Growing Cities Sustainably

Does Urban Form Really Matter?

Marcial H. Echenique, Anthony J. Hargreaves, Gordon Mitchell, and Anil Namdeo

Problem, research strategy, and findings: It is commonly asserted that so-called compact development is the urban form most able to sustainably accommodate growth by reducing travel distances and conserving land, but credible supportive evidence remains limited. This study rigorously and realistically tested the relative performance of spatial options over the next 30 years for three distinct kinds of English city regions. Statistical models first forecast the behavior of people within interacting markets for land and transport. These outputs were then fed to established simulation models to generate 26 indicators measuring the economic efficiency, resource use, social impact, and environmental impact of the spatial options. This permitted an explicit comparison of the costs and benefits of compact against sprawling urban forms for these regions. While the prototypes (i.e., compaction, sprawl, edge expansion, and new towns) were indeed found to differ in their sustainability, no one form was clearly superior. Rather, the change to "white collar" lifestyles and associated population growth dominates the impacts on the natural environment and resources, far overwhelming those attributable to spatial urban form.

Takeaway for practice: Urban form policies can have important impacts on local environmental quality, economy, crowding, and social equity, but their influence on energy consumption and land use is very modest; compact development should not automatically be associated with the preferred spatial growth strategy.

The paradigm of city planning in recent decades has been to promote the compact city of dense development focused around urban centers of employment and local services to reduce the need to travel long distances and to make cities more vibrant. This is a reaction against sprawl induced by the near universal use of private automobiles. Claims that compaction will make cities more sustainable have been debated for some time, but they lack conclusive supporting evidence as to the environmental and, particularly, economic and social effects. Ewing, Bartholomew, Winkelman, Walters, and Chen (2007) and the Commission for Integrated Transport (2009) provide good reviews. The Transport Research Board (2009) analyzed studies based on observed data of U.S. cities to investigate the claim that compaction reduces vehicular travel, and concluded that it had a very modest effect (a conclusion very much in line with results we discuss below). It, nevertheless, retained an optimistic view that there may be benefits under some scenarios that it could not actually find in practice. The neglect of the economic and social costs of compaction is a significant omission in the Transport Research Board's argument.

The SOLUTIONS research project aimed to test the performance of urban compaction and alternative spatial options compared to the trend over the next 30 years for English city regions (for final report, see Echenique, Barton, Hargreaves, & Mitchell, 2010). To do this in a rigorous and realistic manner it is necessary to use models applied to actual city-regions to

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understand the interdependence of design factors, and systematically test and compare alternative policy designs. The models must represent the behavior of both land and transport users and how they react to changing conditions. To judge the benefits, or otherwise, it is necessary to define the sustainability objectives for the cities and to formulate indicators to assess to what extent the policy options achieve the stated objectives. These include not only environmental objectives, but also those measuring social and economic sustainability (see more on methods below).

In England, 10% of the total land area, which includes country roads, is urban and, according to the Department for Communities and Local Government (2008), over 70% of new development is taking place on this previously developed land (i.e., brownfield) at high densities to conserve greenfield land. This is a highly restrictive land use policy, constraining the supply of new houses and limiting lifestyle choice. Transport policy is focusing on public transport provision with correspondingly less highway investment (Banks, Bayliss, & Glaister, 2007). The current U.K. planning policy is to locate new developments where people can access services or facilities without having to rely on a car, focusing development in existing centers and near to public transport interchanges, using existing urban sites efficiently and promoting urban vitality (Department for Communities and Local Government, 2005). This policy is inspired by the compact city concept, but its outcomes are distorted by the restricted availability of development sites.

The sustainability of this policy trend, and alternatives to it, were forecast and assessed for three case studies (Figure 1) of contrasting scale and rate of economic change: 1) the Wider South East (WSE) region (20 million people) centered on London, which is under considerable development pressure due to increases in wealth and international migration; 2) the Tyne and Wear city-region (TWCR) of 1 million people in the northeast region with a declining industrial base and little demographic change, but with growth pressure from rising affluence; and 3) the Cambridge sub-region (CSR) of half a million people, lying within the WSE, with growth pressure from an expanding knowledge-based economy. By applying consistent policy designs, modeling methods, and assessment to each of these city regions we aim to draw robust conclusions on the sustainability of spatial planning policies and judge the extent to which results are scale and context dependent.

Background

Britain has policies for controlling the spread of cities, beginning in earnest with the 1947 Town and Country Planning Act, which has been remarkably successful in preventing suburbanization of open land through the introduction of green belts (urban growth boundaries) around many cities (Hall, Gracey, Drewett, & Thomas, 1973). But what have been the effects? On the one hand, the distinction between countryside and city has been preserved and rural landscapes protected. On the other, restrictions on the supply of development land have led to property price increases, penalizing city dwellers by leading to less dwelling space than in other European countries (Barker, 2004; Meen, 2005; Sak & Raponi, 2002). Higher property prices have affected the affordability of houses and reduced economic competitiveness for some industries. Furthermore, the green belt policy has led some urbanites to jump the protected rings of countryside to reach villages and towns offering the lifestyle they desire (Evans, 1998), leading to longer commuting journeys.

The policy has been reinforced in the last decade so that 72% of new dwellings in 2006 were built on brownfield land, up from 54% a decade earlier. Over the same period, the average net density of new-build housing has risen 64%, from 10 to 17 dwellings per acre in England, and dramatically increased in the London region from 23 to 43 dwellings per acre, an 89% increase (Department for Communities and Local Government, 2008). One downside of this policy is a substantial reduction in choice of dwelling types, with new dwellings being mainly apartments.

This emphasis on brownfield development ignores the fact that employment growth does not necessarily coincide with the location of available brownfield land. Moreover, the mere existence of vacant brownfield sites is precisely because of decline in employment in those areas. The areas around urban brownfield sites are often places of high unemployment, where people live in socially assisted housing. Meanwhile, areas where employment is thriving have severe constraints on land development, further inflating prices, which, in turn, increases the cost of living and production.

The trend to seek more space beyond the imposed green belt planning constraints has only been possible by increasing mobility, which, in itself, is the product of the reduced cost and time of travelling provided by the automobile. The consequences of high mobility are positive for individuals and firms but impose large externalities in terms of congestion, emissions, and accidents.

Alternative Options

Planners and policymakers have proposed three main options (Figure 2) for solving the problems discussed above

