**		**–6.66**				**–6.63**
Gross dwelling density				–0.03				
Net dwelling density	**–0.04**	–0.01	**–0.04**		–0.01	**–0.05**	–0.02	**–0.03**
Net density squared						**0.02**		
Dwellings detached %	0.05		**0.20**					
Dwellings Terrace %	–0.05	**0.13**	**–0.13**		**–0.08**			**–0.14**
Over 4 storeys %	0.03	**0.08**		**–0.13**			**0.15**	–0.09
Gardens % area			**0.24**				0.38	**–0.77**
Average Garden size	**389.88**				**307.32**			
Greenspace %		**0.12**	0.10		0.05		**0.44**	**–0.50**
Greenspace absence	**0.55**							
Garden + Green %				0.05				
Non-Residential Mix	–0.05		**–0.20**	**–0.29**		–0.12	**0.80**	–0.14
Minutes to bus stop-								**–3.03**
Frequency of buses								**–4.39**

Mixed uses appear to be positive for group participation but negative for safety and environment, without being significant for use of local services. Being further from the nearest bus stop reduces the use of local services, but so also does having more frequent buses (perhaps enabling more use of central city facilities).

Most of these individual effects make sense in terms of our prior expectations and reading of the previous literature. This gives further confidence that these models are capturing the main urban form effects, which may have a degree of complexity about them.

Summarizing the Urban form Relationships

The models as just described underline that a number of aspects of urban form vary between neighbourhoods and appear to have differing effects on different outcomes. Can we try to summarize these effects across the broad spectrum, from ‘compact central city’ to more ‘dispersed suburban’ areas, without doing injustice to that complexity? We believe we can do this, by generating a composite function, for each sample household, which measures all of the urban form related effects as revealed by the coefficients in Table 5.3. We then take density (net residential) as a convenient summary scale measure, and chart the relationship between each composite function and density. We also show for comparison the raw scores. Four of the eight outcome indicators are selected to illustrate the varying patterns found.

Figure 5.1 looks at raw scores and ‘urban form effects’ for neighbourhood pride and attachment, which is it should be noted is the best overall summary measure among the eight outcome indicators. The raw scores fall unsteadily, from about 150 to under 100, as densities rise to 150 dwellings per hectare (DPH), after which they fluctuate somewhat. The urban form effect falls from about 140 to a plateau of around 112 at 100 DPH, with a slight further fall to about 107 at 200 DPH. In other words, the modelled urban form effect is less strong than the apparent effect from the raw scores, but is clearly still present.

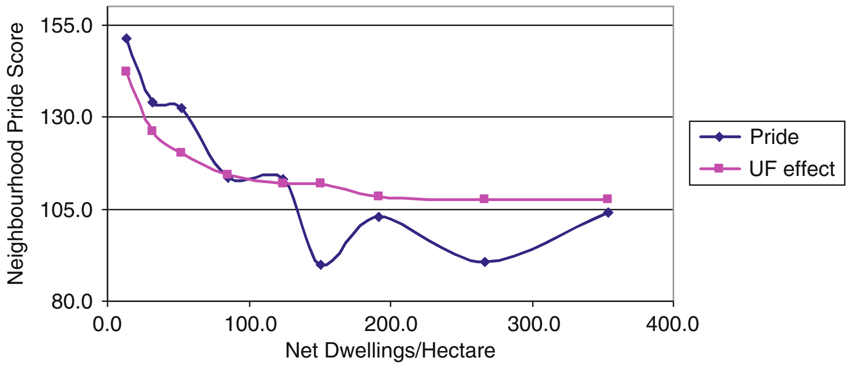

Fig. 5.1 Neighbourhood pride and attachment by net density – overall and Urban form effects

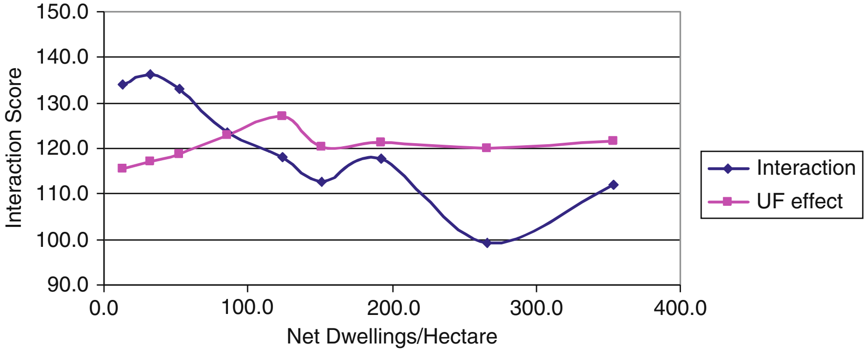

Fig. 5.2 Neighbourhood interaction by net density – overall and Urban form effects

Figure 5.2 looks at the neighbourhood interaction outcome score in the same way. This produces perhaps the most interesting finding of this investigation. Although the raw interaction scores fall as densities rise, over most of the range, the modelled urban form effect rises with increasing density (compactness) up to the level of around 120 DPH (net). This reflects the effect of variables such as terraced housing and storey height as reported above. It also makes sense intuitively and in terms of hypotheses derived from the literature. In sparser suburbs people are less likely to bump into each other, partly because they are more likely to get around by car. In terraced housing or lower flatted areas people are more likely to meet coming and going. In very high density, this is less likely to be the case, or the way in which people meet is less likely to encourage people to get to know each other.

Figure 5.3 looks at home satisfaction. This shows a stronger negative effect of increasing density, up to about 150 DPH. While the urban form effect is slightly less strong than the raw score pattern, it is still quite a strong relationship

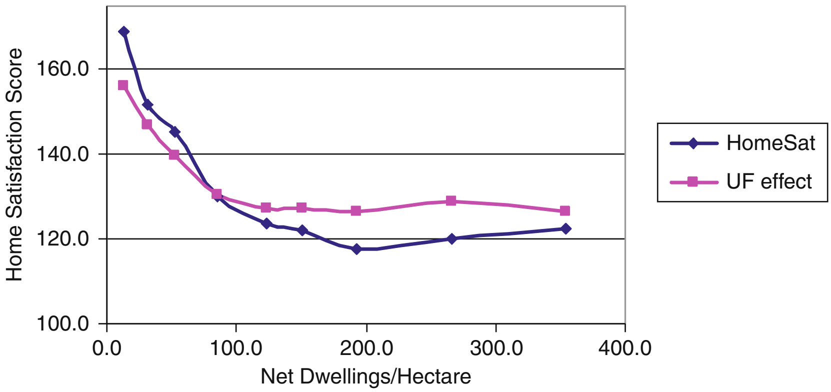

Fig. 5.3 Satisfaction with home by net density – overall and Urban form effects

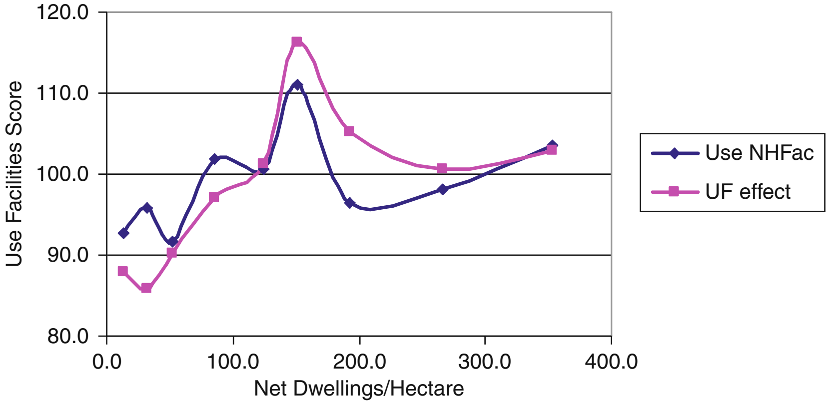

Fig. 5.4 Use of neighbourhood facilities by net density – overall and Urban form effects

Finally, in Fig. 5.4 we look at use of local services. Here both the raw scores, and more particularly the urban form effect, show the opposite pattern, as expected, of rising with density, at least up to the level of 150 DPH.

Other Area Effects

In understanding the difference between what we have termed urban form effects and the overall differences in social outcomes between different types of area, it is worth focusing briefly on some of the other factors which vary between neighbourhoods and which could affect these outcomes. It is convenient to illustrate this point by drawing on an analysis, similar to that just described, undertaken using a national survey dataset, the Survey of English Housing (SEH), linked to neighbourhood characteristics in a similar way. This also serves to illustrate the point that patterns found in our five case study cities are representative of wider national patterns. A more detailed treatment of this analysis may be found in Bramley and Power (2005).

Figure 5.5 reports raw scores for 'dissatisfaction with neighbourhood', essentially the inverse of our 'pride/attachment' factor, and decomposes variations into the parts which can be attributed (on the basis of a regression model) to demography, social factors, urban form and access (the latter treated separately here, rather than being combined as in Figs. 5.1, 5.2, 5.3, and 5.4). As with our survey results, area dissatisfaction increases with density up to the level of about 80 DPH (gross). What Fig. 5.5 shows is that all of the components contribute to the adverse satisfaction scores at higher densities. Even demography is not neutral, and the access-dissatisfaction component is slightly worse at higher density. The urban form effect (shown in red) is adverse up to 80 DPH, but the slope of this effect is much less than that of the raw score. The really striking finding

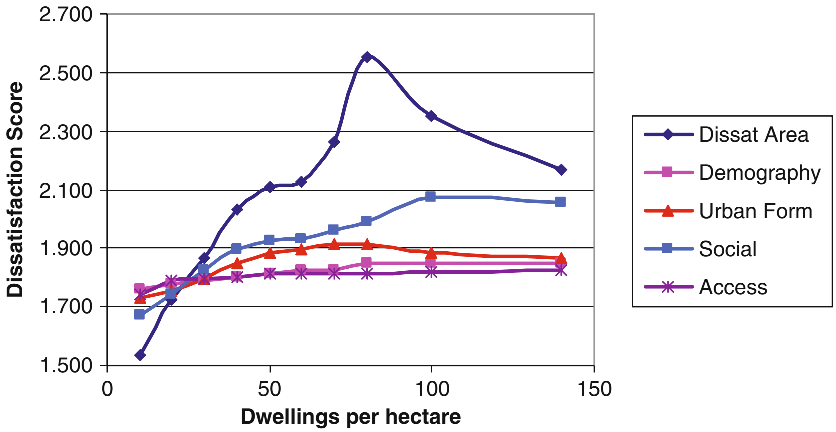

Fig. 5.5 Components of area dissatisfaction by density

is that, across England as a whole, the most important contributor to the higher dissatisfaction of higher density areas is the social component. This comprises IMD neighbourhood poverty and related indicators. The national analysis based on SEH. generally indicates that poverty is more important, for dissatisfaction and common neighbourhood problems, than is urban form per se.

This leads us on to a broader conclusion, which is that 'who lives where' may be as or more important than the physical form of the neighbourhood. Furthermore, this pattern of dissatisfaction may be related to choice, which in turn relates to poverty. Poorer households have less choice in the housing market, often reliant on social rented housing which has been traditionally rationed and allocated administratively.

Qualitative Findings: Use of Focus Groups

To complement the data collected in the household questionnaire survey, focus groups were held with residents in nine of the fifteen case study neighbourhoods. Their purpose was to gather in-depth qualitative data about the links between urban form and particular dimensions of social sustainability. The aim was to build up a clearer picture of how people use their local environment and to get a sense of what the local environment means to them. In doing so, it was hoped that the focus groups would help to explain some of the findings of the questionnaire survey. For example, what is it about a particular street or local environment which makes people feel unsafe? Why is it that particular people use services and facilities in a neighbourhood more than others? Why is it that people feel a stronger sense of pride in their local area than others? In addition, the focus groups were also a way of exploring those dimensions of social sustainability which were not addressed in the household questionnaire survey.

Crudely put, the questionnaire asks respondents what they do in the neighbourhood, and the focus group asks why they behave in such a way and how they feel while in the neighbourhood (Bryman, 2001; Krueger 1994). Since these two research methods complement one another (Miles and Huberman, 1994) it is possible to triangulate the resulting data to strengthen the research findings. Another issue was the ability of focus groups to capture *collective* experiences of the participants' neighbourhood.

Local Services and Spaces

The *use of local services and facilities* was found to be influenced by urban form in terms of their location in relation to residents, which also affected the method of transport used and frequency of use. Those services closer to home were more likely to be reached on foot or bike, and those further away by car. There was no indication that participants necessarily used those services (e.g. supermarket) closest to home as, for some, factors such as product quality were more important than convenience. Some participants also reported using services and facilities en route to and around the workplace (see Chapter 3). However, having accessible key services within the neighbourhood was highlighted as very important for different groups of residents such as the unemployed, older people and young families. Throughout all of the discussions, dissatisfaction was expressed at the closure of local services such as post offices and specialist shops such as butchers and greengrocers. These findings have implications for policy, highlighting the importance for residents of good quality, easily accessible services and facilities in the neighbourhood. A further finding, which should be the basis of future empirical research, shows that there may be potential for local supermarkets (with café) to act as a hub for social interaction, being used as a meeting place by older participants in one particular case study.

The reported *use of, and access to, open space* was, on the whole, high and satisfactory across the different demographic groups living in the different locations. Two important factors affected participants' use of public open space which related to perceived safety and maintenance. Respondents were less likely to report using open spaces if they perceived them to be unsafe. They were also less likely to feel comfortable using public open spaces if they were not well-maintained. The responsibility for maintaining open spaces was recognized to be two-fold, lying both with the user and the local authority, which is supported elsewhere (CABE Space, 2005a, 2005b).

The discussion groups also reported on access to, and use of, shared open spaces which were provided for residents in higher density housing types such as tenements and blocks of flats, but were often not maintained. The findings show that this was cited as a reason for non-use, along with a general perceived lack of comfort and, to some extent, privacy, when using the communal space. This finding has important implications for policy and requires further empirical examination to ascertain if shared open spaces are the most suitable use of space to provide residents with areas in which they feel safe and comfortable. A further finding indicates that formal arrangements for maintaining and managing shared open spaces are more successful than informal collective action on the part of residents. There is a need to empirically examine this further to determine if there is a need to, for example, engage more formally resident participation in the management of shared open space.

A number of features of urban form were found to influence *feelings of safety*. While the household questionnaire findings showed that respondents reported feeling safer the further they lived from the centre, this association did not emerge in the focus group discussions. The maintenance of open spaces was strongly highlighted as an important influence on perceived safety, indicating that secluded, overgrown and poorly maintained spaces were less likely to be used. Characteristics of streets were also influential on feelings of safety and alley-ways and streets that were not overlooked by residences made some participants feel less safe when moving around the neighbourhood. The speed and volume of road traffic also had negative effects on feelings of safety, particularly for the safety of children. A significant non-physical influence on participants' feelings of safety was anti-social behaviour, by children and teenagers among others. Participants were often quick to point out however that this may be resolved (to some degree) by giving young people a place to go and something to do other than hanging around on streets, a well-cited argument (Margo, 2007; Institute for Public Policy Research, 2006).

Community and Attachment

Community stability and *sense of place attachment* were found to be influenced by a number of physical features, including one's accommodation and its location in relation to services/facilities, public transport and the city centre. Other influences include feelings of satisfaction towards the neighbourhood. Older participants were less likely to report a desire to move house than younger participants and those with families, the latter groups citing a need for more space, a garden and a quieter place to live among their reasons. The main non-physical reason given for staying in an area was not being able to afford to move to more desired areas; however friendliness, organized activities and sense of community were also more positive reasons given. There was a sense throughout the case studies that, while some participants may not be living in the ideal place for them, the neighbourhoods functioned well, fulfilling residents' requirements to a considerable extent and therefore constituting a good compromise. The implications for policy here have therefore already been described, in terms of the provision of good services, facilities and open spaces in neighbourhoods.

The household questionnaire found that *social interaction* and *social networks* tended to be stronger the further away from the city centre respondents lived. The focus group findings did not reflect this tendency nor did social interaction seem to be stronger among any one demographic group. Physical features which positively supported social interaction included the physical layout of housing (in tenements however this was reported as a barrier to interaction), services and facilities including schools and shops, and bus stops. Other, non-physical, influences included one's children, organized groups in the neighbourhood, friendliness in an area, the propensity of neighbours to interact socially, and housing tenure. This latter point echoes other findings in that longer-term residents, rather than more transient ones, are more likely to interact and forge social networks in the neighbourhood.

Conclusions

The social dimension of sustainability has become increasingly prominent but there is still a lack of coherence and shared understanding of the concept. Its main dimensions, we believe, are equity and community, and it embraces issues of social inclusion, social capital and social cohesion. In an urban context, social equity is particularly concerned with access to services and opportunities. A community which is sustainable displays higher levels of what some would term social capital and/or social cohesion – pride in and attachment to place, social interaction, safety/trust and stability – and is likely to offer its residents a good 'quality of life', with high levels of satisfaction with home and neighbourhood and an appreciation of the local environment.

So, we would argue that social sustainability is meaningful, policy-relevant and arguably important. Social sustainability represents both public/collective goods and some key drivers of individual private choice. The social 'bottom line' is that people will not choose to move to or remain in a neighbourhood which does not promote these qualities to a degree. We would also argue that social sustainability saves public costs, promotes happiness, and can contribute to the kind of urban vitality which underpins modern economic competitiveness.

For most aspects of social sustainability, (particularly pride/attachment, stability, neighbourhood and home satisfaction and perceived environmental quality) lower density suburbs appear 'best'; so the social perspective somewhat challenges 'compact city' orthodoxy. Some aspects are neutral (e.g. participation), some favour more compact forms, particularly access to services; social interaction is best at medium densities. In order to isolate the effects of urban form it is necessary, through statistical modelling or other means, to control for the effects of other socio-demographic factors. In general the disadvantages of compactness are more marginal once you control for these influences. Poverty is often more important than urban form – who lives where, and whether they choose, matters. Management of urban (public) space rather than design also emerges as an important issue.

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Chapter 6
Energy Use

Keith Baker, Kevin J. Lomas and Mark Rylatt

Introduction

A high proportion of the energy consumption of cities is linked to buildings. In the UK for example it is estimated that energy use in buildings is responsible for around 29% of all energy consumption compared with 37% for transport (Fig. 6.1). This fact is a major driver in sustainability policies in the UK with the government expecting the construction sector and the planning system to deliver all new housing by 2016 that produces zero net emissions of carbon dioxide from all energy use in the home.

There are a series of potential relationships between domestic energy consumption and the influence of urban form in terms of residential density, layout etc. Density is linked to the type of housing so if we all lived in high density terraced houses/flats what would be the impact on energy consumption or is it to do with house size? Urban form also has an impact on the lifestyles of households and this too could potentially influence energy consumption for example through home working.

This chapter focuses on energy consumption in dwellings, and seeks to examine the determinants of energy consumption by reference to the characteristics of the housing stock, urban form and lifestyle factors. The chapter begins by examining the relationship between urban form and energy use. It then considers the state of domestic energy modelling noting the insufficiency of the use of permanent building physical characteristics such as dwelling type and age, and data limitations on occupancy characteristics and behaviour relating to patterns of heating and appliance use and less permanent aspects of the building fabric. The next section sets out the research methods of the study and how these issues are addressed, and the main forms of statistical analysis involved are explained. In the concluding sections results from the analysis are presented with some observations on the significance of urban form.

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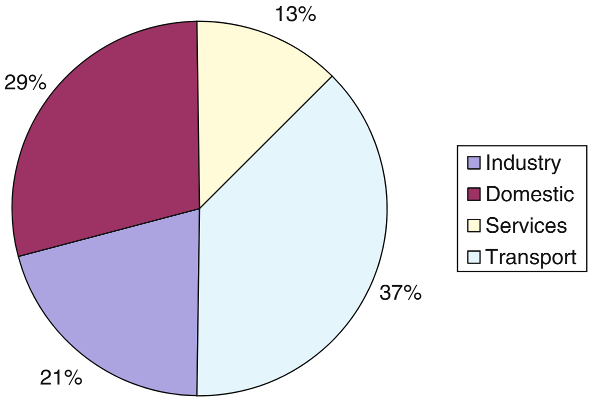

Fig. 6.1 UK Energy consumption by final end use, 2006
Source: Department of Business Enterprise and Regulatory Reform

Energy Use and Urban Form

Unlike other topics in this book research into the relationships between building energy use and broad measures of urban form, such as density, have received limited attention. Usually such variables have been regarded as merely of minor statistical interest; hence the literature is slight. A rare recent example of a study that seeks evidence for more complex relationships is provided by Larivière and Lafrance (1999) but no significant relationship was found between different densities and per capita electricity consumption; indeed they recommend a cautious view of non-trivial urban energy use and population density relationship claims. Ratti et al. (2005) discern a relationship between overall energy consumption and global urban form characteristics but this is based on a city scale morphological categorisation using a novel form of image processing derived from digital elevation models rather than conventional measures and, as an isolated study, cannot be considered conclusive.

More generally, studies of urban form and energy prove to be at the level of what may be termed the local aspects of urban form: the physical form of buildings such as the size of their footprint and curtilage, the number of storeys, and their dwelling type, such as detached, semi-detached, terraced, etc. (e.g. Perkins, 2002). Such aspects do of course relate to measures of density and morphology and the energy consumption and efficiency of buildings is undoubtedly related to their physical form, given that buildings are never perfectly insulated. The influence on energy consumption due to fabric heat loss has long been understood and, *ceteris paribus*, is potentially a useful basis for prediction and comparison (Martin and March, 1972; Yannas, 1994).

The effects of solar gain on heating energy consumption and of overshading on lighting energy consumption are also related to built form and density but are much harder to model reliably. It is possible to crudely estimate the trade-off between gain and loss that might occur under different building density scenarios and to infer that there must be a point beyond which the advantages of reduced heat loss from a higher proportion of dwellings with party walls begin to be outweighed by the reductions in solar gain and illuminance resulting from over shading in closely massed developments (Steemers, 2003). However, crucially, as heat loss standards improve, the benefits of medium to high densities will be far less significant in this respect, while the disadvantages of very high densities and the lack of natural light, though mitigated, will remain.

In the UK the government's zero carbon policy for new build, if successful will mean very low heat loss for all types of buildings, including detached dwellings, and so issues of heat loss abatement related to density of new development will be minimised. For different reasons solar gain and overshading related to density are also unlikely to be a significant factor in new planning guidelines and regulations. This is because although non-statutory guidelines exist for site layouts that optimise passive solar gain (e.g. Littlefair, 1995) and, as such, these encourage medium to low density developments, the trend in this direction observable in the UK from 1970 onwards has since been reversed under Planning Policy Guidance 3 (DETR, 2000), which set a minimum density of 30 dwellings per hectare. It is worth adding that although these regulations have now been superseded by Planning Policy Statement 3 (DCLG, 2006) and the minimum density regulation will no longer be strictly enforced at the national level, it is unlikely that there will be a significant relaxation despite recent signs of green belt policy change to meet the UK housing crisis.

The determinants of energy use are not simply determined by the nature of the built form as it is recognised that life style and the dynamic effects of occupant behaviour, in particular appliance use, and of retrofitted energy efficiency measures, are likely to obscure static physical influences. These are discussed in the next section.

Modelling Domestic Energy Consumption

Domestic energy models used for prediction on a medium to large scale are subject to considerable uncertainty as they commonly operate on just a few data relating to permanent building physical characteristics such as dwelling type and age, and sets of default data and assumptions about occupancy characteristics and behaviour relating to patterns of heating and appliance use and less permanent aspects of the building fabric. Even where full datasets are available such models internally are commonly quite simplistic in their treatment of occupant behaviour related energy consumption. There has for example been criticism of the UK Building Research Establishment Domestic Energy Model (BREDEM) (see Anderson et al., 2002 for a description of the latest version) on these grounds. The detailed influences raised by these issues are now considered.

Fabric

Particularly for older dwellings, any differences in energy consumption that might be predicted on the basis of the building regulations in force at the time of construction, are likely to be masked by changes to the building fabric, which alter the dwelling's energy efficiency, e.g. installation of double glazing, draught proofing. This is particularly so in the UK where a large proportion of the building stock is over fifty years old. Much of this was originally relatively low grade accommodation built to house workers following the industrial revolution and is very likely to have been improved considerably at various times. These changes are for the most part not a matter of record.

Occupancy

Although the UK population increased by 4.1 million from 1970 to 2000, average household size decreased from 2.9 to 2.3 people and the total number of households increased by 6.4 million over the same period (Shorrock and Utley, 2003). Occupancy type is related to dwelling type which in turn is linked to tenure (Fig. 6.2) and so there are strong reasons for expecting a relationship with household energy consumption. Changing patterns of ownership and especially the targeting of energy efficiency schemes may also be very significant. As illustrated by Fig. 6.3, owner-occupancy has shown a steady increase since 1970, and although the number of dwellings rented from local authorities has declined some of this decrease is accounted for by ownership switching to registered social landlords and housing associations. The number of privately rented properties, which fell from 1970 to a low point in 1988, has subsequently shown to be increasing again. This

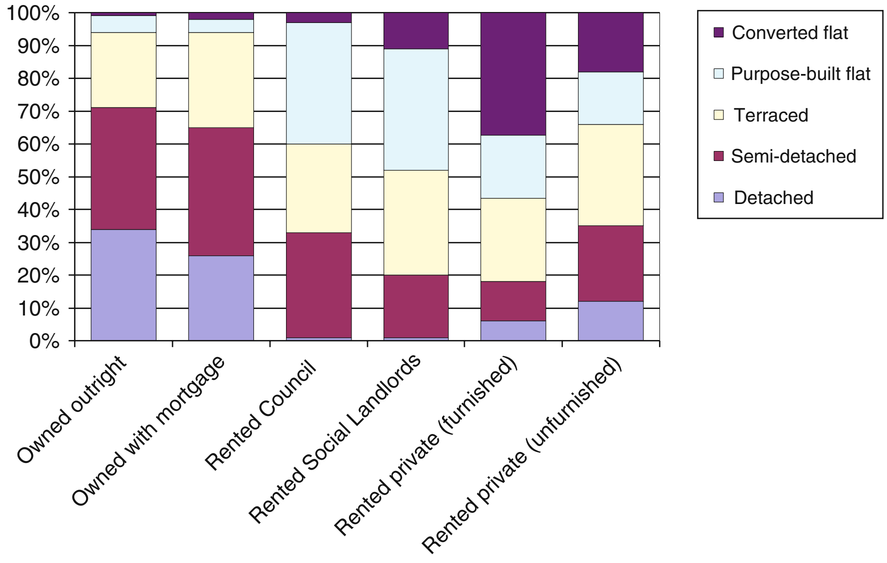

Fig. 6.2 UK dwellings by dwelling type and tenure, 2000
Source: Survey of English Housing, Department of the Environment, Transport and the Regions

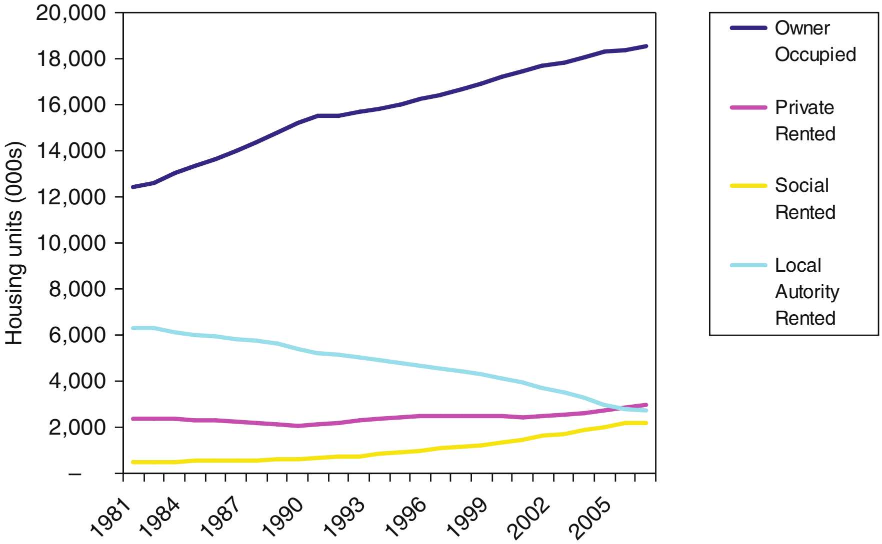

Fig. 6.3 UK Housing trends by Tenure
Source: Communities and Local Government

may well be a reflection of an increasingly mobile workforce and a greater number of households comprised of students and non-related young professionals.

It is to be expected that owner-occupiers, having a substantial investment in their properties will have more interest in and direct control over changes relating to energy efficiency. Local authority and housing association properties are likely to influence overall energy consumption to some degree by implementing energy efficiency improvements to comply with regulations and agreements such as Local Agenda 21 in the UK. However, privately rented homes are likely to benefit least from improvement schemes owing to the fragmented nature of this sector in the UK. Tenants are unlikely to invest in anything other than basic energy efficiency measures due to due to typically short tenancy periods, while landlords are currently not incentivised to make costly improvements just to save money for their tenants.

Use of Household Appliances

Changing patterns of appliance use represent an additional source of uncertainty. As shown in Fig. 6.4, the amount of energy used to light our homes and power appliances increased significantly between 1970 and 2001. The total amount of energy consumed by space heating has changed little over this period, with 2001 representing an unusual high point, and the overall proportion has remained fairly constant at between 60 and 65%. Energy used for water heating has followed a similar trend, averaging around 25% of total consumption over the period. However,

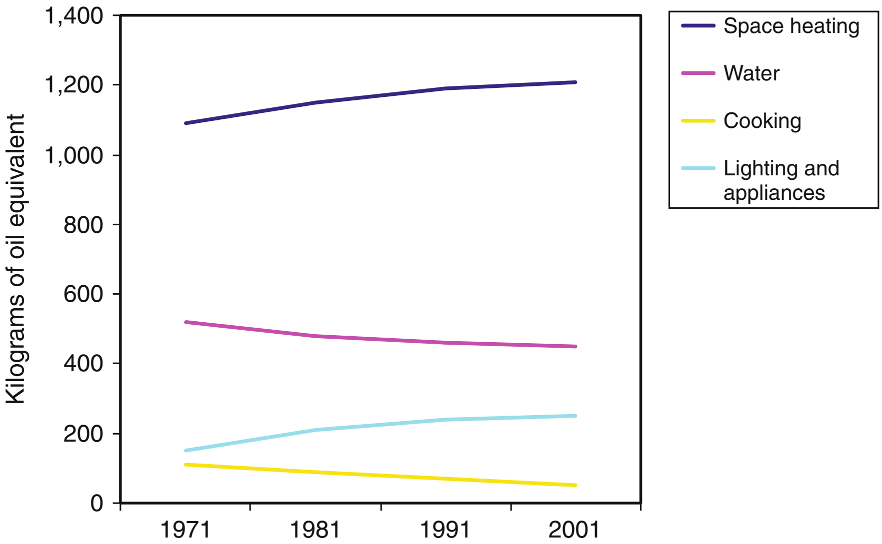

Fig. 6.4 Domestic energy consumption per household: by final use
Source: National Statistics Online

over the same period, significant changes appear to have occurred in the amount of energy used for cooking and lighting and appliances. The amount of energy used for cooking has shown a consistent and steady decline, falling from 6% of total consumption in 1970 to under 3% in 2001, while energy used for lighting and appliances has more than doubled in real terms, rising from 7% to just under 13% of total consumption, despite a rapid rise in the use of energy efficient light bulbs for domestic lighting and the introduction and expansion of energy efficiency labelling for major appliances from 1995 onwards.

It is probable that the increase in the number of households with falling occupancy levels together with a trend towards more background and "mood" lighting has led to more light sources and appliances being shared by fewer individuals. Consumers are purchasing greater numbers of appliances, particularly high-tech goods, and whilst some, such as microwaves and LCD televisions, reduce the usage of other appliances or replace less efficient technologies, others will introduce additional energy demands. One example of the latter is the impact from digital, cable and satellite TV boxes being left on standby rather than being switched off because of poor design and/or unacceptable reboot times.

Research Method

To fully understand all these sources of variation in energy consumption between dwellings requires behavioural studies with intensive observation and recording, and care to avoid observer effects. Additionally, direct observation of attitudes and behaviour risks introduces propagation errors through inaccurate reporting and contextual bias attributable to respondents. The alternative approach adopted in this study factors was less invasive, using methods that focus on the manifested effects of behaviour attributable to ownership and use of types and numbers of lights and major domestic appliances and physical measures taken to reduce consumption such as improving dwelling insulation, rather than reported behaviour such as switching off lights and appliances when not in use.

Selection of Samples

Dwellings were selected to provide, as far as possible, homogeneous samples of dwelling types (e.g. neighbourhoods of exclusively detached houses). A geographical information system was used to identify the most promising areas for this approach within the fifteen case study areas. This would enable between subgroups studies while controlling for built form on a consistent basis. The response rate was expected to be low for a very detailed postal survey on energy issues as the necessary questions are generally unappealing to many potential respondents. The study was based originally on the selection for survey of 1674 terraced and semi-detached dwellings in Leicester (Fig. 6.5), 2083 detached or

Fig. 6.5 Map of Clarendon Park, Leicester. City Form study area is in colour, the sub-area selected for the energy study is in red

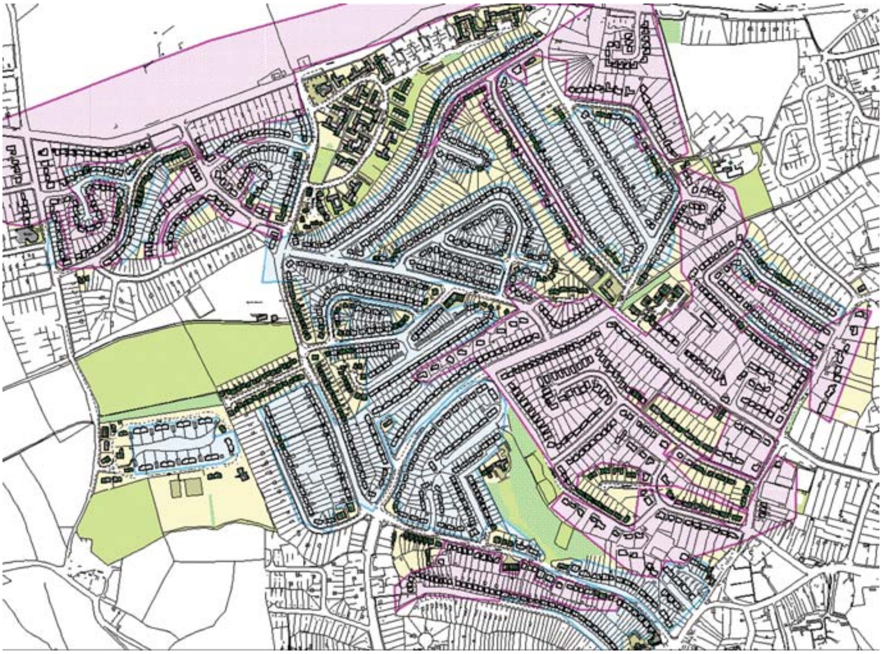

Fig. 6.6 Map of Fulwood, Sheffield case study area is in colour, the dwellings selected for the energy study are in pink (detached dwellings) and blue (semis)

semi-detached dwellings in Sheffield (Fig. 6.6) and tenements and flats in Glasgow which, for reason explained below could not in fact be analysed.

