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TRANSPORT, URBAN FORM AND ECONOMIC GROWTH

ROUND TABLE

137

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REPORT OF THE
ONE HUNDRED AND THIRTY SEVENTH ROUND TABLE
ON TRANSPORT ECONOMICS

TRANSPORT, URBAN FORM AND ECONOMIC GROWTH

OECD

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OF MINISTERS OF TRANSPORT

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SUMMARY CONTENTS

1. INTRODUCTION

Round Table 137 was hosted by the Institute of Transportation Studies of the University of California at Berkeley. The Round Table was chaired by Marty Wachs (RAND, Los Angeles). Background papers were provided by David Banister (University of Oxford), Elisabeth Deakin, (UC Berkeley), Gilles Duranton (University of Toronto) and Matthew Kahn (Tufts University).

Transport technology and the associated transport costs have always been among the dominant determinants of urban location and form. In the first half of the 19th century most cities were tied to waterways, developing around harbours and by rivers and canals. Towards the end of that century, railways competed with inland waterways, and urban growth and form became determined by investments in rail terminals and by their scale economies providing advantages of proximity.

The high cost of intra-urban transport by horse and wagon favoured the creation of single manufacturing districts, located near harbours or railheads, with residential areas surrounding them. Before the advent of horse-drawn and electric street-cars, personal transport was mainly on foot or by horse-drawn carriage, implying a strong need to live close to the city centre.

With street-car transport, residential areas spread out around stations or street-car lines. The urban structure changed into a compact production core, surrounded by residential areas which were determined by mass transport facilities.

Only by the middle of the 20th century did the private car start to compete successfully with mass transit – despite transit fares remaining flat in nominal terms (Barrett, 1983) – by providing speed, privacy and convenience and being facilitated by the expansion and upgrading of public roads.

The concentration of production at the city centre was undermined by the declining cost of inter-city trucking, a development that was particularly helped by the construction and expansion of highway systems.

Similar developments arose in the US and Europe, but were slower and less pronounced on the latter continent. A major reason for these differences lies in the durability of urban capital stock in general and urban transport infrastructure in particular. The lasting impact of urban infrastructure was coupled with a slower pace of urbanisation in Europe, due to: (i) a less rapid transition from an agrarian to an industrialised society in some European countries, and (ii) to the fact that European cities are much older, with historically established city centres containing a greater mixture of dwellings and businesses at the core. However, in Europe as in the US, there has been a massive process of suburbanisation, which has given rise to substantial controversy as to whether or not its social cost outweighs its benefits.

There are contrasting views on how to evaluate the changes in urban size and form, and on how urban transport policy should accommodate, contain or otherwise guide the processes of suburbanisation.

Those who are concerned about the surface growth of city areas or the decrease in population densities associate these trends with a long list of negative effects, making them difficult to evaluate. The perceived costs stem from the loss of open space, decaying historical urban structures, urban air and water pollution, traffic congestion, the loss of a sense of community, patchwork housing developments on what was once agricultural land, the separation between residential and work locations, greater public investment requirements due to spreading urban developments and, last but not least, an increasing reliance on private car use (Nechyba and Walsh, 2004).

At least part of the negative effects seem to have arisen by accident or mistake, and not through attempts to reap private benefits. Strong transport policy conclusions have been drawn from negative views of the current trends of suburbanisation. The UK Urban Task Force, for example, recommended that 65% of all public expenditure for transport should be spent on projects that benefit pedestrians, cyclists and public transport users (Urban Task Force, 1999). Where urban form is concerned, it recommended that: "*Towns and cities should be well designed to be more compact and connected, support a range of diverse uses within a sustainable urban environment which is well integrated with public transport and adaptable to change*." Measures to change the attitudes of transport system users are often postulated: "*The renaissance will require a change of culture – through education, debate, information and participation. It is about skills, beliefs and values, not just policies* (Ibid., p. 3)."

For the US, some analysts see an endogenous return to a lifestyle associated with dense urban developments – the advent of a "new urbanism".

Recently, some economics literature has emerged proposing a more detailed and quantitative assessment of the costs and benefits of urban sprawl, or of the costs and benefits of changing the trends in urban development, *inter alia,* by transport policy measures. The argument emphasizes the identification and quantification of the benefits of the trends towards suburbanisation, and provides a critical review of the claim that, while individuals perceive private benefits from the ongoing changes in urban structure, the social costs outweigh those benefits (Kahn, 2006; Glaeser and Kahn, 2004). Moreover, increasing efforts are being devoted to a research programme designed to determine the importance of urban form (and the system of cities) for the overall competitiveness of national economies and for long-run economic growth rates (Henderson, 2005). Productivity effects result from changing urban structures, such that a maximum of agglomeration economies materialise. These can result from exploiting increasing returns to scale in the provision of public facilities and public services as well as from increasing returns from manufacturing production. The close connection between urban and national economic development was recognised by Lucas (1988) and inspired by the development of endogenous growth models. To the extent that endogenous growth is based on knowledge spillovers and sharing between researchers and producers, and given the importance of face-to-face communication and the requirement of close spatial proximity, much of the interaction and knowledge sharing must occur at the level of individual cities.

The objective of the Round Table was to discuss these recent developments in the perspective of informing transport policies.

There is no unique way to measure urban sprawl. How it is measured is strongly influenced by whether a monocentric urban structure is perceived to be the norm or not. Close to the monocentric view of urban structure is the measure of the share of employment within a certain radius of the Central Business District (CBD) (Glaeser and Kahn, 2004).

A more comprehensive measure has been proposed by Ewing, Pendall and Chen (2005). To construct an index of urban compactness, they combine:

- residential density;
- neighbourhood mix of homes, jobs and services;
- strength of activity centres and downtowns; and
- accessibility of the street network.

This index is a more general measure of sprawl, in that it can capture the polycentric character of metropolitan areas. Based on this index, Kahn (2007) presented "benefits of sprawl" indicators for four categories of urban compactness (high sprawl, sprawl, low sprawl, very low sprawl).

A first difference in consumption patterns and associated benefits concerns home ownership propensities and land consumption. Controlling for other factors which influence consumption, home ownership rates are 8.5 per cent higher in the most sprawled cities relative to the most compact city type. In compact cities, residential lots are about 40 per cent smaller than those of the median household living in a sprawled city. This does not show by how much households value such gains, as households which live in compact urban areas might have different preferences for house sizes compared to those who live in low-density settlements. However, a more compact city would lead to higher land rents, with a negative impact on the real incomes of all inhabitants.

The Round Table discussed the distributional effects of sprawl, or the distributional effects of containing sprawl by appropriate transport or other smart growth policies (e.g. Quigley and Raphael, 2005). Incumbent homeowners may benefit from increased land rents, resulting from higher intra-urban transport costs, as long as job and service locations remain fixed.

Low-income groups, with limited opportunities for wealth accumulation, tend to suffer from higher land rents. For the US, when comparing the minority/majority housing consumption differential in compact cities, it has been found that minorities who live in sprawled cities catch up in some housing consumption dimensions with majority households (Kahn, 2001, 2007).

2. COMMUTING

Much of the concern about urban sprawl has to do with an expected or observed increase in private car use and the associated increase in air pollution. This is based on the assumption that in compact cities people are likely to live closer to their downtown jobs, and that more people use public transit. It is also based on the expectation that sprawl increases congestion, leading to low private car commuting speeds, with high time losses and high costs in terms of value of time lost. As shown in two of the background papers (Kahn, 2007; Banister, 2007), these hypotheses cannot be confirmed in general. For the US, it was found that compared to workers in compact cities, workers in sprawled cities indeed commute over longer distances (1.8 miles further each way) but that their commute times are shorter (4.3 minutes on average), as they travel at higher speeds. The effect of this commuting pattern on air pollution is, *a priori,* ambiguous as longer distances mean more pollution for a given speed, and a higher speed may imply lower emissions per unit of distance.

A closer look at the commuting patterns in the US reveals that it may be misleading to discuss sprawl and its associated commuting patterns on the basis of the general presumption of a sprawling, monocentric structure (Anas, Arnott and Small, 1998).

A combination of the information provided by the US Neighborhood Change Database and the information on distances from the Central Business District provided by the census tracts, revealed that the share of commuters with a short commute declines over the distance 0 to 10 miles from the CBD. From the 11th mile from the CBD, the share of commuters with a short commute stops declining. An increasing share of workers with residences distant from the CBD stop commuting to the Central District. This might reflect the fact that with an expanding city size, initially through households relocating from inner city areas to outskirts, after some time, jobs follow the households, manifested in the increasing importance of polycentric urban forms.

This suggestion is strongly confirmed with a closer look at US and European cases relating urban transport, and in particular commuting patterns, to settlement size, population density, the job-housing balance and mixed-use development, as well as accessibility and neighbourhood design. These four characteristics of urban areas are seen as the central control instruments of urban planners (Banister, 2007). The UK National Travel Survey, for example, revealed a clear correlation between settlement size and a decrease in travel distances. Looking at individual metropolitan areas, London turned out to be a special case in that commuting distances did not stop increasing when the distance of residential location from city centre increased beyond a certain threshold. For Birmingham and Manchester, the threshold distances were seven and five kilometres, respectively.

Both settlement density and the ratio of jobs to workers in a (sub-)urban region seem to have little effect on travel behaviour in general, and commuting behaviour in particular. The design of transport networks seems to have strong effects on travel patterns. The accessibility of public transit stops plays a major role in containing private car use.

Urban street design can have ambiguous effects as an instrument to reduce the demand for sprawl: while a “loops and cul-de-sac” design increases the amount of usable land, and thereby could increase density relative to a grid network (Grammenos and Tasker Brown, n.d.), the latter seems to have the advantage of increasing walking and cycling in cities (Boarnet and Crane, 1999b; Marshall, 2005).

3. PRODUCTIVITY AND GROWTH EFFECTS OF URBAN SPRAWL

Despite a vast literature on agglomeration effects and the concept of an “optimal city size” as balancing economies and diseconomies, the discussion of the pros and cons of an expansion of urban areas made only limited reference to this normative concept of urban form. (As an example, see Prudhomme and Lee, 1999.) One reason why economic activity agglomerates into cities is the provision of indivisible local public goods whose use is associated with transport costs. More importantly, agglomeration is due to the external benefits of production and consumption activities of firms and households. These drivers of agglomeration are, at the same time, the determinants for the long-run growth rates of national economies. Consequently, urban size and urban form might strongly influence the aggregate, national growth process. With urban form being the result of the endogenous location decisions of firms and households, the pattern of urbanisation determines the efficiency of the growth process (Black and Henderson, 1999a). This section reflects the arguments made for the link between urban form and productivity in the Round Table discussions.

External scale economies, i.e. the positive effects of the production of one firm or industry on the production of another firm or industry (Romer, 1986), or knowledge spillovers which increase the returns of private investment in education, training and research (Lucas, 1988), drive long-run increases in productivity. Early work to explain how such spillovers affected urban form simply assumed a spatial decay of the positive external effects (Fujita and Ogawa, 1982). Only recently has there been progress in providing microfoundations for such a decay (see the review in Duranton and Puga, 2004;2004).

– A first source of city size advantages derives from the fact that the higher the level of local production, the higher will be the number of locally supplied intermediate goods. The greater the variety of intermediate goods, the greater will be the productivity of the industries using those goods. Modeling of this mechanism in the urban context assumes that increasing the congestion costs of workers commuting to the Central Business District will ultimately exhaust the benefits resulting from a greater variety of inputs (Abdel-Rahman and Fujita, 1990).

– Secondly, in an argument going back to Adam Smith (1776), the increase in the number of workers in one firm, due to an increased scale of production, allows the workers to specialise on a narrower set of tasks. The resulting productivity increase is due to workers' "learning-by-doing" effects. Moreover, the switching between tasks in production is associated with fixed switching costs, which are saved in the case of a greater specialisation. And finally, a greater specialisation on a small set of tasks allows for more technical change, as simpler tasks can be mechanised more easily (Duranton, 1998; Becker and Henderson, 2000a; Becker and Murphy, 1992). A reduction of transport costs by reducing congestion costs in transport or increasing the supply of public transport, potentially widens the market per firm and allows for a greater specialisation of the work force.

– A third positive productivity effect might result from the fact that lower urban transport costs improve the working of the labour market. A positive productivity effect is brought about by the fact that an increase in the number of firms and households trying to find a superior working relation, enhances the expected quality of a match (Helsley and Strange, 1990) and the likelihood of finding such a match (Mortensen and Pissarides, 1999; Berliant *et al.*, 2000b). The pool of interacting firms and households is limited by commuting costs or, in the longer term, by relocation costs.

– A dynamic productivity effect is expected from cities providing opportunities to enhance production-relevant knowledge. Hypotheses on the positive effects of low transport costs on the creation and dissemination of technical and organisational knowledge are based on the perception that learning is not only an individual activity but involves interaction with others, much of which is of a face-to-face nature. Cities, by bringing together large numbers of people, should therefore facilitate the production and use of technical and organisational knowledge. The smaller the intra-urban transport costs, the greater is the potential number of interacting parties. Knowledge diffusion is mainly considered to occur via a knowledge transfer from skilled workers to lower skilled and young workers. One mechanism, as in Jovanovic and Rob (1989), is that low-skilled workers increase their skill level by successful face-to-face interaction with skilled workers. The number of contacts between the skilled and unskilled increases with city size (Glaeser, 1999). The smaller the urban transport costs, the higher would be the number and quality of the interactions between the skilled and unskilled labour forces.

- City growth has been considered to be based on the dissemination of all workers' knowledge rather than on the transmission of knowledge from skilled to less skilled workers. The learning abilities of individual workers depend on the level of knowledge already achieved and the aggregate stock of knowledge that is available in the city. The latter provides dynamic external benefits to the workers (Lucas, 1988; Eaton and Eckstein, 1997). At least for the US, there is strong empirical evidence that the presence of educated populations in cities drives their further growth (Simon and Nardinelli, 2002; Glaeser and Saiz, 2004).

The arguments on the advantages of city size might suggest that the accommodation of an increasing city size by transport policy leads to the productivity and growth effects mentioned above. Such a conclusion is, however, in contrast to some analysis that sees population densities rather than city size as the main determinant of dynamic efficiency in production. Ciccone and Hall (1996) argue the importance of population density for productivity in a more general context, based on an empirical study. Lucas and Rossi-Hansberg (2002) also emphasize density as a driver of productivity. These arguments suggest that sprawl, a reduction of urban density, could indeed reduce agglomeration economies and therefore negatively impact on aggregate productivity. What makes the tension between the arguments asserting the importance of size and density difficult to resolve is the fact that the latter depend on the choice of the geographic area of study. Glaeser and Kahn (2004), for example, conclude that aggregate density at the metropolitan area level matters in explaining variations in per-capita income across cities, but the degree to which jobs are centralised in a Central Business District seems to be irrelevant.

Firms which are able to split management, R&D and production locations, increasingly site non-management occupations at the edge of major cities (Rossi-Hansberg, Sarte and Owens, 2005). These firms are likely to gain greatly from extensions of the city size area.

What complicates the relationship between productivity, growth and urban form further is the fact that the monocentric urban form increasingly gives way to polycentric structures. In addition, and parallel to this development, "centres" change their socio-economic function over time. As was discussed by the Round Table and argued in one of the background papers, the process of land development shares some similarities with slash-and-burn agriculture (Duranton, 2007). For commercial developments, economic change (sectoral decline, new technologies, etc.) typically involves leaving a vacant or under-utilised, developed site behind. Changes of urban form and structure involve some element of "creative destruction". Because real developments are highly durable, the creative destruction of production activities and firms implies a movement or re-use of company buildings and possibly a partial or complete desertion of land. The US Environmental Protection Agency, using a restrictive definition and focusing on commercial sites, estimates that there are about 450 000 brownfield sites in the US. British authorities estimate that there are 660 square kilometres of brownfield sites in England alone. Only a small part of the brownfield sites is redeveloped.

City governments or developers have to choose whether to redevelop brownfield sites or initiate new developments on greenfield sites. They face a trade-off between redeveloping a brownfield site, which may allow a better use of existing infrastructure but is maybe associated with high demolition and clean-up costs, and a greenfield development that requires new public infrastructure. From a commercial point of view, a relocation to a greenfield site may look advantageous because the costs for the required infrastructure are not, or not fully, charged to the local users, while firms often have to bear the full redevelopment costs. This allocation problem sometimes extends to communal land use and transport policy decisions, when fiscal redistribution implies that part of the infrastructure costs are borne by non-local taxpayers.

4. THE SOCIAL COSTS OF URBAN SPRAWL

Parallel to the progress of research on the economic benefits of the changes in urban form, there is a continuing discussion on social costs. The debate proceeds on distinct levels. A first level concerns the basic discussion of what should be the foundation of urban and transport policy objectives. More concretely, it tries to find an answer to the question whether individual benefits or some aggregate of individual benefits should be the only or dominant determinant of policy objectives. Often implicitly, the debate seems to evolve around the question of whether governments should supply “meritoric” goods, i.e. goods that have a social value distinct from and beyond the individual perception of their benefits. More generally, such normative arguments are related to an organic understanding of the state (Popper, 2003; Wilson, 1942). The Round Table discussion focussed on the quantitative dimension and the consequences of the social costs of sprawl. This mainly concerns the loss of farm and forest land, the consequences of urban sprawl for the transport system, and the effects of the changes of both land use and the transport system on the environment and public health (Deakin, 2007).

4.1. The loss of farm- and forestland

US Census data provide the opportunity to quantitatively assess the loss of open space in the form of farmland and forests due to the extension of urban space. In overall terms, the loss does not seem to be dramatic: Over the period 1974 to 2002, the total number of farmland acres in the US declined by about 8 per cent, according to the Census of 2004. Not all of the decrease was due to expanding cities but to changes in agricultural technologies, changing international competitiveness and restrictions on the provision of agricultural subsidies for some farm products. The US Department of Agriculture estimates the average annual decline to be 0.25 per cent over the 1960-2002 period.

What potentially amounts to a more substantial effect for the agricultural sector is the fact that prime farmland has been converted at two to four times the rate of less productive farm land. The loss of prime farmland is considered to be due to the competition between agrarian and urban interests in land use (USDA, 1999). The loss of forests due to urban developments is in some areas greater than forestland preserved to protect the habitat of flora and fauna, including endangered and threatened species (US Department of Agriculture, Forest Service, 2006).

These problematic trends have been mitigated to some extent by new markets in land development rights (Kahn, 2007): Throughout the US, municipalities are purchasing open space around their borders to guarantee that the land is not developed. The city of Boulder, Colorado has, for example, earmarked a 0.73 per cent sales tax to fund the purchase of open space around city borders to avoid it being developed. Whether and how such initiatives occur depends on the political influence of groups with an interest in new land developments and those who prefer greenbelts surrounding cities. Richer communities and jurisdictions with more home-owners seem to be more likely to initiate greenbelt initiatives (Kotchen and Powers, 2006).

4.2. Immediate costs of urban sprawl for the transport system

About 90 per cent of all person-trips in the US are made by automobile, and trucks account for more than 90 per cent of all shipments. From 1970 to 2000 the number of vehicle miles travelled has doubled and truck travel has tripled. The increasing road transport intensity, due to road transport demand growth being greater than population growth, is associated with the expectation that the cost of public transport per head is increasing. The demand for physical infrastructure is also expected to increase with the rising number of vehicle miles travelled, associated with the relative decline of public transport use and walking as a consequence of urban sprawl.

The reduced commuting times in sprawled urban areas reported above are sometimes expected to be of a transitory nature, giving way to congestion with increasing congestion costs when scattered suburbanisation is followed by subsequent infill and development. The relatively high commuting speeds are then no longer sustainable (Cervero, 1986; Landis and Reilly, 2003).

Low-density development, and the emergence of a polycentric urban structure, make it difficult and costly to provide bus, light rail or metro services. The increased private car use required by these urban forms is sometimes held to lead to greater resource demands for transport than a transport system with a higher share of public transport and a different settlement pattern.

4.3. Environmental costs of the transport consequences of urban sprawl

There is no disagreement that changes in urban form that reduce the compactness of cities and lower the settlement density increase the vehicle-miles travelled by individual households and reduce the share of public transport usage. Both effects contribute to current changes of urban form being associated with higher environmental costs for transport. Greenhouse gas emissions from transport are a function of fuel use. In the US, transport is currently responsible for 32 per cent of total carbon emissions. Moreover, its emissions from transport increase by 1 to 2 per cent annually.

Air pollution more generally remains a public health concern. To some extent, this is due to inadequate responses to more restrictive air quality regulations. Technical standards for transport equipment have so far failed to account for the full health consequences of fine particles, NOx and toxic emissions.

The relationship between urban form and emissions is complicated by the fact that emissions are not a simple product of speed. Stop-and-go traffic, resulting from congestion, is more polluting than steady-flow traffic. On the other hand, very high speeds, which might be associated with sprawl and metropolitan highways, also produce very high emission levels.

While not necessarily providing an argument against the environmental concerns relating to low-density settlements, vehicle emissions regulation has been able to offset increased vehicle mileage due to changing settlement patterns. The Los Angeles Basin, for example, suffers from the highest levels of air pollution in the US, mainly caused by vehicle emissions. The area is, at the same time, a prime example of low-density, car-dependent urban development (Giuliano and Small, 1991). But ambient ozone, a leading indicator of smog, declined by 55% between 1980 and 2002, from 0.21 to 0.095 parts per million on average for the country's nine monitoring stations. This decline occurred despite an increase in population of 29 per cent in the same period of time and a 70 per cent increase in total automobile mileage (Kahn, 2007). Due to developments in vehicle technology, population growth in low-density areas is not necessarily associated with higher air pollution. Kahn found a negative correlation between population growth and increased ambient air pollution for California over the years 1997-2002.

Current research shows that relationships between urban form, infrastructure design and travel behaviour are still not fully understood. Much of the research into the relationship between the transport sector and urban form has focussed on physical effects. It is even more demanding to identify the valuations of external costs and benefits of different urban forms. Only a full evaluation of external effects would allow final conclusions to be drawn on whether current changes of urban form provide net benefits and how these should be maximised by transport policy action.

5. CONCLUSION

The Round Table discussed recent research that throws light on the benefits and costs of changes of urban form. The development of city sizes and structures is driven by the design of the transport system and confronts transport policy with demands to accommodate or contain changes in land use.

The discussion identified two main benefits from current trends of suburbanisation, with an increasing city size and a decreasing housing and population density in urban areas:

- The decrease of housing density has clearly increased the number of vehicle miles travelled but, beyond a certain threshold distance from traditional city centres, commuting times decrease. While passenger transport has become more infrastructure-intensive, travel and in particular commuting times decreased. Higher infrastructure investment has led to time savings due to reduced congestion. The effect of these changes on fuel consumption is ambiguous. Less congestion might lead to lower fuel consumption if speed increases are moderate.