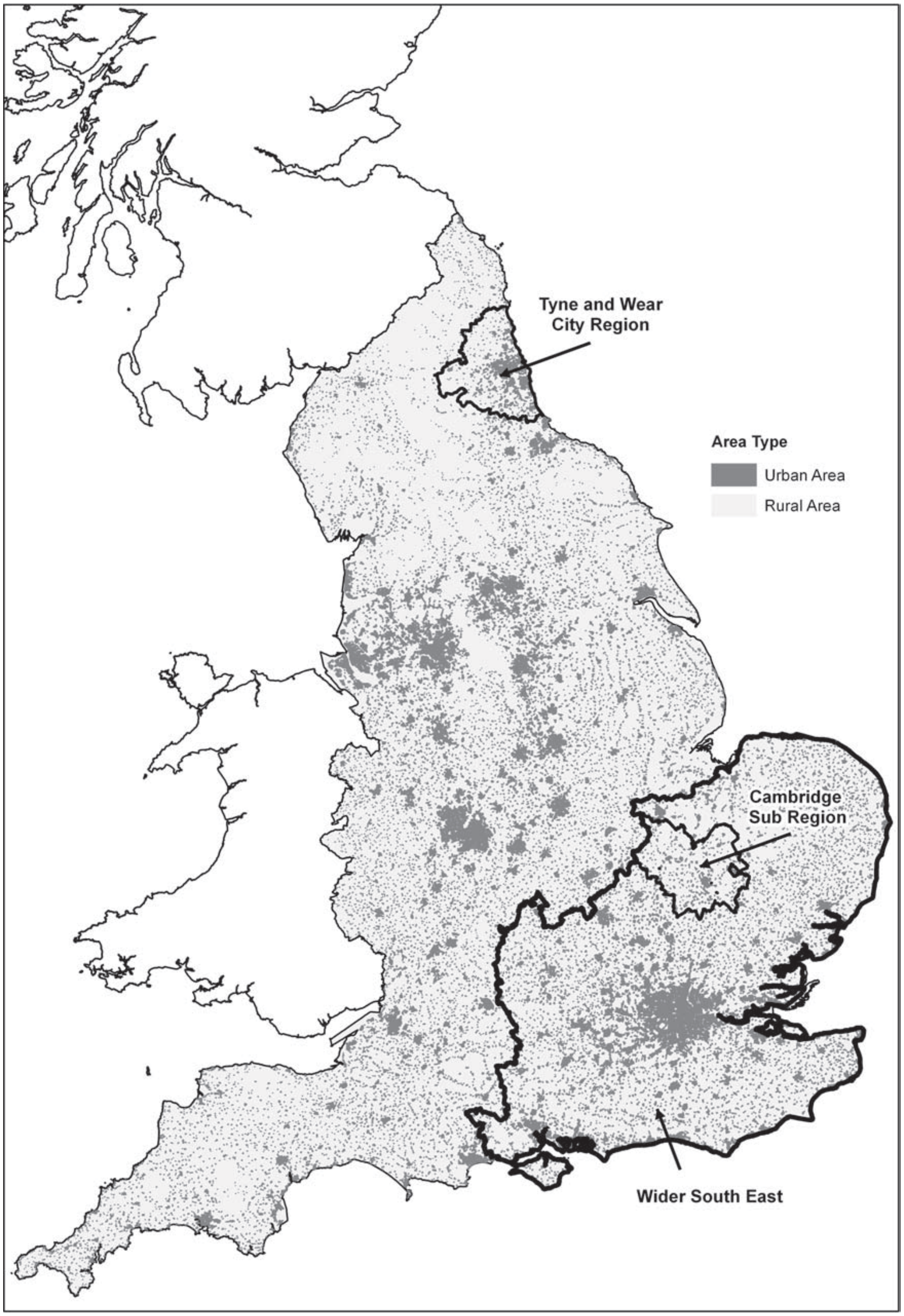

Figure 1. The case study areas.

and making cities more sustainable. These can be characterized as compaction, market-led dispersal, and planned expansion, with each one being a product of differing opinions on priorities for urban development. Compaction increases the intensity of urban areas in order to reduce vehicle travel and increase social diversity and urban vitality. Dispersal

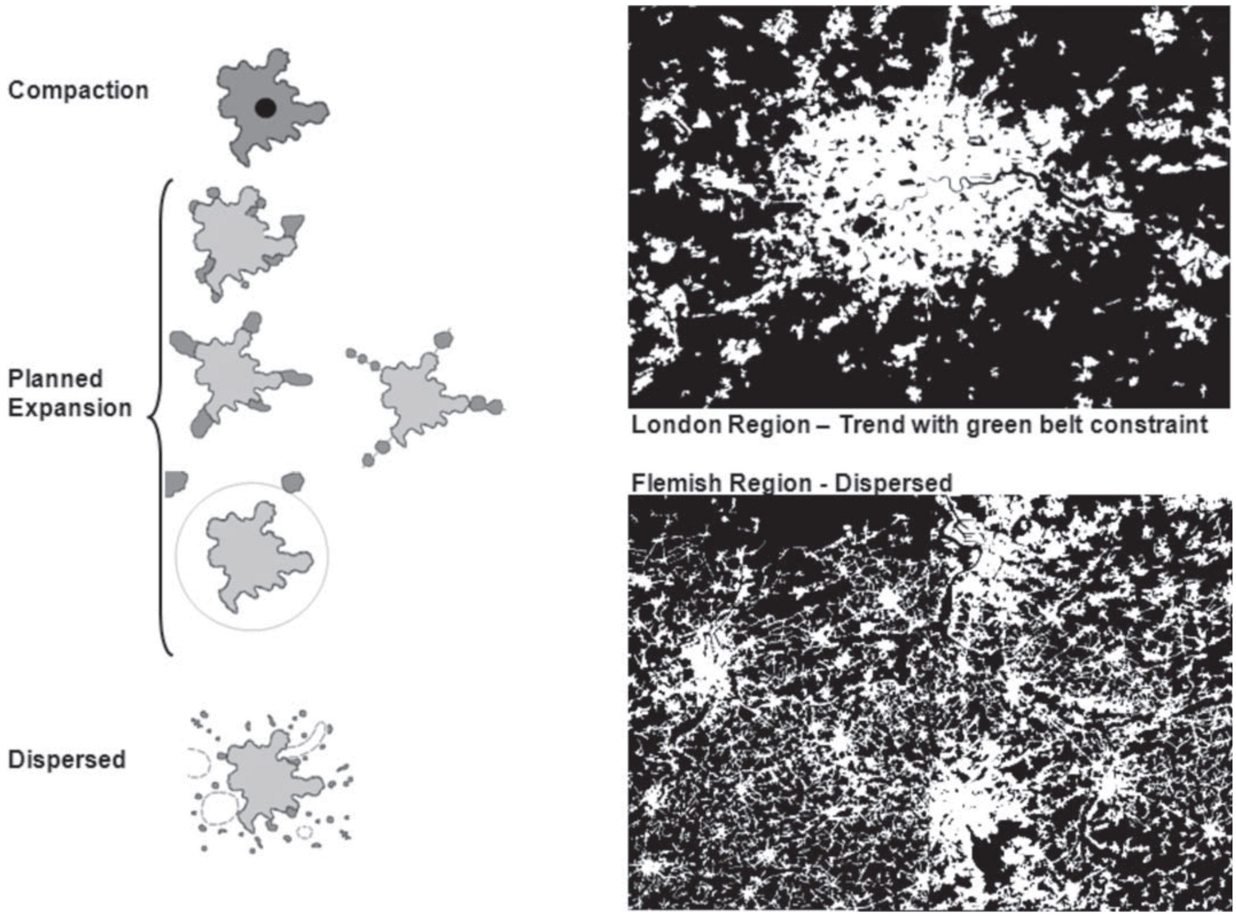

Figure 2. Alternative spatial designs for urban regions.
Source: Adapted with permission from Corine Land Cover, European Environment Agency.

diminishes the intensity of urban land use to reduce the costs of living and production and reflects the demand for affordable space and less crowding. Expansion by planned peripheral development and new settlements attempts to deliver the advantages of the preceding options and minimize their disadvantages by developing communities that are not crammed and protecting the open landscape.