Design of Survey Instrument

Home energy efficiency questionnaires are conducted by pubic agencies in the UK to raise the householder awareness of inefficiencies in their energy consumption. These questionnaires request data for dwelling type and age, number of storeys and rooms, wall and roof type, loft insulation, window frame and glazing type, main and secondary heating type and extent, water heating and cylinder insulation size, cooker type and quantity of low energy lighting. They may also include dimensional data in the form of a floor plan. However in the study survey this was replaced by data acquired from a geographical information system (GIS), which, in combination with returned storey data, enabled reasonable estimates of floor area to be made automatically for all the dwellings. The scope of the study survey was, however, expanded to include more information on occupancy and household appliances to support the aim of investigating the principle sources of uncertainty described above.

A pilot survey was used to assess the responses both to individual questions and the survey as a whole. This confirmed that a very low response rate was likely and so modifications were made where questions were answered unsatisfactorily. Even so the final response rate with signed energy consumption data release permissions averaged only 6% in Leicester and Sheffield, which was considered just adequate for meaningful analysis. Unfortunately postal delivery and other problems in Glasgow produced a sample for tenements and flats well below the size considered acceptable and the study was therefore restricted to detached, semi-detached and terraced dwelling types.

Energy Consumption of Individual Properties

This data was enhanced by energy consumption for individual properties. Disaggregated energy consumption data has rarely been available in the UK to enable detailed investigation. Although this problem is less severe in some other countries, for example Canada, often the building stock is not comparable (Aydinalp-Koksal et al., 2008). The original intention was to approach individual suppliers, of which there are many in the UK, this proved futile. Fortunately the data was ultimately acquired from the Department of Business Enterprise and Regulatory Reform, a government department, which since 2004 has held energy consumption data for all UK households on a central database in order to provide statistics at various levels of aggregation.

Data Analysis Procedure

Cluster analysis is an exploratory statistical technique intended to reveal groupings in the data based on some measure of similarity. Such clusters may correspond to expected classes within the data and the statistically determined centres of the clusters can be used to investigate degrees of association with other aspects. A form of this analysis was applied to the combined gas and electricity consumption data. It was of particular interest to see whether any clusters would centre on dwelling type in the full data sample (i.e. all the responses from Sheffield and Leicester). Selected response variables, using appropriate banding for continuous data, were then cross tabulated to show the strength of any significant associations with the cluster centres.

Simple regression can also be used as an explanatory technique to investigate the strength of linear relationships between one independent variable with a dependent variable, such as energy consumption. This approach is used to explore the relationships between energy consumption and total floor area for smaller subsamples of data categorised by response type (for example the type of wall insulation or the presence of various forms of heating system controls).

Multiple regression analysis is then used to explain the effects of a number of independent variables on the dependent variable, expressed as r^2, the coefficient of determination (e.g. by convention an r^2 of .25 indicates that the regression explains

25% of the variance observed around the mean). It is the basis for a confirmatory phase of analysis in which the variables initially identified are subject to the rigour of model building: with care, variables can be added to the regression to build a model with increasing explanatory power. The effects of interesting variables that showed relatively weak but still significant relationships in the exploratory phase are also tested.

The dataset contains categorical response variables that are mainly dichotomous and these were coded using dummy variables; multichotomous variables generally proved to have quasi-ordinal characteristics (for example single, double and triple glazing) and these were given integer representation (for example 1,2,3). After the addition of each new variable a record is kept of the change in the number of records and the associated change in key statistics (the significance of the F statistic change, and the r^2, adjusted r^2 and p-values). These results are used to determine which variables produce the most statistically significant improvements to the relationships with electricity and gas consumption after carefully checking for any potentially problematic co-linearities (linear relationships between independent variables selected for prediction that might bias the results).

Results of Analysis

Three distinct energy consumption clusters corresponding to low medium and high energy consumption levels are identified from the cluster analysis of the combined electricity and gas consumption data for the whole sample. However, these are not centred on dwelling type as might have been expected. This gives an early indication that built form classification is likely to show at best only a very weak relationship with energy consumption. When the analysis is repeated with sub-samples by dwelling type only two distinct clusters are found. For the Leicester terraces subsample, local knowledge has confirmed that the clusters differentiate between smaller mid-terraces and end-terraces and larger mid-terraces. Cross tabulations based on the full sample do however show quite significant associations with total floor area, occupancy, dwelling age, number of rooms, number of bedrooms, and regular home working. Perhaps surprisingly, the number of bedrooms has the strongest association with the clusters in the full sample and in two of the dwelling type subsamples as Table 6.1 indicates.

The most significant associations found in the cluster analysis phase are confirmed by the regression analysis. Weak but still significant relationships between electricity consumption and storage heaters, TVs in use, showers per week, digiboxes in use, PCs in use, and portable electric heaters in use are reported in Table 6.2. However, the statistic for storage heaters appears to be leveraged by a small number of dwellings from the Leicester subsample with this form of heating. The relationship with the number of showers per week is not been observed in the subsample analyses but this is probably explained by differences in occupancy characteristics. The remaining variables are present in one or more tables for the

Table 6.1 Correlations of key variables with the consumption clusters found within subsamples and the full sample

Response Variable	Statistic	Leicester	Sheffield Detached	Sheffield Semis	Combined dataset
Total Floor Area (20% bands)	ρ	–0.56	–0.24	–0.09	–0.49
	p–value	0.00	0.14	0.56	0.00
Occupancy	ρ	–0.57	–0.47	–0.28	–0.50
	p-value	0.00	0.002	0.06	0.00
Age	ρ	–0.10	0.33	0.27	–0.16
	p-value	0.56	0.04	0.07	0.08
No. Rooms	ρ	–0.55	–0.30	–0.30	–0.44
	p-value	0.00	0.06	0.04	0.00
No. Bedrooms	ρ	–0.63	–0.35	–0.55	–0.59
	p-value	0.00	0.03	0.00	0.00
Homeworking	ρ.	–0.37	–0.29	–0.25	–0.26
	p-value	0.02	0.07	0.09	0.01

Table 6.2 Statistics for the variables found to be the best indicators of electricity consumption for the full sample

Response variables	No. of houses	r^2	Adjusted r^2	Significant. F Change
Total floor area, Total occupancy, Age, No. of Rooms, No. of Bedrooms	142	0.30	0.27	0.00
Homeworking	142	0.32	0.29	0.03
Main heating – Storage heaters	142	0.38	0.35	0.001
No. TVs in use	139	0.40	0.36	0.10
Showers per week	122	0.44	0.39	0.05
No. digiboxes in use	106	0.45	0.39	0.36
No. PCs in use	101	0.47	0.40	0.37
No. portable electic heaters	101	0.47	0.40	0.47

subsamples and their presence is consistent with the findings from the exploratory analyses. The supporting evidence given in Table 6.3 for these variables came from the correlations (the Spearman rank coefficient, ρ, was used as it does not require variables to be measured on ordinal scales) with the three energy consumption clusters discovered within the full sample.

Table 6.3 Correlations between cluster centres and TVs, digiboxes and portable electic heaters for the full sample

Response variable	ρ	p-value
No. of TVs	–0.36	0.00
No. of digiboxes	–0.97	0.04
No. of portable electric heaters	–0.16	0.07

Table 6.4 Relative strengths and significances of the relationships between gas consumption and the numbers of rooms and bedrooms after the addition of total floor area and occupancy to the multiple regression

Response variables	No. of houses	r^2	Adjusted r^2	Sig. F Change
Total floor area, Total occupancy, Age, No. of Rooms, No. of Bedrooms	125	0.45	0.42	0.00
Homeworking	125	0.47	0.44	0.03
Glazing	125	0.49	0.46	0.05
Boiler type	113	0.50	0.46	0.17
Wall insulation	105	0.52	0.47	0.38
Thermostat	105	0.52	0.47	0.46

A smaller number of significant variables were found for gas consumption than that for electricity consumption as indicated in Table 6.4. These findings are consistent with those for the sub-samples and conform with the prior expectation that differences in gas consumption should relate to a smaller range of factors as its uses in dwellings are less diverse than for electricity. The finding for glazing type again appears to be due to leverage by small numbers of dwellings reporting single or triple glazing. The initial phase of the analyis produces evidence of several strong relationships between gas consumption and total floor area when the subsamples are split according to wall insulation type.

Similar but weaker relationships are found when the subsamples are split by boiler type. Thermostats are one of three variables relating to the level of respondents' control over their heating systems, the others being the presence of thermostatic radiator valves (TRVs) and the type of controls (none, clock/timers, and digital controls). It is notable that within the combined dataset a strong and statistically significant relationship is found when gas consumption was regressed against total floor area for the group of 27 households with the highest level of control over their heating systems, i.e. those with TRVs, digital controls and thermostats (shown in Fig. 6.7).

Discussion of Key Findings

The analysis identifies the number of bedrooms as a key indicator of energy demand. This is rare in the literature but has been reported by Colton (1998) as a control variable for changes in occupancy between the time of collection of consumption data and the time of the survey. Although bedrooms are of course a subset of the total number of rooms there is not a straightforward, linear relationship. Trivially of course, the number of bedrooms variable is related to total floor area, although, as would be expected, total number of rooms is a better predictor of this. The variable is also clearly related to occupancy and has been used, for example, as a proxy for hot water use (Cyber Business Centre, 2002).

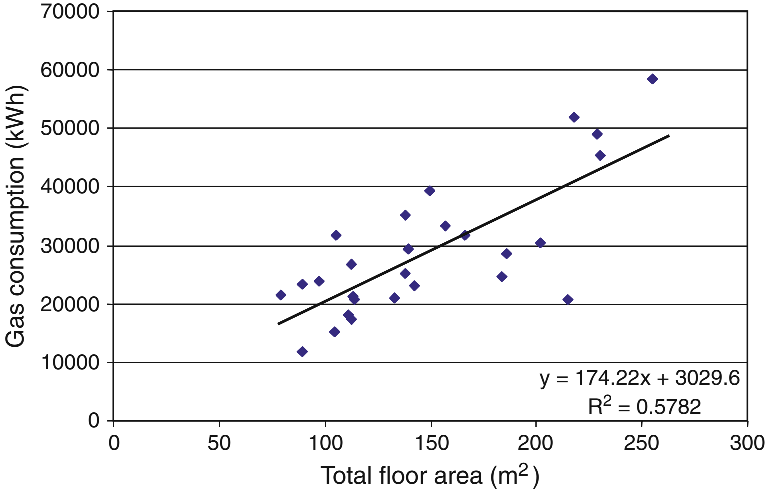

Fig. 6.7 Gas consumption regressed against total floor area for dwellings with TRVs, digital heating controls and thermostats

The predictive power of bedrooms may reflect changes in household behaviour that affect heating regimes: for example, the trend towards smaller households may, firstly, imply that specific rooms rather than entire dwellings may be heated and, secondly, that greater numbers of appliances will be moved into rooms traditionally used only for sleeping. The first possibility finds weak support in other results from this study which show some correlation between the number of portable electric heaters in use and the number of bedrooms. For the second possibility there is at least anecdotal support in reported trends towards more solitary living and the increased freedom of many employees to work from home.

As the questionnaire specified a bedroom as a room in which a bed is permanently set up, rather than whether it was regularly used as such, and as a significant number of respondents reported regularly working from home, it is likely that bedrooms in use as or doubling as home offices have influenced these results. The results also show a significant relationship between electricity consumption and the numbers of PCs and digiboxes in a household. This is quite weak but even so is perhaps stronger than expected given the limitations of the dataset and may be further evidence of the effects of these changes on lifestyle. Bedrooms doubling as home offices can also be expected to be heated during their periods of business use.

After total floor area, occupancy, dwelling age and rooms and bedrooms, the distinction between whether or not respondents reported regularly working from home was found to be the next strongest indicator of differences in gas and electricity consumption within the combined dataset, although the results were weaker within the separate samples. It was also found to be a determining variable for the consumption clusters. The significant trend towards home working is of relatively recent origin in the UK (Energy Star for Homes Website, 2007). Although home working conditions are unregulated, home workers obviously need adequate warmth and lighting and usually some electrical equipment for their work, which will lead to increases in energy consumption.

It is recognised that this issue is complicated by the tradeoffs between transport use (which is certainly more strongly related to measures of urban form) and the relative efficiencies of energy provision at home and at work. These effects on domestic energy consumption have received surprisingly little attention to date, especially in the UK (Boardman et al., 2005). This study contributes to the debate by at least showing that these effects can be observed in a survey on this limited scale and suggests the potential for larger, perhaps longitudinal studies. It is likely that future predictions of domestic energy demand will need to account for changes in occupancy patterns, both in terms of time spent at home and which types of room are occupied most frequently.

Conclusions

The initial review of the relationships between energy consumption in buildings and urban form suggests that the principal association is likely to be via building forms. However, the determinants of energy use are not simply determined by the nature of the built form and life style and occupier behaviour, but also important are the ownership and use of appliances and the fitting of energy efficiency measures.

This chapter has sought to examine these relationships by a study of energy consumption in two different types of neighbourhoods based on the analysis of responses to an extensive energy questionnaire survey and associated annual consumption data. The commonly used broad classifications of types of dwelling have been used as the basis both for controlling analysis of selected subsets of data, on the assumption that they would exert significant effects on energy consumption and on the expectation that these would be observable to some extent despite the anticipated effects of other variables. However, although subsample analysis showed significant differences in key variables, overall analysis did not suggest that these classifications have a very significant effect on actual energy consumption.

These results cannot be regarded as conclusive, which is to be expected as these studies represent path-finding work with a new and small dataset. That the results conform to broad expectations in most respects is a finding of some values in this context and represents a good platform for further work, hopefully with the benefit of a much larger sample size. But beyond this, cluster analysis also revealed an interesting relationship with the number of bedrooms, which is of significance for density metrics, and also effects attributable to regular home working on energy consumption and to the use of modern technology are found to be important. The latter may also be related to transport energy use, which would also be expected to have a relationship with urban form, but it was not possible to investigate this possibility further.

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Chapter 7
Economic Viability

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Introduction

The arguments for sustainable cities are primarily couched in environmental and social rather than economic terms. Nevertheless the economics of cities is a central aspect of sustainability and a number of authors have endeavoured to incorporate economic arguments into the debate about cities. Lynch (1981), for example, preempts the Brundtland definition of sustainable development in the context of the urban economy. He sees the sustainability problem being one of enabling the urban economy to exist long into the future, whilst keeping resource use within levels that allow the earth's finite resources to provide indefinitely, alongside social equity. Inevitably with economics there has not been a consensus.

This chapter seeks first to consider the economics of city form by examining the micro-forces that shape the primary constituent elements set out in Chapter 2. This analysis provides a base for reviewing studies of the relationships between economic performance, city form and sustainability. Economic viability of land use patterns is argued as a prerequisite if spatial structures of cities are to evolve to be more sustainable and the chapter then applies this criterion to different land use sectors. Finally the chapter assesses the relationship between infrastructure costs and city form and draws some policy conclusions.

Economics of City Form

Cities are dynamic entities and their physical form is constantly changing to reflect the underlying economics of land use markets. This section considers each of the primary elements of urban form in turn and assesses not just the underlying economics that establishes these phenomena but also property market and development processes that drive and influence urban change.

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Land Use Patterns

Specific spatial distributions of land use are crucial to the arguments about potential 'sustainable' urban forms and these are influenced by both supply and demand factors. There are two underlying substantive land use demand factors. The first of these is the spatial pattern of revenues and costs (see Alonso, 1964; Dunse and Jones, 2005). The demand for different land uses will depend on the relevant cost of using certain locations, and the revenues they will provide. Land that is deemed to be more productive for one use may not be considered so for another use. This depends on the suitability of the location to generate large revenues, and if a certain area is thought to generate large revenues for one or more land uses then it will be more sought after. Higher demand for a location is likely to result in higher land values. Typically the location attributes preferred by residential users are different to industrial demands, and these will be different to retail and commercial demands. Second, there are agglomeration benefits which arise from firms and shops locating together in the same place (Parr, 2002). These benefits are known as agglomeration economies (see later).

The (changing) supply of land and property has a number of underlying influences. Land availability offers opportunities/constraints to the adaptation of the land use pattern. New development or redevelopment or the conversion of existing buildings requires not only that it is perceived as profitable to property companies but also that there are funds made available from private investors to do so. The property market is very imperfect and both property companies and investors can be constrained by attitudes toward the risks associated with particular land uses and potential locations if they do not conform to established patterns (Jones and Watkins, 1996). For example investors in the UK have been traditionally reluctant to invest in mixed use development. This in turn means that public sector investment can play a key role in pump-priming private development in the initial steps of the development of sustainable markets in non-traditional locations (Jones and Watkins, 1996).

Accessibility/Transport Infrastructure

The transport infrastructure of a city in terms of the quality of its roads, the scale and availability of public transport and location of transport nodes defines the ease by which people can reach buildings, spaces, and places. It provides a set of accessibility relationships within the urban area that can be seen in terms of distances, travel times and travel costs. Infrastructure in the form of transport networks has a direct impact on the scale of local market areas. For example the spatial extent of retail (and other services') catchment areas is partly a function of how easy it is for people to travel to shops, or put another way the costs of travel by customers. In fact a hierarchy of services provision/facilities exists determined by the transport network. This is most evident in retailing where shoppers are usually prepared to travel further to large retail superstores than local supermarkets, which in turn attracts people located further away than corner shops.

From an economic perspective the transport infrastructure primarily determines travel costs. If costs are high then travel trips may be short and some households could be excluded from access or refrain from using services/facilities. These costs take the form of both financial and time costs. Accessibility has a key impact on land and property. There is likely to be a higher demand for a parcel of land or property that has good accessibility both to it, and to other services and infrastructure networks. The land use that benefits most from accessibility to a given location and makes the highest profit will outbid other potential users. This also means that land prices/rents are highest at the most accessible points in a town reflecting their potential for profits at these locations.

Density

The density of a city can be viewed in a number of ways as Table 2.1 examines. Both the city-wide average and the spatial pattern of population and employment densities within a city are usually the consequence of the competition between land uses. In a competitive land market the higher the price the more intensively the land is used for housing or for commercial space and hence the greater the density of utilisation. As a result typically the highest employment density is in the central business district (CBD).

In the housing market inner area locations have the lowest travel costs to the CBD, the main centre of employment, and competition leads to high land prices and high residential densities. In western economies the implications are that low incomes households consume small amounts of housing at high unit costs in inner high density locations and high incomes households consume the converse (Muth, 1969). This general pattern is distorted by the provision of social housing allocated on a non-market basis.

Characteristics of the Built Environment

Investment attitudes of banks and other financial institutions can influence the characteristics of the built environment (the building itself and its environment). While such investors are market led and will invest their funds where they will receive the greatest return, they tend to be risk averse with regard to new types of building form or the introduction of a building form new to an area. For example, they have been ambivalent in the UK until recently to green buildings. Further, banks in the UK are reluctant to lend on flats above a certain storey height. Similarly, house builders have taken a cautious approach to innovation for example in energy conservation, because introducing such measures increases the sale price. Demand factors can also influence the built environment through building type preferences, such as the desire of families with young children to occupy housing with gardens.

The level of building maintenance may also be important. High maintenance buildings, *ceteris paribus*, may not be desirable in terms of the costs they incur and so demand tends to be low.

This brief review has emphasised that city form is the outcome of the operation of real estate markets within a given transport infrastructure framework. Looking at the broader urban picture it can be seen that these processes in turn determine the spatial distribution of employment and population.

Urban Form, Economic Performance and Sustainability

A crucial question for this chapter is how urban form influences economic performance. Many of the economic arguments in favour of the compact city develop from agglomeration economies or benefits and the fundamental reasons why cities exist. Agglomeration economies include localisation economies such as the access to a pool of labour, availability of a range of auxiliary trades and specialised services plus knowledge spillovers from similar firms located near to each other. Urbanisation economies result from the common location of firms belonging to different and unrelated industries. These benefits include the availability of a range of municipal services, public utilities, transportation and communication facilities, the existence of a wide variety of business and commercial services and a complementary of labour supply. Households can also benefit from agglomeration economies or city living in the form of a wide range of shops, amenities and cultural facilities and firms and households from public services/infrastructure (Henderson, 1974). The benefits of agglomerations are linked to urban size. For example the larger the city the greater is the viability of specialist shops and hence the wider the choice to the consumer. Similarly a larger labour market also provides employers with a wider skills base, leading to an increased likelihood of skills-job matching and greater productivity.

The role of density is at the heart of this sustainable urban form debate. Higher employment densities are traditionally linked to potential agglomeration economies. There are knowledge spillovers between firms in an industry in close physical proximity which promote urban economic growth by reducing product costs and the costs associated with product development and innovation (Jacobs, 1969, Porter, 1990). This argument suggests that competitive pressures brought about by the geographical concentration in an industry will stimulate innovation. Prud'homme & Lee (1999) similarly claim that the closer people are to their place of work, the more productive the economy is because workers spend less time commuting. They conclude that the labour productivity is negatively related to sprawl.

High land use densities also have a number of implications for the demand for services and the costs of their provision as high land use density results in a greater concentration of demand, and associated consumer spending, which *ceteris paribus*, reduces the spatial extent of viable social and private services' catchment areas (including business services). This in turn suggests the potential for more consumer choice and diversity in high density areas. Barton (2000) argues that mixed land use is the most sustainable type of urban use, in that it increases the viability of services and transport provision supported by high residential density. Mixed use is linked closely to ideas of ease of access and the provision of a greater choice. A further argument is that by having many types of land use in one development area there is a

> critical mass and level of activity (created) which is greater than the sum of individual users, thereby making a critical contribution to location and character (ODPM, 2002, para 6.1.2).

These arguments tend to be normative, partial and emphasise the benefits of high density cities, and have not been subject to detailed scrutiny. Empirical studies are thin on the ground and suffer data limitations, examples include Camagni et al. (1998), Cevero (2001), and Ciccone and Hall (1996). They do not address the question of urban size or cities as dynamic entities. There is also a contradiction between the arguments that a compact city encourages economic growth and the implicit assumption that the compact city should be tightly defined. A high density compact city is less likely to be able to cope with significant population growth, as there is less potential for expansion if development is already at a high density (Anas et al., 2000). The ultimate logic of the proponents of compact city economics is that market forces would create compact cities yet the opposite is occurring. Urban systems are decentralising driven by market forces and the choices of firms and households. Cities and urban systems have been subject to decentralisation pressures as a result of a combination of the transport infrastructure in large cities unable to resolve congestion and increasingly improved inter-urban transport links fostering growth in medium sized towns. For these and other reasons such as the growth of information technologies arguments that agglomeration economies are becoming more diffuse have also recently emerged (Parr, 2002).

Along side this sustainable city literature and predating it is the related concept of ‘optimal’ city size that spawned a number of papers in the early 1970s including Alonso (1971), Evans (1972) and Richardson (1973). The logic derives from the argument that while agglomeration economies are the driving force for the growth of cities beyond a certain size negative agglomeration economies such as congestion and pollution occur. These theories suggest there may be an ‘optimal’ urban size at a population where the total benefits of size equate with the total costs (McCann, 2001, Capello and Camagni, 2000). Similarly Fujita & Thisse (2002) argue that cities can become too big to be sustainable.

Some authors have extended this concept to the sustainable city, defined by a set of sustainable criteria that establishes an appropriate optimum city size. Camagni et al. (1998) define a sustainable city where the three environments – physical, economic and social - interact in such a way that the sum of all the positive externalities is larger than the negative external effects. In a narrower paper Capello & Camagni (2000) argue that urban size influences location costs and benefits through creating greater potential for more mixed and higher level urban functions, specialisation and integration within the urban system. An optimal efficient city size is one that achieves economic sustainability. However, this efficient size depends on what is produced, how it is produced, and how the area in question operates within the urban economy.

These approaches tend to view a city simply as a static uniform entity rather than a dynamic changing place with neighbourhoods that have different densities and characteristics. The role of spatial structure on economic sustainability in these approaches is also ignored. Just like optimal city size models they do not appear to aid a practical solution. These complex theoretical models contrast with the simple sustainability argument underpinning the ‘smart growth’ or high density/urban containment policies followed by some states in the USA (Cervero, 2001). These policies are based on a study with a very limited evidence base that found the public sector costs of sprawl are much higher than for a compact city (Burchall, 2000).

Urban containment and compact city policies in turn create a number of concerns that follow from the operation of property markets. Limiting land supply by development constraints on greenfield sites, through for example green belts surrounding cities have potential implications for the local economy. In the long term market forces will lead to higher densities as the proponents of the compact city seek. However, this will happen because land values will be bid up and as result land is used more intensively (Cheshire and Sheppard, 1989). It has been argued that as a result economic growth will be siphoned away as increased land and housing costs are followed by demands for higher wages and reduced competitive advantage with firms moving to alternative cheaper locations (Cervero, 2001). The reality is likely to be quite complex and difficult to dissect as the countervailing forces of agglomeration and crowding out from land shortages vary with the sector of the economy.

In the housing market many households will be priced out of the immediate housing market in the sense that they will not be able to afford the type of housing they require and are prepared to commute a longer distance from another settlement. This process exacerbates a wider phenomenon of increasing real household incomes which drives the demand for more housing space usually in low density developments at peripheral locations (see Brueckner, 2000). Proponents of the decentralised solution to urban sustainability extrapolate this trend and stress either the benefits of a decentralised ‘rural’ or ‘semi-rural’ life style with low development costs or that it will happen anyway as unstoppable market forces will create dispersed communities with low energy consumption and congestion (Richardson and Gordon, 1993; Gordon and Richardson, 1997). However, to date the process has led to increased commuting distances.

This review of the economic sustainability of cities reveals that much of the theoretical analysis has simplicities, flaws and serious limitations, and lacks practical application. Much of the arguments incorporate empirical analyses that are not usually designed to address economic sustainability. For example agglomeration economies are normally viewed at city level rather than the neighbourhood. The discussion suggests that the problem can be expressed as maximising potential urban output or productivity that stem from agglomeration economies subject to a series of sustainability constraints. This can be viewed as a form of (non) linear programming problem where a function is maximised subject to constraints that encompass social, environmental and economic factors.

From an economic viewpoint an all embracing constraint is the viability of the urban form that would in turn include the viability of sectors of the local economy. These sectors can be seen in terms of wealth creation, namely manufacturing and services, the labour market, transport, public administration and land use property markets. Real estate markets have to be 'sustainable' as defined in terms of prices being achieved without public subsidy and the ability of the market to sustain itself through downturns in the property cycle (Jones and Watkins, 1996). An additional constraint is an adequate supply of housing for the workforce and their families that can be called an affordability constraint. The upgrading of infrastructure can also viewed as a distinct cost constraint on adapting or shaping the expansion of a city for example through the provision of an efficient transport system.

The precise city form that this formulation of the problem generates is indeterminate as there are too many variables and in any case it lacks a dynamic dimension. The formulation is best seen as a set of guiding principles or economic conditions on making the existing urban form more sustainable.

The Economic Viability of Individual Land Uses

The starting point of the empirical research presented here is that, to make cities more sustainable, policies will need to adapt the existing urban forms. The sustainability of cities will not be driven by economic factors but desired urban forms will need to be subservient to economic viability otherwise market forces will mean they will be not be stable in the long run. A particular focus for the analysis is the viability of land use markets. Urban form, as noted earlier, is primarily determined by the operation of local real estate markets within a framework of transport costs (that determines accessibility relationships) which in turn is dependent on the transport infrastructure. Planning will also shape the market but not alter these fundamental relationships. The research examines different land uses in turn.

Offices

As noted earlier, the very existence of cities is based on agglomeration benefits. Historically the city centre was the preferred or optimum location for office users where these benefits were maximised at the point of greatest accessibility within a city. The nature of these agglomeration economies are a crucial viability constraint on reshaping urban form. It can be argued that over the last half century decentralisation pressures within the urban economy and the property market have been promoted by changes in transport technologies and advances in production and information and communication technologies which have weakened the agglomeration economies of central city locations. The consequence for the city has led to a change in its urban form as the pattern of commercial land use has become more spatially diffused.

Table 7.1 Spatial Pattern of Rateable Values of Offices in the Case Study Cities

Distance band	Edinburgh	Glasgow	Leicester	Oxford	Sheffield
Centre – 3 km	63.1	84.8	69.4	27.6	50.6
3–6 km	16.5	7.1	19.8	24.9	25.0
6–9 km	12.0	6.6	6.6	33.8	15.1
9–12 km	6.9	1.5	1.2	13.4	5.2
12 km +	1.3	0.0	2.9	0.0	4.1

Numbers are percentages of the respective column total

The research problem is that it is difficult to measure these agglomeration benefits. In this study the 'rateable value' of a property is used as an indicator. In the UK commercial and industrial properties are subject to a tax called 'rates'. A rateable value is attributed to each property, broadly defined as its (estimated) market rental value on a given date. In an efficient market the rent of a property is generated from the economic surplus it creates and so the aggregate rateable value of an area is a useful indicator of the agglomeration benefits of locating there. The spatial structure of rateable values for offices within rings from the centre of each of the five cities is given in Table 7.1. The distances applied are based on the actual road network, not "as the crow flies" and are therefore a better representation of true distance from the centre

The spatial patterns show a continuing agglomeration of offices in city centres but the degree of concentration within cities does not vary with city size. Oxford has a very flat dispersed pattern with the 6–9 km band having the highest concentration. At the other extreme Glasgow offices are most focused on the city centre which is partly a reflection of local planning policies. Overall while the city centre remains the dominant location for offices the analysis suggests that the office property market will not constrain different urban forms including decentralised urban systems. Our research also shows that this conclusion applies to the industrial property market too. There is one caveat in that it is probable that the decentralisation of offices is partly the consequence of administration functions moving from city centres.

Retailing

The viability of shops requires a close relationship between the location and catchment of retail centres and the spatial distribution of population, with the latter driving the former. The hierarchy of retailing and associated catchment areas is also driven by transport networks and hence the ease of travel to shop. The viability of individual retailing centres is also based on the expenditure potential of its catchment area. The relationships between urban form and the viability of retailing can be estimated using a 'gravity model'. The basic idea of a gravity model is that a shopping centre exercises a pull on potential customers based on its attractiveness relative to the attractiveness of other shopping centres and how far away they live. A model has been estimated for one of the case study cities, Edinburgh, and provides a

Table 7.2 Changes to Number of Shopping Trips when Density and Size of Retail Centres Change

	Impact of Population Changes on Trip Flows %	Impact of Floorspace Changes on Trip Flows %
–10.0%	–11.4	–16.9
–7.5%	–8.6	–12.8
–5.0%	–5.7	–8.6
–2.5%	–2.9	–4.3
+2.5%	2.9	4.4
+5.0%	5.8	8.9
+7.5%	8.7	13.5
+10%	11.6	18.2

base for exploring the relationship between retailing and various elements of urban form (Orr et al., 2007).

The estimated model is applied to examine how sensitive the level of shopping trips are to changes in the density of residential areas, the size of shopping centres and accessibility relationships. Table 7.2 illustrates the impact of altering the population density in incremental steps on the scale of shopping flows while holding the travel times constant and assuming the number of shopping flows are unconstrained. As can be seen, a rise in the number of residents living within each neighbourhood will yield a higher rise in the number of shopping trips made between all the residential zones and the shopping centres whereas a fall in residential densities will reduce shopping flows. In reality if cities become more densely populated then the growth in some areas will be greater and faster than others and this will result in a more uneven effect on shopping centres. A further caveat is that the growth would also impact on travel times with the greater density resulting in greater travel times, which in turn results in an even greater impact on the shopping centres closer to the neighbourhoods with the greater population rise.

The changes in shopping flows are not the same magnitude for the same sized positive or negative change in density. This is due to the non-linear nature of the model and the existence of exponentials in the gravity model developed. Table 7.2 also illustrates the result of altering the size of the retail centres when the total numbers of shopping trips are not constrained. This reveals that the shopping trip flows are more sensitive to changes in the scale of the retail centres than the density of the population. When travel times are changed in the simulation exercise, the impact is substantially more variable and dependent on the size of shopping centre. Unsurprisingly, residents located in more remote locations are more sensitive to small changes in travel time than more centrally located shoppers.

Commercial and Retail Change

Adapting the provision of retailing and offices to a different urban form is not simply a matter of changing locations. This is illustrated by the changes to these sectors over the last twenty five years of decentralisation pressures within cities of the UK. The consequence for the city has led not only to a changed urban form by influencing the spatial patterns and density of land use but also new property forms such as flexible commercial space usually located in business parks and out of town shopping malls. An analysis by Jones (2010, forthcoming) of the gradual introduction of the new property forms of retail warehouses and office parks that emerged as part of this process demonstrated it took sometime for sustainable markets to develop. The evidence revealed that developers tended to take up these new property forms quickly, and the range of occupiers gradually expanded but financial institutions were slower to embrace them within their property investment portfolios. Changing UK planning policies toward retail warehouses were a particular influence, after initial ambivalence policy switched to restrict their development. This process of establishing investment markets for new property forms is not necessarily a smooth process and in the case of retail warehouses took up to two decades. The analysis suggests that policies to reshape the city form will require a consensual long term public policy framework to ensure confidence for private property investment.