- Households living in low-density settlements, with relatively low land rents, have higher rates of home ownership and occupy more residential land. This has particularly helped low-income households.

Agglomeration economies are central to arguments that an increase in city size increases the productivity of goods and services. Decreasing transport costs are considered to be instrumental for the spatial extension of the mechanisms leading to agglomeration economies:

- An increase in city size might increase the availability of specialised inputs. This in turn increases the productivity of final goods production.

- An increasing city size driven by lower transport costs might allow a greater specialisation of the work force, leading to productivity effects associated with "learning-by-doing".

- Lower passenger travel costs within metropolitan areas may increase the working of the labour market. A higher mobility of the workforce is expected to increase the match probability and the match quality between employers and workers.

Dynamic agglomeration economies have recently received particular attention. The larger cities are, and the easier the interaction between skilled and unskilled workers or knowledge producing agents, the higher is the rate of knowledge diffusion, and the higher will be the rate of knowledge production. Both determine the long-run growth of urban as well as national economies. To the extent that the ease of interaction between individuals who transmit or jointly produce knowledge depends on density, urban sprawl might negatively affect growth. This is strongly influenced by firms deciding to separate management, R&D and production locations. The more companies split production from research and management, the more they will benefit from increasing city sizes.

Intensive research efforts have led to a great awareness on the costs of urban sprawl. Many effects are, however, context specific. A major part of the research focuses on the physical consequences of urban design and the design of transport systems.

- A first social cost of the current trends of urban development is seen in the loss of farm and forest land. While the annual percentage decline of farmland is rather small, some concern exists about the loss being concentrated on prime farmland.

- The immediate, transport related costs are considered to be high, and due to the fact that infrastructure costs are not internalised by users of the transport system. A similar argument is made for congestion costs. The decrease of time losses due to congestion is expected to be a temporary phenomenon, which will disappear with the filling in of vacant land.

- Environmental costs and air pollution, due to the increase of vehicle-kilometres and the reduction of public transit patronage, remain a main concern of critics of the increase of city sizes. This criticism is maintained, despite reductions in ambient levels of air pollution that have been observed in metropolitan areas over the last decades. Rapid developments of car technologies, often induced by a more restrictive regulation, have led to a decrease of emissions despite the increase of vehicle miles travelled that is associated with urban sprawl.

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INTRODUCTORY REPORTS

THE INSATIABLE DEMAND FOR LAND:

URBAN CHANGE AND LAND (RE-)DEVELOPMENT

Gilles DURANTON
University of Toronto
Toronto
Canada

SUMMARY

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INTRODUCTION

Everywhere in the world, the demand for new land seems insatiable.

Most of those who advocate drastic restrictions to further development view rampant new land developments as “fundamentally wrong”. Sprawl (i.e. too much new land development which is too scattered) is a major threat to our communities, our quality of life, our health and the environment, according to the Sierra Club (2005), arguably not the most extreme anti-sprawl advocacy group. At the same time, anti-sprawl groups only acknowledge very minor costs to anti-development policies. “Smart growth” is often presented as a simple (albeit often drastic) set of land management practices, involving, for instance, the setting of urban growth boundaries, giving priority to in-filling, etc.

There is also a large contingent that is more sympathetic to new land developments. Among them, economists often take a benign view of the demand for land. Market failures are acknowledged through new developments being possibly “wrong at the margin” and thus calling for small corrections. In other words, existing commentators of urban sprawl differ in their diagnoses about the costs and benefits of new land developments. They also differ on how stringent land-use policies should be and whether regulation should be applied through prices or quantities. Nonetheless, they all enclose their solutions in a narrow land-use framework.

By contrast, this paper argues that the demand for new land should also be analysed in a broader framework.

The author’s starting point is that major changes in the economy, such as technological progress or possibly the evolving preferences of consumers, all affect the demand for land. In a nutshell, the demand for development reflects a myriad of changes, large and small, that affect contemporary economies. The corollary is that policies which are presented as narrow land-management policies can potentially affect the evolution of the economy in major, unforeseen ways far beyond land-use issues.

This does not mean that land management is unimportant. On the contrary, the message of this paper is that dealing with the demand for land is not only about optimising land use in a narrow sense but also about how best to accommodate major evolutions of the economy.

The first chapter of this paper describes some stylised facts about new land developments. The second chapter looks at the broader causes behind the insatiable demand for land. Chapter 3 contains some preliminary thoughts about possible policy implications, followed by some conclusions.

1. BUILDING AND PAVING LAND: SOME STYLISED FACTS

This chapter mostly describes facts, gleaned mainly from the United States. Other developed economies are considered wherever possible. Developing countries are not taken into account since they face a specific set of land-development issues which are beyond the realm of this paper (squatter settlements, insufficient infrastructure, etc.). The US is the most intensively researched country in the world concerning land development. On some aspects, the evolution in the US is representative of broader tendencies in developed countries. However, the US is also quite specific in its institutions and its large land mass, both of which affect its patterns of land development. These specificities are highlighted where necessary.

The first fundamental feature about land development is how little of it (in relative terms) has taken place in the US and elsewhere in developed countries. Measuring land use on a macro scale is, in fact, a hard technical problem. Covering nearly 10 million square kilometres, the US is a very large territory. Most developments are going to be very small. A house is rarely more than a couple of hundred square metres in size, while roads are usually very narrow strips of concrete whose width does not exceed several metres. Hence measuring land use at the country level involves measuring a very large number of extremely small and heterogeneous observations. A first approach is to try to isolate contiguous blocks of developed land that satisfy a particular population threshold. Depending on the definition, the US Census Bureau calls them “Urbanized Areas” (large units) or “Urban Places” (smaller units). In 1990, Urbanized Areas covered about 1.7% of the US, while Urbanized Areas and Urban Places covered 2.5% of the US territory. This type of measure suffers from two biases. First, it fails to record development outside these units – an under-count. It also records as developed all the undeveloped land inside those areas – an over-count. Hence, measuring development by defining such spatial units is not satisfactory, since it involves a trade-off between these two opposite biases that cannot be assessed.

A more reliable approach is to measure development directly at a very fine level of geographical detail. This implies using either aerial photographs or satellite imagery. Using high-altitude photographs from around 1976 and satellite images from 1992, Burchfield *et al.* (2002, 2006) divide the US territory into 8.7 billion pixels of 30x30 metres. The sheer size of this data set makes it much more difficult to manipulate and process than “normal data”. Burchfield *et al.* (2006) find that 1.92% of the US land area was developed by 1992. In conclusion, and despite important relative discrepancies between them, all these numbers (and others) agree that only a very tiny fraction of the US territory is developed.

What about other countries? The statistics are scarce and less reliable than in the US but they point in the same direction. The European Environment Agency announces that about 5% of the territory of 20 European countries is covered by “artificial areas”. For Japan, Glaeser and Kahn (2004) report that 4.9% of Japanese land is built up. For England, the UK Office of the Deputy Prime Minister (ODPM) announces a figure of 4.2% without gardens and 8.4% with gardens. The (low) numbers for England and Japan are particularly interesting since these are two very high-density countries. Their numbers could constitute an upper boundary for developed countries (excluding, of course, very small countries). Viewed from this perspective, the fear of nature being taken over by concrete is vastly overblown.

The second key fact is the very fast growth of development in the US and elsewhere. If measuring land development at one point in time is hard, measuring its changes over time is even harder, since different methodologies are used at different times according to the changes in land-use measurement technologies. Regardless of these measurement issues, all the available numbers point to a very fast rise in built and paved land for the US. In their detailed analysis of the US between 1976 and 1992, Burchfield *et al.* (2006) report a growth rate for land development of 49% for their period of analysis. This corresponds to an annual growth rate of 2.5%. During the same period, the US population grew by about 17% or slightly less than 1% per year. There is no reason to think that this process dramatically slowed down during the 1990s and early 2000s. According to the US Census, the increase in land covered by Urbanized Areas between 1990 and 2000 was 1.6% per year (which may be an underestimate if new developments are either much more scattered than existing developments or, alternatively, if they are taking place mostly within existing boundaries). For France, the national statistical institute, INSEE, reports an increase of around 40% in artificial areas over the period 1982-2003. This again implies an annual growth rate of 1.6%, against 0.4% for the French population.

This second fact is, of course, the reason behind the worries about new developments. Even though only a tiny fraction of countries is paved or built-up, new developments proceed at a very fast pace - much faster than population growth. On the one hand, we can note that a 2% annual development growth implies a doubling of paved and built land every 35 years, that is every generation. In some already intensively developed states like New Jersey, the exhaustion of developable land may be within sight. This type of projection feeds the worst fears about development being “excessive”. On the other hand, it may be that there is only so much land that people can occupy, so that new developments cannot grow at such a high compounding rate for much longer. Even if each American was using an improbably large 1 000 square metres for housing, only 3% of the US land area would be covered by residential developments. As made clear below, the validity of these polar arguments will depend on which theory of the demand for land applies.

The third main fact is that new developments in the US take place close to earlier developments, and development does not show a great tendency to become more scattered. Despite a widespread perception that new developments are of a different nature from previous ones, Burchfield *et al.* (2006) only find minimal differences between 1976 and 1992. For each developed 30x30-metre pixel, they first compute the percentage of undeveloped land within one kilometre and then average this measure across all developed cells in an area, to construct a measure of scatteredness. First, about 95% of new developments in the US between 1976 and 1992 took place in areas that were at least 20% developed within one kilometre.

Then, it is also true that new developments between 1976 and 1992 were on average more scattered than existing developments in 1976. However, the scatteredness of the entire stock of developed land in 1992 was barely different from that in 1976. This is especially true for residential land: on average 43% of the land surrounding a residential development was undeveloped in 1992 against 42% in 1976. The picture is only slightly different for commercial developments. In 1976, there was a bimodal distribution of existing commercial developments that were located either in very compact areas (e.g. downtown retail and office space) or extremely scattered (factories, malls and suburban offices). By 1992, the distribution was still bimodal but more tilted towards scattered developments.

There is no contradiction between more scattered new developments and the absence of change in the stock. To understand why scattered new developments may not imply much change for the overall scatteredness of the stock, it is important to know that new developments proceed by both leapfrogging and in-filling. In-filling is particularly important in medium-density areas and it greatly contributes to their densification. Hence, the stock of developed land in 1992 was not vastly more scattered than in 1976, only marginally so.

The numbers are crucially lacking for other countries. The only indication we can use is that, among developed countries, it is only in the US that sprawl is viewed as such an important phenomenon. This suggests that the large amount of development in France between 1982 and 2003 (+40%) might have been less scattered than in the US and might have possibly contributed to an increased densification of the country. These are nonetheless speculations that await detailed work on urban sprawl outside the US.

The fourth main fact is that new developments proceed very unevenly across large spatial units. While the previous fact was pointing at the absence of change at the micro-geographic scale (the kilometre surrounding each development), it also needs to be underscored that there are important changes at the macro scale (metropolitan areas or US states). Not all cities and regions have experienced the same proportion of new development. According to Burchfield *et al.* (2006), 27 US states accounted for less than a quarter of new developments between 1976 and 1992 – the same proportion as Florida and Texas put together. In some of its manifestations, this unevenness at a macro-geographic scale is quite specific to the US. The extent to which the US population has "moved" west and south is certainly pretty unique. Among developed countries, major recent changes in distribution of population across large regions have been either inexistent (France, Italy, Spain, Japan, etc.) or have been orders of magnitude smaller (Germany, UK, Canada). Despite this, in all these countries some metropolitan areas have grown a lot, while others have lost population. Consider, for instance, the largest French cities during the 1990s. Saint Etienne lost 7% of its population, Lille only gained 4%, while Toulouse gained 17% and Nice 72%. These are large cross-section differences. With only minor changes in household composition and number of households per dwelling over short periods of time (Glaeser *et al.,* 2006), large differences in population growth rates across cities suggest equally large differences in the growth of new developments.

Although there is much resistance to new developments on small spatial scales, policies that affect new developments on a macro-geographic scale are barely debated. Nonetheless, it may be argued that a macro-geographic change, like the very fast growth of a particular city, may put a lot of stress on the environment and require major infrastructure investment to accommodate it. For instance, the fast growth of some cities in the US implied the development of new and very costly interstate highways. Existing airports also underwent drastic enlargements and new ones had to be built. Large areas of the US wildlife that were previously undisturbed in the West are now criss-crossed by major traffic flows, etc.

2. THE CAUSES OF THE INSATIABLE DEMAND FOR LAND

Most of the existing literature focuses on either the population growth of places or alternatively on the patterns of land development of these places. It is tempting to think of sprawl (and the demand for new developments) as the product of population growth in a place, times its tendency towards scatteredness (or the land intensity of new developments locally). The main determinants behind both the spatial differences in scatteredness (or land intensity) and demographic growth could then be isolated to explain the demand for new developments. In this perspective, the residuals that are left unexplained would typically be interpreted as “noise”. This type of simple-minded growth-accounting approach would nonetheless miss a fundamental aspect of the demand for land. To understand this, note that a city such as Pittsburgh, which lost 9% of its population between 1970 and 1990, saw its urbanized area increase by 30%. Similar magnitudes hold for other shrinking or slowly growing US cities, such as Detroit or Chicago. Hence, new developments occur on a possibly massive scale even in the absence of demographic “growth”. Put differently, the “noise” unexplained by explanatory variables in land development regressions may not be noise at all. It is argued below that it is more insightful to think of the land development process as “slash-and-burn” development (by direct analogy with slash-and-burn agriculture).

2.1. General trends towards more land consumption

A first basic trend behind the insatiable demand for land is of course population growth. Aside from any other change, the amount of development is expected to follow population trends. A growing population simply means more housing, roads, shopping malls, office space, etc. (Actually, with existing land becoming more intensively used in low-density areas, we might even expect a less than proportional increase.) In their detailed decomposition of the changes in the US residential area, Overman *et al.* (2006) find that 36% of the increase in US residential land use between 1976 and 1992 is directly accounted for by population growth.

Population growth in the US – at about 1% per year – is thus a major driver of new land developments. The same type of population growth rate is enjoyed in Canada. Europe and Japan have a much slower population growth. These demographic trends are expected to continue in the medium run. In the longer run, immigration policies may become less restrictive in Europe, leading population growth rates there to increase again. Population growth is thus expected to contribute to new developments for the foreseeable future.

A second obvious trend behind the increase in land consumption is higher income. Although the logic of this hypothesis is extremely strong, quantifying it rigorously is very difficult since it involves estimating the income-elasticity of the demand for land. Unfortunately,the price of land is usually unobserved, since land is bundled with capital to provide housing and other services. This suggests using hedonic analysis to un-bundle land and capital. However, the best land is typically used to develop the “nicest” houses and many characteristics that make a house “nice” are unobserved. This makes implementing hedonic analysis problematic. Then, note also that the relevant elasticity involves computing the increase in the aggregate demand for land when aggregate income increases by 1%. This requires a comparison in the changes in land prices with changes in income *over time,* keeping everything else constant. This last condition is, of course, very hard to satisfy.

Using a sample of households between 1950 and 1980, Margo (1992) finds that slightly less than half of suburbanisation can be accounted for by rising incomes. Unfortunately, Margo’s methodology does not directly yield a more precise number about the income-elasticity of the demand for land. In their cross-section estimates, Glaeser *et al.* (2000) report an income elasticity of the demand for land around 0.4. The “cross-section” elasticity (computed at the individual level) should be higher than the “time-series” elasticity (i.e. an elasticity computed at the aggregate level) because in time series the rise of everyone’s income is likely to push land prices up. Put differently, the “aggregate” income elasticity should be lower than the “individual” income elasticity. However, even an aggregate elasticity as low as 0.2 can have significant effects in terms of land development. With a growth rate in real income per capita of around 2.3% per year in the US over 1950-2000, an aggregate elasticity as low as 0.2 implies a growth in developed land of 0.5% per year.

To partly substitute for the absence of reliable estimates regarding the (aggregate) income elasticity of the demand for land, it is interesting to look at the decomposition of the increase in US residential land consumption performed by Overman *et al.* (2006). They find that 27% of the increase in residential land use (i.e. about 0.5% per year) is indeed accounted for by greater land consumption per household. They furthermore find that the increase in the number of households was also a very significant driver of new residential developments, accounting for 21% of the increase in US residential land use. This importance of household formation may be exceptionally high by historical standards since it corresponds to new household formation by the largest cohorts of the baby-boom (1.7% per year on average during the period *vs.* a population growth of around 1% per year).

That economic growth is an important driver of land development is beyond doubt. It is true that richer households will demand bigger houses and larger backyards. A more interesting question is: which aspects of economic growth led to this surge in the demand for development? Put differently, what are the ultimate (as opposed to proximate) causes of the demand for development? A chief concern here is that whether large land lots for all are feasible depends very strongly on how the larger physical expansion of cities can be accommodated in terms of commutes.

This is where a third fundamental factor, the rise of the car city, comes into play. Large plots of land in remote suburbs can only be developed if households have an easy means to commute to work, shop and live their social life. In this respect, the automobile appears be the crucial element of economic growth that made suburbanisation and the rise of the car-based city possible in North America. According to Glaeser and Kahn (2004), nearly 90% of US workers commute by car. A majority of households have two cars or more and only about 10% have no car. Although it is an expensive technology, most households view it as a superior means of transportation for short distances. It provides unequalled convenience and comfort.

The rise of the car city also hints at the existence of multiple equilibria in urban forms (Turner, 2005b). The car is a constant-returns technology (or even a decreasing-returns technology when congestion kicks in) whereas public transportation involves increasing returns (at least over a large region of utilization intensity). Mass transit systems are associated with very large, localised fixed costs that can be recouped only when very large numbers of commuters are within immediate reach of the transit. These features suggest the existence of multiple equilibria: a car-based equilibrium with low-density cities and an equilibrium with high-density cities and public transport. Whether one or the other equilibrium gets picked up is going to hinge crucially on two factors. First, initial conditions are likely to matter a lot. A fast-growing city with no pre-existing public transport, like Phoenix, is likely to tilt towards the car far more easily than slow-growth European cities with an already well-developed network of public transport. Second, public transport is more likely to be used where driving a car is more expensive. There are again major differences between Europe and the US in this respect. The gasoline taxes in Europe are about five times as high as in the US (Perry and Small, 2005).

Although a more complete welfare analysis is postponed to chapter 3, it has to be said that there is an important asymmetry between these two equilibria. A public transport city may be able to switch and become a car-based city, whereas there is no return to public transportation for car-based cities. This is because it is always possible to create new, low-density developments at the urban fringe, whereas the type of densification that would be required in low-density cities for public transport to become viable is simply unrealistic (Bertaud, 2002).

If the car is indeed a fundamental factor at the root of the massive increase in land development in North America since the 1960s, it is important to note that the transition to car-based cities is now mostly over. North American cities keep growing but their structural transformation and the movement of suburbanisation are now largely completed. With respect to the evidence quoted above, this may explain why there was only a minimal increase in scatteredness in the US between 1976 and 1992 (Burchfield *et al.*, 2006). For Japan and European countries, the transition from public transport to car cities is yet to fully take place. It is, of course, unclear at this stage if this will ever happen. At present this seems unlikely, but a major technological advance in the car industry may challenge the *status quo*.

The car – a relatively new commuting technology – is certainly at the root of the structural transformation of cities in North America. Together with population growth and higher incomes, they constitute the main "trends" behind the rise in the demand for land. They are certainly not the only ones. A number of additional factors, such as highway subsidies and mortgage interest deductibility, also played a role. However, and despite their possibly large (though contested) quantitative importance, they should only be viewed as additional factors. For instance, highways are certainly promoting car usage but it is unclear what would have happened to the US road system in the absence of federal subsidies. Instead, state and local subsidies might have been put in place.

2.2. Geographical differences in land consumption

The literature that discusses the demand for land typically discusses only the three factors mentioned above and gives varying degrees of importance to additional factors such as federal subsidies to the highway system. These additional factors are often underscored to demonstrate the "excessive" amount of new development. However, this type of account possibly misses most of the story about the insatiable demand for land. Worse, the typical decompositions found in the literature arguing that X% of urban development is due to factor A (say, population growth) against 100-X% to residual factor B (say, income growth), and the illusion of completeness that they give, conceals a number of features that play a fundamental role in land development. The first one is that land development does not occur in the same way and the same intensity everywhere: there are very large differences in patterns of land development across areas in the United States. These differences can teach us something about the insatiable demand for land.

When looking at the largest metropolitan areas in the US, Burchfield *et al.* (2006) find major differences. The square kilometre around the average residential development in Atlanta or Pittsburgh is 60% open space against only 30% in San Francisco and 20% in Miami. These differences concern the entire stock of developed land. The differences regarding new developments are also very large, ranging from 34% of open space around new constructions in Miami to 70% in Seattle. In Burchfield *et al.* (2002), the same authors also document massive differences between US states in the amount of developed land per capita. Ignoring the District of Columbia, which may appear artificially compact in the data, there is still a nearly fourfold difference between the states with the lowest amount of built and paved land per capita (New Jersey, New York and California) and those with the highest amount of developed land per capita (North Dakota and Iowa).

These large differences in land use per capita and the scatteredness of development beg for an explanation. In their analysis of cross-section differences in scatteredness, Burchfield *et al.* (2006) distinguish between three groups of factors. First, physical geography is of great importance. Actually the most important factor to explain the differences in development scatteredness across US metropolitan areas is the presence of an aquifer underneath the urban fringe. This result is no longer that surprising, given that aquifer connection fees can be minimal in areas where water is widely available, whereas aquifer connections can cost tens of thousands of dollars in areas where water needs to be brought from far away. The study also shows that scatteredness is more important in metropolitan areas that enjoy a mild climate, since nice weather is naturally linked to more outdoor activities. Finally, terrain irregularities also matter. Small-scale irregularities favour scatteredness, whereas high mountains act as barriers and favour more compact developments. Physical geography alone accounts for 24% of the variance in the scatteredness of new development across US metropolitan areas. (Note that the results are essentially the same regardless of whether one considers only new developments between 1976 and 1992 or all development in 1992.)

Economic and demographic factors are also important. Metropolitan areas with specialised activities that tend to agglomerate in downtown areas, like business services, have more compact patterns of residential development. On the contrary, cities with specialised activities that tend to be more decentralised are more scattered in their residential development. Furthermore, and consistent with the car-city argument exposed above, newer cities that have developed around the car instead of public transport tend to sprawl more (though road density is not a significant driver of scatteredness). By contrast, the relationship between the scatteredness of development and local population growth is more subtle than suggested by a simple extrapolation of the car-city argument. First, and perhaps contrary to one's initial guess, slower population growth leads to a more scattered residential development. This is because going far into the suburbs to enjoy lots of open space is a valid strategy only when this space is expected to remain undeveloped. In a fast-growing city, the natural amenities of the remote suburbs may not last very long, thus discouraging a move there in the first place. It is also the case that when local population growth is highly uncertain and development is subject to lags, it may not pay off for developers to cling to undeveloped, prime land. Consistent with this, a greater variability in population growth at the metropolitan level also leads to more scattered developments.