Compaction

Compaction has been promoted in the United Kingdom by Richard Rogers's Urban Task Force (Rogers, 1999), which led to a White Paper on Urban Renaissance and policy advice (e.g., Department for Communities and Local Government, 2005). The main recommendations were to focus development at much higher densities within cities, mainly on brownfield land, and to invest in public transport. The policy assumes development is focused around a strong urban center where most commercial activity takes place. Compaction is often promoted as the urban form best able to lower CO_2 emissions.

A basic premise behind the prescription for higher density was an assumed relationship between density and fuel consumption proposed by Newman and Kenworthy (1989), who concluded that high-density cities consume less energy. This relationship has been discredited as the causality cannot be attributed solely to density determining fuel consumption; it has been demonstrated that density plays a small part in energy consumption if the price of fuel and other automobile travel costs, relative to income, is included in the analysis (I. Gordon, 1997). A more plausible causal explanation is that in those cities that have cheap travel, people tend to travel further in order to have more living space, as prices are lower outside central areas. Thus, transport cost is the cause of density rather than density being the cause of lower fuel consumption.

The compaction debate is not, of course, restricted to the United Kingdom (see Jenks, Burton, & Williams, 1996, and Williams, Burton, & Jenks, 2000, for international case studies and critiques). In the United States, there has been a vociferous campaign against sprawl promoted by smart growth and by the Congress for the New Urbanism (Calthorpe, 1993; Duany & Plater-Zyberk, 1991; Katz, 1994). They argue for focusing higher density development in areas with improved public transport supply (transit-oriented development). As an example, see the Oregon State Government (2010) urbanization and transportation policies. The evidence so far is rather inconclusive. Boarnet and Crane (2001) analyzed several case studies and were skeptical of the connection between urban design and travel behavior: "Land-use and urban design proposals, *if* they influence travel behavior, do so by changing the price of travel" (p. 103). From a meta-analysis of studies, Ewing and Cervero (2001, 2010) concluded that increasing density itself has only a marginal impact on reducing automobile travel. Doubling the density of a neighborhood only reduces automobile vehicle distance traveled by around 5% per person, although other built-environment factors such as proximity to downtown areas and jobs can reduce automobile distance traveled by around 20%. The obvious conclusion is that an increase in density will increase traffic congestion, and Sorensen (2009) demonstrates that high average density is the main cause of highway congestion in Los Angeles. It can also increase the overall respiratory disease burden as exposure to traffic emissions is increased (Schweitzer & Zhou, 2010).

It is argued that an aging population will demand smaller dwellings and that immigrants tend to live in apartments in central districts. There is, however, no substantial evidence that older couples leave their spacious houses and gardens, as the space may be kept for receiving the family on occasions during the year. When immigrants arrive, they are, on the whole, poorer and younger, and so are prepared to live in small apartments, but, as they become older and wealthier, they move to the suburbs (Department of Environment, Transport and the Regions, 2000). Proponents of high density claim that it will improve health by encouraging more walking and cycling, whereas opponents point out that high-density living would reduce the healthy and popular activity of gardening (Donovan & Halpern, 2002; Gross & Lane, 2007).

Dispersal

Dispersal has been promoted by many economic analysts (e.g., I. Gordon, 2008; Richardson & Gordon, 2001). Reducing restrictions on the supply of land clearly reduces its price, which, in turn, increases its use. The consequences are more living space and lower real estate costs, which, in turn, reduce living, labor, and production costs, making the region more competitive and productive in certain industrial sectors. Sprawl is, generally, the consequence of allowing the market for supply and demand of land to operate without restriction (Bruegmann, 2005). The detractors of this form of development argue that it is environmentally unsound as it increases resource consumption (land, nonrenewable energy), reduces biodiversity, increases greenhouse gas emission, and is socially unjust (Rogers & Power, 2000). Some argue that dispersal requires more extensive utility and road networks than denser districts, but others argue that although the networks are more extensive the unit cost of installation is lower.

The dispersed city idea of mixing rural and urban uses through transport improvements has a long tradition dating from 19th-century planners such as Cerda (1859/1991) with his Barcelona Plan, and the Russian disurbanists, such as Milliutin (Kopp, 1970). The great 20th-century advocate was Wright (1932), who proposed Broadacre city, where inhabitants had an acre per person intermingled with industry, agriculture, and services.

The cost of such designs has been analyzed extensively (e.g., Burchell et al., 2002), but without convincing conclusions. Glaeser and Kahn (2003/2004) argue that sprawl is the inexorable product of automobile-based living that brings considerable improvements in quality of life, and that the social problems of people without mobility should be addressed by targeted public policies. Environmental impacts can, thus, be offset by technological change, such as low-carbon automobiles (King, 2007). One of the main arguments for the dispersed city is that there is no longer a single center where most jobs and services occur. Urban areas, rather, exhibit a dispersed and often polycentric structure, bringing jobs and services closer to residents with a more complex movement pattern not readily served by public transport (Hall & Pain, 2006).

Cities of continental Europe, particularly of Mediterranean countries, which hitherto have been considered as models of compaction, are changing rapidly to the same pattern observed in the United States. The dispersed or diffused city has been the object of substantial analysis, which demonstrates it has become the new city form now that automobile ownership is nearly universal and the necessary highways and utilities are in place. Dematteis (1998) argues that the two types of cities, Anglo-Saxon and Latin, are converging to the same model in which the process of peripheral growth is diluting the importance of the center, while new nodes of activities (e.g., edge cities; Garreau, 1991) are emerging as part of a bigger network of the diffused urban metropolis.

Barcelona, lauded as an exemplar of good compact planning in the Urban Task Force work (Rogers, 1999), is dispersing rapidly with emerging nodes of development (edge cities) beyond the coastal mountain range with most of the new developments following the motorway network. People and jobs are moving out and taking advantage of the emerging mobility to search for space at lower prices (Busquets, 2005).

The dispersal of jobs is also apparent in England. New business and technology parks have emerged in the outskirts of cities with good automobile accessibility (Breheny, 1996), offering a green environment to highly qualified employees.

Planned Expansion

In the United Kingdom, the Town and Country Planning Association (TCPA; 2007) has strongly advocated planned urban settlements as an intermediate form of development, or New Towns. The main ideas are over a century old, originating from Ebenezer Howard (1898/1902). With his garden cities concept, he tried to obtain the best of both worlds, town and country, through a controlled migration from congested urban areas to planned, balanced communities on greenfield sites. The initial new towns were expanded after World War II but came to a halt in the 1970s due to the amount of government funding required and the belief that they contributed to the decline of existing cities. The intention of the planned settlement is to increase the supply of urban land to obtain the economic and social objectives of a dispersal policy without the environmental impacts caused by scattered development.

The U.K. government has recently been considering a new form of town for promoting sustainability: Eco-towns (Department for Communities and Local Government, 2007). Due to cutbacks in funding, only one of just 5,000 homes is planned to go ahead near Bicester, Oxfordshire, funded by the private sector. It has the garden cities' aim of providing open green space and of achieving net-zero carbon emissions using green technologies strongly influenced by new eco-towns, such as Vauban in Germany. It is unlikely, however, that U.K. eco-towns will be sufficiently large and self-contained to avoid becoming automobile-based dormitory towns.

Option Design

The spatial options were designed to be as distinct as possible from the trend to show their benefits and disadvantages; each was designed to achieve its full sustainability potential.

Compaction clustered most of the new development in urban centers at even higher densities than the trend on green space as well as brownfield. This achieves some of the smart growth principles (U.S. Environmental Protection Agency, 2006) at the expense of very limited housing choice and a loss of open urban space.