Housing

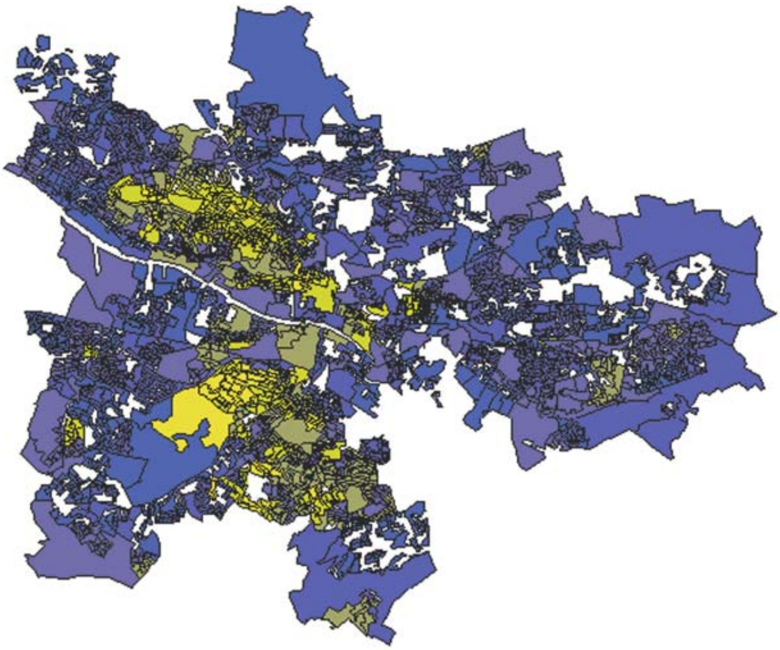
The operation of urban housing markets is the major shaper of city form moderated by the planning system. Simple theoretical models highlight household commuting costs as central to household location decisions, and this gives rise to a house price gradient declining from the city centre. A key influence on a household's choice of location is income (see earlier). This basic model can be adapted by the spatial pattern of social housing and the effectiveness of planning constraints in the form of green belts. Taken together this means that spatial price structures of city housing markets (and hence urban form) are principally determined by the local distribution of income and the affluence of the city, social housing locations, planning constraints such as green belts and the cost and speed of local travel. This theoretical perspective is reinforced by a statistical analysis of the pattern of house prices within the five cities that demonstrates substantial variation between cities.

To examine the potential for adapting a local housing market to a more sustainable form by building more houses/flats for sale the research estimates the spatial patterns of local housing market viability within each of the five cities (Jones et al., 2009). The statistical problem has as its starting point data on individual house prices and data on construction costs for individual development projects. There are four steps to the analysis:

1. Estimate a statistical model of house prices for locations within each city.
2. Estimate a statistical model of construction costs.
3. Combine the two models of price and cost to estimate development 'viability'.
4. Assess the spatial pattern of development 'viability'.

The model of house prices is estimated using multiple regression, a statistical technique that breaks down house prices into its constituent attribute prices. The attributes can be differentiated into housing, location and neighbourhood characteristics including density and are based on data from the Land Registry and the Census. The construction costs model is also estimated using statistical analysis based on data derived from planning applications. The output of these models is used to simulate the development value and costs of standardised new housing projects. Maps of viability within Glasgow and Oxford (the extreme cases) are then constructed and shown in Figures 7.1 and 7.2. Bright yellow represents strong viability and dark blue strong negative viability.

There are a number of striking points that emerge from these maps. First, the absolute level of viability in a city is clearly a function of the affluence of the city, an exogenous factor in the original conceptual framework. Second, the intra-urban



Key – Residual value expressed as a % of gross development value.

- 50 to 80
- 31 to 50
- 10 to 31
- –21 to 10
- –66 to –21
- –161 to –66

Fig. 7.1 Spatial variation in mixed housing/flatted development viability within Glasgow
Source: Jones et al., 2009

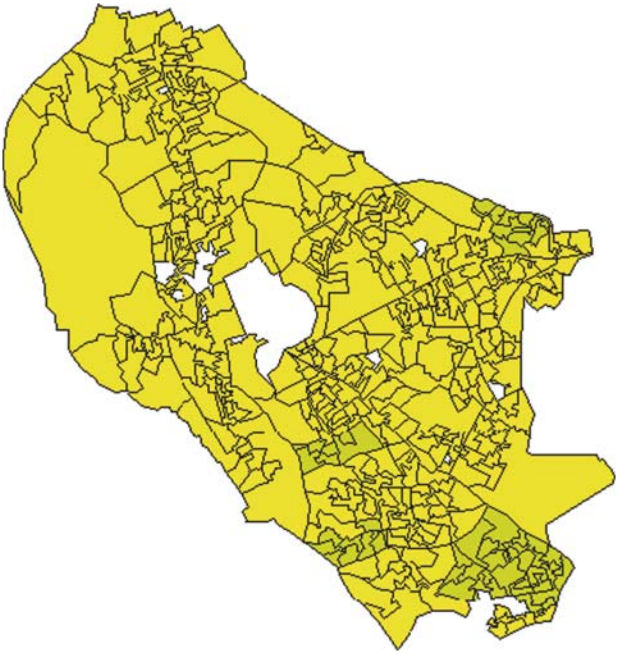


Fig. 7.2 Spatial variation in mixed housing/flatted development viability within Oxford
Source: Jones et al., 2009

patterns of viability are primarily determined by the spatial structure of house prices, which is in turn linked to intra-urban accessibility and the tenure distribution within local neighbourhoods. Neighbourhood density is only a minor influence on viability but this may be partly due to the fact that densities in public sector housing estates are included in the correlation analysis. Densities are also a function of historic development patterns. These conclusions must be tempered by one caveat that while the analysis has abstracted the influence of the role of individual planning permissions the aggregate effect of the tightness of a local planning regime may have an impact on the absolute levels of viability in a city as a whole and in popular submarkets. This effect may contribute to the high levels of viability, for example in Oxford and parts of Glasgow. At the same time a very tight planning regime can constrain housing supply so that there is a serious affordability problem.

The results show a substantial difference between cities that can be attributed not to urban form per se but to socio-economic factors. This demonstrates that in practice it is impossible to divorce the physical structure of cities from their economic and social structure. Viability is also influenced strongly by public policy through the location of social housing and overall planning regime constraints. The research suggests that a major influence/constraint for development viability is the level of neighbourhood house prices. Large swathes of negative viability in some cities are found even without accounting for the additional costs of brownfield development suggesting that there are major constraints to the reconfiguration of housing markets in a piecemeal way.

To examine the underlying influences on these patterns of viability a study of owner occupiers of stated preferences to urban form characteristics in the six case study areas of Glasgow and Edinburgh was undertaken based on a questionnaire survey. Respondents were given a series of paired random ‘choice tasks’ that listed key characteristics of notional neighbourhoods and associated housing and were asked to decide which combination they preferred.

Analysis of the choice task results reveal general preference for low density areas, with the preference for lower density over high density neighbourhoods being stronger for households that already live in suburban areas. Public transport accessibility is important to households but it is not so important that this public transport is within easy walking distance or just within walking distance. It is more important to those already living in city centre locations to have public transport within easy walking distance. Households seem to want amenities to be either just within, or within easy walking distance, but they seem to dislike the idea of amenities not being within walking distance at all. Green space is more important to households currently residing in suburban areas, and also for those in in-between areas, albeit slightly less important. Inner city residents have a less clear pattern of emphasis on the amount of green space.

The household characteristics of the respondents also reveal some interesting findings that could support a household life-cycle element to residential location choice. Younger and non-pensioner single households are more prevalent in the central city areas. The central study areas also have the smallest average household size, with the suburban areas having the largest average number of people in the household. The suburban areas also have the largest proportion of households that consist of a couple with one or more children. Initial findings show that as households grow older and expand, different factors become important in making a residential location choice so that the age structure of a city is an important influence.

Infrastructure Costs and City Form

The adaptation of urban form will be subject to infrastructure cost constraints. There are two types of urban infrastructure costs – social and physical. Social infrastructure costs include education, health, personal social services, environmental, protective and cultural services together with public goods such as police and the fire service. Some of these services are provided simply on a per capita basis. Small area data on these costs are not generally available. Research by Bramley and Evans (2000) of small areas in three local authorities in the UK focuses on the impact of deprivation or concentrations of poverty on increasing costs but also acknowledges other drivers of expenditure such as local population and socio-economic-demographic structure influencing demand and take up of services as well as urban form features. These latter variables comprised population, density, road length per capita, distance from CBD and are generally not significant factors. However, multiple regression analysis finds that density and road length per capita are statistically significant negative and positive influences on cost of providing public goods (keeping other factors constant). Distance to the CBD tends to have a positive effect on different components on social infrastructure costs. However, there is a problem in the interpretation of these variables and Bramley and Evans suggest that these variables approximate to socio-economic/local geographic patterns of social housing influences not included in the model.

Physical infrastructure costs comprise the construction and maintenance of roads, sewers, water, gas, electric and telephone provision. These costs are influenced by local landscape and geology. Costs can also be dependent on the length of the distribution network. Water, for example, has to be transported from treatment plants and hence distribution costs vary geographically with distance from that location. It is useful to set aside these location specific influences as these costs do not vary with urban form and are in effect fixed costs. Similarly while pipe sizes will vary with distance from the treatment plant and density of development the differential costs of pipe size are small relative to the principal cost associated with the physical placement. It is possible therefore to simplify the empirical analysis by ignoring differential component costs. Similar points apply to the other utilities. Variations in physical infrastructure within cities can then be taken as a function of the number of addresses (density) and road length.

Given the discussion above, the empirical analysis here assumes that social infrastructure costs do not vary with urban form and so the focus is only on physical infrastructure costs. The variation in physical infrastructure costs is estimated by applying standard costs per road distance and per address. In this way the research compares the costs to build the physical infrastructure of nine ‘between’ and ‘outer’ case study neighbourhoods in the five cities. The ratios of road length per person to density, as a measure of relative road related infrastructure costs, reveal that broadly doubling density in the Sheffield and Edinburgh case studies results in these costs reducing by more than half and 70% respectively. A 14% reduction in density in Oxford is associated with a more dramatic 62% increase in costs. In Leicester a 40% reduction in density brings a three fold increase in these infrastructure costs. This commentary demonstrates that there is clearly some variation in this inverse relationship and that there are some local influences. Overall Table 7.3 shows while density in the case study areas varies by almost a factor of three, road infrastructure costs per capita controlling for density have a multiple range of 5. In other words road infrastructure costs increase by a higher than proportional rate with falling density.

No allowance is made in the results presented here for differences between flats and houses although some simple sensitivity analysis suggests it would lead to up to a 10% reduction in costs in some areas for electricity connections. The results suggest that while density is a factor influencing infrastructure costs there are clearly additional factors at play for example the lay out of road networks. Nevertheless there is considerable scope for reducing infrastructure costs by higher

Table 7.3 Road Lengths and Densities in Selected Case Study Neighbourhoods

City	Case Study	Persons per Hectare (density)	Road Length per person	Road Length per Person as a ratio of Density (×100)	Infrastructure Costs per Person (£)	Infrastructure Costs per Person as ratio of density
Oxford	between	74	2.0	2.70	6278	85
	outer	64	2.8	4.38	8384	131
Sheffield	between	80	2.4	3.00	7581	95
	outer	43	2.9	6.74	6102	142
Leicester	between	89	2.2	2.47	4955	56
	outer	36	3.5	9.72	8911	248
Edinburgh	between	64	2.3	3.59	6510	102
	outer	31	3.8	12.26	9584	309
Glasgow	between	55	2.5	4.55	6536	119

density development. However, there is some caveats to this conclusion in relation to adapting a city. Much of the road infrastructure and associated services are already in place so greater intensification of land use on brownfield sites it could be argued will only add marginally to costs and if this is instead of development on greenfield sites then the savings are magnified compared to the figures presented. This argument is diluted where infrastructure systems such as water supply and treatment are at full capacity.

Conclusions

This chapter dissects the arguments linking city form and economic sustainability. The fundamental determinants of the elements of urban form are shown to be the outcome of the operation of real estate markets within the city's transport infrastructure and moderated by local planning policies. The housing market as the largest land market and the determinant of population density in particular has a dominant role in urban form and its sustainability. Similarly commercial property market processes determine the spatial distribution of employment. Underpinning the property market are location decisions of firms and households that are based on the associated agglomerations economies and accessibility of individual locations. The spatial structure of cities is also influenced by the wealth, the distribution of incomes and age structures of households through demand influences on the local housing market.

Advocates of high density sustainable cities base their arguments on simple ideas about agglomeration economies and see cities implicitly as almost static phenomenon rather than dynamic entities with spatial land use patterns continuously if gradually changing. More sophisticated models of urban economic sustainability are too abstract to be of practical use. An alternative approach to sustainability that also favours high density cities is the 'smart growth' movement in the USA, but the argument is based narrowly on the high infrastructure costs of sprawl.

It is not clear that the framework of the current debate is fruitful and there is unlikely to be a definitive sustainable economic city form. The approach here is to express the problem as maximising potential urban output or productivity subject to a series of sustainability constraints. These would encompass social, environmental and economic factors. From an economic perspective these constraints include the viability of sectors of the local economy and infrastructure costs. Within the real estate sector this would require an adequate supply of housing for the workforce and their families and sustainable markets. In particular, desired urban forms will need to comprise land use patterns that are economically viable otherwise market forces will mean they will not be stable in the long run. These arguments provide the basis for adapting the existing city form to make it more sustainable.

The empirical research presented suggests some locational flexibility in the commercial and industrial property sectors. While the city centre remains the dominant location for offices and retailing, the analysis suggests that agglomeration economies are no longer focused entirely on central city locations and there are benefits from decentralisation. These patterns suggest that the viability of commercial property market will not constrain different urban forms including decentralised urban systems. However, while decentralised city forms follow market trends it is constrained by higher physical infrastructure costs.

The analysis of the housing market shows that households prefer low density housing and that there appears to be a household life-cycle element to residential location choice. Younger and non-pensioner single households live in the central city areas but move out to suburban locations as they move through the family life cycle. This means that it will be difficult to encourage more concentrated urban forms without significant changes to the underling forces of city housing markets, for example by increasing commuting costs. In addition the patterns of viability in the city housing markets suggest there are major constraints to reshaping local housing markets. To overcome these constraints will require substantial public expenditure costs to engineer a strategic restructuring of price structures. On the other hand in cities such as Oxford, where residential development is severely constrained, it is highly likely that the affordability constraint of sustainability is not being met.

The reshaping of cities will require positive planning policies to achieve a specific more sustainable urban form and must centre on transport infrastructure and redrawing the property market. The need to achieve sustainable local real estate markets means it is essential to understand the operation of these markets. This in turn necessitates developing a policy analysis within a system of functional markets and submarkets and requires the appropriate information systems (Jones, 2002, Jones et al., 2005). The process of adjustment through the establishment of new occupier and investment markets involving new property forms in non-traditional parts of a city is not necessarily a smooth process and can take decades. The analysis suggests that strategies to adapt the city form will require a consensual long term public policy framework to ensure confidence for private property investment. Sustainable land use markets remain a condition of viability.

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Chapter 8
Adapting the City

Hildebrand Frey and Samer Bagaeen

Introduction

The main objectives of this chapter are to develop a theoretical underpinning of and a methodology for urban intensification and regeneration that could help transform currently unsustainable urban areas into sustainable urban neighbourhoods and communities. The key task of the research is accordingly to find ways of translating sustainability into strategic concepts of urban restructuring and regeneration. It is argued that, once this key task has been achieved, the other tasks of dealing with urban growth as well as restructuring inner city and urban fringe areas would follow suit.

The chapter considers first the application of indicators of sustainable development to urban regeneration primarily in the UK. It then considers the dynamic to intensify urban neighbourhoods to meet the growing demand for housing while minimising the ecological footprint of built up areas. This leads on to a discussion of the criteria of sustainable intensification. The subsequent research is presented in three stages:

- The generation of an assessment tool for the systematic measurement and evaluation of levels of (un)sustainability of urban areas with the help of threshold and target values.
- The application of the tool for the assessment of the existing values and deficiencies of selected areas of Glasgow and the formulation of regeneration programmes for these areas based on the discrepancies between their existing values and the threshold and target values developed for the assessment tool.
- The development of two and three-dimensional regeneration models for the selected urban areas and the testing of their achievements and viability.

Finally conclusions are drawn on the practical application and the general approach.

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Emergence of Indicators of Sustainable Development

The publication of Agenda 21 at the Earth Summit at Rio de Janeiro in 1992 (UN, 1993) was an important milestone with the search for a common approach to the assessment of the sustainability of regions, nations and cities. There is, however, a problem with Agenda 21: the vagueness of its action programmes. Indicators help establish profiles and trends of social, economic and environmental conditions in a region, nation or city. But each indicator is assessed separately and no mechanism is provided to establish the interdependence of indicators and data. Furthermore, no guidelines are given for the interpretation of the collected statistical data; no threshold values or benchmarks are made available against which current performance values of urban areas can be assessed. The interpretation of the 'goodness' or 'badness' of data and the decision what action to take is therefore left to the value judgement of regional, national and local authorities. Most of them cannot be expected to have any specialist knowledge and they have, therefore, to rely on more or less intelligent guesswork. On that basis, the effect of chosen action programmes on the environment is unpredictable: they may achieve environmental improvements, but they may also do significant and potentially irreversible harm to the environment.

It is one of the goals of the research to develop not only lists of parameters but also threshold and target values for each parameter as far as they can be established. These values allow development and regeneration decisions to be based on the systematic measurement of the differences between existing values of urban areas and threshold and target values believed to lead to sustainable urban form.

Current Practice in Urban Regeneration and Development

Many urban regeneration projects use Local Agenda 21 lists of parameters, but very few are based on a thoroughly worked out set of objectives and targets to be achieved. In comparison with other disciplines generating products for public use and consumption, current planning and urban design seem largely to be working towards a 'product' without classifying clearly what kind of performance qualities it ought to have in order to work efficiently and economically for the user and the public at large and protect the environment from damage. Within the current planning approach in the UK these performance qualities are the result of negotiations of planners with developers and, at least sometimes, communities. An alternative is developing a general framework of target values of sustainability of the 'product' first and then discuss it with communities and stakeholders to achieve a commonly agreed set of goals and benchmarks. There may be quite a few projects, specifically those focusing on the improvement of social housing areas, that involve the 'community' (the people living in the area), the client (a housing association or co-operative), the planning system (planning and building control) and the developer and architect in the discussion of the qualities that the urban area under investigation ought to have and this is appreciated. But even then the discussion is rarely based on predefined, generally valid sustainability targets and deals with a fraction of parameters only that are of importance to the community and other stakeholders rather than developing a holistic approach.

Clearly, the frequent outcomes of such projects are accordingly at best uncertain, at worst counterproductive. It was one of the motivations behind this research project to investigate how the expected properties of the 'product' to be generated – an urban settlement or new housing or a new transport system or new community facilities – can best be specified to represent clear rules and target as to what is to be achieved and what the impact of the 'product' on people, the local economy and the environment might be.

Urban renaissance and Sustainable Urban Neighbourhoods

The Urban Task Force (UTF) in the UK, formed in 1998, sought to establish

> . . . a new vision for urban regeneration founded on the principles of design excellence, social well-being and environmental responsibility within a viable economic and legislative framework (UTF, 1999, internal front cover page).

The report's main recommendation is the return to a design-based approach of urban development, but it also calls for the return to the compact city and the review of urban densities to achieve viable local amenities and public transport. These recommendations were to yield a new approach to the planning, design and building of new urban villages and sustainable communities, generated on the basis of sustainability criteria and target values. Of importance was the development of models of urban capacity: the report makes it clear that viable local amenities and public transport stops in urban neighbourhoods require a threshold population of 7,500 people, given a socially mixed community and a minimum density of 100 persons/ha (UTF, 1999). To achieve this, existing urban areas that do not meet this threshold population size need to be intensified.

The UK government implemented the UTF's recommended programme of Millennium Villages and Sustainable Communities and so it is possible to see the direct impact in community pilot projects carried out on the basis of a sustainable development framework. This provides governments and researchers with a rare chance: if monitoring of development and of outcomes is consistent then it might be possible to generate values backed up with the currently missing empirical evidence that their application will lead to sustainable development. Unfortunately, most of the target values employed in these Urban Villages and Sustainable Communities projects are dealing with matters of energy, water management, sustainable materials, emissions reduction and so forth, matters of concern in the design and detailed design stage of a project which in this research had to be excluded due to time and resource limitations. Targets such as a threshold population size for urban neighbourhoods or villages, dwelling densities, socio-economic profiles of urban communities and other characteristics important for the strategic planning and conception stage are sometimes not and frequently not consistently used.

The Implications of the Growing Demand for Additional Housing

A major driver of change is the growing demand for new housing as a consequence of the shrinking size of households in the UK. In 1961, the average household size was 3.1 persons but by 2001 the figure had shrunk to 2.4 (Office for National Statistics, Spring, 2002). The Barker Review estimates that by 2021 an additional 3.8 million new dwellings would be needed to reduce the trend in house prices to the European average and increase the supply of social housing to meet the needs of new households and reduce the backlog of needs (Barker, 2004).

The question that needs to be asked is at what density housing development ought to be built. It is very unlikely that the promoted minimum density of 30 dwellings/ha (DETR, 2000a) would generate the population density required to support local services and facilities; inhabitants would therefore be dependent on amenities elsewhere and on the car to get there. In addition, low-density development would cause a loss of undeveloped land, particularly in the south-east of England were pressure for new dwellings is greatest. The UTF recommended densities of 100 or better 150 people/ha for urban neighbourhoods to achieve fully viable public transport and local amenities, all accessible on foot (UTF, 1999). At the average UK household size of 2.4 persons in 2001, this equates to a development density of 42 to 63 dwellings/ha. The average household size of 2.2 persons used by Barton et al. (2003) would equate to a density of 45 to 68 dwellings/ha, which is considerably over the densities recommended by UK planning guidance. Dwelling density is, however, only one important factor for new housing development. Other planning guidance (DETR, 2000b) suggests that development, including housing development, should be co-ordinated with public transport planning and provision to improve access to, and promote a more intensive use of, public transport.

The need to tie development with accessibility appears to be a well-supported policy in the UK. The government's focus on transport – signalled by Planning Policy Guidance Note 13 (ibid.), and reinforced by its revision (DETR, 2001) – has encouraged developers to put greater emphasis on the accessibility of public transport and greater collaboration between developers, local transport authorities and transport providers. But there is also considerable resistance to the increase of housing densities. According to a government study (ODPM, 2003) a majority of developers had increased the density of housing applications in response to their guidance (DETR, 2000a), but two-thirds of the developers indicated that they had encountered barriers in raising density: local political concerns (73%), spacing standards (61%) and parking standards (59%). Other findings of this study suggested that higher densities tended to be resisted in:

- lower-density suburbs – because they were felt to be inappropriate in terms of design and character;
- weaker market areas – where the policy priority is to increase the number of low-density higher-value dwellings;

- some parts of northern regions – where local authorities sought new development to increase the range of type and size of dwellings, and meet modern housing aspirations.

This resistance reflects arguments enunciated particularly by Breheny (1997) that market forces lead to low density housing. Nevertheless there are also urban intensification arguments in order to preserve the countryside. This is frequently regarded as a false argument due to the relatively low percentage of land overall in the UK that is developed and the massive land reserves available for further urban development. Only 16.9% of all UK land is developed, whereas 83.1% of the land is undeveloped and used for agriculture, grazing, forests and woodlands and set aside land (Defra, 2006).

There are, however, two important counter environmental and ecological arguments:

- The necessity to preserve as much of the countryside and biologically productive land as possible in order not only to maintain and strengthen biodiversity, but also to be able to use the land for the production of food, wood and materials to become more self-sufficient and reduce as a result the large ecological footprint of our towns and cities;
- The necessity to reduce car use in the city not only to reduce congestion and to give the public streets and squares back to the people but also to reduce fossil fuel consumption and pollution levels causing global warming.

Urban Intensification

Notwithstanding environmental and ecological arguments, it is indisputable that urban areas still require intensification if their population density were to be too low to support local amenities and public transport because (a) this would require their inhabitants to travel elsewhere to work, get their children to school, go shopping, use entertainment and recreation facilities, and because (b) travel would be car dependent and would generate pollution, contributing to global warming and climate change. Many of UK urban and suburban areas fall into that category.

It is also quite obvious that intensification of urban areas does clearly not automatically reduce vehicular traffic unless:

- first, the achievable population size is large enough and is socially sufficiently mixed to support local services and facilities;
- second, the distances between home and local amenities and public transport stops are walkable;
- third, the intensified area is located along an existing public transport route or, if this is not the case, the installation of such a public transport route becomes viable due to the achievable population size.

If intensification does not achieve these three conditions, it will result in an increase of vehicular transport in and out of intensified urban areas as more people live there but, due to the lack of viable public transport, need the car to travel to work and service outlets outside their living area and this will generate more exported traffic and congestion as well as pollution in more central areas. The research here therefore pursues intensification of areas only if located along existing or achievable new public transport corridors and specifically around public transport stops.

In short, the reduction of car-dependent travel is essential but can only be achieved if urban areas have a large enough socially mixed population to support local amenities and public transport. The arguments discussed in this chapter can now be summarised, and form the basis for the development of the rest of the chapter.

- The use of indicators or parameters of sustainable urban development on their own are not effective unless for each of them threshold and target values are formulated, against which development programmes and projects can be gauged.
- Current UK practice of the development of targets in ad-hoc discussions needs to be modified to use predefined target values of sustainable urban development that set a framework for the discussions between local authorities, clients and communities, developers and the planning and design professions. The target values may be prioritised in response to local conditions and constraints so that over- and under-achievements in different urban areas of cities can be balanced, but they should not be ignored.
- The measurable performance values of millennium villages and sustainable communities projects need to be carefully monitored and documented; feedback may well lead to the formulation of target values based on empirical evidence that is currently lacking.
- The need to accommodate a growing number of smaller households and to provide for a population increase makes new housing essential. Higher-density development inside built-up urban as well as rural settlements will help reduce ecological footprints.
- Intensification of urban areas is, however, only sustainable if (a) the areas to be intensified are located at nodes of existing or new viable public transport links and networks, and if (b) the achievable population size and density is high enough and socially sufficiently mixed to support local services and facilities and public transport that can be accessed on foot.

Developing a Tool for the Measurement of Sustainability

The chapter now develops a tool to establish systemically the intensification of urban neighbourhoods (that are seen as currently unsustainable) based on the threshold and target values that are derived from UN, EU and UK government recommendations, research publications and best practice case studies. It is clearly understood that only a few of the values recommended by these sources are supported by empirical evidence, specifically those derived from the evaluation of pilot development schemes, and so are in need of being upgraded as soon as such evidence is made available. There is also an absence of social thresholds. But using no threshold and target values is clearly not the better option as the outcomes of such an approach are at best uncertain, at worst counterproductive.

The research focuses on the planning and conception stages of the regeneration of urban areas. Accordingly, only threshold and target values for indicators of sustainable development relevant to these two stages are derived from available sources and through case studies. The limitation of this research project to strategic issues of the planning and conception stage should not, however, be a problem for potential users of the tool developed here. Issues of design of urban neighbourhoods are covered in considerable detail by a growing number of publications, among them Bentley et al. (1985), Barton et al. (2003) and the English Partnerships (2000) to mention but a few.

The relevant key indicators for the planning and conception stage of urban regeneration are those concerned with the operational, social, and economic viability of urban areas that in turn generate the quality of life of those who live and work there. Therefore the development of threshold and target values cannot only respond to housing needs but has to focus on sustainable communities with their own services and facilities and public transport. The smallest planning entity and building block of the city for which targets are developed is therefore what is usually called an 'urban village' or an 'urban neighbourhood', the equivalent of a small market town. There are three categories of sustainability indicators for which values have to be formulated:

- Urban form characteristics of a sustainable urban neighbourhood
  - Access to the minimum required services and facilities and public transport.
  - The minimum required population size and density to support services and facilities and public transport.
  - The size, area and development density of a walkable urban neighbourhood (walking time and distance from edge to central area).
  - Graded densities from edge to centre of the urban neighbourhood.
  - Graded densities of urban neighbourhoods from edge to central location in a town or city and accessibility of core areas of neighbourhoods, districts, towns and city.
- Characteristics of a socially balanced and inclusive urban neighbourhood
  - A balanced population age profile.
  - A balanced mixture of dwelling and tenure types.
  - A balanced mixture of household types and sizes.
  - A socially balanced population expressing itself in a mixture of levels of qualification of people in working age, the health condition of the population, and indicators of deprivation.

- Economic characteristics of a sustainable urban neighbourhood
  - A balanced range of economically active and inactive people of working age.
  - A balanced range of property prices and rent levels as key to a socially inclusive urban neighbourhood.

The recommended values are listed in Tables 8.1, 8.2, 8.3, and 8.4. It is not possible within the framework of this chapter to make reference to all arguments that support these targets.

As noted above, there seems to be a lack of research publications and government guidance notes on threshold and target value proposals of a sustainable population profile. Although the call for socially inclusive urban neighbourhoods and communities is supported by virtually all political institutions, from the UN to the European Council and the UK governments, this seems to be the one of the concepts of sustainability most difficult to describe, let alone to achieve. Part of the reason is that there are enormous differences in the community profiles of existing conditions in rural and urban areas as well as in post-industrial cities and towns and those that had never seriously industrialised. The social target profile depends much on the current conditions of towns and cities and in turn on historic development factors. Social population target profiles need therefore to be developed on the basis of local conditions. For our research on Glasgow the recommended value profiles are predominantly based on statistical analysis of Scotland and Glasgow averages (Table 8.3).

The target value Tables 8.1, 8.2, 8.3 and 8.4 can be moderated by the prioritisation of characteristics and values. It can be anticipated, that local context conditions and constraints do not always allow target values to be achieved in full. Weights given to characteristics and values allow for the expression of priorities and permit the generation of a compromise solution. The scale of prioritising suggested in the target value tables is a weight from 4 to 1 with 4 expressing that a value is absolutely essential and must be achieved in full, and with 1 expressing that a value is not essential and may be compromised.

Application of the Tool for the Measurement of Levels of (Un)sustainability of Urban Areas

This part of the chapter is a short account of the application of the tool for the measurement of levels of (un)sustainability of urban areas. The process involved the investigation of a considerable number of urban areas located at the edge of the city (all selected suburban areas of the core programme) and in intermediate or inner-city locations (all Glasgow communities north and south of the River Clyde between city centre and Clyde Tunnel). Within the framework of this chapter a full account of this investigation is impossible. Therefore one area is selected to illustrate the application of the developed tool and the potential achievements if threshold and target values are rigorously pursued. The selected case is Drumoyne in Glasgow's Govan area.

Table 8.1 Services and Facilities at Urban Neighbourhood, District, Town and City Cores

Indicator	**Target Distances**	**Target Uses**	Source
Access to amenities at **local hubs** and **neighbourhood**	**150–250 m walk local hubs**	**Primary school** **Doctor** **Corner shop** **Community park**	Urban Task Force (1999), p. 31
	400–600 m walk neighbourhood	**Public house** **Group of shops** **Post office** **Community office** **Community centre** **Access to public transport stop**	
		Connectivity to other neighbourhoods, district, town and city centres and beyond **A permeable street network** **An integrated public transport system**	Research team; Urban Task Force (1999); Barton et al., 2003
Access to **district and town** amenities	**District** **1,500 m** **2,000 m** **2,000 m** **2,000 m** **1,500 m** **2,000 m**	**Secondary school** **District Centre** **Superstore/larger shops** **Leisure Centre** **Playing fields** **Natural green space (outside district)** **Access to public transport node**	Barton et al., 2003, pp. 96–99
	Town **5,000 m** **5,000 m** **5,000 m**	**Health centre** **Library** **Sports centre** **Cultural/entertainment centre** **Higher education** **General hospital** **Access to public transport node**	Urban Task Force (1999), p. 31
Access to **city** amenities	**City, up to 20 km**	**Stadium** **Cathedral** **City Hall** **Key museums** **Major theatre + public facilities** **University** **Regional exhibition centre**	Urban Task Force (1999), p. 31

Table 8.2 Built Form Characteristics of Urban Neighbourhood (NBH)

Indicator	Threshold Value	Target Value	Source/comments
Population	**7,500**	**7,500[1] NBH around district core** **9,000[2] NBH around town core** **10,500[2] NBH around city core**	Urban Task Force Report (1999), p. 61; Research Team
Distance edge to centre	**670 m**	**Best 530 m** **Average 600 m** **Worst 670 m**	Research Team
Total area	**140 ha (100%)**	**Best 88 ha** **Average 113 ha** **Worst 140 ha**	
Size of housing land	**84 ha (60%)**	**Best 53 ha** **Average 68 ha** **Worst 84 ha**	
Size of non-housing land (communal area & space, amenities, workplaces)	**56 ha (40%)**	**Best 35 ha** **Average 45 ha** **Worst 56 ha**	
Size of housing land	**68 ha (60%)**	**53 ha (60%)**	
Gross population density	**53.6 ppha**	**Best 85 ppha (persons/ha)** **Average 66 ppha** **Worst 54 ppha**	
Net population density	**89.3 ppha**	**Best 141 ppha (persons/ha)** **Average 110 ppha** **Worst 89 ppha**	

Table 8.2 (continued)

Indicator	Threshold Value	Target Value	Source/comments
Net dwelling density at 2.1 persons/household	**52 dpha**	**Best 67 dpha (dwellings/ha)** **Average 52 dpha** **Worst 42 dpha**	Glasgow average 2.1 persons per household - needs to be adjusted to local conditions
Graded density of urban quarter edge to centre, near district core		**52 dpha at edge** **67 dpha at intermediate location** **82 dpha at core** **average 67 dpha**	
Graded density of urban quarter edge to centre, near town core		**67 dpha at edge** **82 dpha at intermediate location** **97 dpha at core** **average 82 dpha**	
Graded density of urban quarter edge to centre, near city core		**82 dpha at edge** **97 dpha at intermediate location** **112 dpha at core** **average 97 dpha**	
Connectivity to other neighbourhoods, district, town and city centre and beyond		**A permeable street pattern (no cul-de-sacs, all streets connected)** **An integrated pubic transport system**	

Key:
ha: hectare
pphh: persons per household
dpha: dwellings per hectare
NBH: neighbourhood

Table 8.3 Social Characteristics of Socially Inclusive Urban Neighbourhood

Indicator		Target Value	Source/comments
Population age profile	age 0–15 age 16–64 age 65+	**20% of population** **64% of population** **16% of age profile**	UK and England average; close to Scotland average
Mixture of dwelling types for graded density in neighbourhoods	Close to district core	**32% flats** **68% family homes (with garden)**	
	Close to town/city core	**56% flats** **44% family homes (with garden)**	
Household sizes		**42.0% 1 person households** **29.5% 2 person households** **14.5% 3 person households** **9.5% 4 person households** **4.5% 5+ person households**	Glasgow average suitable for Govan neighbourhood areas
Mixture of tenure types		**39% social housing** **61% owner-occupied housing**	Target is the Glasgow average to achieve an equitable distribution of households in need of social housing provision
Qualification of people in working age 16–74		**42.0% without qualification** **21.0% with level 1 qualification** **13.5% with level 2 qualification** **6.0% with level 3 qualification** **17.0% with level 4 qualification** **Target is also an intensive education and training programme for those without qualifications**	Target is the Glasgow average to achieve an equitable distribution of underperforming people
Other indicators of poverty and deprivation	% of population with LLTI % of population income deprived % of persons in working age claiming benefits SIMD ranking of neighbour-hood population		LLTI = limiting long-term ill-health SIMD = Scottish Index of Multiple Deprivation

Table 8.4 Economic Characteristics of an Urban Neighbourhood

Indicator	**Target Value**	Source
Economically active	**65%**	Scottish average
Economically inactive	**35%**	
A balanced range of property prices as key of social inclusion	**For Glasgow:** **39% social housing** **25% affordable owner-occupied housing** **36% upper market owner-occupied housing**	Survey of property prices in the Govan area of Glasgow, 2006; Glasgow average

The Investigation of the Govan Areas

A preliminary investigation of the Govan areas generates secondary data by using MapInfo, the valuation roll (property taxation register), Census statistics, ArcGIS, and information provided by the city council. Additional primary data on housing conditions, the quality of services and facilities and their location and catchment populations, are collected in a number of area site visits. The data are collated in maps as well as built form, social and economic characteristics sheets. It is not possible to include this material here, but a brief outline of the key characteristics of the four Govan areas is outlined to enable an understanding of the location of Drumoyne in the Govan area, its socio-economic context, and for each of the four areas the current location of services and facilities (marked with green and red circles) (Fig. 8.1).