Finally, political economy factors are also important. In particular, more sprawl is observed in metropolitan areas where local taxpayers pay a smaller share of local government expenses. This is of course due to the fact that paying a smaller share of local public services makes scattered development less costly. Having large parts of a metropolitan area that are not incorporated into a municipality also favours sprawl since these areas are regulated by state or county planning regulations, which are typically far less restrictive than municipal zoning laws.

These results suggest that development is not only affected by the broad trends discussed above (car, population levels and rising income) but also by a variety of local factors. Overall, Burchfield *et al.* (2006) can explain about 47% of the variation of their scatteredness index across US metropolitan areas. Given that this scatteredness index is rather coarse and captures only one dimension of sprawl, an R-square close to 50% must be viewed as a high explanatory power for the variables considered.

2.3. Population flows also matter

As made clear above, the consumption of land per capita and the scatteredness of new developments exhibit strong cross-section variation. It is also the case that population growth is highly uneven across cities. This latter feature contributes to the demand for development in two major ways. First, there is a fundamental asymmetry between development and its opposite, the return to open space. Residential and commercial real estate tend to be very durable. While decay is typically measured in decades, development takes only a short period of time (development lags are typically measured in quarters). Hence when people move to a new city, new developments take place at destination but developed land remains at the origin so that land use per capita also increases there. Put differently, the durability of construction implies that net migration flows lead to net additions in residential and commercial developments. In support of this, Burchfield *et al.* (2002) note that the increase in land consumption per capita over 1976-92 was largest in states that experienced negative population growth during the period (North Dakota, Iowa or Wyoming).

The second major implication of the changes in the geographical distribution of population is that people may be moving from compact to more scattered cities. There are large population flows from New England and mid-western states (where land consumption per capita is traditionally below the US average) to Florida or Texas (where land consumption per capita is much higher than average). As estimated by Overman *et al.* (2006), this type of migration from small-house-and-backyard states to large-house-and-backyard states directly accounts for 6% of the increase in US residential area and indirectly for another 7% through the interactions between land use and population changes at the state level. Note that this overall figure of 13% for geographical shifts in the population only concerns new developments and ignores the fact that, because housing is durable, an outflow of population in a state will increase residential land use per capita. Hence, population flows are also a major driver of new developments. Before drawing policy implications, it is important to know, in turn, what drives this uneven growth of cities. The literature exploring this issue for the US underscores a series of factors.

The first and most important driver of population growth for US metropolitan areas over the last 20 to 30 years is climate. As argued by Glaeser *et al.* (2001) and Rappaport (2004), in the US there has been a strong pull effect of good amenities and in particular "nice weather". As "quality of life" variables have become more important, the US population has moved to those places that offer better natural amenities, in particular mild winters and dry summers. This move towards nice weather has affected the inactive (i.e. retired) population as well as the population at work. Put differently, the move towards nice weather is not only about pensioners moving to senior-citizen communities in Florida but also about working families going to Arizona, Texas or Southern California. This move is often uniquely attributed to a major one-off piece of technological progress: the introduction of air conditioning. Although air conditioning is certainly a part of the story, it cannot explain everything. Rappaport (2004) convincingly shows that the US population has also moved to places where summers are less hot and humid – in contrast with the prediction of the air-conditioning hypothesis.

The movement towards good natural amenities has been very large in the US. What about other countries? Partridge *et al.* (2005) in a parallel exercise for Canada show that climatic amenities have basically no power to explain the growth of Canadian cities between 1981 and 2001. Worse, in some regressions the coefficients on weather variables even come up with the wrong sign (albeit insignificantly). This reflects the fact that some of the Canadian boom areas are located north of the main population centres (which are clustered along the border with the US). More in line with the US experience, Cheshire and Magrini (2004) also find that climate matters at the national level in Europe (albeit seemingly less so than in the US).

Climate is not the only amenity that matters. *A second (minor) movement is the return towards the "nice" downtown areas*. This change is documented by Glaeser *et al.* (2001) for the US. Here, this return to the downtowns needs to be qualified – only the "nice" ones have benefited. This means mostly New York, Chicago, Boston, Seattle and Saint-Paul/Minneapolis. According to some older evidence by Cheshire (1995), the movement back to city centres is seemingly more important in western Europe. This would be consistent with the existence of, on average, better downtown amenities in European cities.

The third driver of population growth for US metropolitan areas is the presence of an educated population. This fact was noted first by Glaeser *et al.* (1995) and confirmed by the subsequent literature (see Simon and Nardinelli, 2002 and Glaeser and Saiz, 2004, for recent confirmations). This relation is robust to reverse-causation and, interestingly, the effect seems to percolate more through production benefits rather than through better amenities (though Shapiro, 2006, disputes this and attributes only 60% of the effect of citywide skills on growth to higher wages against 40% to amenities). Quantitatively, Simon and Nardinelli (2002) note that a standard deviation in the local percentage of college graduates (1.7 point) in 1940 is associated with a 0.36% difference in annual growth rate over the 1940-90 period, that is, 15% of the mean.

There is a great paucity of studies looking systematically at the determinants of urban growth in other developed countries, so that these results have never been replicated. However, there is a strong suspicion that this type of education effect is not specific to the US. This is because the effects of citywide skills on urban growth percolate mainly through wages and there is good evidence of such wage effects outside of the US (see, for instance, Charlot and Duranton, 2004, for France).

The fourth driver of growth in US metropolitan areas is the presence of migrants. The idea behind this mechanism is the following. It is well known that new migrants tend to settle in cities where previous migrants from the same country/region/village settled in the past (see Greenwood, 1997, for a review). Bartel (1989) documents that 80% of Hispanic migrants in the US were living in the top 25 metropolitan areas (representing less than 50% of the US population) in 1980. Then, it also seems to be the case that there is no one-for-one substitution between natives and new migrants. Put differently, a good proportion of new migrants come as net positive growth for the cities that receive them. Unfortunately, to my knowledge, there is no precise growth-accounting exercise that gives an exact figure regarding how much of the growth of fast-growing cities is accounted for by foreign migrants. As a more indirect piece of evidence, Ottaviano and Peri (2005) document a strong positive correlation between linguistic fractionalisation (driven primarily by recent migrants) and urban growth in the US.

Although they are often ignored, population flows play an important role in explaining the demand for new developments. Their importance goes beyond the quantitative measures given above because the most popular areas (with nice weather and/or educated population) tend to be already under much stronger environmental stress, since they are often already very developed (like Southern California or New Jersey). In terms of public infrastructure, these trends also imply important costs since the geographical relocation of households requires new investment in growing areas and leads to the premature obsolescence of existing infrastructure in declining areas.

An important question is whether the transition to "car-based, post-industrial cities" and the other changes described above are over or if instead these trends will continue to operate and new ones will appear. Although no definitive answer is available, it is hard to imagine that existing trends driving change in the US urban landscape will suddenly stop and that no new trend will appear. It is true that the transition to car-based cities and the decentralisation of jobs may be mostly over, while the rate of household formation in the late 1970s was an historical blip. However, some of the other trends mentioned above, like the pull of nice weather, appear irresistible and will probably matter for the foreseeable future. It is also easy to imagine that some hitherto marginal phenomena may gain strength. For instance, there is a nascent geographical disjunction between new residential developments (taking place close to the coasts) and new commercial developments (more inland), according to Burchfield *et al.* (2006). One can also think that with rising incomes the demand for second homes will increase, etc.

2.4. Slash-and-burn development

The last fundamental element making the demand for land development truly insatiable is usually ignored by most academic discussions of sprawl and urban growth. Interestingly, it figures prominently in more popular discussions of the issue and it is also a matter of fundamental policy interest (at the local level in the US and the national level in the UK). In a nutshell, the process of land development shares some similarities with slash-and-burn agriculture. For commercial developments, economic change (sectoral decline, new technologies, etc.) typically involves leaving a vacant or under-utilised developed site behind. Viewed differently, much of economic life involves some important movements of "creative destruction". Because real developments are highly durable, the creative destruction of activities and firms implies a movement of building and desertion of land.

Systematic evidence about the amount of vacant or under-utilised developed land is very scarce. Establishing some solid facts on this issue should rank high as a research priority. At the moment we can only rely on limited bits of information and back-of-the-envelope calculations. These are nonetheless very suggestive that we are talking about some first-order effects. This aspect of land development may also be why anti-sprawl advocates think of new developments as essentially "wasteful".

The US Environmental Protection Agency (EPA) calculates that there are about 450 000 brownfield sites in the US. Its definition of "brownfield" (as opposed to "greenfield") is rather restrictive since it requires some contamination or a strong probability of it. An empty warehouse or a deserted mall is unlikely to be classified as brownfield by the EPA. The EPA definition will also exclude most, if not all, empty homes. Finally, very contaminated sites are also excluded since they qualify for the Superfund Hazardous Waste Cleanup Program. Hence this number, close to half a million sites, is clearly a lower boundary. The US Conference of Mayors also collected data for a subsample of around 25 000 brownfield sites from 205 cities. These cities reported an average area of five acres per site. Extrapolating these numbers to the number of brownfield sites reported by the EPA would imply an overall area of 9 000 square kilometres of brownfield development in the US. This is equivalent to 75% of the land area of Connecticut, despite the use of a very conservative measure of deserted developments.

The UK ODPM estimates that there are about 660 square kilometres of brownfield sites in England (no figure is available for the whole of the UK). The English definition of "brownfield" is much less restrictive than the US definition since it concerns any previously developed land that is vacant, derelict or available for redevelopment. The 660 square kilometres of brownfield sites represent 0.5% of the area of England or, more tellingly perhaps, more than 5% of total developed land according to the ODPM. At the regional level, the ODPM estimate for brownfield varies from less than 3% in London to nearly 8% in the two northern regions.

Most other developed countries are expected to face a higher proportion of brownfield sites because land is particularly scarce in England. New developments are also very much restricted by stringent planning regulations that apply to the entire country. Finally, England has had a very active policy of brownfield conversion in the last decade. Despite these strong incentives to redevelop land, only 9% of brownfield areas in 2001 had been redeveloped by 2002. This figure points at a very low rate of redevelopment. With new buildings reaching brownfield status every year, the expected steady-state stock of brownfield sites may be very high indeed, despite a very limited supply of greenfield sites and strong policies towards brownfield redevelopment. Alternatively, and more worryingly, for many sites brownfield may be an absorbing state.

To understand what fuels slash-and-burn development, it is useful to consider separately:

(i) the mismatch between the demand for commercial space and the existing stock; and
(ii) the costs and possible market failures associated with the lack of redevelopment.

The mismatch between new demands and the existing stock is considered first, before turning in the next chapter to the policy issues associated with redevelopment or the lack thereof.

A first force behind the mismatch between new demands and the existing stock is the rise and decline of industries. As noted by Glaeser *et al.* (1995) and many others (see Duranton, 2005, for a review), the growth and decline of cities is linked to their industry composition. During the (on-going) era of de-industrialisation, cities with manufacturing specialisations suffered the most. Even when large-scale structural change does not involve significant employment flows across cities, emerging industries will typically prefer new developments. For instance, the structural transformation of London over the last 40 years from a port and manufacturing city into a business service centre is associated with the massive redevelopment of its former dockland area. Nonetheless, and despite very strong location attributes and extremely high land prices in Central London, the London Dockland area was left mostly idle for more than ten years. In the mid-80s, the impetus for redevelopment was given by a major government-led redevelopment initiative, which after more than 20 years is finally nearing completion.

The fact that de-industrialisation has now reached a very advanced stage in the US may give the impression that the main driver of slash-and-burn development is running out of steam. This is likely to be wrong because, even when we condition out the manufacturing-to-services movement, there is a large amount of churning across sectors and cities. These facts are documented in Duranton (2005). In the US between 1976-96, an average of 8.7% of the employment in two-digit sectors in metropolitan areas was wiped out every year. This is much more than the average employment growth of cities (4.2%) and the amount of aggregate sectoral reallocation (5.0%). For France, the numbers are even higher since city employment reallocation was 11.4% between 1985 and 1993 while city growth was 5.2% and aggregate employment reallocation across sectors was also at 5.0%.

This suggests that within-sector technological shocks constitute a second important driver of slash-and-burn development. The existence of this second driver is consistent with well-documented patterns of strong industry mobility (see Dumais *et al.,* 2002, or Duranton, 2005, for a summary of this literature). Industries appear to be geographically quite mobile and move easily across cities. Even (or especially) the most concentrated often relocate. At a lower level of aggregation, it is also well known that there is a large amount of churning at the firm level (Davis and Haltiwanger, 1998) which too can contribute to slash-and-burn development, as new firms decide not to locate where the old firms that they replace were located.

The existence of these shocks affecting sectors within metropolitan areas is also consistent with the large amount of “unexplained” variation in city growth regressions. When trying to explain the population growth rates of cities over periods of ten years or more by a large variety of factors, the regressions explain typically less than 50% of the variance. The performance is much worse when shorter time horizons (five years or less) are considered. By way of comparison, cross-country (income) growth regressions often have an R-square above 70%, despite the obvious measurement problems of cross-country data. Put differently, the trends discussed above explain the long-run changes in city population only moderately well, whereas short-term changes suggest the existence of many shocks at the level of industries within cities. Since commercial real-estate is not seamlessly converted (see below), these shocks are a key driver of development.

This discussion of slash-and-burn development is mostly centred on commercial developments but this phenomenon may percolate directly into residential developments. Abandoned production sites may also imply the desertification of the surrounding residential areas. There is strong anecdotal evidence of this in former mining basins (particularly in France and the UK). More systematic evidence is still lacking. According to the UK charity, the Empty Home Agency, there would be about

700 000 empty homes in England. This corresponds to about 3 to 4% of the existing stock in a country where most of the population lives in extremely tight residential markets. Aside from the extreme case of empty homes, the local decline in activity is likely to translate into much lower local prices for residential real-estate (well below replacement costs) and thus an "over-consumption" of residential space (Glaeser and Gyourko, 2005).

There may also be an independent form of slash-and-burn development in the residential market following some negative social externalities. In a Tiebout-type of framework, the arrival of "undesired" residents in a jurisdiction can lead to a negative fiscal externality and many other technological externalities (Nechyba and Walsh, 2004). For richer residents, this arrival of undesired neighbours may lead to their departure (commonly referred to as "flight from blight") in search of more exclusive surroundings. One can then imagine that the worsening of the average resident characteristics leads to further departures until only the residents with the worst characteristics remain in an area where housing is grossly under-utilized.

Because of its potential importance, more needs to be known about slash-and-burn development. This should be a high priority for future research.

3. WHICH POLICIES TO TACKLE THE INSATIABLE DEMAND FOR LAND?

From the rise of obesity to the alleged ugliness of strip malls, there is a long list of popular grudges against urban sprawl and more generally new developments (see Nechyba and Walsh, 2004, for a large sample of these complaints). These complaints often belong more to the realm of value judgements rather than sound welfare calculations. The economic literature has identified six policy issues. Five of these – all likely market failures (or mixtures of market and government failures) – are only very briefly discussed, and the reader is invited to look at Brueckner (2000a), Glaeser and Kahn (2004) and Nechyba and Walsh (2004) for more detailed discussions. The sixth issue, zoning – a likely government failure – is more complex. The end of this section focuses on the possible inefficiencies associated with the redevelopment process (or the lack thereof).

The first possible inefficiency is that new developments may create congestion. This argument is theoretically straightforward. In standard urban models, fringe developments increase commuting to the city centre (or central business district) while road congestion, a negative externality, is ignored by developers in their development decision. Note that the argument may lose much of its force in a very decentralised city since commutes will take place from anywhere to anywhere, implying a more fluid traffic than in a monocentric city where commuting typically relies on a few major arteries. In multicentric cities, new developments may then have only a small congestion effect. Glaeser and Kahn (2004) report that the empirical support for the argument that sprawl increases congestion in the US is very weak. Instead, new developments associated with the decentralisation of jobs may even reduce congestion. In any case, acting against new developments to fix a congestion externality is certainly not the most direct way to remedy the absence of road pricing. Even worse, the congestion effects of the most commonly used instruments against new developments, such as urban growth boundaries, are very ambiguous. For instance, it could be argued that urban growth boundaries can increase congestion by fostering high densities and preventing the decentralisation of many activities. Fast progress in road pricing technology (and more broadly in traffic management technologies) is likely to weaken the case for dealing with congestion through development caps even further.

The second inefficiency is that excessive development may occur because local public goods and services are not always priced properly. Excessive development can occur when local public goods and services are subsidised by higher levels of government through matching grants and free provision of education, etc. As noted before, impact fees can solve this problem easily. The main complication introduced by the arguments developed above about urban growth and decline is that the calculation of the optimal impact fees should take into account the dynamic nature of land development. This implies, for instance, considering the possible early obsolescence of infrastructure, should an area decline precipitously.

The third possible inefficiency is that new developments may lead to more inefficient residential sorting. For instance, the "flight from blight" of the middle class to the suburbs is sometimes alleged to have reinforced negative social externalities in the central cities in the US. This argument is nonetheless limited, problematic and possibly empirically irrelevant. It is limited because it only concerns new residential developments and not commercial developments (whereas the advocated restrictions often apply to all types of development). This argument is also theoretically very problematic because, although inefficient sorting occurs in many models, restricting sorting in general may obviously limit inefficient sorting but it can also prevent efficient sorting from taking place. Besides, the gravity of sorting inefficiencies appear to depend in complex ways on a wide array of institutional and policy details. It is also unclear what role new developments play in the sorting process. Inefficient sorting can very well occur without new developments. Hence dealing with the negative effects of segregation through caps on land development relies on a very weak second-best argument.

Empirically, the literature has not reached any firm conclusion but a number of elements appear to support the idea that new development may instead reduce negative sorting. In particular, lower density areas are less segregated and segregation has fallen most in those fast-growing metropolitan areas with lots of new developments. Furthermore, there is no strong evidence regarding growing social isolation following new urban developments. Pushing a different (though related) line of argument, Glaeser and Kahn (2004) note that the rise of the car city may induce negative distributional effects for the poor who cannot afford a car (i.e. a pecuniary rather than a technological externality). A subsidy for the purchase of cars by the poor is the obvious solution to this concern for inequality. But then it must be noted that helping the poor to buy a car is likely to increase the demand for new developments rather than curb it.

The fourth possible inefficiency regards a possible loss in agglomeration economies. The argument relies on the idea that higher densities foster more positive interactions. Besides, there is also a lot of evidence arguing that agglomeration effects are subject to strong distance decays (see Rosenthal and Strange, 2004, for a survey). Although the indirect evidence about a market failure here might appear quite strong, a few qualifications are needed. First, economies of density are fairly small (with most productivity measures exhibiting an elasticity to density of 3-6%) and most new commercial developments do not dramatically decrease density, as seen above (provided density can be proxied by scatteredness). Hence, the maximum negative productivity effect of new developments may be quite small. Hopefully, further work will be able to provide more precise estimates on this issue.

There are also theoretical reasons to doubt that the negative productivity effects of new developments are large. It is true that in a static model of land development, density will typically be underprovided in a decentralised equilibrium. However, new commercial developments are often provided by large urban developers who should internalise this externality to some extent. It is also the case that in models of dynamic development, new developments may occur very close to established developments to free-ride on the positive externality that they provide (without accounting for the economy on infrastructure provision that proximity provides). Density may even be overprovided if new developments ignore the congestion externality that they create.

The fifth possible inefficiency relates to the loss of (valuable) open space and other environmental damage. Since new developments are likely to increase the amount of commuting, they can also increase overall pollution. This type of inefficiency can be dealt with by a simple gasoline tax (which nonetheless should be differentiated, since car pollution appears to depend strongly on how old a car is). According to Parry and Small (2005), the gasoline tax is about half its optimal amount in the US against twice its optimal amount in the UK. This suggests that there is much room for improvement. On the other hand, this also suggests that there may be some political-economic forces, pushing towards inefficient taxation, which are hard to tackle. Political-economic inefficiencies are also likely to affect all the other policies discussed here. In any case, the evidence that new developments increase pollution is very weak if not inexistent (Glaeser and Kahn, 2004).

Open space is a more complex issue. Open space can be thought of as being valuable for two different reasons. First, open space has some visual value for local residents. This aesthetic value of open space points to a negative externality of new developments, since they can reduce the natural beauty of the landscape. Pushing the argument further, the existence of a landscape externality suggests that efficient development should be very scattered so that everyone can view open space. The main trade-off should then be between very large plots of land and accessibility/transport costs.

It may nonetheless be more reasonable to assume that what really matters is the direct consumption of open space (e.g. relaxing in a park) rather than its contemplation. In this case, the landscape externality boils down to a complex issue of local public good provision. Efficient residential patterns require providing some green spaces and avoiding "over-development" (Turner, 2005a). Efficiency also indicates that green spaces are more desirable in densely populated areas than where population is sparse. These implications differ sharply from the standard smart-growth prescriptions, such as encouraging the development of open space in areas with already some developments and green belts (which provide open space in low-density areas and tend to intensify development in central areas that are already highly populated). When green space is viewed as a very local public good, it is easy to understand that its provision and management are going to be difficult, just like those of many other local public goods subject to strong distance decay. Issues of park size, spacing and design become crucial. These micro-management issues are not usually something that economists feel comfortable with. Green space provision is all the more difficult since it has to be decided before an area is developed (because creating green space from brownfield sites may be prohibitively expensive). This puts some strong requirements on advanced planning and some places (like unincorporated areas in the US) will face the problem of an absent public decisionmaker *ex-ante* (i.e. when those decisions need to be made).

The last environmental issue concerns the loss of open space on a macro scale. Even a very low level of development may have some effect on the local flora and fauna. For instance, the cohabitation between a small number of humans and large mammals is often uneasy and ends up in large mammals having to leave. These mammals then face an ever shrinking habitat. Major roads are also sometimes fundamental obstacles that drastically reduce the movement of animals and thus make them more vulnerable to local shocks. This can also lead to small, segmented communities of animals that are not genetically viable in the long run. The essence of the solution to these issues is fairly simple and consists in reserving large, undeveloped areas for wildlife. In practice, coming up with an optimal policy will be nonetheless complex, given the inherent difficulty of putting some numbers behind the costs and benefits of large enclaves reserved for wildlife. With so little of the land being developed in the US and many other countries, such reservations are often likely to be inexpensive and should not conflict with urban development, except possibly in coastal areas.