Dispersal was a simulation of market-led development, in which case green belt constraints were relaxed and transport investment focused on highways.

Expansion was based on advice from the U.K. TCPA with many similarities to smart growth principles. It included edge expansion around London, along transport corridors, and five new settlements of around 50,000 dwellings 40 miles from London. The designs optimistically assumed that they could achieve similar attractive urban environments with high levels of walking and cycling to historic English university towns.

Method

Our study took the following three-step approach, applied to each of the case study city-regions (Figure 3). First, select the policy tools; second, simulate behavioral responses to those policies using the best ready-made city region models; and third, use these forecasts to estimate the 26 sustainability metrics.

The policy tools are the various forms of regulation, pricing, and direct investment for land use and transport. The computer models forecasted the likely locational and travel behavior of households and firms within the constraints set by the policy tools. The models used were London and South East Region (LASER) owned by the Department for Transport (see Marcial Echenique and Partners, 2004); Tyneside Area Multi Modal Study (TAMMS), owned by the Highway Agency (Ove Arup & Partners International Limited & Scott Wilson Scotland Ltd., 2002); and Cambridgeshire MENTOR model (MENCAM) owned by Cambridgeshire County Council. All models were based on the MEPLAN (MENTOR is the Windows version) software (Echenique 1994, 2005), models that simulate the market of interaction between demand for land by households and firms and the supply of dwellings and nonresidential floor space. They also simulate the demand for travel by passengers and freight and the supply of multimodal transport. The inputs to the model of dwellings, employment floor space, and transport networks per zone represent the spatial policy strategies. The interaction of supply and demand for land and transport determines the prices of land, the cost of living and production for households and firms, and amount of congestion on transport networks.

Figure 4 shows the growth in dwellings and employment input for each of the case studies, while Figure 5

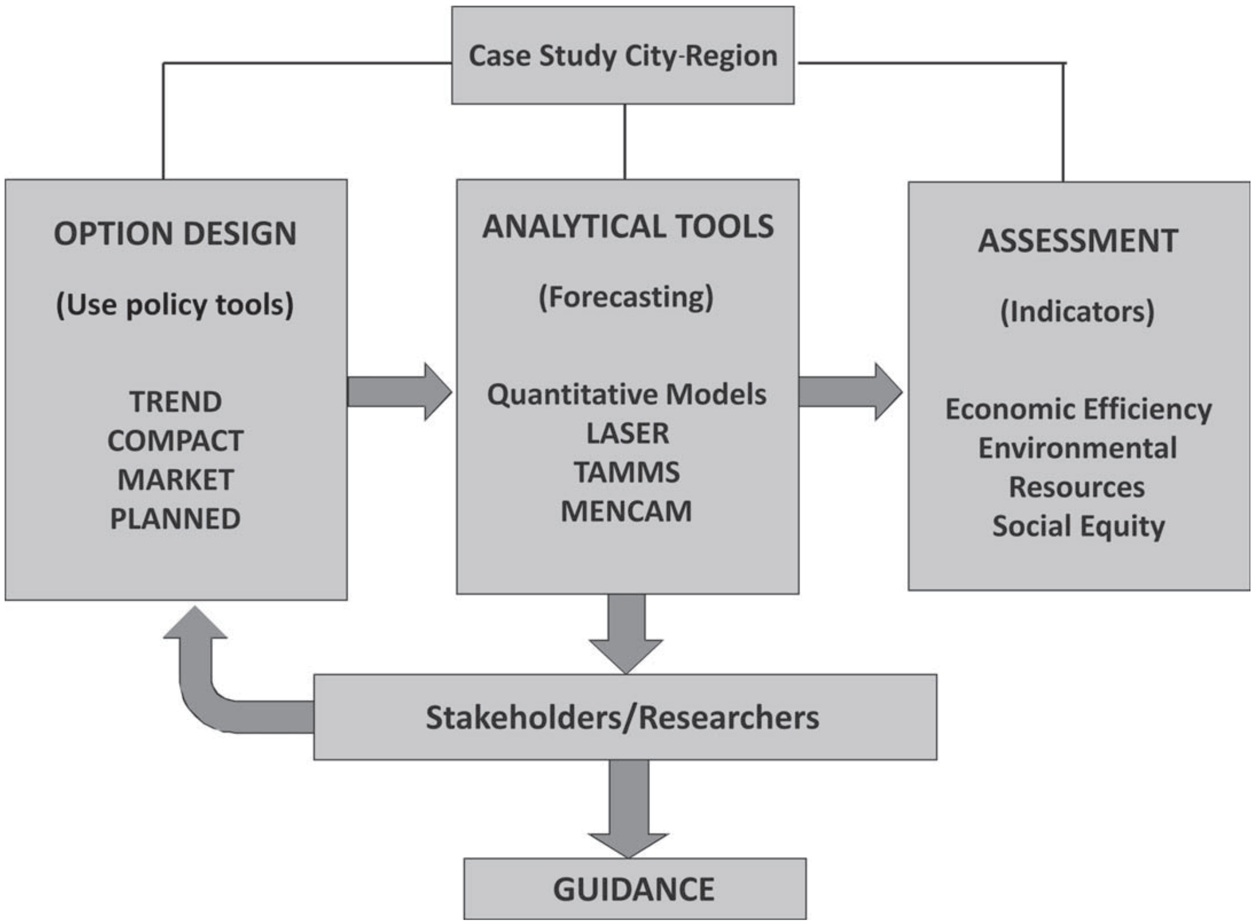

Figure 3. Flow chart outlining the method.

shows the differences in dwellings for each of the options compared to the trend (employment had a similar pattern). Figure 5 shows that spatial policies only make a relatively small difference to existing development at the city-region scale over the forecast periods (WSE and TWCR, 30 years; CSR, 20 years) as most of the urban development of the future is already here (the U.K. dwelling stock and commercial floor space changes 1% per annum).

Finally, MEPLAN model outputs for each spatial policy option were used to drive further models to assess policy outcomes against 26 sustainability indicators that measure economic efficiency, social impact and equity, environmental protection, as well as loss of natural resources. The following quantitative assessment shows that there are tradeoffs between different criteria; improving the outcome on one may be accompanied by negative impacts on others. The preferred option will depend on the weight given to competing objectives within a broader policymaking process.

Sustainability Assessment of the Trend Policy and Its Alternatives

Results of the sustainability assessment are summarized in Tables 1–3 addressing the 26 indicators. Figure 6 compares the changes from base to forecast year on eight of the headline indicators across the four assessment domains (see also Mitchell, Hargreaves, Namdeo, & Echenique, 2011, for a detailed discussion of the energy and carbon analysis, including road user charging sensitivity tests). This illustrates a continuation of the current policy trend, resulting in most indicators becoming substantially worse over the forecast period. The alternative spatial configurations of land use and transport make very little difference compared to the impacts of socioeconomic change and population growth. The only indicators that do not necessarily worsen are those that are relative measures, such as social segregation, or those amenable to technological mitigation, such as noxious vehicle emissions.