- Drumoyne, described in more detail below, is one of the four potential neighbourhood areas of Govan, located to the west of Govan Centre and the Helen Street Industrial corridor (compare Fig. 8.1)
- Govan Centre is an area of considerable historical importance and acts as a town centre. Its housing area is, however just a fraction of what is should be, and so is the population, which also shows high levels of deprivation. Most of the local services and facilities, including a shopping centre, are centrally located and access is even. Expansion is hampered by the river north and industry south and is only achievable through relocation of some of that industry and the redevelopment of part of the river front area.
- Ibrox to the east of the central north-south industrial Helen Street Corridor has a fairly deprived population slightly below the threshold value of one neighbourhood but an area almost twice as large as the equivalent target value. However, much of the area accommodates industrial and sports uses and large-scale relocation is not a viable option. There is, however, a good chance of developing one target size neighbourhood. With a few exceptions, local services and facilities are dispersed or located at the edge and access is uneven.

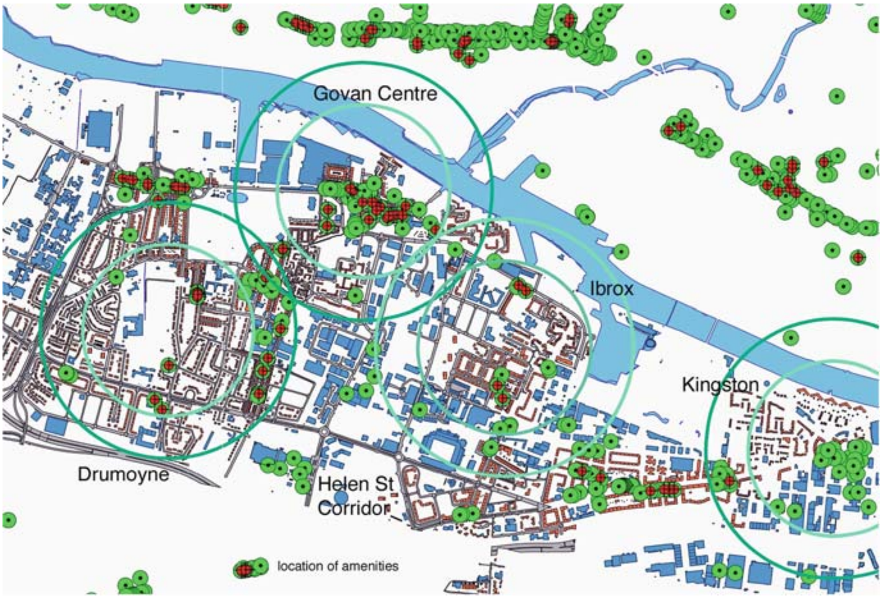

Fig. 8.1 Glasgow's central River Clyde Corridor and the urban areas investigated

- Kingston is, of all the Govan areas, the one with the best socio-economic profile and the most consistent higher-density tenemental development, but half of the area is occupied by industry the relocation of which is not a viable option. Due to the high quality and density of development and the reasonably good population profile there is no chance and no need to remodel the area.

It is clear that with regard to threshold and target values there are serious problems in all Govan areas but Kingston. There are, however, also problems with the built form and the land uses in the Govan areas (compare Fig. 8.1): a considerable incoherence of development form and structure; a very high percentage of the land used for industry that fragments the existing housing areas and potential neighbourhoods; a fragmented street network in Govan's central area, specifically the Helen Street Industrial Corridor, that results in the areas west and east of the industrial corridor to be completely disconnected except for an east-west road north and south at a distance of 1,000m, with the industry in between as an impermeable barrier; a lack of pedestrian and vehicular links from Govan to areas north of the River Clyde, specifically in the central and western areas of Govan, which contributes to the isolation of Govan from the areas of Glasgow's west end and to the socio-economic divide of the well-to-do north and the marginalised south of the river.

Investigation also shows that much of the land along the river – at Govan Centre and the areas west of it – is industrial or disused industrial land that has a considerable potential from new mixed-use development. Except for the 1960s housing estate immediately east of Govan Centre, the river front areas further east are already developed or under development – like the area east of Prince's Dock with the Science Museum, the BBC and ITV Television companies, new executive housing and a new bridge across the Clyde – or is earmarked for development – like the Graving Docks west of Prince's Dock for which a high-density housing scheme has been proposed. It seems a pity that, with the exception of the Govan Centre area itself for which a masterplan has been developed, the potential reuse of other river front areas west of the Graving Docks is not yet investigated.

The key objectives for the overall Govan area are formulated on the basis of this investigation: (a) to remodel all areas such that their potential value profiles are as close to the threshold and target values, (b) to develop all neighbourhoods with their own central services and facilities to achieve even access on foot, and (c) to link all neighbourhood centres with each other by public transport and connect the Drumoyne and Govan Centre areas across the river with Glasgow's west end neighbourhoods.

Detailed Investigation of the Drumoyne Area

Of all areas, Drumoyne to the west (compare Fig. 8.1) shows the most continuous development of housing, but most of it at rather low densities. With 8,240 inhabitants in 2001, the population size is above the threshold value of one neighbourhood, but the total area (excluding the Southern General Hospital area) of 157 ha is almost twice as large as the target areas of two best scenario neighbourhoods with 88 ha each, and this results in a net density of 39 dwellings/ha which is way below the threshold value of 67 dwellings/ha. There is reasonably good access to public transport to the north of the neighbourhood where also most services and facilities are located, but for the southern parts access on foot is difficult. The centre of Drumoyne, where amenities would best be located to achieve even access, is a void: a large secondary school and playing fields and a run-down park have little to offer the local population. But the potential of this area to form a new neighbourhood centre is high. The most problematic characteristic of Drumoyne is the very high level of deprivation.

Table 8.5 shows that Drumoyne's overall area of 157 ha is 65 ha above one best scenario neighbourhood (7,500 people, 88 ha area, 67 dwellings/ha) and 19 ha short of two best scenario neighbourhoods. It is therefore suggested that two neighbourhoods should be formed, one with its centre at the secondary school south of Pirie Park (with an area of about 9 ha) and one with its centre at Govan Road to the north where many shops and community facilities are located but currently struggle for survival. The waterfront area immediately east of the Clyde Tunnel (with and area of about 14 ha) is largely disused and offers the potential of expanding the northern neighbourhood towards the river. The use of Pirie Park and the waterfront area generate 23 additional hectares and a sufficiently large total land area for two neighbourhoods. To that end the number of dwellings, at 2001 level a total of 4,076, has to be extended by a little more than 3,000 new dwellings, around 700 of which

Table 8.5 Potential Achievements of Remodelling Drumoyne

Land	Option	Dwellings	Population at 2.1 pphh
Available land **157 ha**	**For 1 NBH** area is 17 ha over worst scenario **For 2 NBHs** area is 19 ha short of best scenario (see Table 8.2) Land available for new build: • Pirie Park 9.27 ha • Waterfront east of tunnel 13.94 ha	Existing dwellings **4,076**	Existing population **8,240**
Total land needed **176 ha** Add. land required **+19 ha**	**Choice: 2 NBHs** at 7,500 population each	Needed dwellings **7,143** Needed added dwellings **+3,067**	Needed population **15,000** Needed added population **+6,740**
Pirie Park 9.27 ha	Developed at 82 dpha (NBH core area graded density)	Added dwellings +760	
Riverfront 13.94 ha	Developed at 112 dpha (City core area graded density)	Added dwellings +1,561	
Total gain 23.21 ha	**2 intensified NBHs**	**Total dwelling gain +2,321** **Shortfall –991**	
	Options to overcome shortfall: • (a) replace poor quality housing with higher density new build, develop gap sites, reuse disused buildings • (b) develop riverfront area at 127 dpha to gain 209 additional new dwellings and reduce shortfall to 782 dwellings and use options under (a) to overcome the shortfall		

Key:
ha: hectare
pphh: persons per household
dpha: dwellings per hectare
NBH: neighbourhood

can be built on Pirie Park and around 2,000 on the riverfront site; the rest of new housing will be achieved by developing gap sites, disused plots of land and by replacement of poor quality and largely unused housing.

In 2001, 50% of the 4,076 existing dwellings are social-rented; roughly 50% are private-rented and owner-occupied. To accommodate two neighbourhoods with a population of 7,500 each requires, at 2.1 persons/household (Glasgow average), a total number of about 7,140 dwellings, which means that 3,060 new dwellings have to be build. To achieve an overall target percentage of 39% social-rented dwellings and 61% owner-occupied and private-rented dwellings (the Glasgow average), of the new dwellings 750 should be social-rented, 2,320 should be owner-occupied and private-rented of which 580 dwellings (25%) should be affordable housing. This would seriously improve the socio-economic profile of the population of both Drumoyne neighbourhoods (Fig. 8.2), specifically if the building of private sector housing to the magnitude as indicated above would be supported by substantial training and education programmes to get currently long-term economically inactive people back to work. This account clearly demonstrates how strongly threshold and target values guide regeneration briefs and how the potential outcome of regeneration will make a substantial contribution to the formation of two sustainable neighbourhoods.

The detailed investigation of the Govan areas shows that it is possible to achieve two best scenario neighbourhoods in the Drumoyne area, expand Govan Centre to

Fig. 8.2 Computer model of the Drumoyne neighbourhoods as existing and proposed

become a full-size best scenario urban quarter, and restructure the Ibrox area to become a best scenario neighbourhood as well. In addition, two new neighbourhood centres became possible, one in Drumoyne South, one in Ibrox; furthermore the core areas of Drumoyne North and that the Govan Centre area have the potential of being greatly reinforced by enlarging areas and catchment population. This would be a considerable step towards the sustainability of Govan at large, because all neighbourhoods would have their own amenities in walking distance from peoples' front doors but also because these centres would be directly linked by public transport. It has not, however, possible to establish the response of local communities and stakeholders to the proposed restructuring and intensification of the Govan areas and to develop a commonly agreed compromise solution.

One last observation can be made regarding the economic viability of housing development of the scale proposed for Glasgow's Govan area and the question whether there would be opposition by the local communities to generate more social integration and improve the socio-economic profile of the existing communities by suggesting a substantial increase of owner-occupied housing in the area. In Govan there is a good mixture of tenure and dwelling types as well as of old and new build. According to the Register of Sasines for sale in 2006 and the Glasgow City Council 2006 Land Audit, property prices ranged from £3,615 for a first floor flat to £309,995 for a new build sixth floor property at the Garden Festival development. The most expensive property outside the Garden Festival Park development was a second hand non-flatted property that sold for £200,000. Only five years back such high prices in Govan would have been unthinkable. It seems that new development at riverfront locations has wetted the appetite of developers to push further south into Govan areas. Our proposal to link the riverfront development with the neighbourhood centres might therefore have unknowingly followed a trend that seems to have started. This for us has changed our rather pessimistic view on the potential to regenerate Govan's areas at the beginning of the project. If explored with some rigour, this trend would be for Govan perhaps an important lifeline.

Conclusions

As stated at the beginning of this chapter, the main objectives of the research project summarised here were to develop a theoretical underpinning of, and a methodology for, urban intensification that could help transform currently unsustainable urban areas into sustainable urban neighbourhoods and communities. To achieve these objectives, the project develops target and threshold values of sustainable urban settlements and thereby generates a tool to offer important guidance for the development of regeneration and intensification programmes. These values and tool are then rigorously applied to a number of case studies not to generate specific regeneration programmes for particular urban settlements, but to evaluate the potential impact of the established threshold and target values on the form, spatial organisation and structure and the socio-economic profiles of interconnected and integrated neighbourhoods and districts. The exercise has sought to establish the general significance and effectiveness of the tool. The case study tests helped formulate a number of important conclusions rather clearly:

- The values on which the tool is based offer strong and systematic guidance regarding the characteristics that urban neighbourhoods and communities, and the spatial, physical and socio-economic networks they form, ought to have in order to become sustainable.
- The case studies clearly demonstrate that it is possible to restructure currently unsustainable urban areas into a series of integrated sustainable neighbourhoods, all with their own amenities in walking distance from peoples' front doors and all with their local centres directly linked by public transport, provided the sustainability values, and the tool based on them, are rigorously applied.
- The case studies furthermore show that it is possible to physically and visually link neighbourhood cores with upmarket flagship development projects, and thus achieve a degree of social and spatial integration of the stronger and weaker members of urban society.
- The case study tests, however, make it clear that to achieve targets can be a somewhat painful process and requires strategic and multilateral thinking and the courage not to compromise too soon. As long as the existing conditions of underperforming urban areas, specifically their social and spatial segregation, are considered untouchable no sustainable solutions to current problems will be achieved.
- Most importantly, if rigorously pursued, as the investigation of the Govan areas of Glasgow demonstrates, the value-based tool is capable not only of helping to restructure in terms of sustainability currently underperforming individual urban areas into sustainable urban neighbourhoods, but also of interconnecting such neighbourhoods to form physically, spatially and socio-economically balanced urban districts, towns and cities.
- The need to think laterally and holistically is an important key message gained from the theoretical and case investigations:
  - Individual urban regeneration projects do not generate a balanced neighbourhood unless they are planned and executed within a planning and design framework for the entire neighbourhood.
  - In turn, individual sustainable neighbourhoods do not generate a balanced town or city unless they are planned and executed within a structuring framework for the entire town and city.
  - It is thus evident that sustainable urban regeneration, restructuring and intensification of urban areas demand urban planners and urban designers to generate not only land-use strategies but also formal, spatial, transportation, social and economic strategies for urban neighbourhoods and districts and for the town, city or even city region at large.

It is accordingly pertinent to understand that, first, the pursuit of sustainability threshold and target values, and the development of urban regeneration programmes for specific urban areas based on them, requires an integrated and coordinated multilateral approach involving not only all stakeholders but also all relevant professional disciplines, and that, second, the generation of such individual programmes requires a town or city-wide framework based on threshold and target values for the town and city at large. Strategic planning and design at urban neighbourhood and district and at town and city level on the basis of a set of threshold and target value, supported by all those involved in and impacted upon by urban development, are thus the precondition for achieving sustainable urban regeneration and development. Local governments as well as professionals and academics dealing with urban regeneration and development need to recognise that they require a much wider range of skills than those they currently have. It is essential to rethink educational, professional and administrative responsibilities and competences and the role of developers, investors, community groups, associations and cooperatives if sustainable urban form and development is to become achievable.

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Chapter 9
Neighbourhood Design and Sustainable Lifestyles

Katie Williams, Carol Dair and Morag Lindsay

Introduction

This chapter attempts to answer a seemingly simple question: do residents of new housing developments, built according to sustainability principles, behave any more sustainably than the population in general? The research takes thirteen 'sustainable' housing (or predominantly housing with some other uses) schemes in the UK and investigates how sustainably their residents behave. We are only interested in sustainable behaviours that are argued, in planning and urban design theory or policy, to be supported or enabled by the physical design of the schemes. We address this task by comparing our findings with those taken from national surveys and the 'core' case study neighbourhoods' survey. We also give evidence from our study (for ease, termed the 'sustainable behaviours' [SB] study) on residents' self-reported links between their behaviours and the design of their developments.

The chapter has the following structure. First we set out our rationale for undertaking the research, based on an argument that the 'behavioural' aspects of sustainable design are both under-researched and contentious. Second, we set out how the research is undertaken. Third we explain, in more detail, how we define sustainable behaviours, and how we derive our hypothesised links between specific behaviours and the design of housing developments. This is undertaken for three key areas of sustainable behaviour related to neighbourhood-scale design:

- residents' home-based sustainable behaviours; including reducing energy and water consumption, recycling and composting waste and supporting wildlife in gardens
- residents' travel behaviour and car ownership
- residents' 'social sustainability' behaviours; such as social participation and the use of local services, businesses and facilities

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We then move to the empirical part of the project. We start by describing the sustainable housing schemes that we study, setting out which sustainable design features are present. Then we present some descriptive data about the sample of residents surveyed partly to explore whether any differences in behaviour can be explained by either socio-economic differences or by the fact that residents in this SB survey might have 'self-selected' to live in the new developments because they are already more sympathetic to a more 'environmentally friendly' way of life. We then present our findings on how the residents' behaviours compare with the population in general in the three categories of behaviour set out above. Finally, we conclude with a discussion of what these analyses can and can not tell us about the extent to which 'sustainable' developments are associated with sustainable lifestyles.

It should be said at the outset that the SB survey was designed to enable further detailed statistical analyses to determine which physical features support specific sustainable behaviours. It is not the purpose of this chapter to present this aspect of the study, but to set out evidence of comparative behaviours and of specific, self-reported, links between actions and design. This is particularly interesting in relation to the core research case studies.

Why Do We Need to Investigate the Effectiveness of New 'Sustainable' Housing Developments?

It is now widely accepted that the ways in which the built environment is planned, constructed and used are unsustainable (Haughton and Hunter, 1994; Williams et al., 2000). For the last twenty years, finding more sustainable ways to develop the built environment has been the focus of much theoretical and practical effort. Alongside changes in strategic spatial planning policy, a number of discrete projects are being built according to sustainability principles (Williams and Lindsay, 2007). We are seeing 'sustainable business parks', 'sustainable holiday villages' and 'sustainable housing schemes'. All of these projects are designed and built with the aim of seeking a balance between environmental, social and economic performance, both now and in the future.

In the UK there are now a number of flagship residential projects that demonstrate some of the latest thinking in sustainable design. Schemes such as the Millennium Village at Greenwich (English Partnerships, 2004) demonstrate recent best practice, and many more like them are being built. These developments contain a number of physical features now commonly associated with sustainable design, such as energy efficient homes, infrastructure to promote walking and cycling, and a range of housing types and sizes. These sorts of schemes are commonly argued to have a number of benefits over 'normal' housing developments, which are often seen as land-rich, car oriented and socially exclusive.

How was the Relationship Between the Built Environment and Sustainable Behaviour Conceptualised?

What all the sustainable schemes described above have in common is an underlying assumption that they will contribute to sustainability in two distinct ways, which we have termed 'technical' and 'behavioural' sustainability (see Fig. 9.1, Williams and Dair, 2007). Technical sustainability means that the technologies, materials or design features used in the development perform effectively and contribute to sustainability in their own right. They fulfil sustainability objectives by virtue of being present in the development, but do not rely for their effectiveness on any specific behaviour by the users of the scheme. For example, using construction materials with low embodied energy ensures environmental benefits without the residents acting in a particular way.

Behavioural sustainability contrasts with technical in that it refers to the sustainable actions of those living, working and enjoying their leisure time in a development. It is argued that some elements of the built environment can enable or support behavioural sustainability (shown as the area of overlap in Fig. 9.1). For example, providing cycle paths and pedestrian routes is argued to encourage people to walk and cycle rather than drive their cars, and providing neighbourhood recycling facilities may encourage people to recycle their household waste. However, these features have no intrinsic sustainability value, unless they are used properly. There are also sustainable behaviours that are not reliant on the physical environment and can be carried out in any given setting (for example, ethical investing, shown in the right hand section in Fig. 9.1).

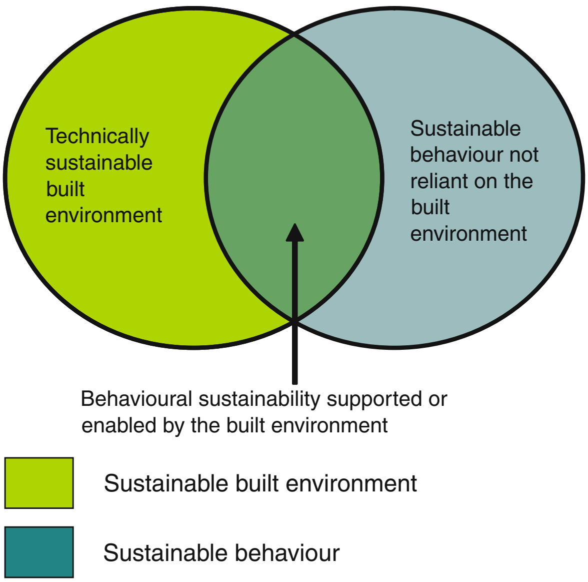

Fig. 9.1 Technical and Behavioural Sustainability and their Relationship with the Built Environment

This chapter concentrates solely on 'behavioural' sustainability supported by the physical environment. We are interested in whether housing schemes built to enable sustainable behaviours actually make any difference to how people act in their daily lives. We recognise that both technical and behavioural aspects of sustainability are important in assessing the success of schemes, but we would argue that the behavioural performance of new 'sustainable' schemes is under-researched (notable exceptions are Lazarus, 2003; Butler, 2004; Mulholland, 2003). Furthermore, where research evidence does exist, it often casts doubt on the extent to which the physical environment can positively affect sustainable behaviour (Breheny 2004; Pett and Guertler, 2004).

Research Methods

The SB survey investigates the extent of sustainable behaviours in thirteen sustainable residential schemes in the UK shown in Fig. 9.2. The developments were chosen to give a spread and range of physical features to be examined. Each development is either solely residential or predominantly housing, with a range of other uses (such as shops, schools etc.). The developments chosen have been occupied for a minimum of two years, to enable behaviour patterns to 'settle'.

In each of the sustainable developments, the behaviour of residents is assessed via a questionnaire, administered to homes, that asks about current actions in a number

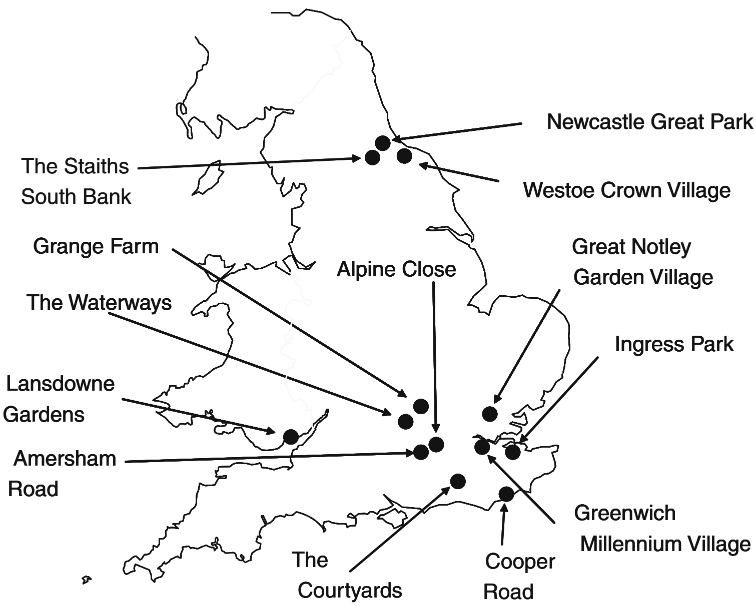

Fig. 9.2 The Case Study Locations

of key areas such as travel and energy use. The questionnaire was administered to all households in smaller developments and a sample in larger ones: 659 completed questionnaires were collected: a response rate of 34%. The physical features of the developments are assessed using a sustainability checklist that lists all the elements that could support sustainable behaviour and, potentially, be provided in a scheme. Researchers completed one checklist for each development by analysing architectural plans and drawings, and undertaking site surveys.

Comparison Surveys

In order to establish if the residents of 'sustainable' schemes are behaving any more sustainably than the population in general, nine comparison surveys are used. These are the core research, and eight national surveys, used as appropriate given their coverage (see DEFRA, 2001, 2007; ONS, 2005; 2006; DfT, 2005; Scottish Executive, 2002; and DCLG, 2005).

Understanding How Sustainable Design Features in Housing Schemes Could Support or Enable Sustainable Behaviour

In order to carry out the research, we had to understand how neighbourhood design is argued to enable sustainable behaviours. We developed a research framework, summarising a number of key hypotheses, by undertaking a literature review which covered planning policy statements, design guidance, and empirical and theoretical material on sustainable design and planning (Williams and Dair, 2007). In order to carry out this review, we needed to define some of the key terms being used in the research.

First, we needed a working definition of 'sustainable behaviour'. The one we adopted is developed from the conceptualisation of sustainability used in the global policy context. This sees three objectives: environmental protection (in terms of reducing resource consumption, waste and pollution); social development (equity and justice); and, more controversially, economic growth, being collective goals of societies. If these goals are to be achieved then people need to behave in certain ways. Hence, 'sustainable behaviours' are behaviours by individuals or groups that contribute to these three sustainability objectives. As a setting for sustainable behaviours, various spatial scales of human activity have been targeted, for example, 'sustainable cities', 'sustainable neighbourhoods' and 'sustainable homes' (Williams et al., 2000; Haughton and Hunter, 1994).

We are interested in behaviours related to (but not bounded by) residential neighbourhood contexts. Behaviours relevant at the neighbourhood scale, which could in some way be enabled or supported by the physical environment are identified. Only those behaviours that could contribute to sustainability in a relatively 'mainstream' built environment are included. We do not include behaviours common only to groups of people with particular philosophies, for example on communal-living or low-tech eco-design. The focus is a built environment that supports a contemporary society and economy, and may require some lifestyle adjustments, but not major cultural or practical changes.

Second, we refine our definition of the ‘physical’ or design features to study. We include any physical feature of the built environment claimed to support sustainable behaviour at a scale from the individual home to the neighbourhood. In terms of home-based technologies we draw a line at features that were included in the building and fitting of a new dwelling. Hence, we include items such as in-house grey water systems and energy-efficient boilers that were installed when the schemes were built, but exclude features subsequently introduced by the residents, such as energy saving light bulbs. Most physical features are relatively easy to identify and quantify: measures were devised for elements such as cycle paths and recycling facilities. However other features are less tangible and some are more qualitative. For example, in the literature, ‘high quality’ designs are commonly associated with behaviours that help to develop social capital (see below), yet defining high quality is subjective and complex (Dempsey, 2007). We study both discrete design features, and also specific ‘qualities’ or ‘levels’ of provision that are claimed to be required for that feature to contribute to sustainable behaviour.

Which Behaviours Did We Study?

As stated above, the study examines behaviours clustered in three key areas: home-based sustainable behaviours, travel behaviour and car ownership, and social sustainability behaviours. These are the behavioural categories that are most commonly cited in literature, policy and design guidance as being affected by neighbourhood-scale design. The next sections of this chapter set out why each is important, and how each is argued to be supported by neighbourhood design.

Home-Based Sustainable Behaviours

Four sustainable behaviours are considered under this category. These are: reducing energy consumption; using water efficiently; recycling and/or composting waste; and supporting wildlife.

Reducing Home Energy Consumption

It is commonly known that UK households need to reduce their energy use in the home to reduce consumption of finite resources, to cut down on pollution and to help reduce fuel costs. Many professions engaged in housing production have looked to residential design to see if and where features can be incorporated into new housing to support residents to reduce their energy consumption. Within homes, energy efficient heating systems can be fitted and residents need to use the systems properly to make savings. For example, they need to time heaters and heating systems to be on only when someone is at home, to set thermostats on heaters and heating systems to the lowest temperature needed to satisfy their comfort needs, to leave empty rooms unheated (or at a low temperature) and to heat only the water they need.

Using Water Efficiently

Reducing the amount of mains water used in the home is an important aspect of sustainable behaviour for several reasons. It conserves scarce water reserves, it limits abstraction and any consequent environmental damage, and it lowers the amount of waste water discharged which in turn helps prevent flooding. In order to enable or support residents to use less water in the home, several physical features can be provided, such as grey water recycling systems, rainwater recycling systems, garden water butts, and dual flush toilets.

Waste Recycling and Composting

Recycling and composting waste are included in the study because they are significant behaviours in terms of environmental impact (DEFRA, 2005a). A number of physical features of new residential schemes are argued to encourage residents to recycle their waste. Within homes, this includes space to sort waste material at source. In multiple occupancy buildings, recycling bins can be provided in shared utility spaces. Refuse chutes can also be provided to deliver segregated waste straight into bins. Within developments, on-site collection facilities can be provided (Barton et al., 2003; Rao et al., 2000). Provision can also be made for composting organic waste, either in private gardens or in shared space for neighbourhood use (Brownhill and Rao, 2002).

Encouraging Wildlife in Gardens

Globally biodiversity is in decline. In the last 200 years more species have become extinct than at any other time in the last 65 million years (TCPA, 2004). Hence, protecting biodiversity is a central aim in seeking a more sustainable future (DEFRA, 2005b). It has been argued that, in urban areas, biodiversity can make a contribution to the quality of life of residents, workers and visitors and add economic value. Residents can encourage wildlife in their gardens by actions such as providing food (although some argue this interferes with eco-systems), providing ‘natural’ habitats such as ponds or ‘undisturbed’ areas, or by using only organic gardening techniques. The physical features in new developments argued to enable householders to do such activities include the provision of private outdoor space in the form of gardens, balconies and roof terraces (TCPA, 2004; Gaston et al., 2003).

Travel Behaviour and Car Ownership

Travel behaviour is one of the most pressing areas of behavioural change required to move society towards a more sustainable future. The predominance of car use, and reduced levels of walking, cycling and public transport usage have created significant environmental and social problems. Here we look at behaviours related to making fewer and shorter journeys using fuel-efficient modes of transport, and car owning.

Making Fewer and Shorter Journeys by Car, and Using More Fuel-Efficient Modes of Transport

Reducing the number and length of trips by fuel inefficient modes of transport (i.e. reducing travel demand, particularly by car) is crucial for a sustainable future as it reduces petrol (and diesel) consumption, and therefore pollutants that affect climate change and air quality. A modal shift away from the car and towards walking, cycling and public transport also has wider benefits: it ensures there are more people 'on the streets' which improves neighbourhood activity and safety, and reduces noise pollution. It also means that public transport services are more likely to be viable. In addition, it could help to improve public health (see DfT, 2004; Transport 2000 Trust, 2003).

Neighbourhood design features claimed to enable residents to make fewer, shorter and less car trips vary in scale and type. At the master planning scale it is argued that high-density developments within existing built up areas can enable most people to live near amenities, facilities and employment and thus reduce the need to travel (DETR, 2000c). Mixed-use developments are advocated for similar reasons (Barton et al., 2003). In addition, the appropriate design of the movement framework is seen as the best way to ensure that car use is limited (DETR, 1998). This means transport networks that are well integrated with the surrounding area, have dedicated, convenient, direct routes for pedestrians and cyclists, and are linked in a grid or deformed grid pattern (rather than a cul-de-sac configuration). They also need to be able to accommodate public transport and offer direct routes to interchanges (DETR and CABE, 2000; Llewelyn-Davies et al., 2000).

Due to the localised nature of short journeys, much importance is attached in design guidance to the detail of the public realm at the neighbourhood scale as a way to encourage walking, cycling and public transport use. A number of elements could contribute to ease of access, legibility, safety and convenience, which are significant in influencing peoples' travel mode choices (Llewelyn-Davies et al., 2000; Civic Trust, 2001; Brownhill and Rao, 2002; Transport 2000 Trust, 2003; DfT, 2003). Such features include signs and maps, adequate seating, and convenient places to park or store a bicycle in homes and at trip ends.

Car Owning

The vast majority of households in the UK (77%) now have access to at least one car. Clearly car ownership and usage rates are related: when people have access to a car, especially if they have invested in buying and maintaining it, they often feel an incentive to use it, rather than use other modes, such as public transport. Designers of new sustainable residential developments have been keen to dissuade residents from owning one or more cars. Overall, the desire is to create places which do not 'feel' car oriented and that are comfortable to walk and cycle around. But, alongside the positive measures set out above to encourage walking, cycling and public transport, there are more punitive attempts to reduce car ownership, such as reducing the amount of parking or providing limited parking space for a pool of shared cars.

Social Sustainability: Social Participation and the Use of Local Services and Facilities

There are elements of neighbourhood design that are argued in policy and literature to be related to social sustainability (see Chapter Five for a fuller discussion). Here we are interested in the simple concepts of social participation (in community groups, for example) and the use of local services and facilities as indicators of social sustainability. We have picked these out for the reasons set out below.

Social Participation

Social participation is seen as the cornerstone for building and maintaining social capital, and in turn social capital is essential to avoid social exclusion (Social Exclusion Unit, 2001). Research findings indicate that people living in communities with high levels of social capital are more likely to benefit from personal well-being, lower crime rates, more empowerment and a higher quality of life than those living in communities where social capital is lacking (Healey and Côté, 2001; Putnam, 2001). Additionally, through positive social interaction, people become more attached to a particular neighbourhood and want to remain there and invest time and energy in maintaining community organisations. In this way, social networks of friends and family are built over time. A sense of 'belonging to' or 'ownership of' a neighbourhood is argued to be a key element in creating sustainable communities (Urban Task Force, 1999).

The relationship between social participation and the physical environment is neither direct nor easy to define, but a number of physical features are argued to support it. An obvious requirement is the presence of community facilities and amenities close to homes (Barton, et al., 2003). In addition, the *quality* of the environment is important (Urban Task Force, 1999; Gehl, 2001). For people to engage with each other they need to feel comfortable and enjoy their neighbourhood. In addition, people need to be able to access space for social interaction easily and efficiently. In this respect the physical features related to the transport behaviours above are also all relevant.