The sixth possible inefficiency relates to the inefficiencies introduced by zoning regulations. This is a complex set of issues since zoning is at the same time a possible solution to the inefficiencies of new developments as well as a likely cause of them. For simplicity, three approaches to urban zoning can be taken. The first is to assume that zoning regulations are implemented in small municipalities (i.e. at the sub-metropolitan level) by benevolent local planners who seek to maximise local welfare. In this case, zoning regulations will be efficient, provided the externalities that they seek to internalise are bounded within the jurisdiction where they are implemented. If, on the contrary, the externalities that zoning tackles are not restricted by municipal boundaries, the unco-ordinated maximisation of local planners will in general be inefficient and can promote too much or too little development. If, for instance, congestion is mostly municipal while agglomeration effects are more diffuse, municipal planners (who do not fully internalise positive agglomeration effects) will unduly restrict development. On the contrary, if congestion is a metropolitan-wide phenomenon whereas agglomeration economies are taking place within municipalities, local planners will induce too much development.

The second approach is to assume that zoning regulations are implemented by benevolent planners for an entire metropolitan area. This will, of course, be fully efficient but recent research on zoning (e.g. Glaeser *et al.,* 2005) suggests that zoning can be far from efficiency-enhancing. To better understand zoning, we thus need to turn to a third approach that views zoning in a political economy framework. Zoning regulations are assumed to be the outcome of some local decisionmaking process (voting, lobbying, etc.) that favours local residents interested in raising their property values. This suggests that zoning regulations are best viewed as restrictions imposed by local homeowners acting as monopolies. We thus expect them to under-provide new development and possibly foster a pattern of development that is too scattered, through the use of minimal-lot-size regulations, for instance.

A broader view of zoning hints at two other types of effect. First, as already mentioned above, there is a strong suspicion (though no direct proof) that urban forms are subject to multiple equilibria (Anas *et al.*, 1998). In the US, zoning regulations are often decided by unco-ordinated municipalities within metropolitan areas and they usually try to limit the amount of development locally. This suggests that an unintended consequence of zoning regulations may be the creation of edge cities and the shift towards multicentric urban structures. This could in turn increase even more the scatteredness of new residential developments.

Second, the political economy approach to zoning also suggests that restrictive zoning regulations should raise the price of housing and new commercial developments in metropolitan areas. This in turn will increase the set-up costs of new firms and their ability to attract labour from elsewhere. In a world where knowledge is freely mobile, high local set-up costs for new firms and the development of new ideas would only lead entrepreneurs to locate in cheaper metropolitan areas. Unfortunately, knowledge is far from being freely mobile, especially that associated with the early stages of new products and new technologies (see, for instance, Duranton and Puga, 2001). Hence the effect of restrictive zoning will not be a diversion of firm creation and innovation to other cities at a great cost for the zoned city. Instead, firm creation and product development will stay but occur at a slower pace. Marginal projects or new projects for which entrepreneurs are credit-constrained may even be discarded. Put differently, even though San Francisco, Boston or New York may be hotbeds of innovations and product developments, their very high rent levels may discourage many new firms from being created and new innovations from being made. The social cost of this may be quite high since innovation arguably generates large positive external effects. A very large share of productivity growth is also strongly associated with the entry of new establishments (see, for instance, Foster *et al.*, 2005).

Turning finally to *the issue of redevelopment*, it should be noted first that the theoretical literature on redevelopment has a primarily positive focus with very little normative interest (see Brueckner, 2000b, for a review). Its main objective is to rationalise some features of land development, such as leapfrog or unconventional lot-size patterns that are impossible to explain in static models (wherein housing is implicitly malleable). These models usually imply optimising extremely complex dynamic programmes, and thus leave aside possible inefficiencies associated with redevelopment in order to remain tractable. The chief result of this literature is that efficient redevelopment occurs when the price of a property after redevelopment exceeds its price before redevelopment by more than the cost of redevelopment (demolition, clean-up and construction). Following Rosenthal and Helsley (1994), there is a small, empirical literature that supports the fact that observed patterns of residential redevelopment are consistent with this optimal redevelopment rule. Unfortunately, this type of approach is not able to recover redevelopment costs (unless of course optimality is assumed). This implies that the existing findings are also consistent with sub-optimal redevelopment. They only indicate the existence of a market response.

When developers choose whether to redevelop a brownfield site or develop from scratch on a greenfield site, they face a trade-off between a potentially better brownfield site for which an extra cost of demolition and clean-up applies, and a greenfield site for which only construction costs have to be incurred. This suggests that demolition and clean-up costs are of fundamental importance to understand the redevelopment process. Unfortunately, very little is known about demolition, clean-up and redevelopment costs. Estimates from the industry suggest that for low-rise residential areas these costs may be relatively small when accounting for the economy in infrastructure provision. Besides, it also seems that for residential housing it is often possible to partially redevelop a unit without having to demolish it completely beforehand. For commercial sites this is another matter, since partial redevelopment is often less of an option and the costs of demolition and clean-up can be extremely high. Anecdotal evidence suggests that the redevelopment process is much more costly for commercial than for residential real estate. The variance is also very large since brownfield commercial sites range from outdated malls (which are typically light structures on non-contaminated land) to deeply contaminated sites covered with very heavy manufacturing structures (even excluding extreme cases, such as nuclear power plants).

It should be noted first that in multicentric metropolitan areas the location advantage of brownfield sites may be quite small. This implies that even when the costs of redevelopment are small greenfield development can be privately optimal. In turn, this then implies that in the absence of market failure for redevelopment, a growing stock of brownfield sites may not be suboptimal unless one puts a large premium on land being virgin rather than developed. Put differently, we cannot attribute the existence of abandoned industrial sites to market failures.

Of course, this argument does not preclude the possibility of large market failures in the redevelopment process. The first one is related to the potential liabilities associated with many brownfield sites. With redevelopers being possibly risk-averse and missing insurance markets for brownfield liabilities, a suboptimal amount of redevelopment may be undertaken in equilibrium. A second possible market failure is related to the existence of positive externalities from redevelopment. For instance, an abandoned industrial site in a residential neighbourhood may negatively affect the price of all the surrounding properties. Some co-ordination failures may also take place when brownfield areas are large and comprise a variety of different properties owned by different owners. The empirical evidence on co-ordination failures in redevelopment is minimal. In a very rare study on the subject, Greenstone and Gallagher (2005) suggest that, in the case of sites being cleaned under the US Superfund Program, the benefits of cleaning up contaminated sites may be quite small, substantially below the cost of cleaning.

Policies addressing redevelopment in North America and Western Europe typically involve a mixture of subsidies for redevelopment (as in the US Superfund Program or many European regeneration programmes) and zoning restrictions which force firms to use brownfield sites. In the UK there is, for instance, an official target for 60% of new developments to take place on brownfield sites. These zoning rules have a number of pitfalls. First, they typically make “new firms” pay for the cost of redevelopment. This implies that the new firms face higher costs following decisions made long ago by “old firms”. As highlighted above, this type of policy which restricts the location sets of firms may also slow down the rate of new entry. In a nutshell, policies that attempt to freeze the location of firms may also lead to a growth freeze.

A more promising line is to include demolition and clean-up costs as fees to be added to the initial construction costs. There are two main challenges to be overcome. First, demolition and clean-up are likely to take place in the far future, for which predictions may not be reliable. Second, not all commercial or industrial developments are equally user-specific. Refining facilities can only be used by a refinery, whereas open-space offices have a wide number of possible users and uses. Since more versatile spaces are less likely to become obsolete and in need of redevelopment, the optimal development tax should be lower for them. Although the idea of imposing a redevelopment fee at the time of the first construction sounds promising, its implementation will not be fully straightforward.

4. CONCLUSIONS

This paper discusses the main forces behind the “insatiable demand for land”. It shows that this demand is not only the product of population growth and higher incomes leading households to demand larger backyards. The movement of workers and economic activity across areas also plays a fundamental role. More specifically, firm creation and destruction and the movement of workers lead to a phenomenon of “slash-and-burn development”. Such slash-and-burn development is possibly subject to a number of market failures. However, attempts to drastically curb development may have effects much beyond those typically considered in land-use analysis.

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THE ENVIRONMENTAL CONSEQUENCES OF SPRAWL

Elizabeth DEAKIN
UC Transportation Center
University of California
Berkeley, California
USA

SUMMARY

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1. INTRODUCTION

In 1950, the US population was just over 152 million. Today, the population exceeds 298 million. Growth has not been even; much of it has occurred in the West and South. Although every state grew in population between 1950 and 2004, just three states – California, Texas and Florida – accounted for 30% of the population growth (Table 1). Furthermore, these three states, which together represent 14% of the US land area, are projected to account for half of the total US population growth over the next twenty years. Yet the New York metropolitan area, with a population of over 20 million, is the largest metropolitan area in the US and one of the largest in the world; the population of the New England and Middle Atlantic States made up 21% of the US total, though the eleven states account for only five per cent of the land area.

Nearly all of the population growth in the US in recent decades has been in metropolitan statistical areas (MSAs), or areas with at least 50 000 residents. As Tables 2 and 3 show, large metropolitan areas have captured much of the United States' overall growth[1]. In 2000, about 80% of the US population lived in MSAs. Over 57% were in metropolitan areas larger than one million, up from 53% in 1990. About 38% of the MSA residents lived in a central city in 2000 – 30% of the US population. A larger share, just over half, lived in other urbanized areas or clusters within a metropolitan region. Some 11% lived in rural sections of metropolitan counties. Of the 19% of the population outside a metropolitan area, only about 12% were in truly rural areas; the other 7% of the non-metro population lived in small towns[2].

The US experience is part of a world-wide trend: 2003 marked the first time the majority of the World's population lived in cities. By the year 2025, when the global population is expected to reach 8 billion, 60% will live in cities (UN, 2004). In the US, the near-doubling of the population since 1950 has been accompanied by major growth and change in the US economy. The standard of living has increased, with annual personal expenditures tripling on an inflation-adjusted, per capita basis between 1950 and 2000. Metropolitan growth in other countries is similarly associated with an increase in the standard of living.

The concentration of populations into metropolitan areas (estimated variously at 3% to 10% of the land area of the Earth) is the result of profound changes in world economies made possible by hard and soft technological innovations. But the effects of this metropolitan growth are quite complex. Metropolitan areas exhibit a vast range of densities; Table 4 shows population densities for US metropolitan areas. However, density can vary substantially with the area included in the calculation. Table 5 shows this for the New York metropolitan region. The table shows that the New York Primary MSA had a 2000 population of 9.3 million in a land area of 1 142 square miles, for a population density of 8 159 persons/sq mi. But the New York Consolidated MSA, covering a much larger 13 100 square miles, has a population of 21.2 million (a density of 2 029 persons/sq mi.)[3]. In comparison, the Atlanta MSA had a population of 4.1 million in 6 124 sq. mi., for a density of only 672 persons per square mile, or one-third the density of the New York CMSA and one-twelfth that of the New York PMSA. (The world's densest major urbanized area is Hong Kong, with about 3.5 million people in 70 square kilometers (27 square miles), for a population density of 48 571 per square kilometer (128 000 per square mile).

Transportation has played a significant role in enabling the growth and spread of metropolitan areas, and over the six decades since World War II the automobile and highways have been especially visible as facilitators of suburbanization in the United States. One reason that East Coast cities have dense cores is that they grew up as walking, and then transit, cities; while most of the cities in the West can spread out over the landscape because they grew up with automobiles and good highways.

However, autos and highways were not the first transportation technology to facilitate the outward spread of cities, nor was transportation the only factor in suburbanization. Many centripetal forces were operating.

Residential suburbanization followed the outward deployment of rail and streetcar technologies in the late 19th century, and accelerated as mass-produced automobiles became widely owned (Warner, 1962; Mueller, 2002). Both upper income and working class households located in suburban locations, the former group attracted by the opportunity for affordable homes with gardens outside the crowded and dirty center, the latter pushed outward by local government policy zoning out industries to the urban fringe, and pulled by the then-emerging industrial production practices and technologies that favoured large floor layouts requiring considerable land.

Other factors that supported the outward movement included housing policies and practices that favoured home ownership (tax deductions for mortgage interest); insurance and lender redlining of inner city and older suburban homes; tax deductions for mortgage interest; mass *de jure* and *de facto* segregation by race and income; production of housing on greenfield tracts; and the modernist idea that new is improved (and bigger is better). Retail and service employment followed the population shifts outward, often pulled as well by lower cost land and a less regulated business environment. Big box retail “super-stores”– new forms of doing business dependent on easy access to large market areas – are of course dependent on auto access, and their large floor plate and parking lots require cheap land.

Today, the US suburbs have both vociferous critics and ardent defenders. However, most discussion in US planning fields is not whether, but in what form future suburban development should take place, and how that development should relate to development of the central city and older suburbs, which themselves continue to be built and rebuilt. Both the extent of metropolitan areas and their urban form are at issue, as are the transportation systems that serve them. This review focuses on three elements of the debate: the effects of land consumption by low-density metropolitan expansion, the transportation consequences of low-density development patterns, and the environmental and public health consequences of low-density development and auto dependence.

2. URBAN SPRAWL, ITS LAND USE AND ENVIRONMENTAL CONSEQUENCES

Urban sprawl has generated a vast literature. The University of California library system contains several hundred volumes on the topic and many more journal articles and reports. Berkeley's Environmental Design Library has established a website that lists eight gateway sites and organizations, a half-dozen bibliographies, and dozens of journal articles and books on the topic, its measurement and proposed approaches for its management (CED, 2006). The literature includes critiques of sprawl from social, aesthetic, cultural and public health perspectives as well as defence of sprawl and its benefits.

The term "sprawl" has been defined in a number of ways. Burchell *et al.* (1998) define sprawl relative to previous patterns of development, with the result that sprawl in New England (for example) means something different from sprawl in Riverside County. Ewing *et al.* (2002) point to four key characteristics of sprawl: low density, segregated land uses, a lack of major centers of higher density development, and street patterns that limit access (e.g. cul de sacs). Galster *et al.* (2001) use a more elaborate definition that accounts for additional factors such as concentration and nuclearity, mixed uses and proximity. In most writings about sprawl, its heavy consumption of land is viewed critically. In the context of urban form and transport, the author uses a definition that reflects auto dependence, in the US generally a density below 15 persons per net residential acre. In the US context, land uses at densities below these levels are usually too dispersed for walking to be feasible for most trips or for transit to be provided at a reasonable cost.

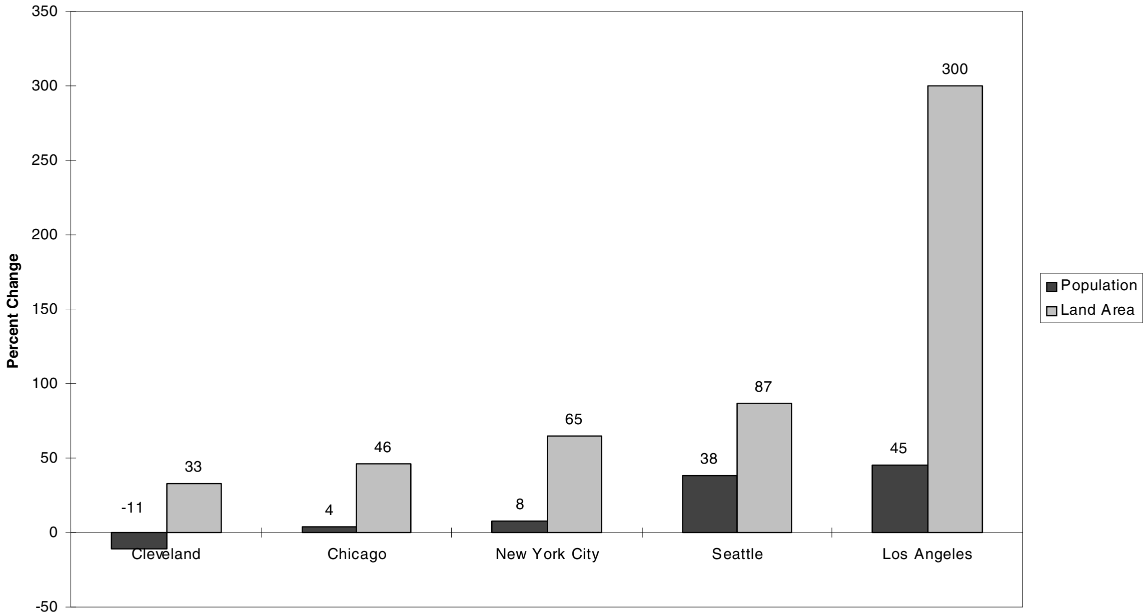
Two issues often raised about the land use effects of sprawl in the United States will be discussed here: its role in the loss of farmland, and its adverse effects on ecosystems.

2.1. Loss of farm, ranch and forest land

For a number of years, metropolitan areas in the United States have been spreading out at rates from two to as much as thirteen times faster than population growth (Figure 1). Much of the growth has urbanized former agricultural land (farms and ranches), with some expansion into forests and other open space, including deserts. Over the period 1974-2002, the total number of farmed acres in the US declined by about 8% (US Census, 2004), but the reasons for the declines were multiple, including increases in efficiency in the use of land for farm production, competition from other countries, and declining markets and/or profits for some commodities. In some cases, land removed from production in urbanizing districts is replaced by land put into production in more agriculture-friendly locations, as has been the case of Southern Californian dairy farmers, some of whom have moved north into the Central Valley (Hirsch, 2006). Table 6 presents some basic statistics on US farms.

According to the US Department of Agriculture, farmland was converted to other uses at a rate of approximately 1.5 million acres per year over the 1960-2000 period. Further, the rate has been accelerating: in the 1990s, Americans converted open space to developed land at a rate of 2.2 million acres per year, a rate of conversion 50% greater than that of the 1980s. Still, the loss amounts to a small rate of decline, about one-quarter of one per cent a year.

Figure 1. **Change in metropolitan population and developed land area, 1970-90**



Source: Diamond and Noonan (1996).

The effects of agricultural land conversion to urban uses and, more broadly, the effects of urban adjacency on farming, ranching and forestry, has been debated in the US for decades. A 1978 article stated,

> "From a national perspective it is unclear whether the continued expansion of urban development seriously affects America's potential food production over the long run. Yet there are clearly regional biases toward conversion of farmland to urban uses and locally important changes in the appearance of the landscape at the rural-urban fringe. Urbanization also generates spillover effects causing the idling of farmland and the shifting from one type of agriculture to another. Land use controls aimed at directly addressing the use of the land may be effective in preventing some conversion of farmland to urban uses but the methods are costly and possibly very complex. Incentives to farmers to keep land in agriculture are generally too weak to be effective in retaining agricultural land in the face of strong urban pressures (Berry and Plaut, 1978)."

Some authors doubt the importance of the losses. Staley (2000) points out that less than one per cent of prime farmland has been lost to urban use. He argues that urbanization is not the most significant factor in farmland loss, accounting for less than 26% of the decline, with a higher percentage of the losses due to land going out of production. Further, he argues that the public interest in open space is often preserved, as idled farmland is converted to forests, prairies and parks.

The US Department of Agriculture is not as sanguine about these losses as the doubters are. For one thing, agriculturalists would point out that agricultural land near the urban edge most often goes out of production as an interim use before urbanization. A recent USDA report cited 1987 data showing that about one-third of all US agricultural products are produced in metropolitan counties adjacent to large cities, and another 25% are produced in counties adjacent to significant urban populations. Nearly 85% of domestic fruit and vegetable production and 80% of our dairy products come from urban-influenced areas (USDA, 1998). Thus, in the USDA's view, the most troubling concern is not the gross acreage of farmland converted to urban development but the loss of highly productive and specialized farmland, perhaps 5% of the farmland total. The USDA states:

> "In most states, prime farmland is being converted at two to four times the rate of other less productive land. Most urbanization takes place as sprawl instead of orderly growth management. In addition, remaining farmland is placed under greater environmental, economic and social strain as agrarian and urbanizing interests compete. For the agricultural producer, increased costs of production and liability risks are negative side effects of urban development. Agricultural producers are also induced by the development pressure to farm the remaining acreage more intensively, thus generating adverse impacts on water quality and soil health. For urban dwellers, the loss of open space and issues related to agricultural production, such as pesticide overspray, animal nutrients, odors, dust and noise, are conflicting concerns (USDA, 2006)."

Florida, California and Texas, the three states expected to account for nearly one-half of total US population growth between 2000 and 2030, are also major producers of fruit and vegetables including specialised crops such as citrus and wine grapes. By most estimates, more than three-quarters of the fresh fruit and vegetables consumed in the US come from these three states. Each is losing agricultural land, including prime farmland and unique lands (suited to vineyards or other specialised crops) to urbanization.

In California, urban development took over almost 91 000 acres of farmland in the 1998-2000 period and an additional 93 000 acres during the 2000-2002 period, a two-year loss of about 287 square miles of agricultural land. The net decrease in irrigated farmland was about 54 000 acres, including 47 000 acres of prime farmland. While new plantings and resurgence of cropping in some districts partly offset the effects of the losses, land idling, ecological restoration, rural residential development and mining operations also put downward pressure on the agricultural total. Florida's losses were about of the same magnitude as those in California, with 454 800 acres of agricultural land converted to developed uses between 1992-97. Pressures for urban development have been especially heavy in the Panhandle area and around Jacksonville. Texas' losses of farmland to urban development have been running over 150 000 acres a year and have been greatest in the highly fertile Texas Blackland Prairie around Austin, Dallas-Fort Worth and Waco, as well as in the Lower Rio Grande Plain, famed for citrus and other fruit and vegetables.

Kuminoff and Sumner (2001) modelled farmland conversion in California using data on the current sale price of land for conversion; expected future farm income; option value for future conversion; relocation and transaction costs; housing prices at the urban edge; zoning, farm protection and related development factors. Their model accounted for agricultural to urban, agricultural to other (e.g. fallow) and other to urban uses, and covered two time periods, the 1980s and the 1990s. They found that urban factors, not low farm income, were the most important explanatory variable in farmland conversion in California.

The interpretation of these numbers continues to be debated. Continued pressures on agriculture in the next years may include reduction or removal of price supports and subsidies from the crops that currently receive them, cost pressures from rising oil prices, and possibly global pathologies (mad cow disease, avian flu, etc.) (Kraus, 2006). At the same time, prices for land put to urban use can be as much as ten times those available for farm uses (Hirsch, 2006). Whether countervailing trends, such as the interest in fresh, local foods, will be enough to offset these pressures is unclear.