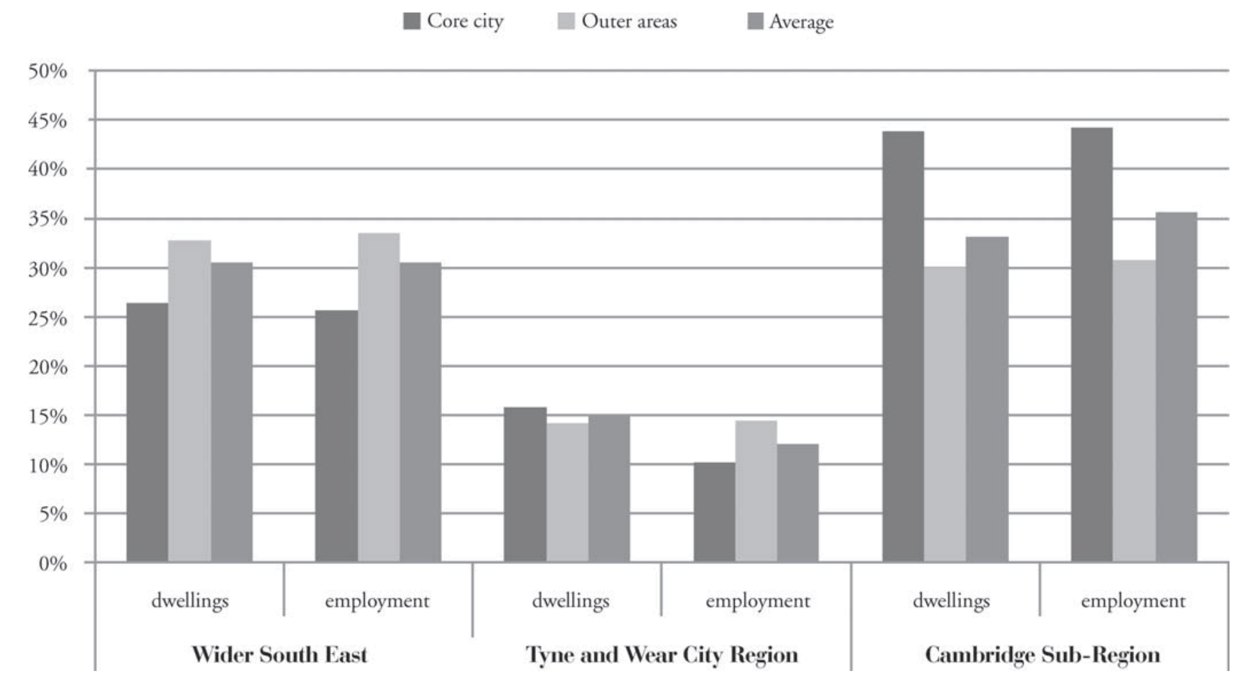

Figure 4. Growth in dwellings (%) and employment from base to forecast year.

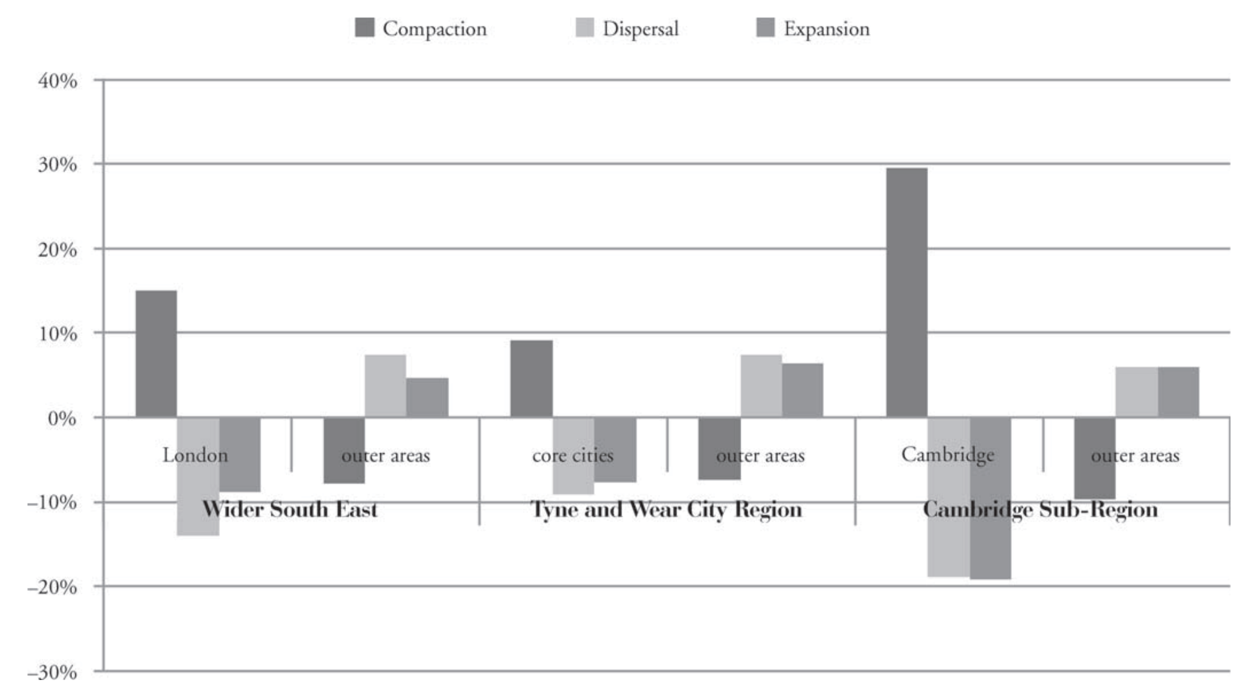

Figure 5. Difference in dwellings (%) between the options and trend at the forecast year.

The pattern of differences between the spatial options, such as compaction or dispersal, are very consistent across case studies on indicators that are directly related to physical characteristics of urban form, such as land take, transport energy use, traffic emissions, crowding and impermeability.

Table 1. Sustainability appraisal, Wider South East region.

CRITERIA	Category[c]	Units	1997 base	2031 trend	Compaction	Dispersal	Expansion
			Quantity	Difference from base year			
Land developed[a]	R	km^2	3,868	18%	10%	23%	21%
Total floorspace growth	R	Million m^2	905	25%	23%	27%	26%
Transport energy	R	PJ/yr	898	38%	37%	42%	38%
Commercial buildings energy	R	PJ/yr	182	35%	35%	35%	35%
Residential buildings energy	R	PJ/yr	550	16%	15%	16%	16%
Total energy consumption	R	PJ/yr	1,630	30%	29%	33%	30%
CO_2 emission (buildings and transport)	E	Mt/yr	113	34%	33%	37%	34%
CO emission transport	E	Kt/yr	1,359	–75%	–76%	–75%	–75%
NO_x emission transport	E	Kt/yr	438	–66%	–66%	–65%	–66%
VOC emission transport	E	Kt/yr	55	–54%	–55%	–53%	–55%
PM_{10} emission transport	E	Kt/yr	18	–74%	–74%	–73%	–74%
High income household expenditure	S	£ pcm	3,250	3%	2%	1%	2%
Low income household expenditure	S	£ pcm	1,483	20%	20%	17%	19%
Personal Injury road traffic accidents	S	Total/yr	200,016	–6%	–8%	–4%	–6%
Vitality	S	index	unity	1.38	1.41	1.46	1.40
		% of	%	Difference from base year (%)			
Mean surface impermeability (sealing)	E	zones	21	3	4	2	3
Aquatic systems likely to be degraded	E	zones	14	2	1	3	4
Less than $28m^2$ per capita floorspace	S	population	10	2	6	–2	–1
Road links traffic noise above 65db[b]	S	network	61	10	10	10	10
High driver stress roads	S	network	13	4	4	4	4
Road crossing time > 30 seconds	S	network	8	4	3	4	4
					Gini index of inequality (GI)		
Social segregation	S	Gini index	0.13	0.13	0.14	0.13	0.13
Social distribution of NO_x emission	S	Gini index	0.19	0.01	0.01	0.04	0.02
Social distribution of traffic noise	S	Gini index	0.13	0.13	0.14	0.13	0.13
				1997–2031 trend	Difference from trend		
Net economic benefit[d]	C	£M/yr		–31,768	–56	574	543
Transport economic efficiency[d]	C	£M/yr		na	–40	292	150

Notes:

a. In the base year, 11% of the land in the Wider South East region was already developed for urban and transport uses.

b. LA_{10},18h emission.

c. Criteria categories: R = resources; E = environmental; S = social; C = economic.

d. Economic benefits are in 1997 prices.