Use of Local Services, Amenities and Businesses

The use of local public services and businesses is argued to support sustainability objectives in a number of ways. First, it supports local economic sustainability: the more people use services, amenities and businesses, the more viable they become, and this in turn creates employment demand. It also supports local supply chains and helps retain money circulating within the local economy for longer periods, with the effect of increasing growth in that area (Dixon and Marston, 2003). There are also benefits in terms of increased vitality of the neighbourhood. There are higher numbers of people in the public realm and this in turn increases feelings of safety and reduces the need for formal security. It also increases opportunities for social interaction and helps guard against isolation and exclusion (Carmona et al., 2001), and makes use of any spare capacity in social provision (DETR, 1998).

As with social participation, the link between using local services, amenities and businesses and the physical environment is not always direct. However, a number of links are commonly made. First, in order to enable people to use local services and businesses, they must be provided nearby. Therefore buildings for services such as surgeries, schools, community centres and commercial activities (e.g. retail and workshops) need to be either provided in new developments, or the developments need to be located near to existing provision. The services and businesses will be more viable if they are located in high density developments with sufficient numbers of people to patronise them. Consideration also needs to be given to accessibility. Hence, the physical features supporting reduced travel demand and supporting the use of public transport, walking and cycling are relevant. High quality urban design, buildings and open spaces are also associated with the regular and frequent use of local facilities (DETR, 2000a and b; Carmona et al., 2001). Research evidence also suggests that the attractiveness of a place has a direct impact on the number of people spending time in an area and using its facilities.

We have now set out the main theoretical and conceptual thinking underpinning the SB study. The next sections of the chapter set out the empirical analysis. We start with a description of the thirteen case study schemes.

The 'Sustainable' Developments

The thirteen 'sustainable' schemes are spread around the UK. The locations are shown in Fig. 9.2. The main characteristics of the developments are set out in Table 9.1. It should be noted that all the information relates to the part of the development that is included within the site boundary for the research (or, in the case of 'uses' in the development or within 500m of the boundary). In some cases this was the whole development, in others part of it.

As Table 9.1 shows, the schemes vary in scale and in the sustainability features they have. Some have almost all features, while others have fewer (in the site survey this information is broken down into a finer grain of measures). This is taken into consideration in the analyses. Another interesting aspect of the schemes is their

Table 9.1 Sustainable Developments in Study

Name of 'Sustainable' development	Grange Farm	Amersham Road	The Waterways	Alpine Close	The Courtyards	Great Notley Garden Village	Greenwich Millennium Village	Ingress Park	Lansdowne Gardens	Newcastle Great Park	Westoe Crown Village	The Staiths South Bank	Cooper Road
General profile data													
No of units	39	172	291	27	104	265	303	216	215	175	122	159	68
Dwellings per hectare (net)	26.0	27.1	42.0	42.0	32.5	28.0	153.0	32.0	38.7	29.1	87.1	55.0	29.9
Total no of uses[1]	1	5	2	2	2	3	5	2	2	2	2	3	1
Uses													
No. parks/play areas	4	5	4	4	0	1	4	4	1	4	6	4	2
No. cafes, pubs, etc	0	2	2	2	0	1	5	4	6	1	9	1	4
No of schools[2]	1	1	6	6	0	3	2	2	4	3	8	2	2
No of local shops	0	1	1	1	0	1	2	2	3	2	2	2	1
Tenure													
% private homes	100	36	87	87	85	89	85	100	75	100	100	100	0
% RSL homes[3]	0	64	13	13	15	11	15	0	25	0	0	0	100
Sustainability features													
% homes + efficient heating systems[4]	100	33	33	33	0	0	33	–[11]	33	0	100	100	33
% homes with sustainable water features	100	26	0	0	64	0	0	0	14	0	0	0	100
% homes with dual flush WCs	100	26	100	100	100	100	100	100	100	100	100	100	100
% homes with recycling	100	100	0	0	64	0	15	100	25	100	0	0	0
Wildlife habitats %[5]	33	33	67	33	33	33	0	33	0	33	0	33	0

Table 9.1 (continued)

Name of 'Sustainable' development	Grange Farm	Amersham Road	The Waterways	Alpine Close	The Courtyards	Great Notley Garden Village	Greenwich Millennium Village	Ingress Park	Lansdowne Gardens	Newcastle Great Park	Westoe Crown Village	The Staiths South Bank	Cooper Road
Quality of development %[6]	89	66	95	89	95	93	95	98	82	91	93	93	89
Quality of routes %[7]	64	61	76	66	71	53	81	63	63	64	68	64	49
Public transport provision %[8]	43	71	43	86	71	57	56	56	57	11	22	33	86
Pedestrian routes %[9]	68	65	85	38	58	50	50	88	10	55	38	88	20
Cycle routes %[10]	100	0	13	0	13	100	33	67	0	13	13	100	0
Average parking standard per home	–	2.00	1.50	1.50	1.50	–	0.75	1.50	1.85	2.00	1.50	1.00	1.94

Notes:
[1] This is simple a count of the number of different uses. Categories were: schools, health facilities, place of worship or community halls, local store (e.g. post office, newsagent or food store), shopping centre or high street, social space (e.g. public house, restaurant, café'), indoor leisure/sports facility, park and public open space. This count is for uses in the development (i.e. within the boundary of the case study area) and nearby (within a 500m radius of the development boundary)
[2] This includes pre-school, primary and secondary in the development or within 500m of the boundary.
[3] RSL: Registered Social Landlord
[4] This is a composite weighted score based on SAP ratings and heating systems ratings.
[5] This is a composite score of three measures in the site survey: the preservation of existing wildlife areas, the creation of new wildlife areas and the management of the wildlife areas
[6] This is a composite weighted score based on assessments of a number of features, e.g.: maintenance, litter, active frontage, building quality, attractiveness, local style and character and quality of public realm
[7] This is a composite weighted score based on assessments of a number of features, e.g.: predominant street pattern, extent of natural surveillance, legibility, active frontage, extent of direct links outside the development, signage and traffic calming
[8] This is a composite weighted score based on, e.g.: number of bus routes, bus lanes, bus stops and distance to public transport interchanges
[9] This is a composite weighted score based on, e.g.: lighting, seating, crossings and direct routes to outside the development
[10] This is a composite weighted score based on, e.g.: quality of cycle paths, number of cycle paths and direct-access routes to outside the development
[11] The '–' indicates missing data (i.e. it was not available for the parts of the developments covered in our case studies)

Fig. 9.3 Millennium Village Greenwich

architectural quality. Some have an ‘eco-aesthetic’, others are more traditionally designed. In addition, the extent to which the schemes are ‘known’ or ‘marketed’ as ‘sustainable’ varies considerably. Developments such as the Millennium Village in Greenwich, are well known for their ‘green’ aspirations, whereas in others, the sustainability elements are conveyed more subtly, or not at all. Figures 9.3, 9.4, 9.5, 9.6, 9.7, 9.8, 9.9, 9.10, and 9.11 give some images of the developments.

Fig. 9.4 Millennium Village Greenwich

Differences Between the Sustainable Behaviours Study and the Comparison Surveys

Before we move on to the results about behaviours, it is useful to comment on our sample of households and how it compares with the comparison surveys. Overall, the SB sample is quite similar to national averages on most key characteristics, such as household type and size, age, and way in which the homes are owned, except that two of our schemes are occupied wholly by tenants of Registered Social Landlords

Fig. 9.5 Amersham Road, Reading

Fig. 9.6 Alpine Close, Maidenhead

(RSLs). As would be expected, people in our sample have lived in their homes for far shorter a time than average: 40% of our sample had lived in the schemes for less than 2 years. This may affect some behaviours, such as social participation, that take time to develop. We also have a moderate over-representation of higher social

Fig. 9.7 Cooper Road, East Sussex

Fig. 9.8 Great Notley, Essex

classes in our sample: 24% higher managerial and professional, compared with a national average of 13%; and 38% lower managerial and professional, compared with 23% nationally. This may have some bearing on the sustainable behaviours as some have been shown in previous studies to be undertaken more by some socio-economic groups than others.

Fig. 9.9 Ingress Park, Kent

Fig. 9.10 Ingress Park, Kent

In terms of variations in urban form or design between the SB study and the samples, clearly our sample has far more sustainability features than either the core study or the national comparisons. There is also a wider range of densities in the core case study neighbourhoods (from 24.5 dph to 270.5 dph) than in the SB sample (26

Fig. 9.11 The Staiths, Gateshead

to 153 dph). The national comparator surveys cover both rural and urban areas, so some differences may be explained by these different contexts. Where data is broken down by area type in comparison surveys, this is mentioned.

Notwithstanding these variations, it should be stressed that it is impossible to control for all socio-economic or urban form variations in this type of research. No samples will ever be identical save one or two key built form variables: comparative built environment research always faces this problem. However, undertaking the comparisons presented here, using carefully selected descriptive data, has value in assessing the question posed at the outset about the relative behaviours of residents in ‘sustainable’ schemes. The inclusion of the self-reported links with the physical environment helps to shed further light on the behaviours.

Residents’ Attitudes Towards, and Knowledge of, Sustainable and Environmental Issues

The first comparative task undertaken is to see if the residents of the SB schemes are more sympathetic to, or knowledgeable of, sustainability issues than the population as a whole. This is to determine any predispositions to behaving sustainably that may not be linked to the physical environment. First, residents were asked if they had heard of the term ‘sustainable development’: 64% of SB respondents had heard of the term, compared with only 32% in the DEFRA survey (2001). The SB study

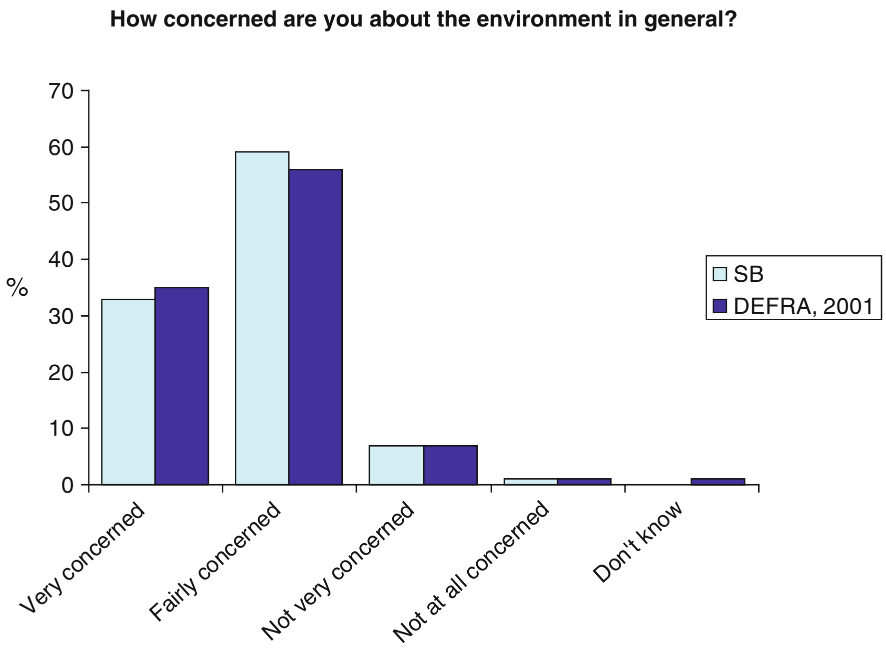

Fig. 9.12 The proportions concerned about the environment in the SB and DEFRA surveys

then asked how concerned residents are about the environment (Fig. 9.12). Here, we found no significant difference between the SB study and the national average. This perhaps suggests that our sample is more knowledgeable, but not more concerned, than the population as a whole.

We also asked our sample if they feel they, or other people, need to change their behaviour so that other people can enjoy a good quality of life and environment in the future (Fig. 9.13). Overall, the SB sample residents have a stronger feeling that both 'themselves' and 'most people' need to change, but both surveys reveal a strong feeling that as well as personal change, other people need to do their bit.

Finally, we asked respondents in the SB study what had been the most important factors when choosing their home (Fig. 9.14). It is interesting that around a third of respondents state that energy and water efficiency was important (34% and 28%), and around 40% state that the quality of the development and of local facilities were factors. One would expect aspects such as size and type of home to be highly rated, but this set of responses shows quite a high degree of conscious prioritising of sustainability features when choosing a new home. Clearly, the high prioritising of parking space (48%) goes against this, but is consistent with most studies of requirements for new housing, particularly in higher social classes.

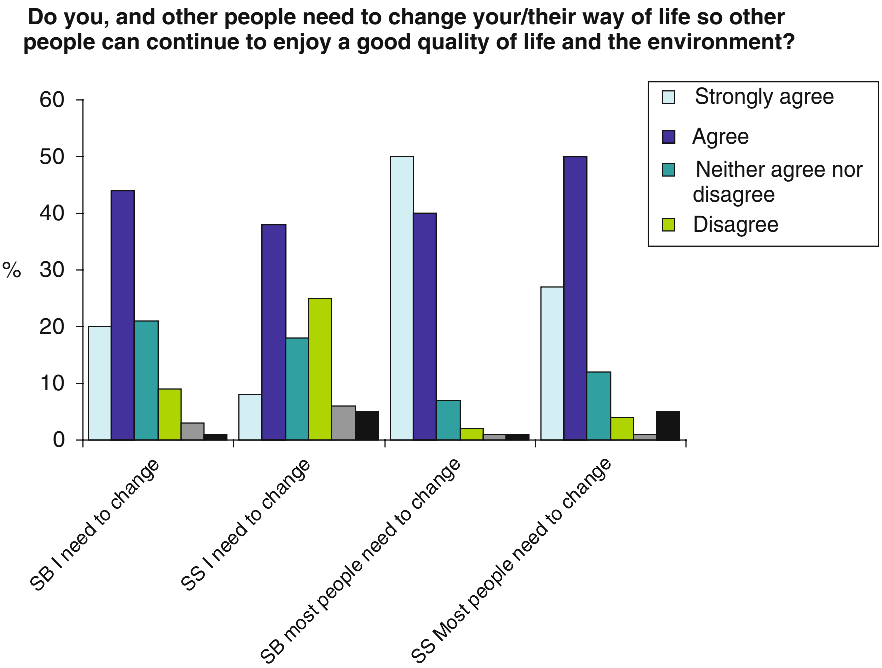

Fig. 9.13 The proportions who see the need for change to improve quality of life and the environment in the SB and DEFRA surveys
Note: SS: Scottish Survey

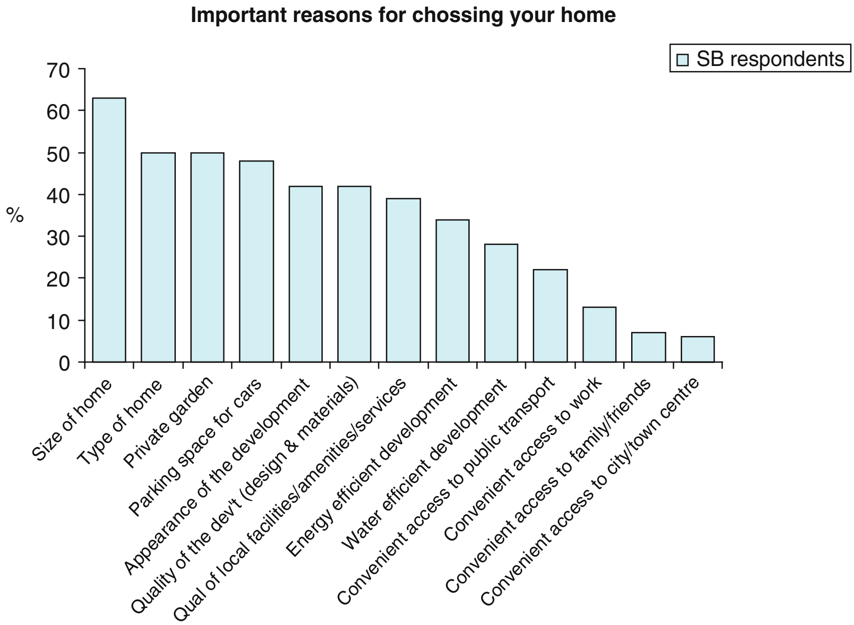

Fig. 9.14 Reasons for choosing a home in sustainable developments

Findings on Sustainable Behaviours

Home Energy Use and Water Efficiency

To see if the SB respondents are efficient in their use of energy and water in the home we asked them about their behaviours in a few precise areas that are also included in national surveys: turning off lights in empty rooms: heating rooms only when they are in them; and taking showers instead of baths. For all three behaviours, the SB sample is significantly more active than the population as a whole, as evidenced by a comparison with the DEFRA Survey 2007 (89% turn off lights, 56% only heat required rooms and 74% shower instead of bathe) (Fig. 9.15).

We then asked the SB sample if living in an energy or water efficient home had made them more cautious about how they used these resources. Figure 9.16 shows the responses only from those who are actually living in energy or water efficient homes in the sample. It shows a positive impact on behaviour, with the majority saying it has made them more cautious about energy (56%) and water use (62%), slightly fewer saying it has made no difference, and only a very small percentage saying they are now less cautious. This indicates a direct impact on behaviour due to the design of homes.

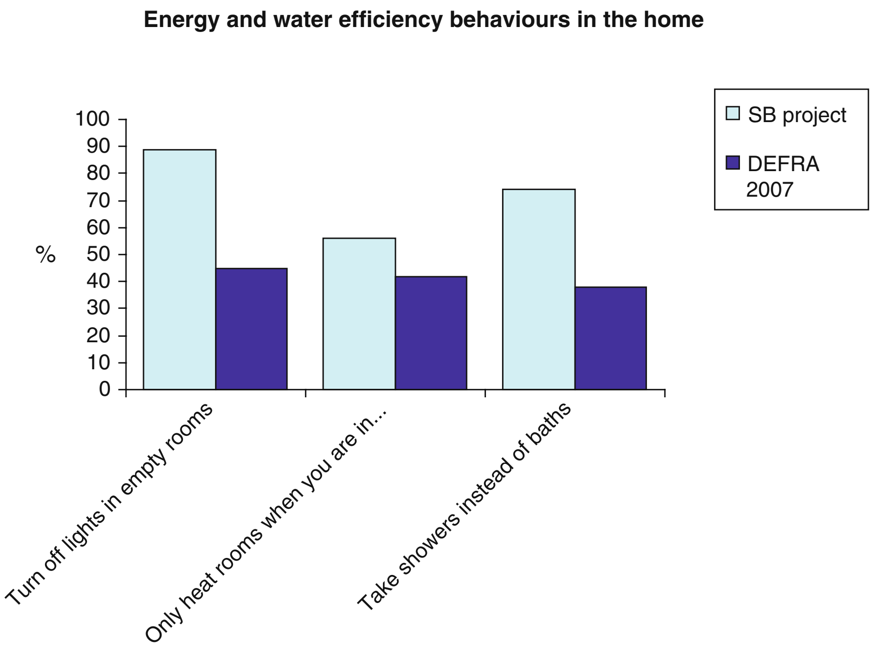

Fig. 9.15 Energy and water efficiency behaviour recorded in the SB and DEFRA Surveys Note: The wording in the DEFRA and SB studies is slightly different, but the data are comparable

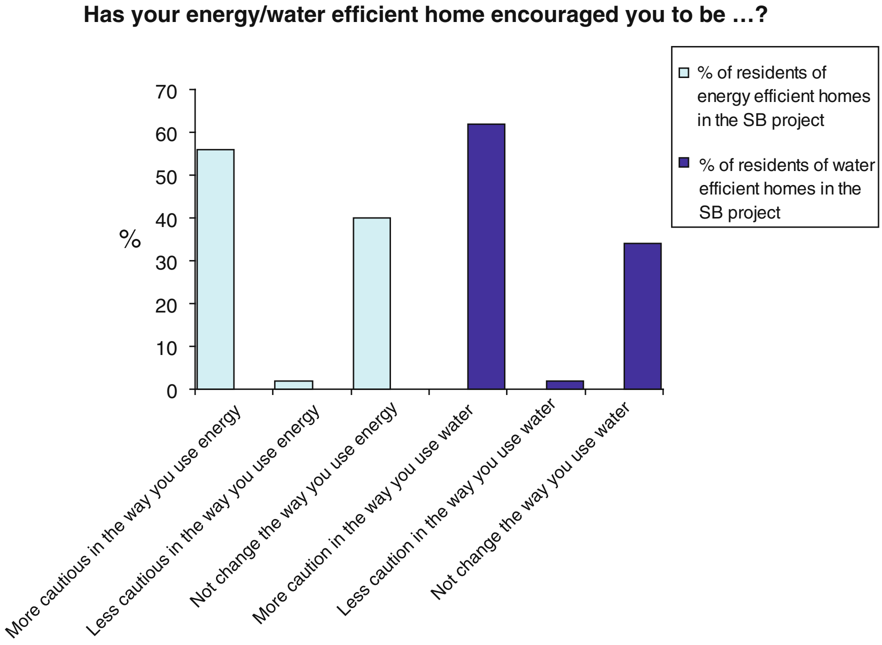

Fig. 9.16 Influence of energy/water efficient home on efficiency behaviour in sustainable developments

Waste Recycling and Composting

We then compared the percentage of the SB study that regularly recycle or compost their waste with national surveys (here we have used the DEFRA surveys from 2001 and 2007 as they illustrate that, in general, these behaviours are becoming more common) (Fig. 9.17). In terms of recycling, the SB study has a higher percentage of recyclers than the 2001 survey, and slightly fewer than the 2007 study. Overall though, almost 79% of SB respondents regularly recycle waste compared with 84% nationally. In terms of composting, the SB study performs less well than both DEFRA surveys. This could be partially due to the fact that composting rates are generally far higher in rural areas (48% compared with an average of 36%), but still does not explain the very low rates. Open-ended responses from the questionnaire suggest reasons for not composting are related to wanting to keep gardens pristine, or not having enough outdoor space.

We asked our sample which recycling facilities they used regularly, to see if local provision of facilities were being utilised (Fig. 9.18). Respondents could tick any facility they used on a regular basis. 55% used kerbside collections, 54% used local facilities, and 37% used facilities in their own homes.

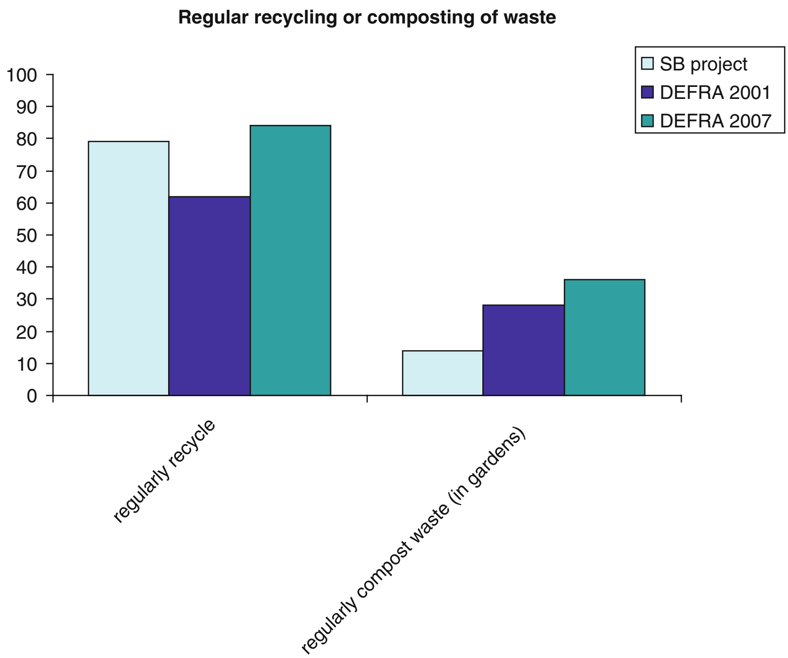

Fig. 9.17 Regular Recycling or Composting of Waste recorded in the SB and DEFRA Surveys Note: The DEFRA data relate to paper recycling only, the SB study does not differentiate

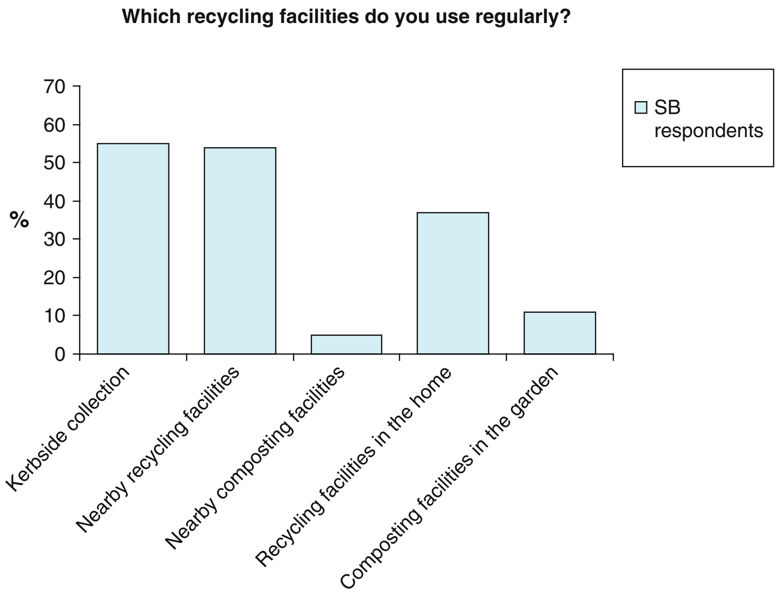

Fig. 9.18 Recycling facilities used regularly in sustainable developments

Encouraging Wildlife

In terms of encouraging wildlife, we compare our findings (Fig. 9.19) with some from the core survey. Interestingly, we find that in the SB study far fewer people provided food for wildlife (30% compared with 52%), and fewer maintained ponds than in the core study (4% compared with 8%). The core data is a useful comparison for this behaviour, because both studies are largely of urban populations, and the data shown here are only for respondents in both surveys that have access to private outdoor space. Reasons given in the SB survey for not providing food or a pond are that people liked their gardens to be tidy, they find wildlife a nuisance, and that they do not have enough space.

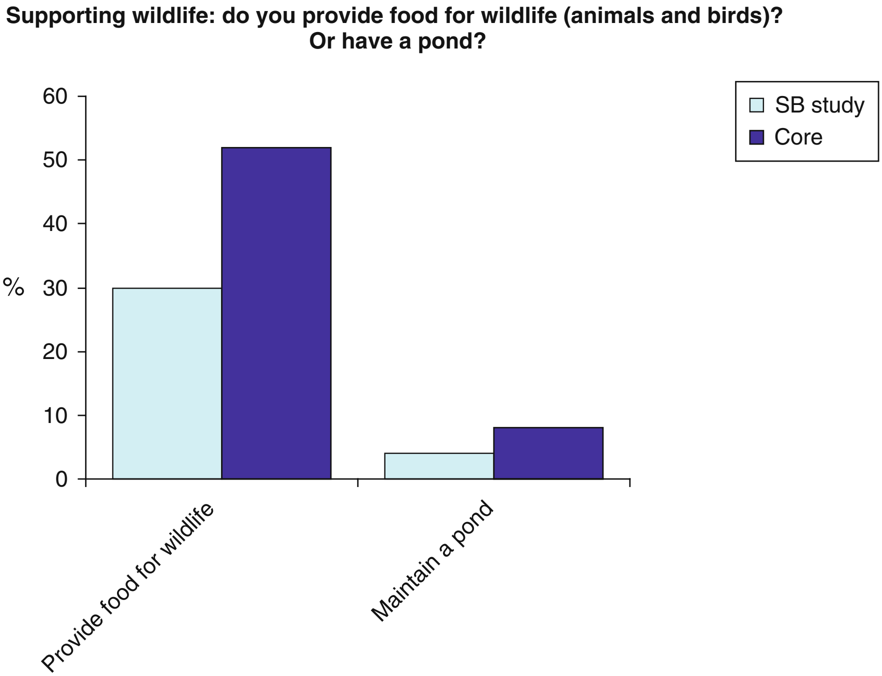

Fig. 9.19 Support for wildlife recorded in the SB and core surveys

Making Fewer and Shorter Journeys by Car, and Using More Fuel-Efficient Modes of Transport

Although, as set out above, numerous claims are made about the travel impacts of new forms of development, it is very difficult to make comparisons because local context is so critical. Hence, here we have chosen the simple measure of

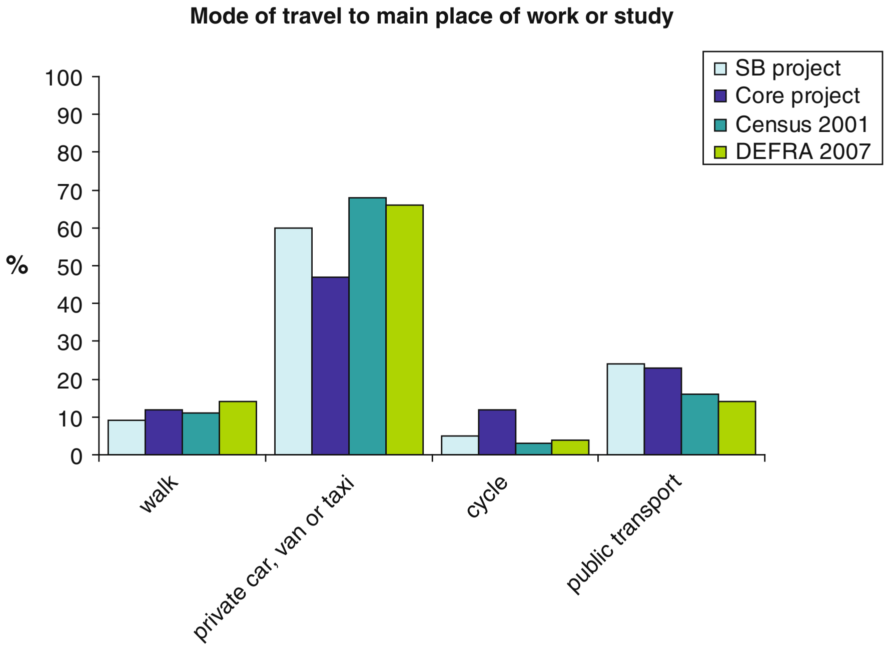

Fig. 9.20 Mode of Travel to Work recorded in the SB, Core, Census and DEFRA Surveys
Note: the DEFRA, 2007 reference makes use of data from the Labour Force Survey (ONS, 2006)

mode of travel to main place of work. Clearly this does not cover travel for non-work uses, nor does it address frequency (which is addressed to some extent below) but it is the most readily comparable measure with wider data sets and is therefore useful. Figure 9.20 shows that fewer people walk to work in the SB study (9%) than in any comparable survey; this is at odds with the theory and policy advice on sustainable housing schemes. Fewer people drive to work than national averages (60% compared with 68% nationally), but more do so than in the core survey. Cycling is also slightly higher than national averages, but less than the core. However, public transport use is higher than all national comparisons and the core survey (24%), signifying perhaps some success in integrating public transport facilities. But, it should be noted that this result is slightly skewed by large numbers of respondents at Greenwich Millennium Village using the tube and bus services.

We asked the respondents who regularly walked, cycled or used public transport (for any trips, not just work) whether any of the common design aspects thought to encourage these modes of travel were important in their choices. We also asked them about non-design related public transport provision such as frequency of services. Just under 40% of people said that convenient pedestrian routes, well lit routes, and direct routes to local facilities were important (Fig. 9.21). The most commonly cited influence was the frequency of regular bus services (45%). We have to remember

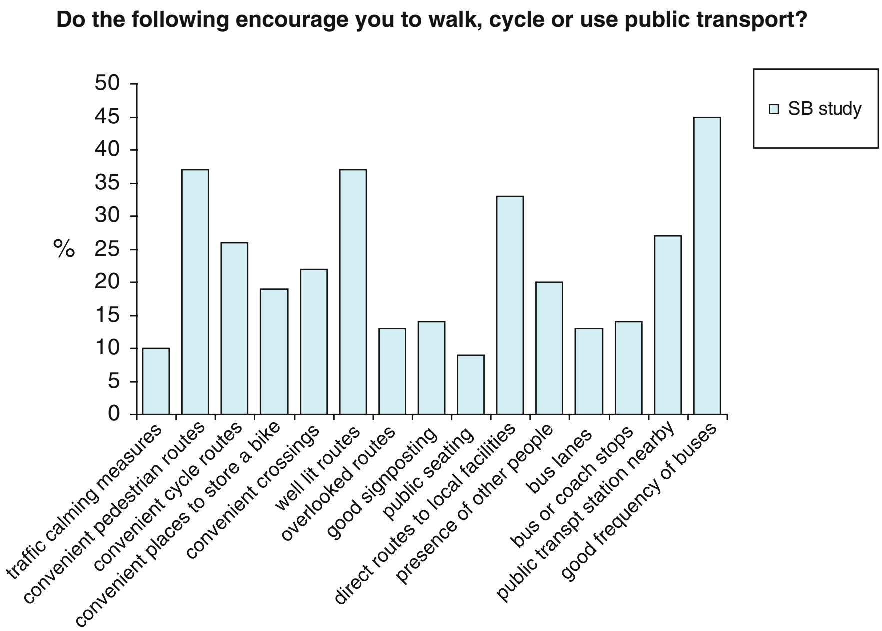

Fig. 9.21 Factors that encourage People to Walk, Cycle or Use Public Transport

for this chart though, that not all the features listed are present in all schemes, so the relative benefit may actually be higher.

Car Owning

We asked SB respondents how many cars they had access to. The hypothesis is that the SB study residents will own fewer cars than the population as a whole. In contrast to this, our sample had the lowest percentage of car-free households in any of the surveys (13% compared with 32% in the core survey) (Fig. 9.22). The SB survey also had the highest percentages owning one and two cars. This result could be explained partially by the proportion of higher social classes in the study, who tend to own more cars, but considering the mainly urban locations and the limited parking, this is an unexpected result.

We asked those in the SB study who did not have access to a car if any of the 'stick' or 'carrot' measures designed to discourage car ownership had been important in their decision. We found that these measures had a negligible impact (Fig. 9.23). A lack of parking was hardly ever reported as a disincentive (5%), even though many of our schemes have limited allocations by recent standards. Positive 'carrots' such as good public transport facilities were only seen as important by 13% of the population. However, it may be that as most of our schemes had at least one parking space per household, the question would have been more revealing if it had asked about owning more than one car.