It is worth noting that while most attention in the US has been given to farmland losses, outward urbanization and sprawl is also putting pressure on forests and other open spaces around our largest cities, many of which are habitats for a variety of flora and fauna including endangered and threatened species. An example is the Highlands region of Connecticut, New York, New Jersey and Pennsylvania, a forested backdrop to the Harford, New York and Philadelphia metropolitan areas. This three-million acre region holds watersheds and reservoirs for the drinking water of about 15 million people and provides open spaces and outdoor recreation opportunities to the 25 million people who live within two hours of the area's 200 000 acres of public open space. The Highlands also serve as a habitat for more than seventy species of migratory birds and for bears, bobcats, otters, beavers and trout. Over one hundred plants and almost fifty animals listed as endangered, threatened or a species of concern are found in the area. However, portions of the Highlands closest to the metropolitan areas are being lost to development. Following a 1990 study, over 25 000 additional acres of forest and 16 000 acres of farmland in the region have been protected, but during the same period about 50 000 acres were developed for suburban housing and industry (USDA, Forest Service, 2006). In California, urban development has raised similar concerns in the Sierra Nevada and its foothills (Duane, 2000); in addition, the growing presence of residences has led to pressures to suppress fires that would actually increase the health of the forests (McCaffrey, 2000).

2.2. Effects on ecosystems

As urban development spreads into farmland and other open spaces, it often has significant effects on ecosystems. Part of the impact results from the loss of the land itself, which can provide not only habitats for flora and fauna but also can serve as corridors connecting the separate "patches" of habitat on which many species depend for resilience and biodiversity. Land development can alter ambient temperature, light, shade and shadow, vegetation, drainage patterns, water availability, water quality, and sedimentation, soil surfaces, compaction and erosion, noise levels and air quality, all of which impact on ecosystems. While farming and forestry certainly have their own impacts on the landscape, urban development typically exacerbates the effects.

Transportation systems are themselves a major use of land in metropolitan areas – often accounting for a third to a half of total land area – and as such they have a major impact on ecosystems. Most of the transport network in the US was in place by the 1970s and was designed without the benefit of the vast increase in ecological knowledge of the past 30-40 years (Deakin *et al.*, 2002). In the ensuing years, the numbers of vehicles and vehicle-miles travelled (VMT) have substantially increased. Increased traffic volumes have produced additional traffic noise, water-transported chemicals, and barriers to wildlife crossing. Air pollution effects have been mixed, with substantial reductions in some pollutants and increases in others.

The outward expansion of urban development usually requires the construction of additional transportation infrastructure, including widening existing roads, adding local streets and other facilities such as parking lots, and occasionally expanding a limited access highway or rail line. While the construction of new facilities can be done with state-of-the-art environmental knowledge, thus mitigating some of the negative effects, current practices in the US, especially among private developers and city and county road builders, often fall short of the state of the art. As a result, the transportation systems that accompany urban development, new and old, typically leave a heavy footprint on ecosystems, visibly through road-kill and less visibly through the barriers and toxic substances they introduce.

Water pollution is a major problem resulting from motor vehicle traffic, and the introduction of transportation facilities and operations into newly urbanized areas expands the impact area. Both groundwater (aquifers) and surface water are affected by highway runoff, which can deliver a wide range of contaminants including brake fluid, antifreeze compounds, lubricating oil, engine oil, grease and gasoline (GKY and Associates 2001). Further, the fast drainage used as a safety measure in most highway designs can inundate and shock aquatic systems (Nelson *et al*., 2001).

Transportation-related air pollutants also can pollute water. SO_2 and NO_x are deposited as acids that leach out aluminium, mercury and other substances in soils, where they can bio-accumulate. NO_x deposition in bodies of water can lead to eutrophication. Not just wildlife and plants but also people can experience negative health effects by drinking, bathing or swimming in contaminated water or eating fish or other organisms that have bio-accumulated contamination or toxics.

Currently, it is difficult to separate the effects of transportation systems, urban development and other land uses and to allocate causal responsibility for ecological changes, so it is hard to assess the costs attributed to specific activities. Additional work needs to be done linking ecologists' spatial models showing ecological movements and flows across the landscape with the analysis of road systems (Forman, 1995; Reed *et al.*, 1996; Turner *et al*., 2001; Forman and Alexander, 1998; Forman, 2000). Regardless of the allocation of impacts, however, there is little doubt that expanded urban development and transportation systems broaden the environmental and ecological damage footprint.

3. TRANSPORTATION CONSEQUENCES OF SPRAWL

Automobiles and trucks have been the dominant means of surface transportation in the United States for well over 50 years and arguably for nearly a century. They have heavily influenced the economy, development patterns and popular culture. Today, more than 90% of all person-trips in the US are made by automobile, and trucks account for more than 90% of all shipments.

Both the benefits and the costs of US transportation systems are high. Private investments in the automobile and public investments in highways allow most adults considerable freedom of movement, despite congestion on some links at some times of day. On the other hand, the costs of owning and operating personal vehicles consume 19% of US household income – equal to expenditures for food and clothing combined. Externalities including air and water pollution, noise and time lost in congestion add to these costs.

The use of motor vehicles has increased everywhere in the US. Since 1970, vehicle miles travelled have doubled and truck travel has tripled. From 1996 to 2000, VMT grew by more than 2 per cent per year, and future VMT growth rates of 1½ to 2½ per cent are widely expected. These increases are larger than the increases in population, economic development or urban expansion. Further, household travel surveys from metropolitan areas, which are usually more detailed and more sophisticated than national surveys, show that VMT is highest in low-density suburban locations, even after controlling for household size, lifecycle and income (MTC, SCAG, SACOG). Transit shares have declined in most urban areas and have expanded only slightly in a few (Table 7), despite significant federal, regional and local subsidies of transit capital and operating expenses.

3.1. Research findings

According to Burchell *et al.,* three factors have contributed about equally to the growth in VMT: changing demographics; growing dependence on the automobile; and longer travel distances. Thus, sprawl, which creates the longer travel distances and increased dependence on the automobile, is a major source of increased vehicle use (Burchell *et al.,* 1998). Gordon and Richardson (2000), have countered that travel times have not substantially increased, despite longer distances; as with both jobs and housing located in the suburbs speeds have increased. The use of autos instead of much-slower transit (or walking) is also a factor in the faster average travel times for suburban trips. Work by Small and Giuliano (1991) on multi-nucleation in Los Angeles, where autos are the main mode of travel for most trips, offers a specific example of the mutual land use/transportation adjustments at work.

However, waves of low-density, scattered suburbanization and subsequent infill and development have been the hallmark of metropolitan growth in the US for many years. As this growth and fill process proceeds, whether fast suburban travel times can be maintained, especially for work trips, has been called into question by the evidence on suburban congestion analyzed by Cervero (1986), among others. In many areas, traffic levels are low and speeds high during early stages of suburban development, but as traffic increases substantially, often to the point of severe congestion, suburban infill follows (Landis *et al*., 2002, 2003).

It remains unclear whether planning interventions can alter these processes. It has long been noted that the longest common trip made by American travellers are journeys to work, and as one would expect, work trips are longer in larger cities and in cities with a dominant job centre than in smaller or more multi-nucleated urban regions. However, journeys to work are a declining proportion of both trips and (to a lesser extent) VMT; shopping trips are the most frequent trip type. Further, studies of trip linking have found that journeys to work are often combined with shopping trips, especially grocery purchases, and with trips to activities that serve children or handle other household responsibilities (see, e.g., Rosenbloom and Burns, 1993).

Recognizing that accessibility could be provided through proximity as well as through mobility, much of the literature to date focuses on the effects of density, neighbourhood design and mix (diversity) of uses as factors affecting mode and, to a lesser extent, destination choice. The findings are inconsistent and are often based on single or a few cases or on highly limited datasets. As one might expect, there is evidence that as population and employment density decline, vehicle trips and usage increase, and transit usage and walking decline (Handy, 1992). Evidence on trip lengths is mixed: Handy, for example, found that local shopping opportunities were associated with more frequent shopping overall, and many of the trips were made by walking, but the local shops did not substitute for, and therefore did not reduce, trips to regional centres. Other studies have suggested that travellers who make very long trips to work actually make fewer trips than either suburban or urban counterparts, suggesting that a time budget constraint operates at some level (Zahavi, 1974).

Researchers continue to study the ways in which land use factors may contribute to travel patterns. For example, current research at the University of California is examining the effects of the presence or absence of pedestrian amenities on willingness to walk among different population groups; the effects of co-location of high-density, mixed-use development and transit stations on mode choice; the availability of car-sharing programmes and transit or pedestrian travel options on auto ownership, the effects of deep-discount transit passes on work and work-related mode choice; the impact of market-rate parking on mode and destination choice; activity scheduling and its effects on travel choices; and neighbourhood characteristics such as crime rates, traffic levels and urban amenities on both housing location choice and travel choices. Most of the studies are small, but they offer promise of improved knowledge of land use/travel behaviour interrelationships.

One point on which there is little disagreement is that low-density development is difficult and costly to serve by transit (even in areas where transit is deregulated and para-transit can operate). Transit captures a significant share of travel in communities and corridors where services are competitive with the automobile, but only about half the communities in the United States even have public transportation systems, and in many other locations, only limited service is provided. In part because the land-use patterns are not suited to travel by transit, the US has the lowest share of transit use of all the advanced economies, at only 2% of total travel. Similarly, there is little disagreement that walking distances, even with good pedestrian facilities, rarely exceed 2/3 mile (1 km) and more typically are half that or less. While walk trip data are notoriously hard to collect, in most US metropolitan areas walk trips are 5-10% of total travel, in part because distances between desired activities are too long to walk. (Suburban locations may also have no sidewalks, making walking hazardous even when distances are not a problem.)

Very low-density suburban environments are likely to be poor markets for transit services and to have low walk mode shares; the auto will tend to dominate travel because it is the only practical mode available. Two dilemmas arise. First, not everyone in these low-density suburbs can drive a car, but if walk and transit options are limited or nonexistent the mobility and access options for these populations are poor. The provision of travel services for children, the elderly and others who need a ride is often a major financial cost in low-density suburban areas. Second, as suburban congestion develops, residents of these low-density areas often demand transit services for the general population. Unfortunately, the services they envisage can rarely be provided, so ridership is low even though the services offered are extremely costly.

In the late 1990s, Americans were found to drive cars and trucks nearly twice as much per capita as did Europeans, and more than twice as much as the Japanese (FHWA, 1998). However, both European and Japanese auto use is growing faster than in the US. The role of urban density and related factors perhaps explains part of this difference, and almost surely makes the provision of cost-effective alternatives more feasible than in most of the US. But fuel prices, parking prices, car ownership costs, and even differences in cultural attitudes are likely to be at least as powerful as explanatory variables.

3.2. Environmental consequences of travel choices

Even with massive increases in urban development, travel and vehicle miles travelled, the US has made substantial progress in improving environmental quality. The air and water are cleaner and many other adverse environmental impacts have been avoided or mitigated as environmental knowledge and consideration has increased. However, several environmental problems are being exacerbated by the increase in VMT and auto trips. To the extent that urban development patterns are associated with these increases, they are candidates for policy intervention in addressing these environmental problems.

First, air pollution remains a public health concern despite large reductions in vehicle emissions during the past thirty years. Many metropolitan regions still have not met basic health standards for air pollution, and several that had achieved compliance became noncompliant when the new, tougher ozone standard went into effect (based on evidence that points to adverse health consequences, especially for children and the elderly, at lower pollution levels than were previously understood). In addition, the health consequences of air toxics and fine particulates were late to be recognized in public law and policy and are just now beginning to be dealt with. Also, NO_x emissions are growing, and they have an adverse effect on water quality as well as air quality.

Emissions are not a simple function of speed. Stop-and-go traffic is more polluting than steady flow traffic. Very high-speed travel also produces high emissions due to fuel “blow-by” during the high-speed accelerations. Heavy emissions are also associated with low engine temperatures (“cold starts”). A household that makes a number of short trips throughout the day can easily produce more emissions than one that makes fewer but longer trips. Research by Kean *et al.* (2002) and others has shown that emissions inventories and projections that rely on assumed driving cycles and trip patterns can greatly underestimate actual on-road emissions. More research on emissions by driving mode and fuel type is underway but, for now, considerable caution is warranted in interpreting emissions data based on old and flawed assumptions and methods.

Greenhouse gas emissions from transportation are a function of fuel use. Transportation currently produces about 32% of total US carbon emissions, and these are increasing at a 20% faster rate than overall emissions from all sources – 1 to 2% annually in the US transportation sector (Oak Ridge National Laboratory, 2000). A growing body of evidence links carbon dioxide (CO_2) and other greenhouse gas emissions to major changes in global climate and to such consequences as the flooding of human settlements and natural habitats, changes in growing seasons and water supplies for agriculture, desertification, and the introduction of tropical disease vectors into temperate regions (IPCC, 2001). The contribution of the US transportation system to greenhouse gas production, in particular, the increasing output of CO_2, is a major concern internationally.

While the technical energy efficiency of vehicles and engines continues to improve through more efficient combustion and the use of lightweight materials and improved vehicle designs, fuel consumption continues to increase as a result of the production and sale of larger and more powerful vehicles and increases in travel. Indeed, both motor vehicle stock and total VMT are growing more rapidly than the nation's population. While this pattern is repeated throughout the world, in most other countries private vehicles are smaller and driven substantially less (Schipper *et al.*, 1994). Alternative fuels and engines could change this picture substantially, but costs, timing and other consequences are hardly known.

A final issue worth noting is diesel emissions from trucks and, affecting port cities, ships.

The health consequences of these emissions are severe, and strategies to reduce the emissions are years away from full implementation. Tougher emissions standards for diesel engines will go into effect soon, but will percolate slowly through the fleet; strategies to address emissions from ships (whose registration is usually non-US) are inchoate. Clearly, the issue is an international and national one, but it does have some implications for urban form. On one hand, to the extent that we cannot find other ways to address these emissions, urban policies to restrict the location of populations in heavy truck corridors and port locations may be needed. On the other hand, to the extent that scattered retail and industrial locations are factors in the massive increases in trucking that the US is experiencing, here is an added cost. Clearly, we know very little about these issues compared to what we would like to know in shaping appropriate policy responses.

4. CONCLUSIONS

This review has focused primarily on the environmental consequences of sprawl development. Sprawl development has environmental consequences through its land consumption and through its transportation impacts. Land consumption per capita is, of course, higher at low densities and, while this may be a benefit *per se* to the consumer, it has identifiable adverse consequences. Farmland loss is one possible adverse consequence: although the US is in no danger of running out of farmland as such, the farmland at the urban edge does appear to be of high value both for food production and open space. In addition, development of farm land and other open spaces can adversely affect water quality and ecosystems.

While the evidence comparing suburban and urban travel and its environmental consequences is mixed, data from metropolitan-level studies in the US show that low-density suburban development is associated with higher vehicle miles travelled and vehicular trip-making. Because pollutant emissions are heavily affected by cold starts, speeds and distances travelled, the analysis is better made with regional travel data sets and networks rather than with national datasets, which lack such details. As a consequence, general conclusions are risky. However, if VMT are higher in suburban locations, as several US metropolitan studies suggest, greenhouse gas emissions are also likely to be higher.

Given these findings, roles for both planners and researchers are needed. Researchers still have much to do to understand the dynamics of metropolitan growth and change. Planners should consider a broad range of environmental consequences in their role as managers of environmental mitigations for new development. Strategies to preserve the farmland, and other open space at the urban edge that is indeed unique or highly valuable, should be devised and studies to determine what lands meet those criteria should be carried out. Landscape ecology should be better connected to land use and transportation planning as well as infrastructure design, so that better outcomes for ecosystems can be achieved.

NOTES

1. The MSA is an imperfect measure of urban development and economic activity, and federal agencies from time to time change boundaries and definitions. Consolidated MSAs (CMSAs) have also been established to reflect the increasing interactions among adjacent MSAs in some regions, and the tables show both MSAs and CMSAs. The CMSA is "*a geographic entity designated by the federal Office of Management and Budget (OMB) for use by federal statistical agencies. An area becomes a consolidated metropolitan statistical area (CMSA) if it qualifies as a metropolitan area (MA), has a census population of 1 000 000 or more, has component parts that qualify as primary metropolitan statistical areas (PMSAs) based on official standards, and local opinion favors the designation. CMSAs consist of whole counties except in New England, where they consist of county subdivisions (primarily cities and towns).*"

2. According to the US Census, the term "urban" means "*All territory, population and housing units in urbanized areas and in places of more than 2 500 persons outside of urbanized areas. 'Urban' classification cuts across other hierarchies and can be in metropolitan or non-metropolitan areas*."

3. Density can be measured in terms of population, housing units, jobs or other metrics of interest, and can be expressed as a function of gross acreage, acreage devoted to a particular use such as housing, and so on. Density is also affected by "granularity", or the extent to which development is evenly distributed *vs.* concentrated in centres. For example, the New York metropolitan region has a dense city centre with much lower density suburbs. The Los Angeles metropolitan region lacks the same density in its downtown – in fact LA has some thirty significant sub-centres of employment (Small and Giuliano, 1991) – and its average density shows less variation across the region than does New York. Treatment of areas in terms of water and roads can also substantially affect the calculation of density; the City of San Francisco is 40% larger if its land beneath the Bay is counted; its developable land, minus roads, parks and other public works, is less than half of its land area. Finally, the degree of land-use mixing can also affect the density calculation. Population density per net residential acre yields a much higher number for Manhattan than density per acre of land.

TABLES

Table 1. **Population growth: selected States and US, 1950-2025**

		Population (millions)					Population/sq. km		
State	**Land area, sq. km**	**1950**	**1980**	**2000**	**2005**	**2025**	**1950**	**2000**	**2025**
California	403 933	11	24	33.9	36.1	49.3	27.2	83.9	122.0
Florida	139 670	2.8	9.7	16	17.8	20.7	20.0	114.6	148.2
Texas	678 051	7.7	14.2	20.9	22.9	27.2	11.4	30.8	40.1
Illinois	143 961	8.7	11.4	12.4	12.8	13.4	60.4	86.1	93.1
New York	122 283	14.8	17.5	19	19.3	19.8	121.0	155.4	161.9
US	9 162 368	151.3	226.5	281.4	296.4	335.1	16.5	30.7	36.6
3 State Share of US		14.2%	21.1%	25.2%	25.9%	29.0%			
2 State Share of US		15.5%	12.8%	11.2%	10.8%	9.9%			
3 State Total		21.5	47.9	70.8	76.8	97.2			
2 State Total		23.5	28.9	31.4	32.1	33.2			

Source: Population: http://www.census.gov/population/projections/state/stpjpop.txt
2025 projections are for series A.
Land area:US Census. Water Area not included: 4.87% of US Total.
US Total with Water Area: 9 631 418 sq. km. (4.87% water area).

Table 2. **Metropolitan areas over 1 million, 1990 and 2000**

Metropolitan area	1990 Population	1990 Employment	2000 Population	2000 Employment	Change in population	Change in employment
Atlanta, GA MSA	2 833 511	1 481 781	4 112 198	2 060 632	1 278 687	578 851
Austin-San Marcos, TX MSA	781 572	404 016	1 249 763	649 645	468 191	245 629
Boston-Worcester-Lawrence, MA-NH-ME-CT CMSA	4 171 643	2 141 717	5 819 100	2 898 680	1 647 457	756 963
Buffalo-Niagara Falls, NY MSA	1 189 288	531 122	1 170 111	520 350	-19 177	-10 772
Charlotte-Gastonia-Rock Hill, NC-SC MSA	1 162 093	604 856	1 499 293	751 629	337 200	146 773
Chicago-Gary-Kenosha, IL-IN-WI CMSA	8 065 633	3 841 337	9 157 540	4 218 108	1 091 907	376 771
Cincinnati-Hamilton, OH-KY-IN CMSA	1 744 124	812 766	1 979 202	742 390	235 078	-70 376
Cleveland-Akron, OH CMSA	2 759 823	1 242 099	2 945 831	1 375 774	186 008	133 675
Columbus, OH MSA	1 377 419	677 859	1 540 157	777 922	162 738	100 063
Dallas-Fort Worth, TX CMSA	3 885 415	1 976 606	5 221 801	2 527 648	1 336 386	551 042
Denver-Boulder-Greeley, CO CMSA	1 848 319	964 912	2 581 506	1 346 025	733 187	381 113
Detroit-Ann Arbor-Flint, MI CMSA	4 665 236	2 079 880	5 456 428	2 482 457	791 192	402 577
Grand Rapids-Muskegon-Holland, MI MSA	688 399	337 335	1 088 514	531 924	400 115	194 589
Greensboro-Winston-Salem-High Point, NC MSA	942 091	493 926	1 251 509	618 921	309 418	124 995
Hartford, CT MSA	1 085 837	561 969	1 183 110	573 114	97 273	11 145
Houston-Galveston-Brazoria, TX CMSA	3 711 043	1 759 796	4 669 571	2 081 607	958 528	321 811
Indianapolis, IN MSA	1 249 822	624 971	1 607 486	795 755	357 664	170 784
Jacksonville, FL MSA	906 727	443 882	1 100 491	527 718	193 764	83 836
Kansas City, MO-KS MSA	1 566 280	771 309	1 776 062	881 258	209 782	109 949
Las Vegas, NV-AZ MSA	741 459	371 128	1 563 282	702 535	821 823	331 407
Los Angeles-Riverside-Orange County, CA CMSA	14 531 529	6 809 043	16 373 645	6 767 619	1 842 116	-41 424
Louisville, KY-IN MSA	952 662	446 876	1 025 598	492 821	72 936	45 945
Memphis, TN-AR-MS MSA	981 747	448 237	1 135 614	438 310	153 867	9 927
Miami-Fort Lauderdale, FL CMSA	3 192 582	1 476 085	3 876 380	1 642 866	683 798	166 781
Milwaukee-Racine, WI CMSA	1 607 183	772 752	1 689 572	816 880	82 389	44 128
Minneapolis-St. Paul, MN-WI MSA	2 464 124	1 307 624	2 968 806	1 540 304	504 682	232 680
Nashville, TN MSA	985 026	495 717	1 231 311	621 221	246 285	125 504
New Orleans, LA MSA	1 238 816	514 726	1 337 726	570 423	98 910	55 697
New York-Northern New Jersey-Long Island, NY-NJ-CT-PA CMSA	18 087 251	8 550 473	21 199 865	9 319 218	3 112 614	768 745
Norfolk-Virginia Beach-Newport News, VA-NC MSA	1 396 107	698 999	1 569 541	760 401	173 434	61 402

Table 2. **Metropolitan areas over 1 million, 1990 and 2000** (continued)

Metropolitan area	**1990 Population**	**1990 Employment**	**2000 Population**	**2000 Employment**	**Change in population**	**Change in employment**
Oklahoma City, OK MSA	958 839	450 122	1 083 346	509 262	124 507	59 140
Orlando, FL MSA	1 072 748	557 448	1 644 561	786 243	571 813	228 795
Philadelphia-Wilmington-Atlantic City, PA-NJ-DE-MD CMSA	5 899 345	2 794 917	6 188 463	2 815 405	289 118	20 488
Phoenix-Mesa, AZ MSA	2 122 101	996 495	3 251 876	1 466 434	1 129 775	469 939
Pittsburgh, PA MSA	2 242 798	956 154	2 358 695	1 057 354	115 897	101 200
Portland-Salem, OR-WA CMSA	1 477 895	724 532	2 265 223	1 105 133	787 328	380 601
Providence-Fall River-Warwick, RI-MA MSA	1 141 510	125 726	1 188 613	555 540	47 103	429 814
Raleigh-Durham-Chapel Hill, NC MSA	735 480	399 701	1 187 941	617 475	452 461	217 774
Rochester, NY MSA	1 002 410	481 467	1 098 201	516 814	95 791	35 347
Sacramento-Yolo, CA CMSA	1 481 102	685 945	1 796 857	799 989	315 755	114 044
Salt Lake City-Ogden, UT MSA	1 072 227	479 338	1 333 914	642 688	261 687	163 350
San Antonio, TX MSA	1 302 099	569 149	1 592 383	698 685	290 284	129 536
San Diego, CA MSA	2 498 016	1 230 446	2 813 833	1 299 503	315 817	69 057
San Francisco-Oakland-San Jose, CA CMSA	6 253 311	3 200 833	7 039 362	3 432 157	786 051	231 324
Seattle-Tacoma-Bremerton, WA CMSA	2 559 164	1 308 338	3 554 760	1 776 224	995 596	467 886
St. Louis, MO-IL MSA	2 444 099	1 144 336	2 603 607	1 238 964	159 508	94 628
Tampa-St. Petersburg-Clearwater, FL MSA	2 067 959	914 711	2 395 997	1 063 957	328 038	149 246
Washington-Baltimore, DC-MD-VA-WV CMSA	3 923 574	3 406 163	7 608 070	3 839 052	3 684 496	432 889
West Palm Beach-Boca Raton, FL MSA	863 518	380 260	1 131 184	475 572	267 666	95 312
Metropolitan areas over 1 000 000 population	131 930 956	64 449 880	161 517 899	74 730 606	29 586 943	10 280 726
Percentage of US	53.0%	56.0%	57.4%	58.3%	90.4%	77.8%
United States	248 709 873	115 070 274	281 421 906	128 279 228	32 712 033	13 208 954

Source: Urban Transit Factbook, http://www.publicpurpose.com/ut-jtw2000metro.htm, using data from US Census 2000 and 1999, as edited by Deakin.
Note: Boundaries and definitions changes between 1990 and 2000.