As expected, compaction performs the best on conserving land take. The dispersal and expansion options would both require more land than the trend and much of this would be greenfield. However, there is a lot of undeveloped land available in the case study areas so the increase or reduction in urban land compared to the trend is less than 1% of the total.

Vehicle distance traveled would also increase over the trend broadly in line with population growth for the WSE and TWCR as automobile ownership and trip lengths increase offsetting the growth in rail trips, which result from investment in public transport. Only the CSR would achieve a reduction in vehicle miles traveled (VMT) per person. This is a result of relaxing the green belt constraints to allow development closer to Cambridge by allowing edge expansion with improved public transport, as a radical departure from the past tightly constrained policy.

Table 2. Sustainability appraisal, Tyne and Wear city-region.

CRITERIA	Category[c]	Units	2001 base	2031 trend	Compaction	Dispersal	Expansion
			Quantity	Difference from base year			
Land developed[a]	R	km^2	314	13%	8%	16%	16%
Total floor space growth	R	Million m^2	75	13%	12%	14%	14%
Transport energy	R	PJ/yr	45	10%	8%	9%	10%
Commercial buildings energy	R	PJ/yr	16	13%	13%	13%	13%
Residential buildings energy	R	PJ/yr	48	8%	7%	9%	8%
Total energy consumption	R	PJ/yr	109	10%	9%	9%	10%
CO_2 emissions (buildings and transport)	E	Mt/yr	8	11%	10%	11%	11%
CO emission transport	E	Kt/yr	30	–68%	–68%	–68%	–68%
NO_x emission transport	E	Kt/yr	22	–70%	–70%	–70%	–70%
VOC emission transport	E	Kt/yr	2	–52%	–51%	–51%	–50%
PM_{10} emission transport	E	Kt/yr	1	–76%	–76%	–76%	–76%
High income household expenditure	S	£ pcm	1,950	20%	23%	17%	19%
Low income household expenditure	S	£ pcm	1,067	21%	23%	18%	20%
Personal Injury road traffic accidents	S	Total/yr	4,482	–21%	–21%	–21%	–21%
Vitality	S	index	unity	1.23	1.24	1.29	1.26
		% of	%	Difference in % from base			
Mean surface impermeability (sealing)	E	zones	23	3	4	2	2
Aquatic systems likely to be degraded	E	zones	27	4	0	9	4
Less than $31m^2$ per capita floor space	S	population	9	4	14	–2	–2
Road links traffic noise above 65db[b]	S	network	34	5	4	5	5
High driver stress roads	S	network	16	5	5	5	5
Road crossing time > 30 seconds	S	network	3	1	1	1	1
				Gini index of inequality (GI)			
Social segregation	S	GI	0.15	0.13	0.14	0.13	0.13
Social distribution of NO_x emission	S	GI	0.24	0.01	0.09	0.01	0.02
Social distribution of traffic noise	S	GI	0.15	0.12	0.11	0.13	0.13
				2001–2031 trend	Difference from trend		
Net economic benefit[d]	C	£M/yr		–1,272	–24	55	64
Transport economic efficiency[d]	C	£M/yr		n.a.	24	13	35

Notes:
a. In the base year, 14% of the land in the TWCR was already developed for urban and transport uses.
b. LA_{10},18h emission.
c. Criteria categories: R = resources; E = environmental; S = social; C = economic.
d. Economic benefits are in 2000 prices.

The alternative spatial options have relatively little impact on VMT for the city region compared to the trend forecast. Compaction would reduce VMT by 5%. This finding was remarkably consistent across all three case studies. The expansion option could be achieved without an increase in VMT, provided the expansion areas are planned around good public transport links, in areas with strong local employment growth, which achieve a high degree of self-containment of jobs and services, and encourage walking and cycling. The dispersal option would increase VMT, but only by around 5% compared to the trend (although it would gradually increase if the policy continued beyond the forecast period). This small increase in automobile travel for dispersal becomes less surprising when considering the relative changes in development between the central and outer areas. For example, the dispersal option would have 19% fewer dwellings in Cambridge than the trend at the forecast year. Dispersing

Table 3. Sustainability appraisal, Cambridge sub-region.

CRITERIA	Category[c]	Units	2001 base	2021 trend	Compaction	Dispersal	Expansion
			Quantity	Difference from base year			
Land developed[a]	R	km^2	144	13%	8%	17%	15%
Total floor space growth	R	Million m^2	23	24%	23%	25%	25%
Transport energy	R	PJ/yr	22	11%	7%	16%	10%
Commercial buildings energy	R	PJ/yr	5	26%	26%	26%	26%
Residential buildings energy	R	PJ/yr	14	16%	15%	17%	17%
Total energy consumption	R	PJ/yr	41	15%	12%	17%	15%
CO_2 emissions (buildings and transport)	E	Mt/yr	3	16%	13%	18%	15%
CO emission transport	E	Kt/yr	19	–73%	–75%	–72%	–74%
NO_x emission transport	E	Kt/yr	8	–69%	–70%	–68%	–68%
VOC emission transport	E	Kt/yr	0.7	–60%	–62%	–58%	–61%
PM_{10} emission transport	E	Kt/yr	0.3	–64%	–65%	–63%	–64%
High income household expenditure	S	£ pcm	2,729	40%	27%	38%	52%
Low income household expenditure	S	£ pcm	1,951	46%	30%	44%	58%
Personal injury road traffic accidents	S	Total/yr	2,826	–25%	–26%	–22%	–26%
Vitality	S	index	unity	1.35	1.30	1.38	1.38
		% of	%	Difference from base year (%)			
Mean surface impermeability (sealing)	E	zones	11	2	3	1	1
Aquatic systems likely to be degraded	E	zones	3	1	0	1	2
Less than $29m^2$ per capita floor space	S	population	11	4	13	–4	–4
Road links traffic noise above 65db[b]	S	network	46	5	5	7	2
High driver stress roads	S	network	18	3	3	2	3
Road crossing time > 30 seconds	S	network	1	2	1	2	1
				Gini index of inequality (GI)			
Social segregation	S	GI	0.16	0.18	0.18	0.17	0.19
Social distribution of NO_x emission	S	GI	0.24	0.29	0.27	0.28	0.28
Social distribution of traffic noise	S	GI	0.18	0.20	0.20	0.20	0.22
				2001–2021 trend	Difference from trend		
Net economic benefit[d]	C	£M/yr		–1,667	711	278	–204
Transport economic efficiency[d]	C	£M/yr		n.a.	–3	–2	0

Notes:

a. In the base year, 6% of the land in the CSR was already developed for urban and transport uses.

b. LA_{10},18h emission.

c. Criteria categories: R = resources; E = environmental; S = social; C = economic.

d. Economic benefits are in 1991 prices.

these, however, into the surrounding areas results in an increase of only 6% more than the trend (Figure 5), because the population of the surrounding area is much greater than Cambridge itself. In addition, many of the dispersed dwellings and employment in the modeling simulation coalesce along the transport corridors, where the accessibility and demand for dwellings is greater than the more isolated rural areas. Consequently, the broad pattern of development that emerges would not be dissimilar to the trend and expansion options, although it would be more dispersed at the local scale.