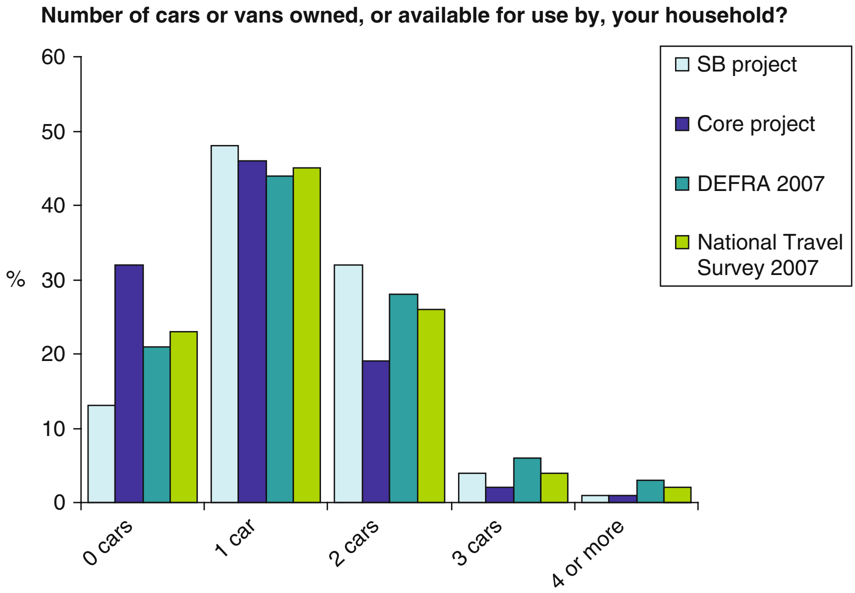

Fig. 9.22 Number of Cars owned/available recorded in the SB, Core, National Travel and DEFRA Surveys

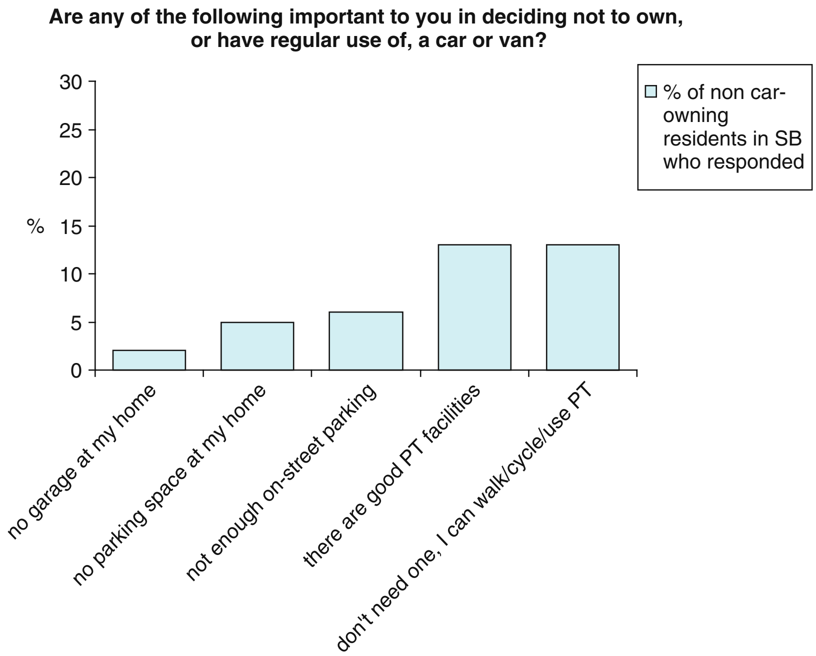

Fig. 9.23 Factors influencing Car ownership

Social Participation

As explained above, social participation is a complex concept. Here, we have chosen a simple measure of 'participation in local community or neighbourhood groups' as an indicator. This leaves out any measure of individualised and less formal social participation. The SB study results for participation are very similarly to those in the core study: the numbers involved are very low, with only 10% of respondents in the SB survey, and 13% in the core survey regularly taking part. Whilst there is no direct national comparator, the DEFRA 2007 survey records that half of the population (50%) had been involved in a social activity in their local area in the two weeks previous to the survey. This count allows for a wider definition of social activity, and does not directly imply 'regular' participation, but the percentage still seems significantly higher than the core and SB survey to raise the question of whether these rates are particularly low.

Use of Local Services

As with social participation, use of local services and facilities is a particularly difficult behaviour to measure meaningfully in a comparative context, as so much relies on the extent and provision of services. Hence, we have chosen to look not at absolute numbers of trips to facilities, but at the most commonly recorded frequencies of use to see if the SB residents use local facilities more frequently than

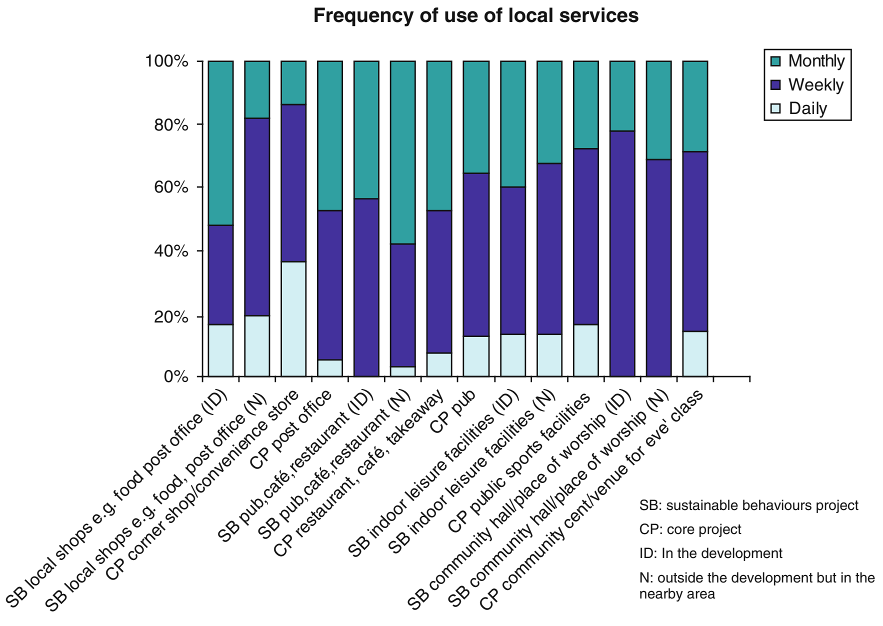

Fig. 9.24 Use of local services

those in the core survey. SB residents were asked about their use of facilities both 'in' their development, and 'outside their development but in the nearby area'. This distinction is obviously not relevant for the core sample, hence the differentiation is not made. Also, some of the categories of facilities are framed slightly differently in the two surveys. Hence, the data shown is presented exactly as it was collected from the respective surveys.

The facility that is most commonly used on a daily basis is the corner shop/convenience store in the core survey (Fig. 9.24). The local shops in the SB survey both inside the development and nearby are the next most commonly used on a daily and weekly basis. Community and sports facilities are also used relatively regularly (weekly) with cafes, pubs etc. used less frequently.

Conclusions

We began this chapter by asking the seemingly simple question: do residents of new housing developments, built according to sustainability principles, behave any more sustainably than the population in general? We have answered this by looking at key sustainable behaviours identified in policy and literature as being linked to neighbourhood scale design. This has been done through the use of descriptive data from the SB survey and comparable national surveys.

Overall, our answers are mixed, but more negative than positive. The residents of the 'sustainable' schemes only seem to behave more sustainably than the rest of the population in home-based resource efficiency behaviours, such as water and energy use. Results for recycling and frequency of use of local facilities are about the same as national comparisons. For most other behaviours, such as travel to work by car, owning (or having access to) a car, social participation, encouraging wildlife, and composting they behave less sustainably than the population in general. For around a third of residents energy and water efficiency is important in choosing their home, and many feel that living in a more sustainable house has either affected their resource consumption behaviour positively, or at least not changed it. Just under half of residents who regularly walked, cycled and used public transport feel supported in doing so by elements of neighbourhood design, but hardly any are dissuaded from owning a car. What we see, in general, are residents who are more knowledgeable about sustainability issues than the general population, but not necessarily more concerned or 'active'. However, as with all research of this type, the devil is in the detail and these results need further unpacking to give a more critical picture.

First, we need to consider the fact that these settlements are all new. As we stated above, many residents have only recently moved to them. This may have an impact on certain behaviours in comparison with more established places (unfortunately no comparable studies of 'normal' new developments exist). Behaviours related to social participation, for example, traditionally develop over time. Similarly, we find that behaviours like outdoor composting and encouraging wildlife in gardens are often unpopular because people feel their gardens are 'new and pristine' and want to keep them like this. Many also said they do not have enough space in the new development: a consequence of higher density policies.

Second, not all the case studies have all the sustainability features (or only have them in small degrees), so in some cases it could be seen as ‘unfair’ to judge the case study in terms of consequential behaviours. Where appropriate in the analysis we present results via subsets (for example by selecting samples only of energy and water efficient homes), but in some instances this has not been undertaken as we are attempting a general comparison at this stage. To a certain extent we are interested in the totality of sustainable behaviours and also the extent to which they ‘add up’ to form sustainable lifestyles in these new settlements.

Third, as has been mentioned throughout the analysis, the SB survey does not have a representative social profile: it has higher proportions of managerial/professional residents than would be expected. This could be affecting the results: some negatively, for example, for issues like car ownership where we would expect higher rates, yet we would also expect higher rates of, for example, recycling and energy efficiency, but these results are more mixed. We should also say that in the case studies that were populated by RSL tenants some differences in both opinions and behaviours could be noted and these also require further analysis.

This comparative research has proved useful in setting our results alongside national data, but we are now undertaking further statistical analysis to examine in detail the relationships between the specific behaviours and individual elements of physical design to determine if any relationships exist at this level, and what the nature of these relationships may be. During this analysis we will test for the impact of socio-economic and other contextual variables, and examine additional behaviours, such as travel for other uses.

As a footnote, it is interesting to stand back from this research and contemplate the value of trying to build housing schemes to support sustainable lifestyles at the present time. Although evidence of sustainable behaviours does not seem strong at present in the SB survey, it could be argued that the real benefit of the schemes studied is that they provide built environments that *can* support more sustainable lifestyles if and when people are ready to take them up. Increases in fuel costs, for example, see people reduce their car use and start walking, cycling and using public transport instead. The SB schemes allow residents to make this transition easily, unlike many ‘normal’ schemes where residents are locked into car use. It would be interesting to revisit these schemes in ten years.

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Chapter 10
Ecological and Psychological Value of Urban Green Space

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Introduction

In urban environments, perhaps more so than in any other setting, people and nature must coexist in close, and sometimes uncomfortable, proximity. With half of the world's human population living in cities and a continued decline of biodiversity in the wider landscape, urban nature plays an increasingly important role in creating cities that are both ecologically and socially sustainable. However, understanding the value of urban green spaces as a resource requires an integration of several, rarely overlapping, approaches to evaluating and managing these places.

Ecologically, urban green spaces form significant components of regional and national biodiversity conservation networks. However, few urban ecologists have explicitly studied human interactions with biodiversity which hampers a full understanding of urban ecosystems in two important ways. First, many urban biodiversity patterns arise in response to, and are maintained specifically by, repeated human activity. Therefore, understanding urban ecosystems must entail knowledge of human motivations and responses in relation to biodiversity. Second, human interventions not only degrade but can also improve urban ecosystems. The progress of conservation efforts in cities frequently depends on decisions made by individual householders, yet ecologists often lack the tools to engage with human communities to understand and encourage their involvement.

From a social-psychological perspective urban nature is an important component of quality of life for urban residents. Researchers have generally focused on benefits gained from "nearby nature", often measured as proximity to or amount of green space, or even a window view. The biological components as typically measured by ecologists (e.g. species richness, vegetation characteristics) are often subsumed into a single entity, such as the "greenness" of the urban landscape. However, all green space is clearly not equal, and there is emerging evidence that treating it as such will mask important responses by people to specific components of biodiversity.

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Also, other, more direct human interactions with urban biodiversity have received scant attention, such as wildlife gardening, feeding wild birds, damage to habitats and disturbance to wildlife. Whether properties of the natural environment itself can influence the strength of these interactions is unknown. To more fully integrate urban green space into human well-being requires an understanding of the biological form and function in these spaces.

The literatures on urban green spaces rarely cite one another, and there are few examples of collaborative research projects as typically divergent language is used, different data are collected, and questions are framed in different ways. This chapter considers the inter-relationship between biodiversity and human well-being in public and private urban green space, the links between the distribution of people and biodiversity in the city, and the potential trade-offs between managing green spaces for people and for biodiversity. We begin with a review of relevant literature from several research perspectives, then provide examples of people-nature interactions drawn principally from our collaborative research between ecologists and environmental psychologists, and, lastly, identify key management and policy implications.

People and Urban Nature

Human Impacts on Urban Nature

The process of urbanization dramatically transforms natural landscapes. Specific elements of urban form that impact patterns of biodiversity include the type of development, the amount of impervious surface, distance to city centre, tree cover and housing density. The impacts of such factors on the spatial distribution of biodiversity across urban landscapes have been amply reviewed (e.g. Niemelä, 1999; McKinney, 2002; Pauleit et al., 2005; Garden et al., 2006). Importantly, increasing urban intensity does not always lead to a simple linear decline in the number of species (species richness) or the number of individual plants and animals (abundance), and the biological response varies markedly depending on the group of organisms under study (Chace and Walsh, 2006; McKinney, 2008).

Many features of a city result from large-scale land use planning decisions. The consequences of decisions made by individual landowners are not so obvious. Many householders have land attached to their property, and the results of many thousands of individual decisions on how that land is managed can sum to a significant effect at a landscape scale. Physical garden features such as trees, shrubs, bird feeding stations, compost heaps, ponds, bird baths and nest boxes provide specific resources for urban biodiversity and can occur at high densities across the urban landscape (Gaston et al., 2005, 2007). In the UK, it has been estimated that more than 60% of households with a garden feed wild birds (DEFRA, 2002), and that 60,000 tonnes of food are presented annually to birds (Glue, 2006). Moreover, garden size, tree cover, the amount of shrubs and the species composition of vegetation are correlated with invertebrate richness and abundance (Smith et al., 2006a, 2006b), and garden characteristics predict the composition of bird communities (Chamberlain et al., 2004).

A sample of 70 gardens within the three case study neighbourhoods in Sheffield (inner, between, outer) had on average 33% of their area covered with impervious surfaces (Tratalos et al., 2007a), and there are concerns that gardens across the UK are increasingly being paved over, leading to elevated storm water run-off and a decline in biodiversity value (Royal Horticultural Society, 2006). Reductions in garden size, resulting from an increase in housing density through infill development are also associated with a decline in tree cover and habitat heterogeneity (Pauleit et al., 2005; Smith et al., 2005).

Human factors can have a marked effect on how urban green spaces, both public and private, are used – and abused. For example, in Sheffield it has been found that access to public green space is poorer for more affluent sectors of society (Barbosa et al., 2007). Additionally, the proportion of the human population feeding wild birds declines as socio-economic deprivation increases (Fuller et al., 2008), and the popularity of wildlife gardening varies with householder age and employment status, although these effects depend on spatial scale and cultural context (Lepczyk et al., 2004; Fuller et al., in press). Disturbance and damage to habitats can result from heavy recreational, criminal and waste disposal use, leading to increased openness and poor vegetation quality (Moran, 1984; Matlack, 1993).

Urban Nature Impacts on People

People living in cities tend to be less healthy than their rural counterparts (e.g. Verheij, 1995). Natural environments can offset demands associated with city living, such as exposure to noise, crowding and traffic exhaust (e.g. Freeman and Stansfield, 1998; Hunt et al., 2000). While environmental exposure often emphasizes the potential for negative effects (asthma, cancer, etc; e.g. McMichael, 2001), the idea that nature can be beneficial has a long history. Gardens were at one time part of hospitals (Gerlach-Spriggs et al., 1998), and women and children regularly left the city for country homes during the pre- and early-industrial age. In early nineteenth century England there was a call for “breathing zones” around London (MacDougall, 1980); the value of urban green spaces was further recognised during the Victorian era with the creation of large, publicly funded city parks designed to provide places for recreation and to encourage social interaction (Conway, 2000).

Research supports this intuitive belief of a beneficial relationship between contact with nature and quality of life (for review see e.g. Rohde and Kendle, 1997; Irvine and Warber, 2002). Multiple dimensions of health respond positively to the availability of nearby nature including objective measures of the physiological effects of stress (e.g. Ulrich et al., 1991; Parsons et al., 1998), self-reported sensitivity to stress (Stigsdotter and Grahn, 2004), surgical recovery time (Ulrich, 1984), mental fatigue (e.g. Kuo, 2001), cognitive functioning in children (e.g. Wells,

2002) including attention-deficit/hyperactivity disorder (Kuo and Taylor, 2004), mood (e.g. Hull and Michael, 1995; Shibata and Suzuki, 2002), self-discipline (Taylor et al., 2002) and opportunities for reflection (e.g. Herzog et al., 1997). The availability of nearby nature is shown to promote social interaction and a sense of community (Coley et al., 1997; Kim and Kaplan, 2004) as well as reduce aggressive behavior and crime (Kuo and Sullivan, 2001a, 2001b). There is also evidence that people form emotional attachments with natural areas (e.g. Ryan, 2005) and that these spaces contribute to personal identity (Bernardini and Irvine, 2007).

Several recent studies have explored urban green space as a factor in understanding population-level health; de Vries et al. (2003) and Maas et al. (2006) find positive relationships between the amount of green space in a neighbourhood and self-reported health, with stronger effects among the elderly, less affluent socioeconomic groups and women at home. Greater longevity has been found among the elderly in Japan with access to “walkable green space” (easy to walk in and filled with “greenery”; Takano et al., 2002) and the availability of a garden appears to offset the negative health effects among public housing residents (Macintyre et al., 2003). In the light of these findings, public policy in the UK has recently emphasized the need for high quality green space as an additional component of urban form (ODPM, 2002, 2006).

The benefits of urban nature are experienced widely (by adults and children, at work or home, in healthcare and neighbourhood settings) and can be gained from a variety of different types of “nature”, including wilderness, residential gardens or managed parks, trees and grass around an apartment building, and potted plants. Natural elements, particularly water features, large trees or woodlands are consistently preferred to built ones often irrespective of culture or nationality (e.g. Kaplan and Kaplan, 1989; Herzog et al., 2000). Yet there has been little study of the direct effects of specific biological components of the landscape on human quality of life (Brown and Grant, 2005).

Interactions Between People and Urban Nature

The foregoing discussion highlights the prevalence of intradisciplinary research into people-urban nature interactions. This section presents findings from an interdisciplinary collaboration on the two-way interactions between people and nature – in both public and private green space – using examples from the CityForm’s case study neighbourhoods survey, an intensive study of Sheffield green space, and population-level data linked with GIS spatial analysis.

Public Green Space

Patterns of Use and Visit Motivations

Public green spaces (often referred to as open space or parks) have been the focal point for much of the work on interactions between people and urban nature (Speirs, 2003; Balram and Dragicevic, 2005; Pincetl and Gearin, 2005). Research on the use and design of public green space has typically focused on its amenity function, crime reduction, and ways to encourage physical activity and social interaction (Dunnett et al., 2002; Commission for Architecture and Built Environment [CABE Space], 2005, 2007). Variation in the use of these spaces also affects the quantity and quality of interactions that urban residents experience with nature. Viewed from this perspective, urban parks, quite often (although not always) located close to where people live and work, become important arenas for contact between people and nature.

Within the UK there are about 27,000 urban parks and in England alone some 33 million people make more than 2.5 billion visits a year. These designated areas, which form the bulk of publicly provided (thus publicly accessible) green space, compose about 14% of total urban space (Dunnett et al., 2002). Within the city of Sheffield alone the 87 municipal parks attract over 25 million visits per year (Beer, 2005). Varying in purpose, facilities provided and catchment area, these spaces also differ in the amount and type of natural features present (e.g. grass, woodland), as well as their intrinsic biodiversity value. While studies suggest that just knowing these spaces are available can facilitate well-being (Bell et al., 2004), our research focused on actual visits, emphasizing the interplay between people and biological diversity with respect to benefits and management possibilities for both. To this end, using ecological surveys, interviews with 312 park users, and direct observation of usage and visitors, we studied 15 parks in Sheffield that varied in size and biological diversity and were located between the city centre and the western suburbs (see Fuller et al., 2007 for further details).

While a wide range of people make use of parks, demographic differences do exist. For example, women may be less likely to visit woodlands alone (e.g. Burgess, 1998), and a study of green space in the East Midlands region of the UK found that they are less well used by women, individuals with disabilities, and those from ethnic minorities (Bell et al., 2004). Sheffield park users were predominantly of European ethnicity, and comprised roughly equal numbers of men and women, individuals and groups as well as a wide age range (Table 10.1).

Common among the reasons for visiting urban green spaces are sport, relaxation, socializing, entertaining children, dog walking and to “be in nature” (e.g. Ulrich and Addoms, 1981; Burgess et al., 1988; Garvin and Berens, 1997; Chiesura, 2004; Dines et al., 2006). Results from CityForm’s case study neighbourhoods survey show recreation to be the most frequent reason for using local green space (Table 10.2; see Gaston et al., 2007 for details). This result is confirmed by direct observation of people using Sheffield parks (Table 10.3); the most frequently mentioned motivation among interview participants is walking (walking the dog, taking a stroll, or walking en route to another destination). Exercise and sport (e.g. cricket, football, skateboarding) are also commonly cited reasons for visits with recurrent reference to bringing children to play. Other activities include having a meal, reading, sitting, photography and socialising. As might be expected some places are visited specifically because of their facilities (e.g. play area), the type of space (e.g. cemetery) or because it is the closest space. Some of the less tangible

Table 10.1 Visitor composition across 15 public green spaces in Sheffield

	Total people	Gender		Age (years)				Group size		
		Male	Female	<10	10–16	Adult <60	Adult >60	Single	Couple	>2
Pre-Holiday										
Weekend (1400–1500)	1823	52	48	16	9	71	4	25	41	33
Weekday lunch (1300–1400)	1040	47	53	10	6	81	3	47	34	19
Weekday post-lunch (1400–1500)	569	51	50	16	4	76	5	42	40	18
Holiday										
Weekend (1400–1500)	895	59	41	21	13	52	14	26	42	32
Weekday lunch (1300–1400)	332	53	47	30	18	46	6	35	29	36
Weekday post-lunch (1400–1500)	431	52	48	31	25	36	8	32	25	43

Values for gender and age are the percentage of all people of known gender and age that were male/female or in the different age groups. Values for group size are the percentage of all groups of known size that were made up of singles, couples and groups of three or more people.

Table 10.2 Use by Urban Residents of Local Neighbourhood Green Spaces

Visit Motivation	Number of responses	Use at least occasionally (%)	Never visit (%)
Recreation	4056	72	28
Be in natural environment	3872	69	31
See local wildlife	3849	55	45
Meet friends/family	3959	53	47
Feed ducks	3621	36	64
Children to play	3714	36	64
Sport	3831	33	67
Walk dog	3622	16	84

Values in the second column are the number of responses to each individual question. Individuals reporting no access to green space are excluded.

functions of these spaces are as places for peace and quiet, relaxation, rest and taking a break. Clearly, there is potential for these latter kinds of functions to be linked intimately to the quality and extent of green space within urban parks.

While wanting to be in nature is consistently reported as a reason to visit public green space (e.g. Hayward and Weitzer, 1984; de Groot and van den Born, 2003), little is known about which components of the natural environment are particularly important, and whether this is related to biodiversity. Responses to

Table 10.3 Activities of visitors to 15 public Green Spaces in Sheffield

	Total people	Lie/sit	Walk	Walk dog	Child oriented	Sport	Exercise (run/cycle)	Café	Feed ducks	Other
Pre-holiday										
Weekend	1706	50	22	3	10	7	2	4	0	2
Weekday lunch	1018	58	24	3	6	2	1	5	0	1
Weekday post-lunch	825	46	31	3	6	8	1	3	0	2
Holiday										
Weekend	543	17	39	3	14	7	5	6	1	7
Weekday lunch	320	23	37	7	12	2	4	9	1	6
Weekday post-lunch	417	16	32	5	23	6	3	4	0	11

Values are the percentages of all people where activity was recorded that engaged in each activity. See Table 10.1 for observational time periods.

CityForm's case study neighbourhoods survey indicate that 69% use local parks to "be in a natural environment", 55% to see local wildlife, and 36% to feed ducks (Table 10.2). Similarly, Sheffield park interviewees strongly endorse the importance of nature to the park experience, and at least two-thirds said that the diversity of flora and fauna is valuable. Interestingly, when asked to give specific reasons for visiting, explanations rarely refer to flora and fauna directly (those that did included greenery, feeding ducks, collecting seeds, looking at birds/squirrels), although broader constructions of nature are mentioned (e.g. fresh air, being outside, peace and quiet, open space, topography). This suggests that specific elements of biodiversity value (e.g. species richness, habitat heterogeneity) may not be directly perceived as important, yet the combination of these components into a natural scene is part of the reason why green spaces are used.

Sheffield park interviewees commonly reported feeling relaxed, refreshed, calm and peaceful after leaving green spaces. Interview responses also indicated that visits to green space facilitate the ability to reflect, engender strong emotional attachments and support both feelings of uniqueness as well as a connection to one's past experiences. This reflects two of the more intangible purposes of parks identified in recent UK policy initiatives, that of contemplation and a sense of place (CABE Space, 2005). Moreover, the degree of psychological benefit gained increased with park area, the variety of habitats present in the park, and plant species richness (Fuller et al., 2007). This suggests that biological complexity is directly related to the quality of the urban green space experience.

A less frequently studied component of urban green spaces is the "soundscape" (acoustic environment) and its quality. In three Sheffield parks, located in the three case study neighbourhoods (inner, between, outer), the sounds most frequently mentioned by visitors are those of natural origin (e.g. bird song, dogs, wind in the trees). Vegetation buffers could have reduced the prevalence of mechanical sounds (e.g. traffic, building ventilation, construction; Irvine et al., 2009). Mechanical sounds are consistently rated less pleasant than natural sounds both within green spaces (e.g. Payne et al., 2007) and in public squares (Yang and Kang, 2005) and the soundscape has been shown to affect opportunities for reflection (Payne et al., 2007).

Biodiversity Management

A traditional view of biodiversity management in urban green spaces might emphasize the exclusion of people to allow vegetative growth and reduce disturbance to specific species of flora and fauna (Sorace, 2001). Parks and remnant fragments of original vegetation that have been managed in this way do tend to support a greater diversity of species than the urban landscape in general (Jokimäki and Suhonen, 1993; Hadidian et al., 1997). The variety of habitats available and the presence of particular park features such as rough grass are associated with elevated species richness (Chamberlain et al., 2007). Species richness is positively correlated with park area, and biological communities within parks are structured in a way that mirrors that found in more natural environments (Fernández-Juricic, 2001; Cornelis and Hermy, 2004; Fernández-Juricic et al., 2005). However, the emerging evidence for a positive relationship between biodiversity value and benefits to psychological well-being, along with the importance that green space users attach to an experience of nature, suggests, at the very least, that management for people and biodiversity should be considered simultaneously, and even that carefully planned management to enhance biodiversity value will also benefit park users, in a win-win scenario.

Managing for biodiversity necessarily raises a number of issues given that recreation is, and rightly so, an important use of parks. Viewing the function of parks as an amenity for people has historically led to provision of large formal spaces (e.g. botanical gardens) that include sizable expanses of mown grass (amenity turf) for sport and recreation, and open spaces with few trees and shrubs (Hunziker et al., 2007). There is also a large and thriving literature suggesting that this "urban savannah" design is fundamentally preferred (Kaplan and Kaplan, 1989). This presents a clear challenge in terms of maintaining biological diversity. Additionally, given the range and intensity of activities undertaken in these spaces, there could be concerns over constraints that biodiversity management might place on usage.

These concerns are apparent in comments from Sheffield interviewees in response to a question about the use of rough grassy areas or fences as management tools for the "welfare of plants and animals". Specific activities mentioned that could be negatively impacted included sport, sitting, walking and children playing, with additional comments concerning aesthetics (e.g. it would look neglected, fences are ugly), the purpose of parks (e.g. parks are for people, parks should be accessible), and safety (e.g. things could hide in the grass, children could hurt themselves on fences).

Yet just as many interviewees are not opposed to the use of fences or rough grass areas, seeing the potential benefits (e.g. educational opportunity, people doing something for nature), and, among those opposed, most provide suggestions for circumstances under which such management could coexist with human use. Crucial to that coexistence is the degree to which recreational use coincides with the distribution of biodiversity. Our study of Sheffield park usage included observation of the distribution of people across a number of sub-areas within each park. These sub-areas were determined based on dominant land cover type – amenity planting (e.g. flower beds), building, grassland, scrub (e.g. shrubs, bushes), impervious surface (e.g. paved paths), water and woodland. Usage of sub-areas declined as the amount of woodland and grassland increased (Fig. 10.1a). Conversely, coverage by

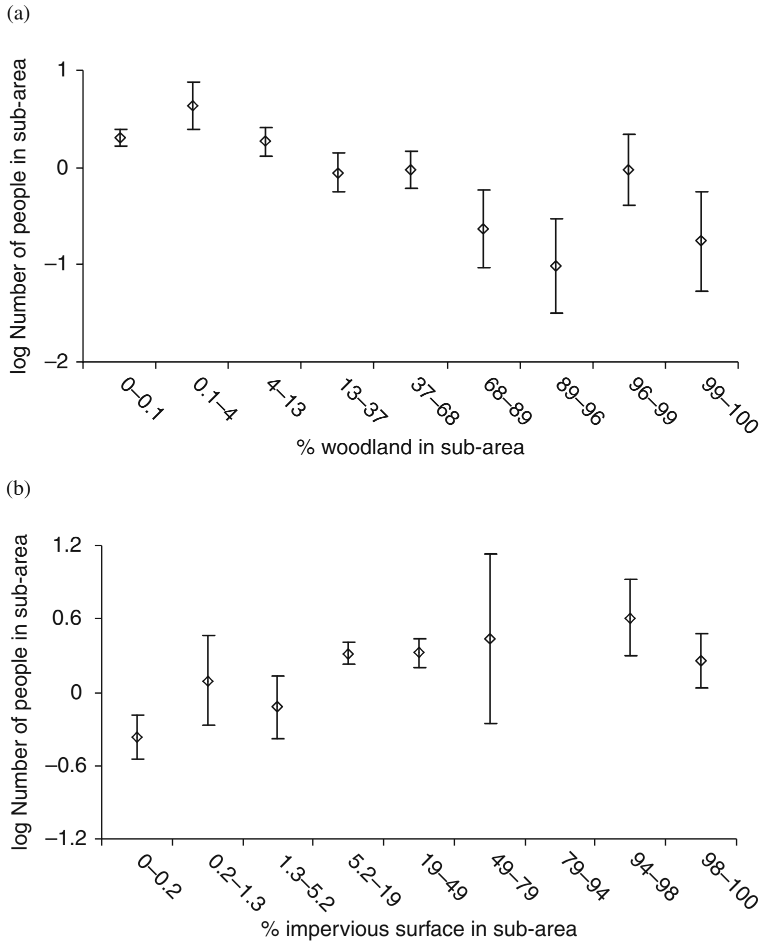

Fig. 10.1 Relationships between the Number of People using Sub-areas within 15 Public Green Spaces in Sheffield and the Proportion of that Area Covered by (**a**) Woodland and (**b**) Impervious Surface. Values of woodland and impervious surface coverage were divided into deciles for presentation. There was only one data point with a value for sealed surface of 1.36–2.74, so the point is omitted from (**b**). Error bars are ± One Standard Error

impervious surfaces was positively correlated with frequency of use (Fig. 10.1b). This suggests that habitats associated with elevated biodiversity, such as woodland and rough grassland, might be less heavily impacted by recreational use than turfed and paved areas, which are more suited for amenity use. Crucially, these more complex natural features are among the motivations for visiting, despite the fact they are not always directly used.

The foregoing suggests that the strategic development of areas specifically managed for biodiversity could in fact enhance the green space experience without negatively affecting use of the space as a whole. While these may vary culturally and regionally, acceptable circumstances mentioned by Sheffield park users include (i) the use of small patches, (ii) locating areas along the edges of fields, on hills, in already existing woodlands or along unpaved paths, (iii) providing an educational component, and (iv) making it look orderly and purposeful (e.g. the use of signs, a mown strip of grass at edge). The use of such "cultural cues to care" can offset the perceived "messiness" of more naturalistic management (Nassauer, 1995, 2004).

The development of more natural, less manicured landscapes also raises issues of safety. There is evidence that a high density of vegetation in urban parks leads to negative perceptions of safety (Schroeder and Anderson, 1984; Bixler and Floyd, 1997). Our work suggests a more complex relationship. Across the fifteen parks in Sheffield the perception that a park contained unsafe places is significantly positively correlated with the amount of shrubs present (shrub layer volume) per hectare. Yet the relationship with the amount of tree cover (tree canopy volume) per hectare is non-significant, as were relationships between actually feeling safe and both vegetation measures (Table 10.4). While vegetation is mentioned by interviewees as a feature contributing to making a place appear unsafe, it is not necessarily the presence of vegetation per se, but also that these areas were secluded, less well lit and offering hiding places for people (e.g. walkways under trees, woodlands, overgrown bushes).

Vegetation might also influence perceptions of safety by affecting the ability to see long distances, or ease of locomotion (e.g. Nasar et al., 1993; Nasar and Jones, 1997; Forsyth, 2003). This, however, contradicts research within the landscape preference literature involving the concept of "mystery"; vegetation structure and structural designs that obscure the view explains why some landscapes are well-liked (e.g. Herzog and Miller, 1998). This highlights the need for a more refined understanding of the perceptions of safety in urban green space and

Table 10.4 Correlations between Perceptions of Safety and Vegetation across 15 Public Green Spaces in Sheffield

	Shrub layer	volume (m^3/ha)	Tree canopy	volume (m^3/ha)
	r_s	p	r_s	p
There are unsafe places	0.63	0.01	0.36	0.19
I feel safe	–0.47	0.08	–0.23	0.41

Safety items measured on a 5-point Likert scale from strongly disagree to strongly agree researchers have begun to explore the relationship among naturalistic designs, safety, preference and use. For example, Bjerke et al. (2006) find a preference for more densely vegetated parks among middle-aged, educated individuals as well as among those with an interest in wildlife and a more pro-environmental attitude. Jim and Chen (2006) note a similar preference for more naturalistic design in China, while Özgüner and Kendle (2006) demonstrate that both the naturalistic and the more manicured designs are equally appreciated among the public in Sheffield. In contrast, signs of neglect may also influence perceptions of safety. Indeed, park interviewees in Sheffield mention signs of neglect, just as much as vegetation, as contributing to places feeling unsafe. These comments often are related to the people and their activities (e.g. anti-social behaviour), poor maintenance (e.g. cracked hardscape under children's play areas, dilapidated buildings), and litter.