Table 3. **Population change in the most populous metropolitan statistical areas: 1990-2000 and 2000-2003**

Rank in population size in 2003	Metropolitan statistical area title	Population (thousands)			Population change			
					Numerical		Percent	
		1990	2000	2003	1990-2000	2000-2003	1990-2000	2000-2003
1	New York-Northern New Jersey-Long Island, NY-N	16 846	18 323	18 641	1 477	317	8.8	1.7
2	Los Angeles-Long Beach-Santa Ana, CA	11 274	12 366	12 829	1 092	464	9.7	3.7
3	Chicago-Naperville-Joliet, IL-IN-WI	8 182	9 099	9 334	916	235	11.2	2.6
4	Philadelphia-Camden-Wilmington, PA-NJDE-MD	5 435	5 687	5 773	252	86	4.6	1.5
5	Dallas-Fort Worth-Arlington, TX	3 989	5 162	5 590	1 172	428	29.4	8.3
6	Miami-Fort Lauderdale-Miami Beach, FL	4 056	5 008	5 289	952	281	23.5	5.6
7	Washington-Arlington-Alexandria, DC-VAMD-WV	4 123	4 796	5 090	673	294	16.3	6.1
8	Houston-Baytown-Sugar Land, TX	3 767	4 715	5 076	948	360	25.2	7.6
9	Atlanta-Sandy Springs-Marietta, GA	3 069	4 248	4 610	1 179	362	38.4	8.5
10	Detroit-Warren-Livonia, MI	4 249	4 453	4 484	204	31	4.8	0.7
11	Boston-Cambridge-Quincy, MA-NH	4 134	4 392	4 440	258	48	6.3	1.1
12	San Francisco-Oakland-Fremont, CA	3 687	4 124	4 157	437	34	11.9	0.8
13	Riverside-San Bernardino-Ontario, CA	2 589	3 255	3 642	666	388	25.7	11.9
14	Phoenix-Mesa-Scottsdale, AZ	2 238	3 252	3 593	1 013	342	45.3	10.5
15	Seattle-Tacoma-Bellevue, WA	2 559	3 044	3 142	485	98	18.9	3.2
16	Minneapolis-St. Paul-Bloomington, MN-WI	2 539	2 969	3 084	430	115	16.9	3.9
17	San Diego-Carlsbad-San Marcos, CA	2 498	2 814	2 931	316	117	12.6	4.2
18	St. Louis, MO-IL	2 581	2 699	2 736	118	37	4.6	1.4
19	Baltimore-Towson, MD	2 382	2 553	2 616	171	63	7.2	2.5
20	Tampa-St. Petersburg-Clearwater, FL	2 068	2 396	2 532	328	136	15.9	5.7
	Total, Top 20	92 265	105 355					
	US	248 710	281 422					
	Top 20% of US	37.1%	37.4%					

Source: US Census Bureau, 2003 Population Estimates Program, 1990 Census of Population and Housing.

Table 4. **Population and housing densities US CMSAs and MSAs**

Geography	Population	Housing units	Area in sq. miles: Total area	Area in sq. miles: Water area	Area in sq. miles: Land area	Density per sq. mile of land area: Population	Density per sq. mile of land area: Housing units
New York-Northern New Jersey-Long Island, NY-NJ-CT-PA CMSA	21 199 865	8 213 523	13 118	2 668	10 450	2 028.7	786.0
San Juan-Caguas-Arecibo, PR CMSA	2 450 292	913 918	2 058	623	1 436	1 706.4	636.4
Chicago-Gary-Kenosha, IL-IN-WI CMSA	9 157 540	3 485 845	9 296	2 369	6 927	1 322.0	503.2
Miami-Fort Lauderdale, FL CMSA	3 876 380	1 593 321	3 751	599	3 151	1 230.0	505.6
Philadelphia-Wilmington-Atlantic City, PA-NJ-DE-MD CMSA	6 188 463	2 539 825	6 839	904	5 935	1 042.7	427.9
Boston-Worcester-Lawrence, MA-NH-ME-CT CMSA	5 819 100	2 318 422	6 193	565	5 627	1 034.1	412.0
San Francisco-Oakland-San Jose, CA CMSA	7 039 362	2 651 275	8 799	1 431	7 368	955.4	359.8
Tampa-St Petersburg-Clearwater, FL MSA	2 395 997	1 143 979	3 331	777	2 554	938.1	447.9
Detroit-Ann Arbor-Flint, MI CMSA	5 456 428	2 208 124	7 048	483	6 565	831.1	336.3
Cleveland-Akron, OH CMSA	2 945 831	1 246 124	6 274	2 663	3 612	815.6	345.0
Washington-Baltimore, DC-MD-VA-WV CMSA	7 608 070	3 043 659	10 492	915	9 576	794.5	317.8
Atlanta, GA MSA	4 112 198	1 589 568	6 208	84	6 124	671.5	259.6
San Diego, CA MSA	2 813 833	1 040 149	4 526	326	4 200	670.0	247.7
Houston-Galveston-Brazoria, TX CMSA	4 669 571	1 777 902	8 778	1 073	7 705	606.0	230.7
Dallas-Fort Worth, TX CMSA	5 221 801	2 031 348	9 469	366	9 104	573.6	223.1
Seattle-Tacoma-Bremerton, WA CMSA	3 554 760	1 467 176	8 166	941	7 225	492.0	203.1
Minneapolis-St Paul, MN-WI MSA	2 968 806	1 169 775	6 364	301	6 063	489.7	192.9
Los Angeles-Riverside-Orange County, CA CMSA	16 373 645	5 678 148	35 317	1 362	33 955	482.2	167.2
St Louis, MO-IL MSA	2 603 607	1 092 915	6 548	156	6 392	407.3	171.0
Denver-Boulder-Greeley, CO CMSA	2 581 506	1 042 779	8 552	56	8 496	303.9	122.7
Phoenix-Mesa, AZ MSA	3 251 876	1 331 385	14 598	26	14 573	223.1	91.4

Source: Census 2000.

Table 5. **Population and housing densities New York CMSA and component PMSAs**

Geography	**Population**	**Housing units**	**Area in sq. miles: Total area**	**Area in sq. miles: Water area**	**Area in sq. miles: Land area**	**Density per sq. mile of land area: Population**	**Density per sq. mile of land area: Housing units**
New York-Northern New Jersey-Long Island, NY-NJ-CT-PA CMSA	21 199 865	8 213 523	13 117.93	2 668.07	10 449.86	2 028.70	786.0
Bergen-Passaic, NJ PMSA	1 373 167	509 868	443.85	24.39	419.46	3 273.60	1 215.5
Bridgeport, CT PMSA	459 479	179 318	276.98	15.15	261.83	1 754.90	684.9
Danbury, CT PMSA	217 980	82 542	402.05	15.15	386.9	563.4	213.3
Duchess County, NY PMSA	280 150	106 103	825.38	23.78	801.59	349.5	132.4
Jersey City, NJ PMSA	608 975	240 618	62.43	15.74	46.69	13 043.60	5 153.8
Middlesex-Somerset-Hunterdon, NJ PMSA	1 169 641	430 692	1 065.32	20.97	1 044.35	1 120.00	412.4
Plymouth-Ocean, MA PMSA	1 126 217	489 595	1 581.00	472.78	1 108.21	1 016.20	441.8
Nassau-Suffolk, NY PMSA	2 753 913	980 474	2 826.15	1 627.26	1 198.89	2 297.10	817.8
New Haven-Meriden, CT PMSA	542 149	223 326	450.55	20.63	429.92	1 251.00	519.5
New York, NY PMSA	9 314 235	3 680 360	1 414.55	272.91	1 141.64	8 158.70	3 223.8
Newark, NJ PMSA	2 032 989	766 020	1 615.05	37.38	1 577.67	1 288.60	485.5
Pittsburgh, NY-PA PMSA	387 669	157 435	1 405.18	42.04	1 363.15	284.4	115.5
Stamford-Norwalk, CT PMSA	353 556	139 224	282.96	72.84	210.12	1 682.70	662.6
Princeton, NJ PMSA	350 761	133 280	228.84	2.91	225.93	1 552.50	589.9
Westerbury, CT PMSA	228 984	94 668	237.66	4.15	233.51	980.6	405.4

Source: Census 2000.

Table 6. **US Farms 1974-2002**

	2002	1992	1982	1974
Land in farms (acres)	938 279 056	945 531 506	986 796 579	1 017 030 357
Number of farms	2 128 982	1 925 300	2 240 976	2 314 013
Average farm size (acres)	441	491	440	440
No. farms with sales over 50 k	451 867	521 625	553 881	NA
Percent farms with sales over 50 k	21.2%	27.1%	24.7%	NA
Change, land area 74-02	-7.7%			
Change, no. farms 74-02	-8.0%			
Change, number of farms with sales over 50k 82-02	-18.4%			

Source: www.nass.usda.gov/census/census02/volume1/us/st99_1_001_001.pdf

Table 7. **Journey to work, metropolitan areas, 1990 and 2000**

Metropolitan area	1990 population	1990 employment	1990 transit	1990 % commute by transit	2000 population	2000 employment	2000 transit	2000 % commute by transit	Change in % by transit	Change in employ-ment	% change in employ-ment
Atlanta, GA MSA	2 833 511	1 481 781	69 822	4.7%	4 112 198	2 060 632	75 272	3.7%	-1.1%	578 851	14%
Austin–San Marcos, TX MSA	781 572	404 016	13 615	3.4%	1 249 763	649 645	16 691	2.6%	-0.8%	245 629	20%
Boston–Worcester–Lawrence, MA-NH-ME-CT CMSA	4 171 643	2 141 717	227 948	10.6%	5 819 100	2 898 680	261 862	9.0%	-1.6%	756 963	13%
Buffalo-Niagara Falls, NY MSA	1 189 288	531 122	24 943	4.7%	1 170 111	520 350	18 278	3.5%	-1.2%	-10 772	-1%
Charlotte-Gastonia-Rock Hill, NC-SC MSA	1 162 093	604 856	11 186	1.8%	1 499 293	751 629	10 433	1.4%	-0.5%	146 773	10%
Chicago-Gary-Kenosha, IL-IN-WI CMSA	8 065 633	3 841 337	524 756	13.7%	9 157 540	4 218 108	484 835	11.5%	-2.2%	376 771	4%
Cincinnati-Hamilton, OH-KY-IN CMSA	1 744 124	812 766	29 758	3.7%	1 979 202	742 390	23 098	3.1%	-0.6%	-70 376	-4%
Cleveland-Akron, OH CMSA	2 759 823	1 242 099	56 675	4.6%	2 945 831	1 375 774	47 111	3.4%	-1.1%	133 675	5%
Columbus, OH MSA	1 377 419	677 859	18 587	2.7%	1 540 157	777 922	17 958	2.3%	-0.4%	100 063	6%
Dallas-Fort Worth, TX CMSA	3 885 415	1 976 606	46 504	2.4%	5 221 801	2 527 648	45 765	1.8%	-0.5%	551 042	11%
Denver-Boulder-Greeley, CO CMSA	1 848 319	964 912	40 961	4.2%	2 581 506	1 346 025	58 471	4.3%	0.1%	381 113	15%
Detroit-Ann Arbor-Flint, MI CMSA	4 665 236	2 079 880	50 568	2.4%	5 456 428	2 482 457	45 119	1.8%	-0.6%	402 577	7%
Grand Rapids-Muskegon-Holland, MI MSA	688 399	337 335	4 082	1.2%	1 088 514	531 924	4 457	0.8%	-0.4%	194 589	18%
Greensboro-Winston-Salem-High Point, NC MSA	942 091	493 926	5 735	1.2%	1 251 509	618 921	5 348	0.9%	-0.3%	124 995	10%
Hartford, CT MSA	1 085 837	561 969	20 567	3.7%	1 183 110	573 114	16 107	2.8%	-0.8%	11 145	1%
Houston-Galveston-Brazoria, TX CMSA	3 711 043	1 759 796	66 540	3.8%	4 669 571	2 081 607	68 249	3.3%	-0.5%	321 811	7%
Indianapolis, IN MSA	1 249 822	624 971	12 999	2.1%	1 607 486	795 755	10 530	1.3%	-0.8%	170 784	11%
Jacksonville, FL MSA	906 727	443 882	9 458	2.1%	1 100 491	527 718	8 042	1.5%	-0.6%	83 836	8%
Kansas City, MO-KS MSA	1 566 280	771 309	16 504	2.1%	1 776 062	881 258	11 305	1.3%	-0.9%	109 949	6%
Las Vegas, NV-AZ MSA	741 459	371 128	7 530	2.0%	1 563 282	702 535	28 526	4.1%	2.0%	331 407	21%
Los Angeles-Riverside-Orange County, CA CMSA	14 531 529	6 809 043	310 563	4.6%	16 373 645	6 767 619	315 544	4.7%	0.1%	-41 424	0%
Louisville, KY-IN MSA	952 662	446 876	14 323	3.2%	1 025 598	492 821	10 898	2.2%	-1.0%	45 945	4%
Memphis, TN-AR-MS MSA	981 747	448 237	12 661	2.8%	1 135 614	438 310	8 550	2.0%	-0.9%	9 927	-1%
Miami-Fort Lauderdale, FL CMSA	3 192 582	1 476 085	64 240	4.4%	3 876 380	1 642 866	64 135	3.9%	-0.4%	166 781	4%
Milwaukee-Racine, WI CMSA	1 607 183	772 752	37 737	4.9%	1 689 572	816 880	32 841	4.0%	-0.9%	44 128	3%
Minneapolis-St. Paul, MN-WI MSA	2 464 124	1 307 624	69 125	5.3%	2 968 806	1 540 304	70 973	4.6%	-0.7%	232 680	8%
Nashville, TN MSA	985 026	495 717	8 597	1.7%	1 231 311	621 221	5 937	1.0%	-0.8%	125 504	10%
New Orleans, LA MSA	1 238 816	514 726	37 337	7.3%	1 337 726	570 423	31 946	5.6%	-1.7%	55 697	4%
New York-Northern New Jersey-Long Island, NY-NJ-CT-PA CMSA	18 087 251	8 550 473	2 271 949	26.6%	21 199 865	9 319 218	2 320 155	25.0%	-1.7%	768 745	4%

Table 7. **Journey to work, metropolitan areas, 1990 and 2000** (continued)

Metropolitan area	1990 population	1990 employment	1990 transit	1990 % commute by transit	2000 population	2000 employment	2000 transit	2000 % commute by transit	Change in % by transit	Change in employ-ment	% change in employ-ment
Norfolk-Virginia Beach-Newport News, VA-NC MSA	1 396 107	698 999	15 319	2.2%	1 569 541	760 401	14 240	1.9%	-0.3%	61 402	4%
Oklahoma City, OK MSA	958 839	450 122	3 049	0.7%	1 083 346	509 262	3 071	0.6%	-0.1%	59 140	5%
Orlando, FL MSA	1 072 748	557 448	8 617	1.5%	1 644 561	786 243	13 323	1.7%	0.1%	228 795	14%
Philadelphia-Wilmington-Atlantic City, PA-NJ-DE-MD CMSA	5 899 345	2 794 917	284 579	10.2%	6 188 463	2 815 405	245 909	8.7%	-1.4%	20 488	0%
Phoenix-Mesa, AZ MSA	2 122 101	996 495	21 184	2.1%	3 251 876	1 466 434	29 581	2.0%	-0.1%	469 939	14%
Pittsburgh, PA MSA	2 242 798	956 154	75 995	7.9%	2 358 695	1 057 354	65 345	6.2%	-1.8%	101 200	4%
Portland-Salem, OR-WA CMSA	1 477 895	724 532	39 259	5.4%	2 265 223	1 105 133	63 126	5.7%	0.3%	380 601	17%
Providence-Fall River-Warwick, RI-MA MSA	1 141 510	125 726	3 984	3.2%	1 188 613	555 540	13 774	2.5%	-0.7%	429 814	36%
Raleigh-Durham-Chapel Hill, NC MSA	735 480	399 701	8 003	2.0%	1 187 941	617 475	10 433	1.7%	-0.3%	217 774	18%
Rochester, NY MSA	1 002 410	481 467	15 372	3.2%	1 098 201	516 814	10 329	2.0%	-1.2%	35 347	3%
Sacramento-Yolo, CA CMSA	1 481 102	685 945	16 462	2.4%	1 796 857	799 989	21 763	2.7%	0.3%	114 044	6%
Salt Lake City-Ogden, UT MSA	1 072 227	479 338	14 266	3.0%	1 333 914	642 688	19 126	3.0%	0.0%	163 350	12%
San Antonio, TX MSA	1 302 099	569 149	20 870	3.7%	1 592 383	698 685	20 213	2.9%	-0.8%	129 536	8%
San Diego, CA MSA	2 498 016	1 230 446	40 378	3.3%	2 813 833	1 299 503	43 757	3.4%	0.1%	69 057	2%
San Francisco-Oakland-San Jose, CA CMSA	6 253 311	3 200 833	297 363	9.3%	7 039 362	3 432 157	325 212	9.5%	0.2%	231 324	3%
Seattle-Tacoma-Bremerton, WA CMSA	2 559 164	1 308 338	82 619	6.3%	3 554 760	1 776 224	119 919	6.8%	0.4%	467 886	13%
St. Louis, MO-IL MSA	2 444 099	1 144 336	33 994	3.0%	2 603 607	1 238 964	29 915	2.4%	-0.6%	94 628	4%
Tampa-St. Petersburg-Clearwater, FL MSA	2 067 959	914 711	13 367	1.5%	2 395 997	1 063 957	14 940	1.4%	-0.1%	149 246	6%
Washington-Baltimore, DC-MD-VA-WV CMSA	3 923 574	3 406 163	393 527	11.6%	7 608 070	3 839 052	361 877	9.4%	-2.1%	432 889	6%
West Palm Beach-Boca Raton, FL MSA	863 518	380 260	5 118	1.3%	1 131 184	475 572	6 671	1.4%	0.1%	95 312	8%
				7.0%							
Metropolitan areas over 1 000 000 population	131 930 956	64 449 880	5 478 595	8.5%	161 517 899	74 730 606	5 550 960	7.4%	-1.1%		
% of US	53.0%				57.4%	58.3%				1	
										0	
United States	248 709 873	115 070 274	6 069 589	5.3%	281 421 906	128 279 228	6 067 703	4.7%	-0.54%		

Source: http://www.publicpurpose.com/ut-jtw2000metro.htm, using data from US Census 2000 and 1999, as edited by Deakin.

Note: Boundaries and definitions changes between 1990 and 2000.

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QUALITY OF LIFE AND PRODUCTIVITY IN SPRAWLED VERSUS COMPACT US CITIES

Matthew E. KAHN[1]

Tufts University
Fletcher School
Medford, MA
USA

SUMMARY

Medford, April 2006

INTRODUCTION

Today, most Americans who live in metropolitan areas live in single detached homes and commute to work by automobile. New York City is America's sole urban centre where a significant fraction of the population lives in apartment buildings, works downtown and commutes by public transit. As transportation costs continue to decline and household incomes rise, we are choosing to sprawl as we live and work in the suburbs.

The conventional wisdom is that this trend imposes major social costs relative to its benefits. An advanced Google search reveals that there are 39 500 entries for the exact phrase "costs of sprawl", while there are only 455 entries for the exact phrase "benefits of sprawl". The beneficiaries of sprawl may be a "silent majority", who are not as politically active as centre-city promoters, environmentalists and the urban poor's advocates in voicing their views on the merits of the ongoing decentralization of jobs and people that is taking place across cities in the United States.

This paper seeks to address this intellectual imbalance by presenting original empirical work, documenting some of the benefits of the sprawled metropolitan area. This paper uses a number of US data sets to explore how sprawl improves the quality of life. We focus on how sprawl affects consumers, workers and firms.

Opponents of sprawl often argue that suburbanization may offer *private* benefits but that it imposes *social* costs. The "cost of sprawl" literature posits that there are many unintended environmental consequences of the pursuit of the "American Dream", ranging from increased urban air pollution and greenhouse gas production to farmland paving. The last chapter of the paper argues that environmental regulation, new markets and technological advance have helped to mitigate several of the social costs of sprawl.

1. MEASURING SPRAWL IN THE UNITED STATES

The first step for comparing quality of life indicators in compact versus sprawl cities is to find objective data that allows major cities to be classified by "sprawl category". A 2005 study by Reid Ewing, Rolf Pendall and Don Chen, entitled "Smart Growth America", creates such data for 83 major US metropolitan areas in the year 2000 (see www.smartgrowthamerica.org). These areas represent nearly half of the nation's population. Table 1 lists these areas and reports their "compactness" ranking. Major metropolitan areas are listed from most sprawled to least sprawled. These authors base their sprawl index on four factors: residential density; neighbourhood mix of homes, jobs and services; strength of activity centres and downtowns; and accessibility of the street network.