For comparative purposes, each scenario has the same city-region-wide totals for dwellings, population, and employment. The compaction option has higher densities in the urban centers but less development in the surrounding areas. This is reversed in the dispersal and expansion options. It is, therefore, difficult to directly compare the model forecasts with the survey-based methods in the

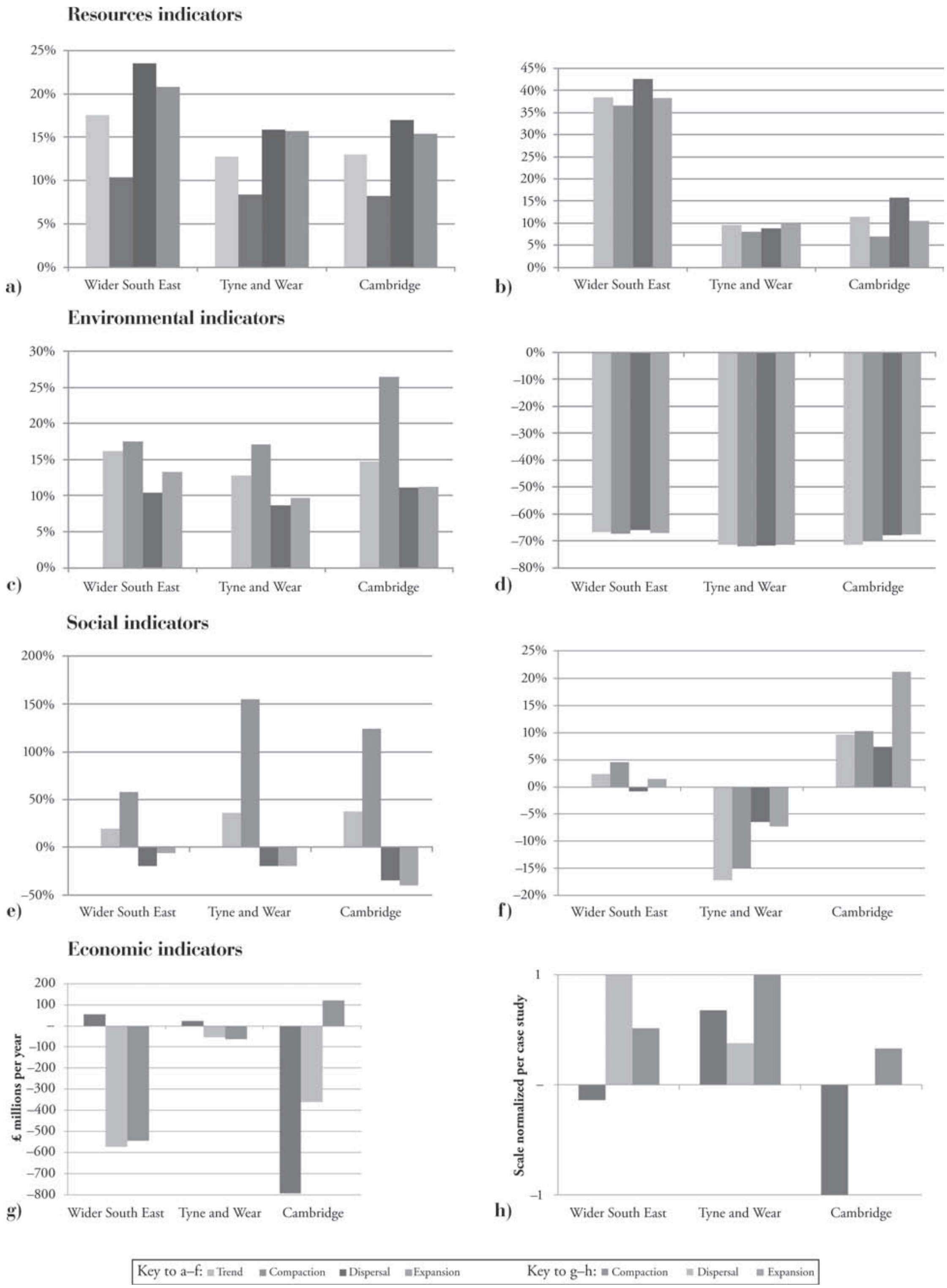

Figure 6. Comparison of alternative policies with respect to headline indicators. Resources indicators: a) urban land-take compared to base year, b) transport energy compared to base year. Environmental indicators: c) impermeability compared to base year, d) NO_x from transport compared to base year. Social indicators: e) crowding compared to base year, f) social segregation compared to base year. Economic indicators: g) net economic cost compared to the trend, h) transport efficiency compared to trend.

Figure 7a. Compacted areas for Wider South East compaction option.

literature. Figures 7a–7c show the areas of compaction for the case study city-regions. The average increase in gross density ranged from about 40% in London, 60% in Tyne and Wear, to 75% in Cambridge. (These gross densities are measured at the electoral ward level, the smallest U.K. administrative area. The areas of urban compaction are arbitrarily defined as those where the density is at least 15% greater than the trend.) Hence, the 5% reduction in VMT is equivalent to a 10% reduction from a doubling of density. This is broadly consistent with the elasticity from the literature reported earlier, given that the design of the compaction option includes higher densities, clustered in downtown areas close to jobs.

Surface impermeability from built surfaces such as roofs and roads increases over the trend. Compaction adds the least new impermeable surface area of any option, but does so in areas that are already among the most impermeable. These localized increases in impermeability would elevate flood risk and loading of diffuse pollutants (such as heavy metals) draining into receiving rivers, with potential impacts on water and ecological quality. Dispersal adds more impermeable land than the other options, but flood risk and diffuse source loadings would be lower because development tends to be in areas that are not heavily built up and so have an initially low impermeability value.

Noxious air pollution from transport has declined substantially and will continue to improve over the next decade as a result of significant improvements in vehicle standards, but will then begin to worsen as the emission reductions per vehicle are overwhelmed by traffic growth.