Private Green Space

Many urban residents have access to a parcel of private land around their home, an additional avenue for contact with nature. Because the land is privately owned, people make independent decisions about how to manage their garden, even if the decision is to do nothing and let the garden grow "wild", or to pave the area over entirely and treat it continually with herbicides (both extremes observed during fieldwork in Sheffield). Coupled with the fact that gardens cover around a quarter of the area within a typical UK city (Loram et al., 2007), these decisions must inevitably sum to influence urban nature at a landscape scale across the city.

Gardens and Well-Being

Having a view over gardens has been shown to increase residents' satisfaction with the community and to contribute to neighbourhood satisfaction (Kaplan, 1985, 2001), and having physical access to a garden positively influences self-reported health (Macintyre et al., 2003; de Vries et al., 2003). Gardens are used in a variety of ways, as places to socialize, play, retreat from the world, gain pleasure from horticulture, watch nature and act as venues for household projects or for self-expression (Bhatti and Church; 2001, 2004). They also appear valuable for the psychological processes of self-esteem, self-efficacy and personal identity (ARCWIS 2002; Bernardini and Irvine, 2007). Among gardeners, peace and quiet, sustained engagement with the natural environment, and stress reduction are cited as important benefits (Kaplan, 1973; Catanzaro and Ekanem, 2004). Gardens also connect people with their personal history; daily or seasonal cycles may bring reminders of the past (Francis, 1988; Sime, 1993). Other benefits derived include a sense of accomplishment, and the joy of anticipation that comes through the planning, planting and harvesting of one's garden (Catanzaro and Ekanem, 2004).

Wildlife Gardening

At one extreme of the continuum of possible garden management decisions, one might explicitly attempt to attract wild plant and animal species into the garden. Providing resources in this way for birds and other animals is a popular activity across much of the world. For example, between one-fifth and one-third of households in Europe, North America and Australia provide supplementary food for wild birds (Clergeau et al., 1997; Rollinson et al., 2003; Lepczyk et al., 2004), and in the United States alone some 52 million people frequently feed garden birds (United States Fish and Wildlife Service, 2001). As well as benefiting the birds themselves, pleasure in observing birds is presumably one of the motivations for engaging in this kind of activity, although we are aware of no published studies on this issue. Collectively, such activities are typically referred to as “wildlife gardening”, which can broadly be defined as any actions conducted in private gardens to increase their suitability for wildlife. It thus encompasses both a general approach to garden management and specific provision of resources for wildlife. Areas might be left to grow as a wild flower meadow, weeds might be tolerated, or supplementary resources such as feeding stations or nest boxes for birds, a compost heap or log pile to encourage invertebrates, or a wildlife pond might be established. If the occurrence of these features is sufficiently widespread across the urban landscape, this may represent a substantial resource for, and substantial effect on, urban biodiversity levels.

Evidence that wildlife gardening increases richness and abundance of invertebrates is equivocal but the effect on birds is somewhat clearer. Overall bird abundance, and the abundance of selected urban specialist birds in Sheffield, had a strong positive relationship with the density of bird feeding stations (Fuller et al., 2008, Fuller et al., in press), hinting intriguingly that the provision of food for birds can influence the structure of urban bird communities at a landscape scale.

Incidence of wildlife gardening varies with urban form. Across CityForm’s case study neighbourhoods 56% of households with access to outside space provide one or more “wildlife-friendly” garden features (Gaston et al., 2007). The occurrence of such garden features, and the proportion of households providing food for birds and other animals, are positively associated with the amount of garden coverage in the local area and average garden size, but is independent of household density, proportion of households in the professional socioeconomic group AB, and the amount of coverage by non-garden green space (Gaston et al., 2007).

Spatial Configuration of Biodiversity and People in the Landscape

As well as people modifying and responding to biodiversity at local scales in public green spaces and private domestic gardens, decisions by local authorities can dictate city-wide patterns of built form and conversely green space coverage (Kinzig et al., 2005). Aspects of biodiversity within such green spaces, for example vegetation structure or habitat heterogeneity, will, in turn, impact the types of human activities that are conducted in them. Human activity and management patterns will again modify the pattern of biodiversity (e.g. through trampling, seed dispersal, bird feeding). Thus, while urban form can strongly influence the distribution of biodiversity, the resulting pattern of biodiversity also constrains and modifies human access to nature.

In urban areas, coverage by green space (be they parcels of countryside, parks, gardens, road verges or other patches of vegetated surface) is an important correlate of biodiversity value, both in terms of species richness and sometimes abundance. For many groups of organisms, species richness declines as coverage by green space declines. Furthermore, the influence of green space on biodiversity can act at different spatial scales, both locally and regionally (Clergeau et al., 2001; Melles et al., 2003). In other words, the level of biodiversity may depend not only on the extent of green space at that locality, but also on the extent of green space in the wider region in which the locality is embedded.

Within Sheffield, coverage by green space is correlated with the diversity of both birds and plants. The proportion of land cover comprising green space in the 100 m radius around a series of survey points across the city shows a strong positive association with bird species richness, although the explanatory power was rather low (Fig. 10.2a). Bird abundance initially increases as the amount of green space increases but eventually declines in areas with very high green space coverage (Fig. 10.2b). The initial rise is probably associated with an increase in habitat heterogeneity in the early stages of urbanizing an area (Tratalos et al., 2007b), whereas continuously-vegetated areas (e.g. woodland habitats) tend to support homogeneous communities of native species. There is a strong positive relationship between green space coverage and native plant species richness (Fig. 10.2c), and a hump-shaped relationship between green space coverage and non-native plant species richness (Fig. 10.2d).

The rather low explanatory power of many of the foregoing relationships suggests that although green space is clearly associated with the distribution of biodiversity, there are many other factors at play. Research is beginning to identify fascinating predictive relationships between socioeconomic variables and patterns of urban biodiversity (Collins et al., 2000; Hope et al., 2003; Martin et al., 2004). In Sheffield, bird species richness varied significantly across 47 neighbourhood types (Fuller et al., 2008). One important study, conducted across the Central Arizona-Phoenix region in the United States, reveals that in addition to elevation and current and former land use, spatial variation in plant diversity is best explained by family income and age of housing (Hope et al., 2003). Such relationships presumably reflect either subtle habitat characteristics not easily measured by standard habitat parameters, or variation in the way in which different kinds of urban areas are managed by residents and local authorities (Kinzig et al., 2005).

While spatial variation in human society might impact strongly on the distribution of biodiversity, for example though variation in how land is managed, there are clear interactions in the opposite direction. Sheffield alone supports over 600,000 birds, equating to 1.18 birds per person (Fuller et al., 2009), so urban areas are potentially important arenas for contact between people and wildlife.

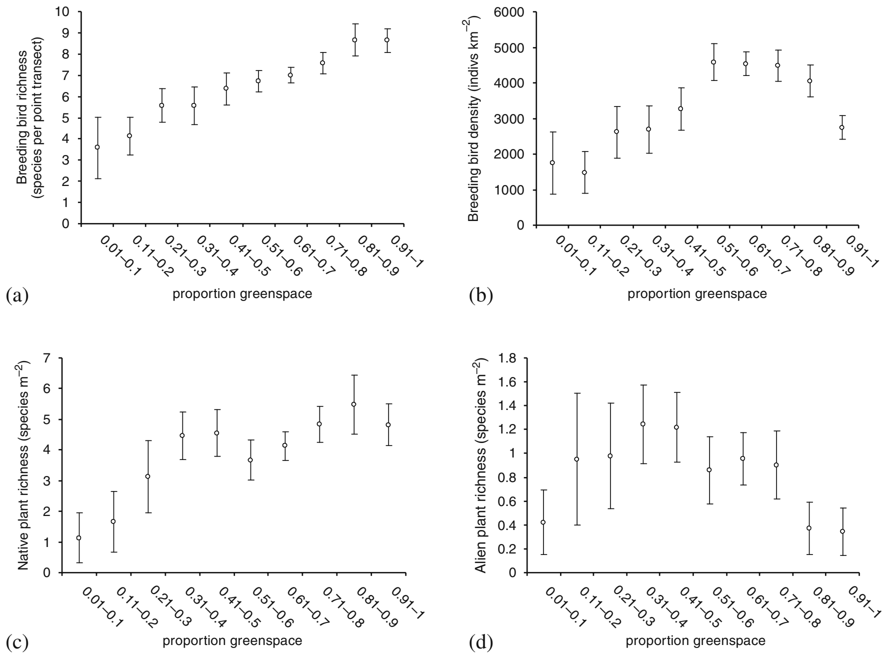

Fig. 10.2 Relationships between Green Space Coverage around a Series of Sampling Locations in Sheffield and (**a**) Breeding Bird Species Richness, (**b**) Breeding Bird Density, (**c**) Native Plant Richness and (**d**) Alien Plant Richness. Green space was measured in 100 m buffers around survey locations. Error bars are 95% confidence intervals

Urban biodiversity can be framed as a quality of life indicator, promoting enhanced psychological and physiological well-being. For example, the UK government has established five biodiversity indicators "to ensure that urban areas contribute fully to the goals of biodiversity conservation and enhance the quality of life of people who live there" (DEFRA, 2002). Within Sheffield there is a negative relationship between bird species richness and the level of deprivation among neighbourhoods, as measured by the Index of Multiple Deprivation (Fig. 10.3); less privileged sectors of society have lower levels of biodiversity around the places where they live.

Although access to green space is an important issue in urban planning, rather little is known about actual levels of such access across the human urban population (Wray et al., 2005). This is despite the fact that regulatory agencies provide explicit guidance to safeguard access to green space in urban areas. The European Environment Agency (EEA) recommends that people should have access to green space within 15 minutes walking distance (roughly equivalent to 900 m), a condition that appears to be met for several of Europe's smaller cities (Stanners and Bourdeau, 1995). More stringently a UK government agency recommends that "people living in towns and cities should have an accessible natural green space less than 300 m

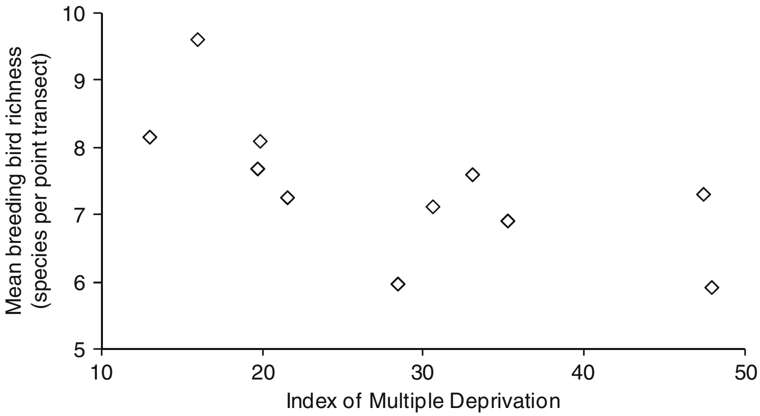

Fig. 10.3 Relationship between Local Levels of Deprivation and Avian Species Richness in Sheffield. Data points are for eleven neighbourhood types and represent mean bird species richness derived from point transect surveys in summer 2004

from home" (Wray et al., 2005). In Sheffield, 64% of households are located more than 300 m from the nearest public green space and 72% are more than 300 m along the road network from the nearest municipal park (Barbosa et al., 2007). Some households are more than 20 times this distance. Additionally, proximity varies significantly across society, with households in wealthier neighbourhood types tending to live further from public green space than households in less affluent neighbourhoods. While wealthier neighbourhoods might have greater access to gardens, the two types of green space play very different roles (Kellett, 1982; Bernardini and Irvine, 2007), and the degree to which they can substitute for one another is unclear (Barbosa et al., 2007).

In terms of urban planning, access to green space depends closely on where and how that space is located across the landscape. An uneven distribution might lead to the kinds of social inequalities described above. For a given total area of green space, the spatial configuration of the component patches is also likely to play a role in its biodiversity value (Donnelly and Marzluff, 2006). Urban environments are highly fragmented, with habitat patches of various sizes being isolated from each other by the road network and buildings. Despite this, the degree to which urban habitat patches are isolated from one another shows no general relationship with patch species richness (e.g. Bastin and Thomas, 1999; Fernández-Juricic, 2000; Gibb and Hochuli, 2002). In part, this may result from links between habitat patches formed by interstitial vegetation within the urban matrix (most notably gardens). Additionally, some mobile organisms, such as birds, may be able to disperse among widely separated patches of suitable habitat. While there appears to be no strong general effect of patch connectivity in urban environments, larger patches do typically contain higher species richness, and some native species only occur in such patches (e.g. Dickman, 1987; Mörtberg and Wallentinus, 2000; Park and Lee, 2000). Ecological surveys of gardens in Sheffield reveal that on average those which are larger contain greater numbers of plant species, although small gardens can nonetheless be very species rich (Smith et al., 2006a).

Overall, the amount of green space is the single most important predictor of biodiversity levels in a city. Thus, for example, while enhancing connectivity can be important, maximizing the amount of vegetated space within cities should always feature strongly in planning for urban biodiversity (Rebele, 1994). The same can be said for the provision of green spaces as places for people to engage with the natural environment (Ward Thompson, 2002; Gomez and Salvador, 2006). Of course, conservation of biodiversity is not and should not always be the key driver of green space management within cities. In some cases, increased urban density and the subsequent isolation of small city green spaces may reduce pressure elsewhere in the landscape (Merrill 2004).

Conclusion

Urban green space has been studied extensively from both ecological and psychological perspectives with little communication between the groups of disciplines involved. We suggest that a fuller understanding of urban green space depends on considering simultaneously factors such as the amount of green space, density of housing, socio-economic-demographic composition and distribution of local human populations as well as the spatial configuration, quality and type of green space available. While clearly there is still much to learn about the interactions among humans, green space and biodiversity within cities here, we close this chapter by outlining the management and policy implications of what we do know, and identify the most pressing research challenges for the future.

While a large body of literature has documented positive effects of human contact with nature, and is useful for developing general approaches to urban planning, more specific knowledge about the magnitude or enduring quality of responses by human well-being to the presence of natural features in the urban landscape would enable a more quantitative approach to siting and managing green spaces, both public and private. The degree to which these two radically different types of green space can substitute for one another is unclear. Our data suggest they facilitate quality of life through different routes. Similarly, assessments of the quality of urban green spaces typically emphasize tidiness, the absence of litter and graffiti, and the presence of well-maintained facilities. Our demonstration that levels of biodiversity are positively linked to human well-being adds another angle to the debate over what constitutes quality in urban green space. We must now begin to understand the mechanism by which biodiversity in a landscape promotes human well-being.

The designation and management of green space is typically not strategic, frequently resulting in a collection of land parcels which, for various reasons, have not been developed for other purposes. This can lead to an ad hoc approach to green space planning and provision. However, designing spaces to meet the needs of all users or establishing uniform criteria to be met may ultimately be detrimental for both biological and psycho-social benefits. We suggest a need to recognize the value and importance of local differences, creating a mosaic of opportunities for different kinds of interactions with green space (Thwaites et al., 2005). Given the importance of geographic proximity for green space usage and that access varies across society, explicit spatial planning is required for this kind of strategy to work. Yet the tools to predict the consequences of alternative plans for biodiversity and human well-being are limited and the extent to which access to green space equates with access to biodiversity is currently unknown. Given that psychological benefits increase with biodiversity levels, it is imperative that biodiversity measures be incorporated into audits of green space access for urban residents. Understanding these issues is central to designing cities that improve the experience of nature while also addressing biodiversity conservation.

Broad public participation is vital for the creation of public green spaces that address these multiple issues of quality. Working at local scales and providing meaningful opportunities for involvement may not only facilitate acceptance of what necessarily may be radically different types of spaces but could generate solutions that are more extensive and economical than otherwise might be possible (Irvine and Kaplan, 2001). An additional intriguing arena for public involvement is the private residential urban garden where multiple individual management decisions can result in landscape scale effects. This raises the fascinating possibility that, for example, garden bird feeding could be explicitly harnessed to influence the conservation status of a particular species that occurs within urban areas in order to achieve regional biodiversity targets. Despite the prevalence of private gardens in many modern cities, surprisingly little is known about the motivations for particular garden management decisions or the propensity to engage in "wildlife-friendly" activities.

From a policy perspective, both the conservation of urban biodiversity and the enhancement of public health depend on a better understanding of the interactions between people and urban nature. There is growing realization that urban green spaces are valuable resources for creating sustainable cities. These places are not only a contribution to achieving biodiversity conservation objectives but they form one of the main routes through which urban residents can benefit from nature. The interactions between people and urban nature are surprisingly finely tuned, with feedbacks occurring in both directions. Management strategies must therefore be sought that complement both the ecological and the human value of urban green space. Because of the highly synergistic quality of the relationship between these two types of benefits, the needs of management for biodiversity value and human well-being may not always indicate divergent solutions.

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Chapter 11
Complementarities and Contradictions

Colin Jones, Mike Jenks and Glen Bramley

Introduction

The final chapter addresses the key question which brings together the research presented in the book: *to what extent and in what ways does urban form affect sustainability?* It begins by recounting the elements of urban form and the oft repeated mantras so prevalent in policy. It summarises the relationships between urban form elements and the dimensions – social acceptability, energy use, travel and mobility, ecology and biodiversity and economic viability – set out in earlier chapters. The lessons drawn from some key overarching sustainability issues – the potential impact of building sustainable developments on lifestyles, the use of open space and adapting the city are then examined. The next sections identify the essential links between sustainability and elements of urban form and the important messages for sustainability policies identified in the earlier chapters. The chapter concludes with some ideas about rethinking sustainability.

There is an increasingly intense debate in policy and practice about sustainability and a key issue is to what extent the adaptation of the physical form of cities and the way people live in them and travel around them can improve it. To date many of the dominant arguments about urban sustainability policy have been put forward in simple black and white terms, couched as the compact urban form versus dispersed urban form or urban sprawl. Viewed from this perspective it is perhaps not surprising that 'compact city' arguments have been more attractive to governments and sustainability policies have focused on increasing the density of urban development, improving public transport, ensuring a mix of uses and containing sprawl. Despite this widespread adoption of these policies, the evidence base supporting it is very limited.

The book has sought to get beneath the veneer of the sustainability debate by, first, looking in depth at the issues and second, to present the evidence from a study that has been designed to assess individual components of the arguments.

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The analysis has attempted to unpack some of the complexities of the relationships between urban form and sustainability.

The task is not straightforward as the measurement of urban form is not easy and sustainability itself is an elusive concept widely open to interpretation. Despite the apparent simplicity of policy prescriptions, the concept of urban sustainability has arguably become increasingly complex. The issue can be as wide as a city's ecological footprint, influenced not just simply by the physical urban form of a city but also the transport network, the nature of the wider (national) urban system and links between the urban areas. This could include factors such as the degree of inter-urban commuting and freight distribution patterns, as well as the waste disposal process and air pollution. However, this research has viewed sustainability from a defined perspective – it draws a line and defines and tests the key arguments in theory and literature that have been used to link urban form to sustainability (Figure 11.1).

Unlike many other texts on this subject, the core of the book looks at the sustainability of cities from the environmental, social and economic perspectives. There are a series of potential contradictions and complementarities as social acceptability, environmental concerns and economic forces vie for hegemony. The planner's challenging task is to address and resolve the tensions from this triangle of potential conflicts. On the one hand cities are the centres for wealth generation, the consumption of goods and services and the hubs of the economy. On the other hand they are consumers of land and the primary polluter or producer of waste. At

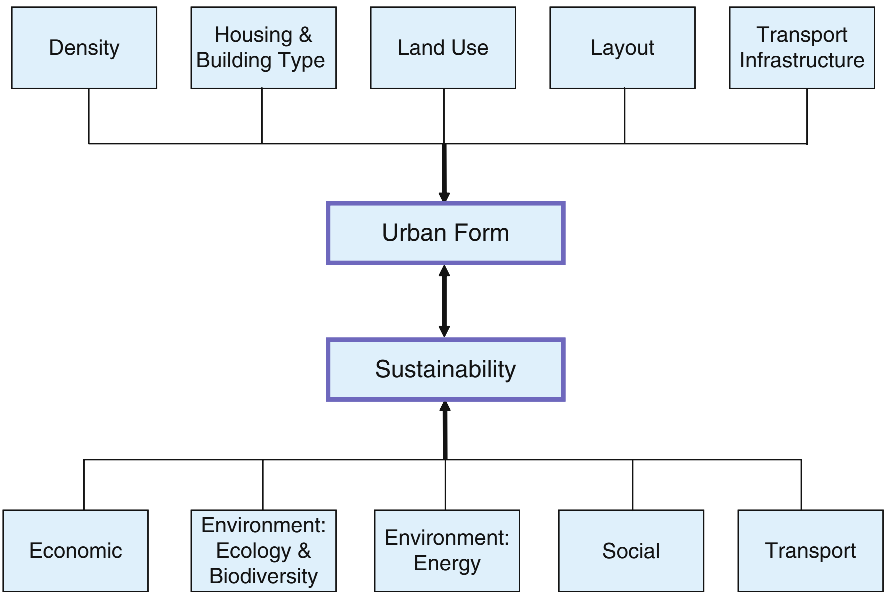

Fig. 11.1 The relationships between elements of urban form and sustainability dimensions researched

the same time cities are where the majority of the population lives and so need to be places in which they are happy to live. Weighing up these different factors is not simple – there are different languages and metrics applied by professional specialists and there are also divergent interests and time horizons from different groups of the community that create barriers to a commonality of views.

This chapter explores and attempts to draw some conclusions about these apparent conflicts based on a structured review of empirical evidence. As a first step it is useful to have a reminder of urban form and this is followed by a review of the different dimensions of sustainability and summary of the findings.

Urban Form

Urban form can be considered at a number of different spatial scales and can be measured in a number of different ways. In this research it is characterized in terms of five elements – the pattern of land use, accessibility defined by transport infrastructure, density, housing/building characteristics and urban layout. Each of these, to a degree, overlap and it is difficult to completely isolate individual components.

The core research in this book is based on five UK cities. Within these cities, case studies were selected comprising neighbourhoods located in the inner, middle and outer areas, effectively representing a slice through each city. These offer a range of different types of British city, and have some similarities to other cities in a wider world context. They are cities that historically grew around a central core, and have a mono-centric urban form, with central business and commercial cores, higher density housing in the inner core with lower densities moving out towards the peripheries. In general terms they are at the lower point in the global spectrum of urban densities (although relatively high by UK standards) and are also less dominated by their central cores than, for example, US cities. The analysis of street networks reveals a broadly consistent negative gradient from the city centre in terms of their density and complexity, interconnectedness and degree of sprawl. Gross population densities follow a similar spatial structure.

This internal physical spatial structure is mirrored by the housing tenure and demographic patterns. Younger people with few children live primarily in the higher density inner areas while older households and families are predominantly in low density suburban areas. Private rented housing is focused in the inner areas and outer rings are often mainly owner occupied. Social housing in British cities is spatially concentrated and located mainly in inner areas but with some larger peripheral estates. The spatial structure of each of the five cities therefore aligns closely to the more 'traditional' mono-centric city form and there is a strong relationship between physical urban form of neighbourhoods and socio-economic-demographic characteristics of households. Nevertheless, there were also some decentralising trends apparent.

Core Sustainability Dimensions

Transport: Travel and Mobility

The adverse environmental and energy consumption consequences of the dominant use of private cars in cities are perhaps the most fundamental source of demands for more sustainable urban policies. The increasing use of the car has contributed to the widespread suburbanisation of cities and urban sprawl. The process is self-reinforcing as new low density residential areas necessitate the use of a car for commuting, accessibility to shops, schools and virtually every facet of everyday life. It is a significant worldwide issue and has intensified calls for sustainable transport policies based on the promotion of public transport. As a result many have argued that cities can be designed to create urban neighbourhoods with local services nearby in such a way as to stimulate the use of public transport, walking and cycling.

This approach faces a number of major hurdles. There is the obvious travel flexibility provided by a car that means that it is often chosen over other convenient transport modes. In the absence of constraints such as road pricing or parking restrictions at key destinations the car is likely to continue to be the principal method of travel to most activities for those who have access to one. Indeed people often choose to travel further distances by car to access a ‘better’ range of shopping than use the more limited local options. Even if urban neighbourhood design could stimulate greater use of local amenities, it is probable that the savings generated will only be used for wider travel. In addition not all urban travel is determined by reference to a person’s home and surrounding neighbourhood, so that for example shopping and leisure travel patterns may be linked to commuting and work location. Overall the assumption that redesigning urban form can bring about a substantial change in travel behaviour is open to question. A key issue is to what extent residential location choice is the consequence of household travel preferences. Chapter 3 addresses this question and investigates the effectiveness of urban form as a means to induce more sustainable travel patterns. In particular the chapter contributes to our understanding of the underlying relationships by exploring the extent to which the availability of cars, trips made and distance travelled by a household is influenced by urban form.

Chapter 3 finds that traditional urban forms characterised by moderately high densities of housing, mixed land-uses, proximity to public transport and grid-pattern road layouts are definitely linked with lower levels of car availability which in turn are associated with lower trip frequencies and shorter travel distances. Overall car ownership levels are found to increase with decreasing population density and increasing distance from city centre. There are a number of explanations for these phenomena. Localities with high population density can support a greater range of local services and facilities while at the same time usually offering good public transport services. In the highest density areas, limited parking supply and regulatory control can also be expected to play a role in deflating car demand. However, self-selection of residential location on the basis of travel preferences is *not* found to be a major influence on car travel. Household income is a strong influence on car ownership, although this is lessened in higher density areas; it also influences trip making behaviour but has no measurable effect on distance travelled.

A distinction can be drawn between travel within neighbourhoods and commuting. Local travel is influenced by the frequency of use of a number of key services/facilities and these are found to decline with distance from home. There remain a number of limitations to these conclusions. For example, residents with lower levels of access may organise their use of services more efficiently than those living in close proximity to local services, or may be more likely to use services located close to their workplace.

The relationship between travel and urban form is therefore not simple. Generally, urban form is not found to influence the number of work-day journeys of the employed, the number of trips for work and non-work journeys and the additional distance required to undertake work travel over and above the shortest route from home to work. At the neighbourhood level, too, the relationships between travel and use of local services is clouded and the analysis suggests that (re)designing a neighbourhood per se will not necessarily bring substantial change to travel behaviour. Other measures will be needed to secure a fully ‘sustainable’ shift in travel behaviour, for example relating to the higher taxation and pricing of fuel, increased regulation and stronger direct management of travel demand. Nevertheless, the research does provide some support for basic propositions linking density with car ownership and use.

Environment: Ecology and Biodiversity

The growth of the urban landscape across the world has a substantial impact on the natural habitat and hence on the disruption of ecosystems and biodiversity. Much has been written on these transformations but very little focus has been placed on how the precise geography of towns and cities can and does shape and moderate these processes within their boundaries. Given the inevitability of an increasing proportion of the world’s population living in urban areas it is an important sustainability policy area. A key variable is the spatial pattern of green spaces in a city in terms not only of its extent but also its composition. The road network in particular configures green spaces and potentially forms a barrier (or a conduit) for dispersal of animals and plants.

Chapter 4 assesses relationships between urban form and green space extent, ecosystem service provision and biodiversity. In this context urban form is best measured in terms of population density, the patterns of coverage of different land use types, and the degree of connectivity of different patches of land cover. The analysis is based primarily, although not exclusively, from empirical studies of these issues undertaken within the five case study cities.

Looking first at biodiversity, higher urban density is found to be strongly associated with a reduction in total green space coverage, and to influence the connectivity of vegetated patches across the townscape. Increased population density has implications for essential elements of the local ecosystem that are mediated by green space. These encompass the regulation of water and temperature regimes, carbon sequestration and the provision of pest control and pollinators across the urban landscape. One striking relationship between biodiversity and density is given by the incidence of bird species. Levels of bird species richness showed a hump-shaped relationship with housing density, rising initially as density increased, but then declining sharply at highly urbanized locations. In addition, reductions in the scale and quality of green space through higher densities lead to substantial restrictions on recreation within urban areas and access to an experience of nature, especially for children.

An understanding of the distribution of ecosystem elements and the associated pattern of biodiversity across the urban landscape is crucial for predicting the consequences of policies designed to increase urban density. There is a clear message from the evidence that there is a decline in ecosystem functions and biodiversity potential with increasing urban density at the higher end of the range. Nevertheless the analysis suggests that there are opportunities for policies that are designed to improve the environmental and ecological performance of urban areas for any given level of urban density. But this will require further research.

There are more worrying issues linked to high densities, notably observed reductions in numbers of species, even those expected to be most able to live in and exploit urban environments. The result is a difficult ecological trade-off between using more green fields for new development and accommodating more people into existing cities. Greater urban management is required to minimise the ecological impact of urban change. Spatially explicit area selection exercises could help identify areas that are crucial to maintaining an effective ecosystem function, and those areas that might efficiently be used for high density residential developments. A better understanding of this trade-off is urgently required if we are to plan for increasingly dense urban forms and ensure that declines in green space and biodiversity will not lead to an substantially impaired ecosystem function, and by implication the provision of ecosystem services to the majority of the human population. Such declines would also degrade human experiences of nature such that contact with the natural world will be diminished in both quantity and quality. There are no easy answers to the sustainable ecological dimension of cities.

Social Acceptability

A sustainable city must be a place where people want to live and work. Closer examination suggests that social acceptability comprises two broad concepts – social equity and the sustainability of the local community. The social dimension of sustainability therefore incorporates issues of social justice, social inclusion, social capital and social cohesion. Social equity can be defined in terms of ease of access to local services, facilities and opportunities. A community which is sustainable displays high levels of what is formally described as social capital and/or social cohesion that can be translated as pride in and attachment to the locality, good social interaction, safety/trust and stability. These attributes offer residents what can be summarised as a good ‘quality of life’. Overall social sustainability is reflected in high levels of satisfaction with home and neighbourhood, and an appreciation of the local environment.

In Chapter 5 elements of social sustainability are measured and their relationships with urban form are quantified. For most aspects of sustainability of community (particularly pride/attachment, stability, neighbourhood and home satisfaction, and perceived environmental quality) lower density suburbs appear ‘best’. These aspects of the social dimension challenge the ‘compact city’ orthodoxy, but there are some counter-balancing benefits of compactness in the equity aspect of social sustainability, particularly access to services. The complexity of the relationship with density is reinforced by the finding that social interaction is best at medium densities, while some aspects are neutral (e.g. community participation).

Some care has to be taken in the interpretation of these relationships as they are also partly the result of factors not directly linked to urban form, such as housing tenure and the social composition of neighbourhoods. In general, disadvantages of compactness are more marginal once socio-demographic characteristics of residents are controlled for. Poverty is often more important than urban form – who lives where, and whether they are able to choose where they live, matters. However, accessibility to key services, including a supermarket, within the neighbourhood are identified as very important for different groups of residents such as the unemployed, older people and young families and play a significant role in social and community life.

The relationship between open space and social sustainability is not straight forward. The use and social benefits derived from open and public spaces are not just based on design but also dependent on the maintenance and supervision of these spaces. Perceptions of safety within open spaces are crucial to their use and linked to maintenance. However, management solutions are not necessarily easy and shared communal gardens and spaces in higher density flats can in particular be problematic.

The social dimension of urban sustainability cannot be linked to a precise urban form, although lower density neighbourhoods have a significant advantage in quality of life and community. Good quality, easily accessible services and facilities in a neighbourhood are important, and are promoted by higher density, confirming the findings of the analysis of travel in Chapter 3. Services will also reflect public provision policies and local planning. Everyday management of urban space, rather than its spatial pattern and scale, is a crucial contributor to social sustainability. Overall social sustainability is not just dependent on neighbourhood physical characteristics and urban form but also a function of urban management and limited in particular by the extent and concentration of poverty within a city.

Environment: Energy Use

A key imperative of the drive toward a sustainable future is the reduction of energy consumption and a high proportion of the energy consumption of cities is linked to buildings. Long term policies can be aimed at adapting the existing housing stock to improve their energy conservation and promote carbon neutral new housing. A wider question is to what extent domestic energy use is influenced by the type of housing and the built form. Arguments in favour of high density development in the form of terraced housing or flats have emphasised a potential reduction in transport (energy) use, and evidence from Chapter 3 provides some support for this view albeit with significant qualifications. It is possible that these types of housing also lower domestic energy consumption to some degree compared with semi-detached and detached houses.

Chapter 6 assesses this proposition but the analysis on domestic energy use finds only a weak relationship with built urban form. Residential energy use is determined less by house type and more by the level of occupancy within a home, and the type of heating and domestic appliances used. Lifestyles and demographics therefore influence energy consumption more than building type, so urban form is of only marginal importance. Thus the connection with urban form is an indirect association with occupancy (particularly number of bedrooms) – the smaller the house the less energy used, and the smaller the house the more likely it is to be part of a higher density urban form. There is also a slight suggestion that the organisation of a city's economy and urban form in shaping commuting may impact on energy consumption via home working.

Economic Viability

The environmental and social dimensions are at the centre of sustainability concerns for cities but economics is also a key influence on why cities exist in the form that they do. The urban economy is a fundamental influence on sustainability, as any policy solution will find it difficult to work counter to spatial market forces in the long term. Sustainability policies have to balance wealth creation, economic performance and the spatial pattern of economic activity determined primarily by markets (albeit usually subject to planning) with meeting social and environmental objectives.

It is in this context that Chapter 7 assesses the arguments and examines to what extent the spatial economy constrains change. The crux of the debate has centred on normative models of high density cities versus dispersed communities. Proponents of the former view base their case on the benefits from magnified agglomeration economies in a compact city and/or on the high infrastructure costs of sprawl. The chapter finds that these high density arguments are based on too simplistic a concept of agglomeration economies which does not take into account cities as dynamic entities with spatial land use patterns subject to change. The urban dispersal 'alternative', partly the inevitable outcome of market forces, is found to have the draw-back that the existing longstanding urban dispersal trends have substantially increased commuting distances and travel to work, as well as public/shared infrastructure costs. These ‘externality’ effects are not considered by individual market decision-makers in their individual decisions to decentralise.

There is no single urban form that satisfies economic sustainability uniquely. Despite this, spatial economic forces are still a key to sustainable cities in that land use patterns must be economically viable; otherwise market forces will mean they will not be stable in the long run. An adequate supply of housing for the workforce and their families is also necessary to ensure affordable housing.

The evidence suggests a potential for adapting the existing city form to make it more economically sustainable. The commercial and industrial property sectors demonstrate some locational flexibility and imply that the viability of these land use markets will not constrain different urban forms, including decentralised urban systems. However, the analysis of the housing market shows that many households prefer low density housing and that there appears to be a household life-cycle element to residential location choice. Younger and non-pensioner single households live in the central city areas but move out to suburban locations as they move through the family life cycle. This means that it will be difficult to encourage more concentrated urban forms without significant changes to the underlying forces of city housing markets. In addition the patterns of viability in the city housing markets suggest there are major constraints to reshaping local housing markets, particularly where concentrated poverty makes market-led redevelopment unviable.