As discussed by Ewing, Pendall and Chen (2005), "*The most sprawling metro area of the 83 surveyed is Riverside, California, with an Index value of 14.22. It received especially low marks because it has few areas that serve as town centers or focal points for the community: for example, more than 66 percent of the population lives over ten miles from a central business district; it has little neighborhood mixing of homes with other uses: one measure shows that just 28 per cent of residents in Riverside live within one half-block of any business or institution; its residential density is below average: less than one percent of Riverside's population lives in communities with enough density to be effectively served by transit; its street network is poorly connected: over 70 per cent of its blocks are larger than traditional urban size.*"

It is important to note that even in compact metropolitan areas such as New York City, there is significant suburban growth at the fringe. A broader definition of the New York City metropolitan area would include large pieces of New Jersey and Connecticut.

In previous research, the author has used the share of employment within a certain radius of the Central Business District (CBD) as the prime measure of sprawl (see Kahn, 2001; Glaeser and Kahn, 2004). The Ewing, Pendall, Chen (2005) measure is more comprehensive and offers an independent measure of sprawl. For an alternative measure of sprawl, see Burchfield, Overman, Puga and Turner (2006) (for data details, see http://www.chass.utoronto.ca/~mturner/research.htm).

Throughout this paper, their compactness index (see Table 1) is used to partition metropolitan areas into four groups (i.e. high sprawl, sprawl, low sprawl, very low sprawl). The most sprawled metro areas are those whose compact index lies between the 0 and 25th percentiles of the empirical distribution, as listed in Table 1. The least sprawled metro areas are those in the top 25th percentile of the empirical distribution. This simple classification system allows the comparison of outcome indicators in low sprawl versus high sprawl areas.

2. OUTCOME MEASURES

The ideal would be to observe how people who currently live in sprawled cities *would have* lived their lives had they lived in a compact city. This counter-factual would allow us to measure how sprawl affects household wellbeing[2]. If this information could be combined with preference information on how much people are willing to pay for such amenities as a short commute or a nice house, then it would be straightforward to estimate the benefits of sprawl. In reality, this counter-factual can only be approximated by examining the outcomes for observationally similar people who live in high sprawl and compact cities.

2.1. Housing consumption

The 2003 American Housing Survey (AHS) micro data set is a representative national sample for examining housing consumption in high sprawl and low sprawl cities. Over 20 000 people are sampled. Using the geographical identifiers in this data base, the metropolitan area sprawl measures are merged into this micro data. For 77 major metropolitan areas, housing consumption is examined in compact versus sprawled cities.

Table 2 focuses on home ownership propensities and land consumption as a function of urban form. As shown in the top row of Table 1, home ownership rates are 8.5 percentage points higher in the most sprawled cities relative to the most compact cities. In compact cities, the median household lives on a lot that is 40% smaller than that of the median household living in a sprawled city (i.e. the 0 to 25th percentile of the compact distribution). The differential with respect to interior square footage is smaller. The median household in a compact city lives in a unit with 158 fewer square feet than the median household in a sprawled city.

While there are clear housing consumption gains for households in sprawled metropolitan areas, these observable differentials do not reveal *how much* households value such gains. The population differs with respect to its housing preferences. Those people with the greatest taste for large, single detached housing will migrate to cities and areas where they can cheaply achieve their housing goals.

Some cities such as New York City remain compact due to maintaining a large share of employment downtown. Other cities have increased their compactness by fighting sprawl through Smart Growth policies of land use controls. A political economy literature has examined the distributional effects of who gains and who loses when cities battle sprawl (Katz and Rosen, 1987; Portney, 2002; Glaeser, Gyourko and Saks, 2006; Quigley and Raphael, 2005). Incumbent homeowners gain twice from such anti-growth policies. By limiting increases in housing supply, these policies raise the value of existing homes. If these policies increase the quality of life of the city, then this will increase the demand for the existing homes.

Who loses from "Smart Growth" policies? It is well known that minority homeownership rates have lagged behind those of the white population (see Collins and Margo, 2001). Part of this gap is due to differentials in wealth accumulation. In previous research, the author has documented that blacks who live in sprawl cities "catch up" on some housing consumption dimensions to whites relative to the black/white housing consumption differential in compact cities (Kahn, 2001). Table 3 presents some new evidence on this question, through using the 2003 AHS data and focusing on one measure of housing consumption, the number of rooms in the housing unit. Multivariate regression techniques (i.e. ordinary least squares) are used to control for such important demographic features as household income, the household's size and presence of children. Controlling for these factors, we examine how urban form affects housing consumption[3].

As shown in Table 3, an increase in the metropolitan area compactness index reduces minority household housing consumption. This estimate is statistically significant. For white households, the compactness index has a negative but small, statistically insignificant coefficient. Moving the average minority household from a high sprawl city (Atlanta) to a low sprawl city (Portland) would reduce its rooms consumption by $-.52 = -.6658*\log(126.1/57.7)$.

Why could sprawl increase minority housing consumption? Housing is more affordable in high sprawl areas. Such areas are not erecting entry barriers. This may explain why the level of residential racial segregation has been lower in the newer, car-based cities of the west and the south than in the older, public transportation-based cities of the northeast. Fast-growing metro areas, such as Orlando, Las Vegas and Phoenix, have experienced a sharper decline in segregation relative to slow growth areas (Glaeser and Kahn, 2004).

These US-based findings may have implications for Europe's housing market. Future work might study whether immigrant housing consumption in European cities is more comparable to natives in more decentralized cities.

2.2. Commute times

Are commute times higher or lower in compact cities? In compact cities, people are likely to live closer to their downtown jobs but people are more likely to commute by relatively slow public transit. In a monocentric city, workers who commute by private vehicle are likely to slow each other down as they each impose congestion externalities on each other. In contrast, in sprawled metropolitan areas featuring multiple employment centres, workers commute by private vehicle at faster speeds (Gordon, Kumar and Richardson, 1991; Crane, 2000).

To begin to examine these issues, commuting data from the 2003 American Household Survey are used. This data set reports the distance to work, and commuting time for heads of households. Table 2 shows summary statistics for workers in compact versus sprawled cities. Relative to workers in compact cities, workers in sprawled cities commute an extra 1.8 miles further each way, but their commuting time is 4.3 minutes shorter. Over the course of a year (400 trips), they save 29 hours. While the workers living in sprawled cities have a longer journey measured in miles, they are commuting at higher speeds. Table 2 shows that workers in sprawled cities commute at a speed 9.5 miles per hour faster than workers in compact cities.

The Neighborhood Change Database reports the share of census tract commuters who have a less than 25-minute journey by year. In Figure 1, this is graphed with respect to the census tract's distance from the Central Business District. The figure shows that in both 1980 and 2000, the share of commuters with a short journey declines over the distance 0 to 10 miles from the CBD. Starting at the 11^{th} mile from the CBD, the share of commuters with a short journey actually stops declining. This is strong evidence of the effect of sprawl. A large share of residents at such locations are not commuting downtown. Note the differential between the 1980 and the 2000 graphs. Over these twenty years, suburban households (i.e. those living more than ten miles from the CBD) have experienced a large percentage increase in short commutes. For example, ten miles from the CBD between 1980 and 2000, there has been over a fifteen percentage point increase in the share of commutes with a time of 25 minutes or less. This is strongly suggestive evidence of the commuting gains brought about by employment suburbanization. Employment sprawl has shortened commuting times for suburban residents, as such workers can travel faster over a shorter distance than if they worked downtown.

3. ADDITIONAL BENEFITS OF SPRAWL

This chapter briefly highlights a variety of potentially important benefits of sprawl. Data limitations preclude presenting original data analysis measuring the size of each of these effects, but the author believes that each contributes to household wellbeing in sprawled cities.

3.1. Suburban consumer prices and the "Wal-Mart" effect

Wal-Mart and other "superstores" could not exist in an urban world of compact cities with binding zoning laws. "*Wal-Mart has sometimes had difficulty in receiving planning approval for its stores. Currently, Wal-Mart has either no presence or an extremely limited presence in New England, the New York metro area, California and the Pacific Northwest. However, its expansion into new areas has proceeded over the past few years* (Hausman and Leibtag, 2005)."

These stores require large physical spaces and large parking lots to accommodate their inventory and to attract shoppers. Such stores offer one-stop shopping and prices that can be 25% lower than regular supermarkets (see Hausman and Leibtag, 2005). The diffusion of these stores may mean that the US consumer price index overstates inflation because this index does not properly reflect the prices that people face for core goods. These stores are disproportionately located in suburban and rural areas where land is cheap. Centre-city residents often drive to suburban locations to shop at such stores. While the popular media often reports stories criticising Wal-Mart's employee compensation, and its effects on driving out of business smaller "mom and pop" stores, it cannot be denied that consumers gain from having access to such large stores. The key counter-factual here is what prices would residents face in a compact monocentric city without Wal-Mart and other superstores?

3.2. Public safety

Does sprawl protect the suburban rich from crime? If criminals have less access to cars, then physical distance from the urban poor is likely to reduce the risk that the relatively wealthy face.

It is true that over the last decade centre-city crime has sharply decreased (Levitt, 2005). While the causes of these quality-of-life gains continue to be debated, the consequences of this trend are clearly visible. City centres will be better able to compete for the skilled workers (especially those with few children living in the household) against suburbs if the city is perceived to be safe. The reduction in urban crime will differentially increase quality of life in more compact cities such as San Francisco and New York City.

Compact cities do face greater risks from terrorist attacks. While only a small share of any city's population is killed in even very large attacks, such as 9/11/2001, people do tend to over-estimate the probability of unlikely events (Rabin, 2002). Sprawled cities are also less attractive targets for terrorists (Glaeser and Shapiro, 2002; Savitch, 2005). It is no accident that the major terrorist attacks have taken place in dense cities, such as at the World Trade Center and the London bus bombs. A sprawled city offers the terrorists fewer casualties and thus less media coverage.

4. FIRM PRODUCTIVITY IN COMPACT VERSUS DECENTRALIZED CITIES

A growing urban economics literature has investigated how urban productivity is affected by urban form (Prudhomme and Lee, 1999). This literature has shown the connection between density at the county level and agglomeration (Ciccone and Hall, 1996). Jaffe, Trajtenberg and Henderson (1993) provide the best evidence that ideas do move more quickly when people are in close proximity. Lucas and Rossi-Hansberg (2002) also argue for the importance of density in speeding productivity. These papers all suggest that sprawl might indeed reduce agglomeration economies and deter overall productivity. But, Glaeser and Kahn (2004) conclude that aggregate density at the metropolitan area level matters in explaining variations in per-capita income across US cities, but the degree to which those jobs are centralized in the city centre appears to be irrelevant.

Firms gain by having the option of locating some of their employment further from the high-land-priced Central Business District. The key reasons for why firms choose particular locations include 1) land costs, 2) access to ideas, 3) access to workers, and 4) transport cost savings for inputs and output. For example, manufacturing industries that are more land-intensive are more likely to decentralize while skill-intensive industries are less likely to decentralize (Glaeser and Kahn, 2001). Those firms that gain from “Jane Jacobs” learning from other types of firms have an incentive to locate in diverse, high-density downtowns.

Within firms, non-management occupations are increasingly being sited at the edge of major cities (Rossi-Hansberg, Sarte and Owens, 2005). This cost saving increases firm profits. Firms that are able to split their activities between headquarters and production plants are likely to gain greatly from sprawl[4]. Standard agglomeration forces encourage firms to only keep those workers at the centre-city headquarters who benefit from interactions in the denser downtown (Rossi-Hansberg, Sarte and Owens, 2005).

Other firms may gain by being able to construct large campuses where members of the same firm can interact across divisions. Microsoft’s Richmond, Washington campus will cover ten million square feet after it completes its expansion, and there will be 12 000 workers there[5]. Google now has 5 680 employees and is adding 1 million square feet to the 500 000 it now occupies in Mountain View, California. In the year 2000, only 21% of Atlanta’s jobs were located in zip codes within 10 kilometres of the CBD (Baum-Snow and Kahn, 2005)[6]. If Microsoft were located in downtown Manhattan or London, how would it have configured its operations? Would it have been as productive a company relative to what it has achieved at its suburban campus?

5. SOME OF THE LOCAL ENVIRONMENTAL COSTS OF SPRAWL ARE DECLINING

Sprawl's opponents are likely to concede that the "American Dream" offers private benefits for consumers and firms. They would counter that suburbanization imposes important social costs that no one household has an incentive to internalize. This chapter seeks to examine some of these environmental costs.

Environmentalists often argue that sprawl contributes to a large ecological footprint because people consume more resources when they live at low density. Table 2 presents some evidence supporting this claim. The 2001 National Household Transportation Survey reports for each household how much gasoline they consume each year. Merging the city compactness index (see Table 1) to this data, we examine gasoline consumption in compact and sprawled cities. As shown in Table 2, the average resident in compact cities consumes 335 gallons less per year of gasoline than the average resident of sprawled metropolitan areas. Within metropolitan areas, suburban drivers drive over 30% more miles than centre-city residents and are more likely to drive low fuel economy sport utility vehicles (SUVs) (Kahn 2000, 2006)[7]. The average Atlanta household would drive 25% fewer miles if it relocated to relatively compact Boston (Bento *et al.*, 2005). As a result, there are significant differences in average gasoline consumption across the country. Cross-national studies suggest that gasoline consumption could be 20% to 30% lower in sprawling cities like Houston and Phoenix if their urban structure more closely resembled that of Boston or Washington, DC[8].

People are less likely to use public transit when they live in sprawled cities. This has environmental implications because public transit is a "greener" transport technology than private vehicles. To document this fact, census tract data from the Urban Institute and Census Geolytics' Neighborhood Change Database are used. This is a set of repeated cross-sections from the 1970, 1980, 1990 and 2000 decennial censuses at the census tract level, normalized to 2000 tract geography. Census tracts are areas of roughly 4 000 people. GIS software is used to calculate each census tract's distance to the CBD and focus on those census tracts within 25 miles of the CBD for the metropolitan areas listed in Table 1. As shown in the bottom two rows of Table 2, in 1970, 6.8% of workers in sprawled metropolitan areas and 24.6% of workers in compact metropolitan areas commuted using public transit. In both areas, these shares shrank between 1970 and 2000. In the year 2000, 2.8% of workers in sprawled metropolitan areas and 17.1% of workers in compact metropolitan areas commuted using public transit.

Income growth plays some role in explaining this trend. As household incomes increase, people are less likely to use public transit, which is typically slower than commuting by car. Car travel takes about two minutes per mile for commutes under five miles. In contrast, bus commuting takes more than three minutes per mile for trips under five miles. In addition, the average bus commuter waits 19 minutes to board the bus[9]. Using data from the 2000 Census of Population and Housing, we find that the probability of using public transit is 2.5 percentage points lower for a household at the 75^{th} percentile of the income distribution (USD 65 339) than for a household at the 25^{th} percentile (USD 41 159)[10].

However, sprawl also helps explain the decline in public transit ridership. Based on the same data, we find that simulating sprawl by moving a person from the 75th percentile of the population density distribution (2 528 people per square mile) to the 25th percentile (142 people per square mile) reduces public transit use by 8.6 percentage points.

Baum-Snow and Kahn (2005) examine public transit use trends in sixteen major United States cities that have spent billions of dollars constructing new light rail and heavy rail lines between 1970 and 2000. They study whether the share of workers who commute using public transit increases in communities that have increased access to rail transit because they now live close to a new rail line. While they find some evidence of increased usage (especially in more compact cities such as Washington, DC and Boston), the observed “treatment” effects are small. New rail transit expansions are unlikely to encourage mode switching from vehicles to public transit. To reduce the ecological footprint impacts of private vehicle use, induced innovation is needed to encourage producers to develop high fuel efficient vehicles and for consumers to demand such vehicles. Expectations of high future gas prices would play a key role in providing incentives for such products to be demanded.

5.1. Air pollution

A standard argument that environmentalists make about sprawl is that this trend contributes to urban air pollution. But new vehicle emissions regulation has offset increased vehicle mileage. The Los Angeles Basin suffers from the highest levels of air pollution in the United States, with the pollution caused mainly by vehicle emissions. But Los Angeles has made dramatic progress on air pollution over the last 25 years. For ambient ozone, a leading indicator of smog, the average of the top 30 daily peak one-hour readings across the county’s nine continuously operated monitoring stations, declined 55%, from 0.21 to 0.095 parts per million, between 1980 and 2002. The number of days per year exceeding the federal one-hour ozone standard declined by an even larger amount -- from about 150 days per year at the worst locations during the early 1980s, down to 20 to 30 days per year today[11].

Recent pollution gains are especially notable because Los Angeles County’s population grew by 29% between 1980 and 2000, while total automobile mileage grew by 70% (Census of Population and Housing 1980 and 2000; California Department of Transportation, 2003). For air quality to improve as total vehicle mileage increases indicates that emissions per mile of driving must be declining sharply over time.

To document this fact, two waves of the California Random Roadside Emissions tests are used, spanning the years 1997 to 2002, to estimate vehicle level emissions production functions (see Kahn and Schwartz, 2006). Intuitively, we control for a number of vehicle characteristics such as the vehicle’s mileage, and the zip code of the vehicle owner. Holding these factors constant, we estimate how vehicle emissions vary as a function of vehicle model year. How much cleaner are 1990 makes relative to 1980 and 1975 models?

Figure 2 presents predicted vehicle emissions by model year, holding all vehicle attributes at their sample means. For each of the three pollutant measures the predictions are normalized by dividing through by the predicted value for 1966 model year vehicles. The figure shows sharp improvement with respect to model year and documents emissions progress, even during years when new vehicle regulation did not tighten.

The vehicle emissions progress by model year means that the average vehicle on the road in any calendar year is becoming greener over time. In each subsequent calendar year, there are fewer high-emitting, pre-1975 model year makes on the roads. This greening of the average vehicles has greatly contributed to the reduction in ambient pollution, despite ongoing city growth and increased vehicle mileage. To document this, the author uses ambient air pollution data from California Ambient Air Quality Data CD, 1980-2002 (California Air Resources Board). This CD-ROM provides all air quality readings taken in the state during this time period. Figure 3 shows the percent change in ambient ozone smog for 29 major Californian counties over the years 1980 to 2000 with respect to county per cent population growth. Included are data for the 29 California counties that had population levels greater than 200 000. Ambient ozone by county/year is measured by the maximum one-hour reading at each monitoring station within the county and then these maximum readings are averaged by county in each year.

Anti-sprawl advocates would argue that counties experiencing greater population growth should experience rising ambient air pollution. As shown in this figure, there is no correlation between county growth and ambient air pollution. The correlation equals -.08. These major counties, even those such as Riverside that have experienced the greatest growth, have enjoyed large pollution reductions over this time period. The vehicle pollution progress documented in Figure 2 has helped to offset the scale effects of California's population growth.

5.2. Open space

In addition to greenhouse gases and ambient air pollution, a third environmental concern often voiced by sprawl opponents is the conversion of farm land. Farmers provide green space. Such green space is privatized when farmers sell their land to suburban developers. If nearby households value the open space, then farmers impose a negative externality on existing urban and suburban residents when they sell to a developer. Fortunately, new markets in land development rights have helped mitigate this problem.

Throughout the United States, municipalities are purchasing open space around their borders to guarantee that the land is not developed. For example, the city of Boulder, Colorado, has earmarked a 0.73% sales tax to fund the purchase of 25 000 acres to establish a green belt around the city. It has also set aside 8 000 acres in the Boulder foothills to be used as parks. Some of the Boulder open space is leased to farmers and remains in agricultural use. Other parcels are maintained as natural areas. This allows residents to enjoy recreational activities such as walking, bicycling and horseback riding. In the Seattle metropolitan area, King County has adopted a different strategy with a similar goal. Drawing upon a USD 50 million bond issue, the county is purchasing development rights from farmers. Farmers gain an increase in their income and in return they promise not to convert their "green space" into suburbia (see Kahn, 2006).

Such government initiatives solve a free-rider problem. In the absence of government intervention, environmental organizations such as land trusts might go door to door, asking people to contribute money to help preserve open space. But few people are likely to give under these conditions. The "win-win" for any one household is to contribute nothing to such programmes and let everyone else underwrite their cost. As a result, too little money is invested in protecting local public goods. Government's unique ability to collect taxes and allocate revenue solves this problem. However, not all governments can take this approach: like many green policies, "open space" initiatives are more likely to succeed as local incomes rise. After studying voting patterns for all open space referenda in the United States between 1998 and 2003, Kotchen and Powers (2005) found that richer jurisdictions and jurisdictions with more home-owners were more likely to vote to hold such ballot initiatives and to enact them. Nearly 1 000 jurisdictions had open space referenda and nearly

80% passed. From an ecological perspective, the key issue here is whether jurisdictions hire competent ecologists who can prioritize what are the most valuable pieces of open space to purchase and protect.

CONCLUSION

Major cities in the United States offer households a diverse menu to choose from. People with a taste for "new urban" living can move to New York City or San Francisco. Such compact cities offer walking access to stores, and public transit. In these cities, a significant fraction of people live in apartment buildings. Other people have a taste for living in a single detached home with its own private lot and commuting by private car. They might prefer to live in Houston, Texas. Low migration costs across cities allow households to move to their desired area. In the United States, between 1995 and 2000 over 22 million domestic migrants changed their state of residence (see www.census.gov/prod/2003pubs/censr-7.pdf). Migration patterns reveal that in the United States, millions of households are moving to decentralized, sprawled metropolitan areas.

This paper has attempted to present a balanced analysis of the private benefits and social costs of living in compact versus sprawled cities. Compact cities feature greater congestion and higher commuting times, while in sprawled cities certain global environmental externalities, such as greenhouse gas production, are likely to be exacerbated. Technological advance has mitigated many of the environmental problems associated with sprawl.

Similar to the United States, nations in Europe face the challenge of providing desirable urban areas for heterogeneous people and firms to live and operate, while minimizing perverse social consequences. As Europe's population ages and the immigrant population grows, will this increase the demand for decentralized living or for more compact living?

NOTES

1. Fletcher School, Tufts University, Medford, MA 02155, Matt.kahn@tufts.edu, Fax: 617-627-3712. This paper was prepared for the OECD/ECMT Regional Round Table 137, Berkeley, 27-28 March 2006.

2. For example, recently there has been national news coverage of the theory that sprawl contributes to obesity. The logic behind this claim is that people who drive their cars walk less and gain weight. A recent study by Eid, Overman, Puga and Turner (2005) examines migration data for the same people over time. This paper documents that when centre-city residents move to the sprawled suburbs, they do not gain weight. This paper demonstrates that sprawl *does not* cause obesity.