Crowding would increase over the forecast period for the trend because of current policy of higher density

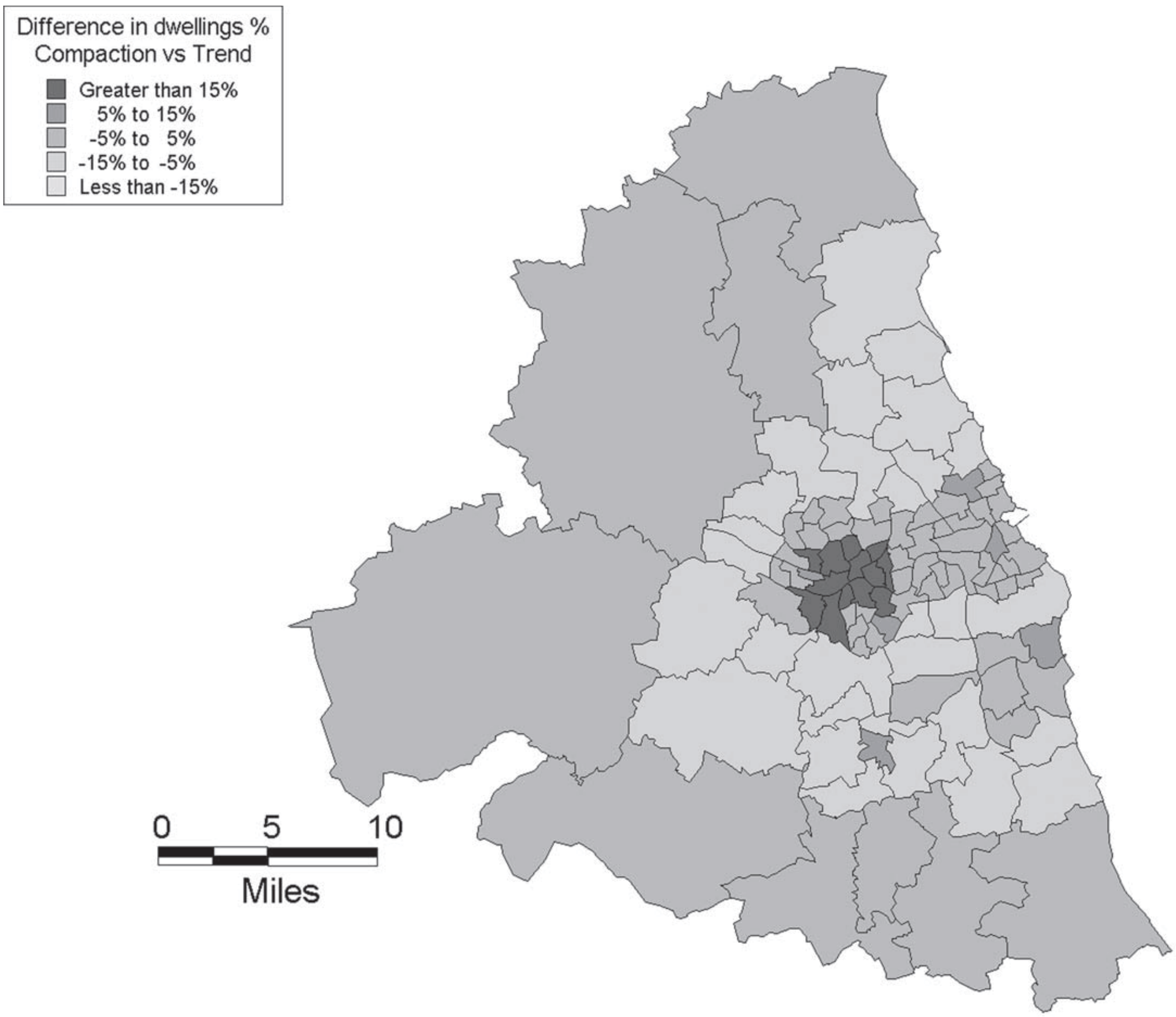

Figure 7b. Compacted areas for Tyne and Wear city-region compaction option.

development. Compaction would increase crowding still further as most of the new dwellings would be apartments. Dispersal and expansion would reduce crowding as a result of releasing more land for housing.

The costs to the economy increase over the forecast period in all of the case study areas because the supply of dwellings and transport capacity fails to keep pace with growing lifestyle expectations. The shift to a more service-oriented economy leads to an increasing proportion of professional and clerical workers who have greater demands for living space and mobility. The current policy trend does not satisfy the demand for housing types in the right location as it restricts the supply of dwellings to mainly apartments on brownfield sites in locations that do not necessarily correspond to where the employment is growing. The knowledge- and service-based jobs increase in the environmentally attractive areas where there is a lack of land being supplied for development. The spatial disparity between supply and demand pushes the house prices up, while it adds to wage costs and increases automobile travel.

The net economic cost indicator measures the impact on those sectors of the economy that cannot pass on higher prices to others. These include changes in costs to export industries (basic sector) and costs imposed on retired and unemployed people. The total increase in costs over the forecast period to 2031 is estimated to be about £30 billion per annum for the WSE (in 1997 prices), about £1.3 billion per annum for Tyne and Wear (in 2000 prices),

Figure 7c. Compacted areas for Cambridge Sub-Region compaction option.

and £1.6 billion per annum for the CSR (in 1991 prices). These cost increases arise from the shift toward white-collar employment combined with increases in house prices and transport congestion, which would reduce economic competitiveness. For the WSE and Tyne and Wear, the spatial allocation of housing and transport makes relatively little difference to economic costs compared to these increases over the trend period. However, differences in economic costs between the spatial policy options are more apparent in the CSR, where there is greater pressure for growth within a smaller area. These growth pressures also tend to increase social segregation, especially if the spatial policy allocates new housing to less desirable locations.

The direction of change on the socioeconomic indicators varies among case study areas due to their differing underlying socioeconomic characteristics. They depend on the tendency for activities to either coalesce or disperse from the core cities. As with many other U.K. city-regions, employment and population tend to disperse from the post-industrial urban areas of London and Tyne and Wear into the greener outer suburbs. Compaction would exacerbate the shortage of housing in outer areas, and this imbalance between supply and demand would push average rents up and hence the cost of living and wage costs. Conversely, Cambridge is a focus of employment growth with a university, hi-tech economy, and an attractive low-density urban environment. Compaction would help to meet the growing shortage of housing in Cambridge and reduce average prices, although this may reduce its attractiveness over the longer term.

No single policy would be suitable for all of the case study areas. Planning policy should therefore allow flexibility within sustainable planning guidelines.

Conclusions

The current planning policy strategies for land use and transport have virtually no impact on the major long-term increases in resource and energy consumption. They generally tend to increase costs and reduce economic competitiveness. The relatively small differences between options are overwhelmed by the impacts of socioeconomic change and population growth. The differences between land use and transport policies are greater for a smaller area with pressure for growth as in the CSR. The impacts of a policy, though, tend to even out when applied over a larger, more diverse area.

Smart growth principles should not unquestioningly promote increasing levels of compaction on the basis of reducing energy consumption without also considering its potential negative consequences. In many cases, the potential socioeconomic consequences of less housing choice, crowding, and congestion may outweigh its very modest CO_2 reduction benefits.

Achieving the targets on reducing CO_2 emissions can be more effectively pursued using technological improvements such as switching to non-fossil energy sources. This can also be achieved by substantial behavioral changes such as shifting from the automobile to public transport. The latter demands strong incentives or penalties to make a significant difference, which would have a detrimental effect on some of the social and economic indicators. Relying on technological improvements is arguably more plausible because it has been estimated that they can contribute an order of magnitude to the abatement of CO_2 emissions for transport (King, 2007; McKinsey & Company, 2010) and buildings (MacKay, 2009).

Creating successful communities means first having broader planning objectives. Appropriate green technologies designed along ecological principles can be included to reduce the environmental impacts. Urban form can affect the feasibility of introducing green technologies. Ground-source heat pumps, for instance, require relatively low-density development, while combined heat and power systems require a concentration of activities provided by compact forms of development. These interrelationships between urban form and green technologies are being explored by further ongoing research (see www.regionalvisions.ac.uk) to reach a broader understanding of the sustainability of spatial planning policies.

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