Some Key Sustainability Issues

While the individual dimensions of the sustainability city have been examined, it is evident that these overlap. The social dimension incorporates social equity and the use of local services which in turn are linked to their economic viability. An important contributor to environmental sustainability is the amount and location of green space but this is similarly a major contributor to the quality of life and social sustainability. The extent of green space is also a function of the operation of the housing market and the relative profitability of different housing types. Three chapters examine these inter-relationships focusing on practical issues to improve sustainable urban living – increasing neighbourhood density, providing sustainable developments for sustainable lifestyles, and the provision and management of green space.

Intensifying Neighbourhood Density

A major theme of many protagonists for change is the need for higher residential densities to enhance sustainability. As the analysis above demonstrates these arguments are not entirely founded on empirical analysis. Nevertheless Chapter 8 accepts this paradigm and seeks to develop a theoretical underpinning of, and a methodology for, urban intensification and regeneration. It transforms indicators of sustainability into strategic concepts of urban restructuring and regeneration and applies them to an inner city area of Glasgow. The core of this research is generation of an assessment tool for the systematic measurement and evaluation of levels of (un)sustainability of urban areas with the help of threshold and target values. The output of this analysis in the form of a land use plan is then presented using two and three-dimensional models for the selected neighbourhoods, which are then tested for viability.

The detailed investigation of Govan, a working class area of Glasgow, shows that a systematic tool can be applied to restructure cities into a series of sustainable neighbourhoods, all with their own amenities within walking distance of peoples' front doors with local centres directly linked by public transport. However, the outcomes of the analysis also demonstrate that the achievement of intensification targets can be a rather painful process, which will require both strategic and multilateral thinking and the courage not to compromise too soon given the substantial upheaval involved.

Sustainable Developments and Sustainable Behaviour

In addition to sustainability strategies for the restructuring of neighbourhoods is the building of developments designed to be sustainable. Chapter 9 addresses a seemingly simple question: do residents of new housing developments, built according to sustainability principles, behave any more sustainably than the population in general? The research examines three elements of sustainable behaviour related to neighbourhood-scale design:

- residents' home-based sustainable behaviours; including reducing energy and water consumption, recycling and composting waste and supporting wildlife in gardens
- residents' travel behaviour and car ownership
- residents' 'social sustainability' behaviours; such as social participation and the use of local services, businesses and facilities

These elements encompass all aspects of domestic sustainability behaviour. The analysis is based on a survey of households living in thirteen 'sustainable' developments and the findings are benchmarked against more general national surveys.

The findings are, perhaps surprisingly, more negative than positive. Households living in the 'sustainable' developments only appear to behave more sustainably than the rest of the population with regard to home-based resource efficiency activities, such as water and energy use. Behaviour toward recycling and frequency of use of local facilities are equivalent to national benchmarks. More importantly when it comes to other activities, such as travel to work by car, owning (or having access to) a car, social participation, encouraging wildlife, and composting they behave less sustainably than the population in general. While living in these developments supported positively a more sustainable lifestyle it does not make the residents take further steps in the process. Although the residents are more knowledgeable about sustainability issues than the general population, this is not necessarily translated into positive activity.

It is possible that the fact that these developments are new, works against a social sustainability indicator such as social interaction because households may not have had time to put roots down. The nature of high density may also militate against such activities as outdoor composting and encouraging wildlife in gardens. However, the residents in these sustainable developments have a social profile biased toward higher proportions of managerial/professional households, and this could act negatively against reducing car use but positively on other attitudes toward sustainability. The analysis suggests that while sustainable developments can provide the built environment to support sustainable lifestyles they do not necessarily lead to a change in behaviour.

Ecological and Psychological Benefits of Urban Green Space

Public green space in cities is generally designed and managed to support the recreational activities of people with little or no reference to the ecological benefits. At the same time from a social-psychological perspective urban nature is an important if under-recognised component of quality of life for urban residents. Similarly urban public and private green spaces are an understated ecological resource and represent significant components of regional and national biodiversity conservation networks. In addition urban biodiversity patterns arise in response to, and are maintained specifically by, repeated human activity. Human interventions can not only degrade but can also improve urban ecosystems. Chapter 10 argues that there are benefits to managing urban green spaces better from an ecological perspective that will also increase the benefits to people.

The analysis examines biodiversity and human recreation activities in private and public green space. Proximity to green space is a strong selection factor in park usage and proximity has been shown to play a role in levels of physical activity and self-reported health. This research suggests that access to green space varies across social groups. However, the extent to which access to green space equates with access to biodiversity is currently unknown, and will depend on how the biodiversity value of urban green spaces is distributed across the urban landscape. Given that the psychological benefits of green spaces increase with their biodiversity, there is a need to incorporate biodiversity measures into an audit of access to green space for urban residents.

The research on private gardens demonstrates that individual decisions made by landowners can result in large scale effects on environmental conditions. This raises the intriguing possibility that garden bird feeding could be galvanised to influence the conservation status of a particular species occurring within urban areas. Urban environments support nationally important populations of some species, yet in many cases conservation biology has yet to incorporate the urban environment into conservation planning exercises. The degree to which people-nature interactions can be harnessed to achieve national biodiversity targets remains unknown. Such interactions might also contribute to targets relating to urban liveability. Given that private gardens cover such a large proportion of many modern cities, surprisingly little is known about motivations and drivers of private garden management. From a policy perspective, both the conservation of urban biodiversity and the enhancement of public health depend on a better understanding of this issue

Public green space and private gardens might, to some extent, provide alternatives for contact with nature in urban settings. Indeed, in Sheffield there is a negative correlation between the extent of public green space and private garden space across the city. However, the degree to which these different kinds of green space can substitute for one another to support biodiversity is unclear as these two very frequently play different roles. For example, public green space can promote community integration while social interactions in gardens are focused around a private social network. The persistence of privately provided green space may also be less secure as gardens are built over during infill development.

Overall urban green spaces are valuable for both biodiversity and for people, and management solutions must complement both values. Because of the highly synergistic nature of the relationship between these two types of benefits, the needs of management for biodiversity value and human well-being need not always indicate divergent solutions. To discover and implement such solutions will require systems of implementation that can actively trade off ecological value and benefits to human well-being. Urban design and management strategies must therefore be sought that complement both the ecological and the human value of urban green space.

Urban Form and Sustainability

Having examined how the different dimensions of sustainability link to elements of urban form, this section suggests how some relationships between them work. As noted earlier, elements of urban form overlap, and for simplicity the general focus here is on density in its broadest sense as a key physical variable. It is a useful vehicle to summarise our findings and also represents the primary variable at the centre of much debate about the shape of sustainable cities. However, some caution must also be applied as there are various measures of density, and related urban form elements do not reduce to a single dimensional variable.

The conclusions from the preceding chapters can be summarised in the following points:

- Green space in total, and its connectivity, is reduced at higher urban densities, which affects the level of ecosystem services provided as well as opportunities for recreation and other benefits to human health and wellbeing.

- There are positive relationships between biodiversity and human well-being across both public and private green spaces within the city, so indirectly relating wellbeing to urban form in conjunction with the above point
- One key measure of biodiversity, bird species richness, shows a hump-shaped relationship with housing density, initially increasing but declining sharply in more highly urbanized sites.
- Road and associated infrastructure costs increase by a higher than proportional rate with falling density.
- Energy use in buildings is only weakly linked to the built urban form, being determined primarily by socio-demographics and lifestyles.
- There is some flexibility in the intra-urban location of commercial and industrial land uses. While the city centre remains the dominant location for offices and retailing there are benefits from decentralisation. These patterns suggest that the economics of these land uses will not constrain the establishment of compact or dispersed urban forms.
- Residents' sense of pride and attachment to neighbourhood, their sense of safety, their rating of environmental quality, satisfaction with the home and residential stability are all greater in lower density neighbourhoods, controlling for a wide range of other influences.
- Social interaction and friendliness and participation in local collective activities tend to be highest in areas of medium density, after allowing for socio-demographics.
- Use of local services is greater in areas of higher density and better accessibility.
- Car ownership, particularly the propensity of higher income households to have two cars, is markedly less in higher density areas allowing for other factors. Limited parking supply and regulatory control in high density neighbourhoods can also be expected to play a role in reducing car demand.
- Travel distances in general and by car tend to be less in central and higher density areas, and where employment locations are closer, and these tendencies will reinforce the car ownership effect. These effects are not simply due to selection effects but appear to be causally related to density and location.
- Private residential choices in general favour low density suburbs but there is a household life-cycle element to residential location choice. Younger and non-pensioner single households live in the central city areas but move out to suburban locations as they move through the family life cycle.
- Gardens emerge strongly as a positive feature for both individual preference satisfaction and social/public goods, including biodiversity and ecosystem services.

The interpretation of some of these relationships between urban form and dimensions of sustainability must be treated with some care. In studying these links, for example between density and social outcomes it is essential to control for the influence of other intervening variables, as these factors can have significant influences and affect conclusions. For example, poverty in particular is a key influence on the social sustainability of a neighbourhood. Lifestyles, including the use of cars, are not necessarily determined by urban physical form, although they may be influenced and constrained by it. Consumption in its broadest sense is more broadly determined by incomes and social class. This is reflected in the patterns of the spatial viability of new housing development being more dependent on the socio-economic status of a neighbourhood than any particular feature of urban form.

The implication of the above findings is that there are indeed complementarities and contradictions, and that there will be trade-offs between them. The detailed findings that measured each aspect give a clear understanding of the magnitude or significance of each. Thus this research challenges the simple compact city thesis in that, for example, the social dimension of sustainability is compromised by high density living while there are no clear economic benefits to this urban form beyond the greater viability of local services. Very high density cities also have significant negative biodiversity and ecosystem effects. These negative effects mean that from an environmental perspective there are ecological pluses and minuses of different urban forms within a sub-regional context and that minimising the built up urban area through high densities/maximising the surrounding green space may not be the optimum solution.

Towards Urban Sustainability

The research presented in this book queries the implicit direct role of physical determinism on human behaviour in many of the sustainability arguments. Creating high density cities does not necessarily reduce car travel. Building sustainable developments does not mean that the residents have sustainable lifestyles. Simply (re)designing a series of 'sustainable' neighbourhoods is not a sufficient condition for the sustainable city. Wider socio-economic-demographic influences can be more dominant influences. In policy terms, these point towards other measures, for example the use of social marketing via media and promotion, tax incentives, regulations and so forth.

The relationships between household behaviour, lifestyles and attitudes and urban form is complex, although there is a clear family life cycle relationship. While high density living may be socially acceptable to some for others, particularly families, suburban living appeals as a compromise between providing space and the availability of services. Not only is there no single optimum density for a neighbourhood but market forces will ensure that density will vary with location, shaping any planned urban form in the medium to long term. Sustainable planning policy and guidance cannot ignore these forces.

The influences on the elements of urban form are argued to be the outcome of the operation of real estate markets within a framework set by a city's transport infrastructure and moderated by local planning policies. They reflect a myriad of private choices, whether by individual households seeking a home (balancing affordability and access against a wish for more space) or by developers looking at the optimal mix for developments within constraints set by planning. However, these decisions also have pervasive external or 'public' effects: each new development changes the outlook for existing residents, reduces or changes green space, increases congestion, and has consequences for urban sustainability. There are inevitably contrasts between the private and public perspective on urban form that planning policy has to manage.

Policies toward housing as the dominant land use in cities are key to urban sustainability. The evidence on commercial and industrial land uses is that they are relatively agnostic with regard to specific urban forms. The housing market and household attitudes toward and satisfaction from particular built forms are keys to the sustainability of cities. This requires not only market viability (derived in part from household preferences) but also a sufficient supply of housing that is affordable. Cities are dynamic entities it is not sufficient for urban planning to stifle physical development simply to create a compact city; the city-region must also be able to accommodate any urban growth in a sustainable manner. Our findings suggest a range of densities should be accommodated, and this will require a holistic approach that encompasses the provision of social and physical infrastructure to ensure a sustainable solution.

An important aspect of sustainable urban policy (and shaping urban development) is changing the transport infrastructure and public/private travel costs. To date explicit sustainable transport policies primarily aimed at switching people from private to public transport have not been very effective; stronger price incentives or demand management measures may be necessary.

Achieving sustainability may require fundamental change to existing neighbourhoods and cities, and where necessary it has to be accepted at the outset as a long term process. The substantial upheaval that is often necessary within a neighbourhood to establish more intensive land use and higher densities may engender public opposition. Any reshaping of cities requires major adjustments to the local real estate markets and may require substantial public expenditure costs. Such strategies to adapt the city form will require a consensual long term public policy framework to ensure confidence for private property investment.

Thus, policy emphasis may be better placed on improved management of cities, especially of neighbourhoods, infrastructure and green space. The message is that sustainability is not a simple concept and hence policies to address it will be diffuse and vary by neighbourhood. There may be scope for greater intensification in some areas that have underused space, while in others the reverse may be true. Neighbourhood strategies need to be bespoke rather than be subject to a generalised ‘one size fits all’ approach.

A Wider Perspective

The evidence presented in the book questions some of the established views on sustainability and urban form. The research presented in this book is set within a UK context, so how far can the lessons of urban sustainability be taken?

The cities investigated here are relatively high income, with modest population growth, or even decline. Within them there are variations in wealth and poverty, and densities, although varied, are neither very low, nor very high by international standards. The five cities show that lower density areas tend to be associated more with higher income groups with higher levels of satisfaction, and that high density is more associated with poorer people. This may be fairly typical of most cities in the UK, although there are exceptions. For example, some of the wealthiest areas of London or Edinburgh have high density urban forms, and there are many examples of impoverished low density estates on the periphery of the UK's larger cities (including a couple of examples within our sample).

If the frame of reference is widened, and cities are considered in other parts of the world, then again the issues, or at least balance between them changes. In cities of burgeoning size and complexity, with rapid growth and extremes of poverty, such as Mumbai with some 50% of its population living in slums, the balance, management of growth and development will require different solutions. Nevertheless, the principles expounded in this research and the forces identified here are of use in all urban contexts. First, it has identified the key elements of urban form and the potential relationships with the three key dimensions of sustainability. Second, it has shown how this can be measured and understood. Third, it has indicated where potential trade-offs might be found, albeit in the context of Western cities.

A city form is neither wholly sustainable nor unsustainable, rather it is a question of degree. Further, the extent of sustainability depends on which dimension of sustainability is considered. The complexity of the various dimensional trade-offs in terms of different metrics, value judgements, essential or acceptable standards and location specific factors, and the weighting between them means that policy decisions aimed at improving sustainability are not necessarily easy.[1]

The scale and context of any such comparison or assessment has also to be considered. A city/region as a whole may be more or less sustainable, but so also may be different neighbourhoods within a given city. A city is a system of parts and different parts are needed for the whole to function – a city needs its centre, its suburbs, and so forth, and different demographic groups or businesses need different types of place to function most effectively. Furthermore, cities are not static phenomena so that any such scoring would need to consider a trajectory or change or only represent a guide to future policy.

This discussion suggests that, given the dynamic nature of cities and in the absence of an single uniquely sustainable urban form, sustainability policies should not seek as a long term goal to create a definitive urban form. A single such form does not exist, but instead, as we have shown, there are a number of avenues down which more sustainable forms can be achieved. It also indicates that simply examining the sustainability dimensions of a core city is not enough, and that it is necessary to consider at least the city region and probably the urban system with a sub-region.

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[1] The use of multi-criteria evaluation is one way forward for this general problem, e.g., see: Munda G (2006) 'Social multi-criteria evaluation for urban sustainability policies', *Land Use Policy*, 23, 1, 86–94.

A more incremental and varied approach to urban sustainability implies the development of a set of guiding principles to adapt and manage the existing city forms and to plan urban development. It accepts that sustainability policies have to start with the cities and towns that already exist, and planning is often about incremental change. Given the complementarities and contradictions within the dimensions of urban sustainability, this implies examining strategic sustainability options for a particular city in a holistic manner. Such strategies could encompass a range of generic urban development or management scenarios including: intensification of some neighbourhoods within the existing built-up area of the city; integrative green space planning, incremental expansion at the edge of the existing urban area; corridor developments with intensive nodes oriented to transport network changes; reconfiguration of transport infrastructure linked to expansion of existing satellite towns or one or more new settlements. The list is only indicative but it would also be intrinsic to these sustainability options to integrate the principal infrastructural investments which would accompany them. Beneath these strategic level options there are many micro issues about the constraints on individual new developments, adaptations to the existing built environment and the integration of land uses.

Conclusions

There are no simple messages from this book. There are no easy sets of urban form sustainability rules or forms for policy makers, there are many trade-offs, and often conflicting ones at that. Indeed much of the existing debate is to a certain extent misplaced, as it is of little value to polarise the issues into either the compact city or the dispersed urban form. Both exist side by side, and it is the balance between them, and the way in which they can be enhanced, merged, connected and made more sustainable that matters. Policies to improve urban sustainability must be more bespoke. Urban form does affect sustainability but the relationships are subtle and they can be overstated. Many influences on urban sustainability are not the consequence of a city's form but exogenously determined by the socio-economic-demographic characteristics of the local population or non-spatial factors such as the price of energy.

The book does show that there is scope for re-engineering existing cities. It suggests a sensitive management of urban intensification that is targeted on key urban areas, especially related to accessible public transport. It means that where higher densities are achieved, the management and incorporation of both public and private green space needs to be maintained, perhaps through green corridors and smaller, but useable private gardens. It suggests that, where family homes are to be built, forms need to be designed to discourage urban sprawl at the same time as fulfilling family aspirations, and some of the medium density schemes illustrated in Chapter 9 could provide a model. It suggests that a holistic approach to urban management is desirable. The research here has shown that there is a need to manage the trade-offs between, for example, density in relation to biodiversity, social acceptability, transport, and the real estate market. A balance could be achieved if it is accepted that densities will vary from the lower (not lowest) to the acceptably high, and that it is the transport links between them, and overall cumulative effect on sustainability that might be managed to accommodate growth.

It is a universally accepted truth that research tends to raise more questions than answers. This book is no exception. It has uncovered some new and surprising relationships. It has given both comfort and pain to advocates of the compact city. It has shown that it is possible to measure something as complex a city in relation to sustainability. It has identified some key aspects where trade-offs can be identified, and which can provide a basis for policies for the sustainability. But, in the end we have to conclude that there are no simple answers or clear relationships between urban form and the dimensions of the sustainable city. Instead we offer strong pointers for policy makers on strategies to improve the sustainability of cities.

Appendix A
MCA Spatial Analysis

The aim of the spatial network analysis applied in this research is to:

- identity type of layout (e.g. gridded, tree-like etc.);
- numerically express the level of compactness and complexity of the layout.

The total length of streets in a neighbourhood along with node density and sprawl can express the compactness of layout, for example, more accurately mathematically speaking than a simple measure of the residential density of land area. Multiple Centrality Analysis (MCA) provides an objective way of consistently identifying elements such as streets and junctions as well as a set of scale variables that distinguish the spatial and network characteristics of an urban layout.

Fundamental to MCA is the representation of spatial relationships in a city or neighbourhoods as a primal graph and then the calculation of a centrality space (point) by its location in the network (betweenness) or by its physical distance to all other spaces in the network (closeness). Thus a space with high 'betweenness' value indicates a strategically central space that it is crucial to a large number of short routes[1] between two other spaces. While betweenness and closeness values are useful in distinguishing relative centrality or compactness of individual spaces within a neighbourhood, measures such as cost, efficiency, meshedness and fractal (sprawl) dimensions and complexity distinguish the structural characteristics (size, type, shape) of the spatial network of a whole neighbourhood or sub area.

Two indicators of the structural characteristics of the street layout of a neighbourhood, taken from the range detailed in Table A.1, have been used in the book. First, node density is calculated as the number of street intersections per hectare. Second, a composite 'complexity index' is derived to systematically identify types of layouts such as grid-like or tree like patterns (see Fig. A.1). The relationship between the index and the layout typology was tested by a number of schematic layouts before validating them with real cases from the study areas.

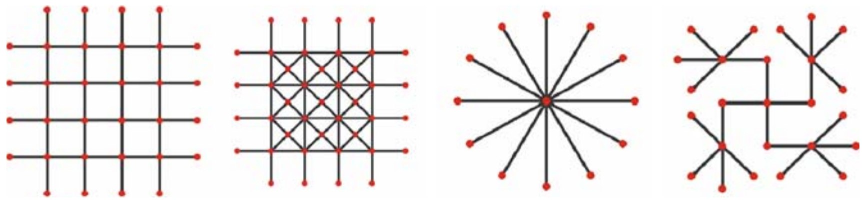
The complexity index is constructed in two steps based on assessments of the 'efficiency' of a spatial network that is determined by reference to the choices of routes available. Choices of routes within a network can be calculated using two MCA efficiency indicators: ('network efficiency' and 'MST efficiency': for details see Cardillo et al., 2000[2]). Network efficiency calculates the efficiency of the actual

M. Jenks, C. Jones (eds.), *Sustainable City Form*, Future City 2,
DOI 10.1007/978-1-4020-8647-2,

Table A.1 Indicators of urban layout

Measurement	Description	Examples of aspects/features measured
Indicators of spatial characteristics		
Betweenness Centrality *(individual space, neighbourhood & Sub-area)*	Strategic spaces that are located on the short routes between a pair of spaces in the network	Spaces within the city and neighbourhoods
Closeness Centrality *(individual space, neighbourhood & Sub-area)*	The proximity of a space to all other spaces using shortest path	All possible routes from A to B Average distance of all paths between A and B
Indicators of structural characteristics		
Node density	Number of street junctions per hectare	Street junctions (e.g. T-junctions, culs-de-sac)
Cost of network	The total physical length of the spaces	Size of network
Efficiency of network *(Neighbourhood & Sub-area)*	The evenness of distribution and connectedness of a network	The ratio of proximity of two spaces compared with the virtual distance (i.e. ‘as the crow flies’ distance)
Note on Cost and efficiency *(Neighbourhood & Sub-area)*	Efficiency and cost of network indicates the layout’s compactness MST (Minimum Spanning Tree) used to compare above with most efficient layout	Cost of network + node density MST: spatial network is reduced to a tree pattern by removing choices of routes before calculating the cost and efficiency
Meshedness *(Neighbourhood & Sub-area)*	– Meshedness of whole network calculates the complexity of a network	Number of circular routes in the network
Fractal dimension *(Neighbourhood & Sub-area)*	– The sprawl of a network measured by taking into account both physical area and the network	Measure a regular sized box to cover the perimeter of the network
Complexity index *(Neighbourhood & Sub-area)*	– Index can indicate the layout pattern (i.e. more tree-like or grid-like)	Ratio of MST to Network cost

network, while MST (Minimum Spanning Tree) efficiency calculates the efficiency of the network once all the possible choices of routes have been reduced to a minimum. These two indicators are then combined to give the ‘complexity index’ which is the ratio of efficiency values calculated by the minimum spanning tree (MST) to network method. A high value ratio (where there is a greater difference



The more choices of routes, the more grid-like the pattern The fewer the choices of routes, the more tree-like (cul-de-sac) the pattern

Fig. A.1 Urban layouts and the 'cost' and 'efficiency' of their networks

between the two values) indicates fewer choices of routes, and a more tree-like pattern and a less efficient network. A low value ratio (where there is a lower difference between the two values) indicates a higher number of routes, a more grid-like pattern and a more efficient network. Fig. A.1 shows some schematic urban layouts to illustrate this assessment.

Notes

1. For more information on MCA, see www.humanspacelab.com
2. Cardillo, A., Scellato, S., Latora, V. and Porta, S. (2006) Structural properties of planar graphs of urban street patterns, *Physical Review E*, **73**: 66–107

Appendix B
Overview of Case Study Neighbourhoods

The analysis presented is based on the statistics listed in Chapter 2, Table 2.6 and Table B.1.

Inner Neighbourhoods

The highest densities are in the inner neighbourhoods of Edinburgh and Glasgow where traditional tenements and flats are prevalent. Both of these neighbourhoods have net densities above 225 dwellings/ha. A very high proportion of buildings in these neighbourhoods are more than four storeys in height. Although a traditional form of housing in Scotland, there are now few families living in these tenemented neighbourhoods, which tend to be dominated by small households with one or two adults. Aside from tenements, the inner case studies in the English cities are very similar with lots of tall buildings, lots of flats and few families. The main exception to this is Oxford, where only half of homes are flats and there is a significant proportion of terraced housing. Patterns of tenure vary greatly between the inner case study neighbourhoods. In both Leicester and Sheffield more than 70% of homes are rented, with social housing making up more than 50% of housing stock. Edinburgh and Glasgow's inner neighbourhoods have more of a balance between owner occupation and rented accommodation – with owner occupation accounting for around 50% of housing stock and private renting for 25% of housing stock. Oxford is also exceptional here with little social housing in the inner case study neighbourhood and just over 30% privately rented.

As might be expected, residential buildings are only part of the building stock in these inner neighbourhoods. In the neighbourhoods studied, around 15–20% of the land in the neighbourhood is covered by non-residential buildings – although the Edinburgh inner neighbourhood is notable for having a much smaller proportion of land covered by non-residential buildings (6%). These buildings are mainly used for retail, with office uses also occupying a significant proportion of non-residential properties. The inner neighbourhood of Glasgow is the main exception to this rule, with a far higher proportion of offices than retail uses. This is largely explained by the location of the case study neighbourhood which coincides with the commercial rather than retail centre of the city.

Table B.1 Some Physical Characteristics of the Neighbourhoods

	Urban Form	
Edinburgh Inner (2958 ha)	*Density*	Gross density 92.3 Net density 270.5
	Land use	*5% of buildings are mixed use* 14% of the area is covered by residential buildings, 11% by residential gardens and 6% by non-residential buildings. *24% is green space*
	Public transport	Mainly buses/ 34% residents do not own a car
	Layout	Compact, with grid and cul-de-sac form
	Building characteristics	78% of buildings are between 4 and 6 storeys 13% have access to a private garden; 73% access to a shared garden
Glasgow Inner (3694 ha)	*Density*	Gross density 34.7 Net density 226.2
	Land use	14% of the area covered by residential buildings; 1% by residential gardens; and 21% by non-residential buildings; *29% is green space*
	Public transport	Buses and train station within case study area/ 37% residents do not own a car
	Layout	Deformed compact grid
	Building characteristics	62% of buildings between 4 and 6 storeys, and 13% more than 6 storeys 8% have access to a private garden; 28% access to a shared garden.
Leicester Inner (3635 ha)	*Density*	Gross density 15.7 Net density127.1
	Land use	7% of area is covered by residential buildings, 4% by residential gardens and 21% by non-residential buildings; *27% is green space*
	Public transport	Mainly buses/ 86% residents do not own a car
	Layout	Deformed wheel, radial
	Building characteristics	34% of buildings between 4 and 6 storeys, and 28% more than 6 storeys 10% have access to a private garden; 25% access to a shared garden.
Oxford Inner (3363 ha)	*Density*	Gross density 30.6 Net density 83.7
	Land use	10% of the area is covered by residential buildings, 10% by residential gardens and 15% by non-residential buildings; *31% is green space*
	Public transport	Mainly buses (with main bus station) and train station close to case study/ 59% residents do not own a car

Table B.1 (continued)

	Urban Form	
	Layout	Crucifix form, with small blocks at the centre
	Building characteristics	35% of buildings are 2 storeys and 37% are 3 storeys 43% have access to a private garden; 25% access to a shared garden.
Sheffield Inner (4027 ha)	*Density*	Gross density 22.8 Net density 116.9
	Land use	*14% of buildings are mixed use,* 6% of the area is covered by residential buildings, 10% by residential gardens and 9% by non-residential buildings; *38% is green space*
	Public transport	Buses and trams with train station outside 400 m buffer zone/ 81% residents do not own a car
	Layout	Deformed compact grid
	Building characteristics	35% of buildings are 3 storeys 27% are more than 6 storeys 22% have access to a private garden; 20% access to a shared garden.
Edinburgh Between (4107 ha)	*Density*	Gross density 37.9 Net density 69.5
	Land use	14% of the area is covered by residential buildings and 31% by residential gardens; *24% is green space*
	Public transport	Mainly buses/ 26% residents do not own a car
	Layout	Predominantly gridded, not orthogonal
	Building characteristics	29% of buildings between 4 and 6 storeys 56% have access to a private garden; 45% access to a shared garden.
Glasgow Between (9863 ha)	*Density*	Gross density 33.1 Net density 68.4
	Land use	14% of the area is covered by residential buildings and 40% by residential gardens *16% is green space*
	Public transport	Buses and train station within case study area/ 15% residents do not own a car
	Layout	Deformed grid with some compact grids
	Building characteristics	36% of buildings are 3 storeys and 47% are 4 to 6 storeys 31% have access to a private garden; 66% access to a shared garden.
Leicester Between (2066 ha)	*Density*	Gross density 48.2 Net density 79.9
	Land use	22% of the land is covered by residential buildings and 37% by residential gardens *9% is green space*

Table B.1 (continued)

	Urban Form	
	Public transport	Mainly buses/ 37% residents do not own a car
	Layout	Deformed grid
	Building characteristics	79% of buildings are 2 storeys 71% have access to a private garden; 8% access to a shared garden.
Oxford Between (4049 ha)	*Density*	Gross density 39.9 Net density 80.8
	Land use	14% of the area is covered by residential buildings and 33% by residential gardens *22% is green space*
	Public transport	Relatively poor provision of bus routes due to proximity to city centre. Train station is close to case study/ 50% residents do not own a car
	Layout	Elongated deformed grid with compact grid within
	Building characteristics	47% of buildings are 2 storeys, 30% are 3 storeys 57% have access to a private garden; 25% access to a shared garden.
Sheffield Between (4964 ha)	*Density*	Gross density 37.5 Net density 59.1
	Land use	16% of the area is covered by residential buildings and 47% by residential gardens *13% is green space*
	Public transport	Mainly buses with tram stops close to case study/ 47% residents do not own a car
	Layout	Deformed compact grid
	Building characteristics	79% of buildings are 2 storeys 75% have access to a private garden; 8% access to a shared garden.
Edinburgh Outer (17227 ha)	*Density*	Gross density 18.3 Net density 26.6
	Land use	10% of the area is covered by residential buildings and 34% by residential gardens *38% is green space*
	Public transport	Mainly buses/ 9% residents do not own a car
	Layout	Compact super grid
	Building characteristics	32% of buildings are single storey and 60% are 2 storey 88% have access to a private garden; 13% access to a shared garden.
Glasgow Outer (6456 ha)	*Density*	Gross density 8.2 Net density 46.3
	Land use	2% of the area is covered by residential buildings and 8% by residential gardens *77% is green space*
	Public transport	Mainly buses with train station outside case study area/ 19% residents do not own a car

Table B.1 (continued)

	Urban Form	
	Layout	Clustered dispersed culs-de-sac
	Building characteristics	84% of buildings are 2 storeys 86% have access to a private garden; 4% access to a shared garden.
Leicester Outer (4998 ha)	*Density*	Gross density 17.2 Net Density 24.5
	Land use	9% of the area is covered by residential buildings and 54% by residential gardens *17% is green space*
	Public transport	Mainly buses/ 19% residents do not own a car
	Layout	Very deformed grid with culs-de-sac
	Building characteristics	96% of buildings are 2 storeys 97% have access to a private garden; 1% access to a shared garden.
Oxford Outer (4449 ha)	*Density*	Gross density 30.8 Net density 62.8
	Land use	11% of the area is covered by residential buildings; and 30% by residential gardens *27% is green space*
	Public transport	Buses only/ 46% residents do not own a car
	Layout	Predominantly culs-de-sac
	Building characteristics	76% of buildings are 2 storeys 80% have access to a private garden; 12% access to a shared garden.
Sheffield Outer (8660 ha)	*Density*	Gross density 18.6 Net density 26.5
	Land use	11% of the area is covered by residential buildings and 57% by residential gardens *13% is open space*
	Public transport	Buses only/ 22% residents do not own a car
	Layout	Curvilinear with culs-de-sac
	Building characteristics	79% of buildings are 2 storeys 84% have access to a private garden; 11% access to a shared garden.

Between Neighbourhoods

As a group the between case study neighbourhoods are characterised by their diversity. Net residential density ranges from 60 to 80 dwellings/ha. Two and three storey homes are common, although in both Glasgow and Edinburgh around one third of homes are between 4 and 6 storeys (e.g. tenements), and the vast majority of residents have access to a private or shared garden. Flats dominate the Glasgow between neighbourhood making up 80% of housing stock, while terraced houses dominate in Sheffield. The other between neighbourhoods have a more mixed housing stock, and tend to include a variety of terraced, detached and semi-detached houses as well as flats. Tenure mix is also variable, ranging from almost no social renting in the Leicester case study neighbourhood (lowest) to around one-quarter in the Edinburgh case study neighbourhood (highest). As might be expected, the variety in housing type and tenure is reflected in the resident population. Retired and family households both feature here, although they usually account for no more than half of households.

Non-residential land uses also vary considerably amongst this group. While retail is the most important non-residential land use in all of the 5 between neighbourhoods, both Glasgow and Oxford are distinguished by a significant proportion of office buildings. Generally between neighbourhoods are also included some industrial buildings, which are not so plentiful in either inner or outer case study neighbourhoods.

Outer Neighbourhoods

The outer case study neighbourhoods fall into two groups: Sheffield, Leicester and Edinburgh typically have net densities around 25 or 26 dph. Glasgow and Oxford on the other hand have much higher residential densities of 46 and 63 dph respectively. In the lower density suburbs, the housing stock is almost exclusively 2 storeys in height, with some single storey housing (bungalows) in the Edinburgh neighbourhood. Residential gardens account for a significant proportion of land cover in these neighbourhoods. This is particularly true in the outer neighbourhoods of the English cities studied. Here, around 50% of land is taken up by residential gardens *in addition to* open green space. The outer case study neighbourhoods are also notable for the small proportion of rented accommodation – although Oxford is also exceptional here, with 40% of homes owned by social landlords and 10% in shared ownership.

Non-residential buildings in the outer case study neighbourhoods are more varied in their character than in the inner and between neighbourhoods. No clear pattern is evident here. Retail uses dominate in the Edinburgh and Sheffield outer neighbourhoods, while warehouses are dominant in Leicester and industrial uses in Glasgow and Oxford.

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Note: The letters ‘f’, ‘n’ and ‘t’ following the locators refer to figures, notes and tables respectively

C