3. The reported standard errors are clustered by metropolitan area.

4. For example, in 1999 the *Washington Post* moved its printing operations away from its headquarters in downtown Washington to neighbouring Springfield, Virginia. In 2000, the tyre manufacturer Michelin, headquartered in Greenville, South Carolina, located its rubber production operations in nearby Anderson County. Currently, Home Depot is moving a distribution centre to McDonough, Georgia, outside Atlanta, which is the location of its corporate headquarters (see Rossi-Hansberg, Sarte and Owens, 2005).

5. See http://seattletimes.nwsource.com/html/microsoft/2002796093_microsoft10.html

6. There are at least two quality-of-life benefits from employment suburbanization. The previous section documented the reduction in commuting times in suburban communities as more suburbanites now live closer to their jobs rather than commuting downtown. A second quality-of-life benefit from suburbanized employment is that this creates a separation of land uses. In the past, when cities were much more compact, millions of people lived too close to dirty, noisy manufacturing and slaughterhouse activity (Melosi, 2001). Declining transportation costs have allowed a separation of where goods are produced and where people live.

7. Ewing, Pendall and Chen (2005) report evidence that this increased driving in sprawled cities leads to more traffic fatalities.

8. Newman and Kenworthy (1999).

9. Glaeser, Kahn and Rappaport (2000).

10. This data set provides data at the zip code level on public transit use, housing density and household income. The author uses data for over 14 000 urban zip codes, and estimates the following ordinary least squares regression:
    Percent commute using public transit = state fixed effects – 5.30*log(income)
    + 2.98*log(population density).

Controlling for state fixed effects acknowledges the fact that states differ with respect to their investments in public transit. In this regression, there are 14 600 observations and the R2=.58.

11. Data source: California Ambient Air Quality Data CD, 1980-2002 (California Air Resources Board). This CD-ROM provides all air quality readings taken in the state during this time period. In this data-set, the unit of analysis is a monitoring station.

TABLES AND FIGURES

Table 1. **Compact index for 83 major cities from high sprawl to low sprawl**

MSA	Name	Compactness Index
6780	Riverside-San Bernardino	14.2
3120	Greensboro-Winston-Salem	46.8
6640	Raleigh-Durham	54.2
520	Atlanta	57.7
3160	Greenville-Spartanburg	58.6
8960	West Palm Beach	67.7
1160	Bridgeport-Stamford-Norwalk-Danbury	68.4
3840	Knoxville	68.7
6000	Oxnard-Ventura	75.1
2800	Fort Worth	77.2
2960	Gary-Hammond	77.4
6840	Rochester	77.9
1920	Dallas	78.3
8720	Vallejo-Fairfield-Napa	78.4
2160	Detroit	79.5
8160	Syracuse	80.3
5640	Newark	81.3
4400	Little Rock	82.3
160	Albany-Schenectady-Troy	83.3
3280	Hartford	85.2
5880	Oklahoma	85.6
8280	Tampa-St.	86.3
1000	Birmingham	88.0
760	Baton Rouge	90.1
9240	Worcester-Fitchburg-Leominster	90.5
8840	Washington DC	90.8
1840	Columbus	91.1
3760	Kansas City	91.6
3600	Jacksonville	91.6
1680	Cleveland	91.8
4920	Memphis	92.2
3360	Houston	93.3
3480	Indianapolis	93.7
1760	Columbia	94.2
7040	St. Louis	94.5
3000	Grand Rapids	95.2
5720	Norfolk-Virginia	95.6
5120	Minneapolis-St.	95.9
1640	Cincinnati	96.0
5860	Orlando	96.4
360	Anaheim-Santa	97.1
5775	Oakland	98.8
8560	Tulsa	99.1

Table 1. **Compact index for 83 major cities from high sprawl to low sprawl** (continued)

MSA	Name	Compactness Index
7600	Seattle	100.9
4480	Los Angeles	101.8
7320	San Diego	101.9
6920	Sacramento	102.6
4120	Las Vegas	104.7
80	Akron	105.9
8200	Tacoma	105.9
6280	Pittsburgh	105.9
5480	New Haven	107.0
8400	Toledo	107.2
7240	San Antonio	107.8
2680	Fort Lauderdale	108.4
8520	Tucson	109.1
7400	San Jose	109.7
9040	Wichita	110.1
640	Austin	110.3
2840	Fresno	110.3
6200	Phoenix	110.9
7160	Salt Lake City	110.9
6160	Philadelphia	112.6
720	Baltimore	115.9
2320	El Paso	117.2
5080	Milwaukee	117.3
1280	Buffalo	119.1
1600	Chicago	121.2
8000	Springfield	122.5
240	Allentown-Bethlehem-Easton	124.0
1720	Colorado Springs	124.4
200	Albuquerque	124.5
2080	Denver	125.2
5560	New Orleans	125.4
5000	Miami-Hialeah	125.7
6440	Portland	126.1
1120	Boston-Brockton	126.9
5920	Omaha	128.4
3320	Honolulu	140.2
7360	San Francisco	146.8
6480	Providence-Woonsocket	153.7
3640	Jersey City	162.3
5600	New York City	177.8

Table 2. **Economic outcomes as a function of urban form**

		Compactness distribution based on the index reported in Table 1			
		Percentile			
Attribute	**All 83 metro areas**	**0-25th**	**25th to 50th**	**50th to 75th**	**75th-100th**
Home ownership	0.581	0.625	0.619	0.588	0.539
Median lot size	7250.000	10000.000	7800.000	6250.000	6000.000
Median unit square footage	1295.000	1358.000	1350.000	1280.000	1200.000
Distance to work	12.590	13.661	12.688	12.603	11.888
Commute time	23.895	22.663	22.295	23.095	27.015
Speed to work	32.333	36.079	34.206	32.970	27.597
Gallons of gasoline consumed	939.493	1132.209	1061.295	965.038	793.371
Public transit commute share in 1970	.151	.068	.092	.088	.246
Public transit commute share in 2000	.092	.028	.047	.061	.171

Table 3. **Household consumption of rooms as a function of urban form**

	Whites		Non-whites	
	Beta	**s.e**	**Beta**	**s.e**
Log(household income)	0.5365	0.0546	0.4124	0.0353
Head's age	0.0944	0.0046	0.0542	0.0074
Head's age squared	-0.0006	0.0000	-0.0003	0.0001
Persons	0.3275	0.0427	0.3798	0.0343
Woman	-0.0733	0.0409	0.1222	0.0506
Children present	0.2077	0.0603	0.1377	0.0912
Log(metro area total jobs)	-0.2226	0.0954	-0.1154	0.0795
Log(compactness index)	-0.2468	0.2665	-0.6658	0.3537
Constant	0.3687	2.0817	2.7349	1.9959
Observations	15289		4878	
Adjusted R2	.233		.244	

This table reports two ordinary least squares regressions. The dependent variable is the count of rooms in the respondent's house. The omitted category is a man who does not have children living in the house. The Compactness Index varies across metropolitan areas but not within metropolitan areas. These data are reported in Table 1.

Figure 1. **Share of commuters with commute less than 25 minutes**

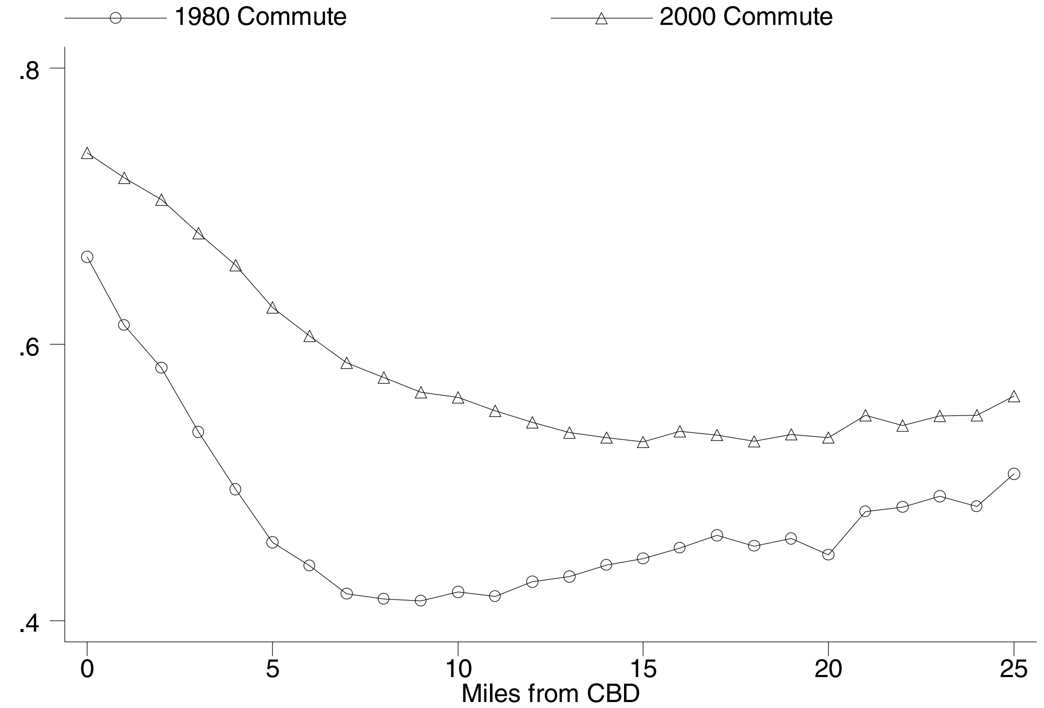


Figure 2. **Predicted vehicle emissions by model year**

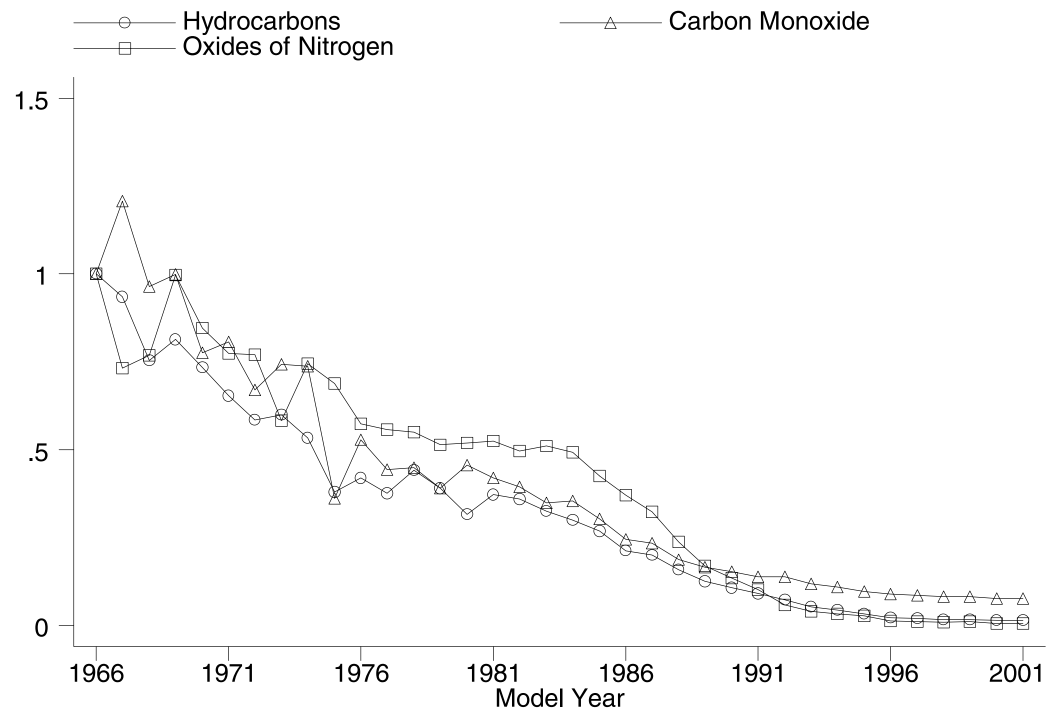
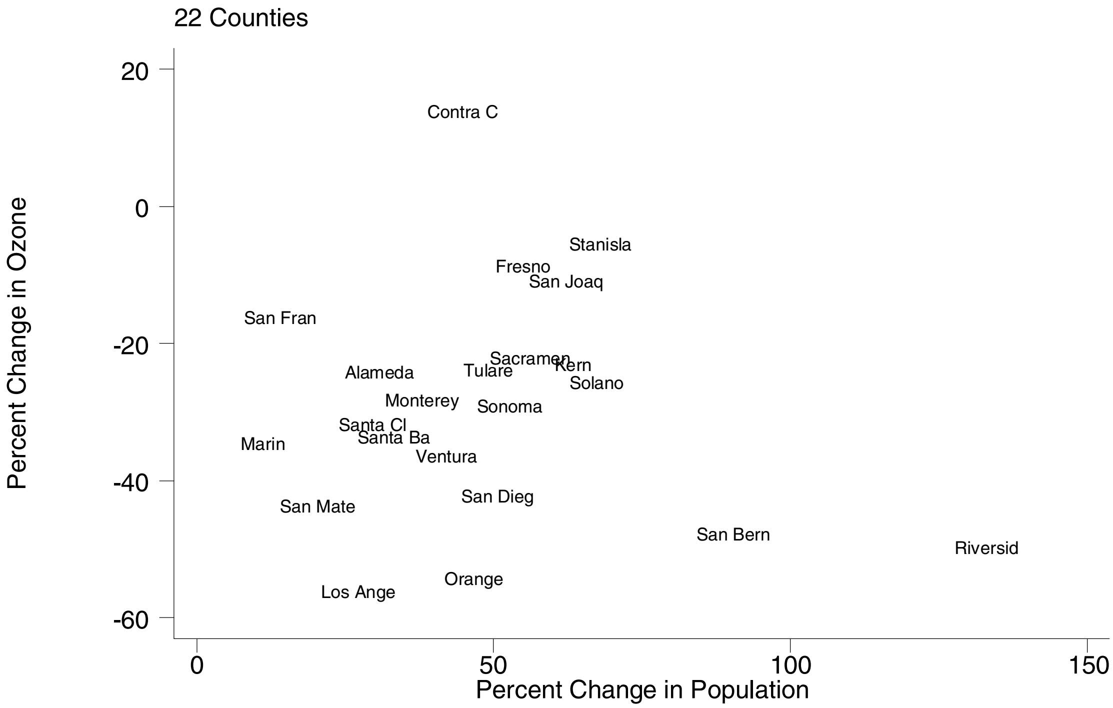


Figure 3. **California County ambient ozone and population trends, 1980-2000**



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CITIES, URBAN FORM AND SPRAWL:

A EUROPEAN PERSPECTIVE

D. BANISTER

University of Oxford
Oxford
United Kingdom

SUMMARY

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1. INTRODUCTION

Throughout history there have been many transitions that have marked key turning points in the ways in which societies live and work. The industrial revolution was characterised by the separation of work and homes for the first time, with factories being grouped together and people having to walk there from their homes. Vast portions of the city were taken up with distinct land uses – monofunctional land uses. Work-related activities were time constrained and the workers themselves had to order their lives according to fixed times and locations. The market was inflexible and transport was seen as the means to maintain the efficient workings of that new industrial society.

The post-industrial revolution has also fundamentally changed society, with the growth in service based industry and the emerging possibilities of carrying out a range of activities in the same location, whether it is the office or the home. Multifunctional land uses have allowed the reintegration of the city, taking advantage of clusters of activities and agglomeration economies (Priemus *et al.*, 2004). Many activities are no longer time constrained or location constrained, and this has presented planners and decision-makers with a series of interesting choices as to how cities might develop. This new flexibility has now been given additional impetus with the rapid growth of Information and Communications Technologies (ICT), as the potential for even greater flexibility in both the use of time and space become apparent. The technological revolution is likely to be just as important for cities as the industrial revolution was some two hundred years ago[1].

Transport has played an instrumental role in recent city development, through providing the means to get the workers and the raw materials for manufacture to the city. Mono-functional and multifunctional land uses are both heavily dependent on transport, even though the networks and modes used might differ. Cities with radial road and rail networks allow easy access to the centre, whilst grid cities, linear cities and those with hybrid designs all have different advantages. In addition to the physical configuration of the network, there have been huge changes in the use of the network and in the land uses adjacent to that network. The city is continuously evolving and adapting to the changing patterns of use. Sustainable urban development will be focused on the city, as this is where most people now live and are projected to remain, and where most economic activity will take place – in the UK, for example, some 80% of the population live in urban areas. It is important that the city is seen to be attractive in terms of its built environment, as well as for the opportunities that it provides in terms of its jobs, housing, open space, education, amenities and recreational facilities. It must also be seen to provide a safe and secure environment for individuals and families, and for people of all ages and ethnic groups. This is the sustainable city, where the economic rationale for prosperity is matched by an equal concern over the inclusiveness and fairness of the city and the quality of the environment, including the buildings and spaces that make up the city. Such aspirations are often found at the beginning of many strategy statements for city development, but actions that are consistent with these high-level aims are often difficult to devise and implement (Banister, 2005).

Transport is an essential part of any city and it should be seen as an integral part of the more sustainable and fairer built environment; not separate from it, nor working against it. The central argument in this paper is that transport provision must no longer adversely dominate city design, but instead play an important, supporting role in improving the quality of life in the city. Hence our future transport system can still act as the "maker and breaker" of cities, but it must work to facilitate an improved quality of city life.

The initial part of the review addresses issues relating to the design of cities, including the links between urban form and travel. Here it is argued that the structure of cities (strategically and locally) is influential in determining the main characteristics of travel – the numbers of trips made, journey lengths, modes of travel used, and the resulting energy consumption and emissions. It is recognised that there are strong social and economic factors (e.g. income, car ownership, family size and structure, employment) that also influence travel. Critically, in terms of sustainable development, it is the physical environment that is within the scope of intervention and under the control of urban planners and developers. The decisions made concerning the location of new development (including housing and employment) are a key determining factor towards future changes in travel behaviour.

The second part of the paper reviews the evidence on urban sprawl and suburban development, where the new debate is taking place on efficient urban forms that are also both socially diverse and environmentally sustainable. It is in these suburbs that most people live and where most jobs are now located. This transformation is well illustrated by the changing distribution of population in London, and it also encapsulates the transition from the industrial to the post industrial city (Table 1).

Table 1. **The growth, decline and growth of London**

	Total – 621 sq miles		**Inner London – 118 sq miles**		**Outer London – 503 sq miles**	
	Population	**Density***	**Population**	**Density**	**Population**	**Density**
1801	1 096 784	1 764	959 310	8 137	137 474	273
1851	2 651 939	4 266	2 363 341	20 045	288 598	573
1901	6 506 889	10 466	4 536 267	38 476	1 970 622	3 912
1951	8 196 807	13 185	3 681 552	31 226	4 515 255	8 962
1971	7 368 693	11 852	2 959 315	25 100	4 409 378	8 752
1991	6 679 699	10 744	2 504 451	21 242	4 175 248	8 288
2001	7 172 036	11 536	2 765 975	23 460	4 406 061	8 746

* Density is measured in population per square mile.

The population in London has grown rapidly over the last two hundred years, increasing by more than 4.4 million people in the 19^{th} century, peaking in 1951 and then declining until recently, with the expectations that growth will continue, and that in 2006 the population will again reach 7.5 million (ONS, 2005). Densities also grew rapidly to 1901 and then stabilised, but even today they are high at 11 536 people per square mile (4 453 per square kilometre). The Inner London densities have also risen, to peak at 38 476 people per sq. mile in 1901, and then fallen with the outward migration and changes of land use; but even here there have been signs of change, with a recent increase to 23 460 people per sq. mile (9 057 per sq. km.). The densities were comparatively low in Outer London until 1901, but rose to stable levels in 1951, with a current level of 8 746 people per sq. mile (3 376 per sq. km.). The final statistic worth pointing out is the proportion of the population of London living in the Inner and Outer areas and how this has changed over time. In 1801, 87% of London's population lived in the inner area, and this proportion has reduced over time to 70% in 1901 and 45% in

1951. The current level is 39% in the Inner area and 61% in the Outer area, with a density ratio of 3 to 1.

Such a commentary is reinforced by Hartog (2005), in his recent study of 40 European cities over time. He took a measure of space (square metres) per head of population, concluding that medieval cities gave a generous space allowance to each person and that movement was mainly by foot. The industrial cities were the worst in terms of their space allocation, but this has now improved, with most medium-sized European cities having about 270 m^2 per person, falling in the largest cities to about 200 m^2 per person (in 2001, London's density was 224 m^2/pers and Paris' was 190 m^2/pers).

2. CITIES, URBAN FORM AND TRANSPORT

"*The siting of employment, retail and leisure centres outside urban areas, for instance around motorway junctions, undermines the economic viability of the city centre as a commercial district, encourages car use and excludes citizens who do not have access to a car from these jobs and services* (CEC, 2004, p. 26)."

2.1. The debate

There has been a healthy debate in the literature about the relationships (if any) between urban form and transport. Some have argued for the compact city or polycentricity, whilst others have suggested that continued dispersal will lead to a natural "co-location" of residential and employment locations (Breheny, 2001). There is certainly a continuous and dynamic process going on, which results in centralisation and decentralisation, as people and jobs are located in response to each other and other factors. In all cases (ironically) the aims are much the same, namely, to reduce average journey distances, trip frequencies, traffic volumes, energy consumption and/or transport emissions (Banister, 2005).

The compact or polycentric city achieves this through higher densities and the dispersed city through locating work near to where people live. The crucial difference between the options is that the compact city is amenable to the provision of public transport, as well as walking and cycling, whilst the dispersed city is more likely to depend on the car, as travel patterns are more diverse. In terms of sustainability, the compact city has more to offer if public transport is well used, and it provides opportunities for those without access to the car. Underlying this debate on compactness and travel is the premise that higher densities make the best use of available land (often a scarce resource), reduce travel distances and provide a greater intensity and diversity of activities – this is at the heart of the urban renaissance movement in the UK (Urban Task Force, 1999 and 2005).

Although such a polarisation of the debate is interesting, the reality is far more complex. Much of the available empirical analysis has tended to be rather simplistic in its approach, with the data being open to several interpretations, and causality is usually unproven (Crane, 2000). The complexity, in the physical sense of the built environment, revolves around at least four separate themes – population size, density, jobs-housing balance and mix of use, and location – all of which are under the control (to a greater or lesser extent) of urban planners. Table 2 provides a summary of the research field, showing many contradictory findings. These urban form variables must be related to wider socioeconomic variables that also influence travel, but are not emphasized in this table.

Table 2. **Summary of research findings**

Urban Form Variables
1. Settlement size
▪ No correlation between urban population size and modal choice in the US (Gordon *et al.*, 1989a and b). ▪ The largest settlements (>250 000 population) display lower travel distances and less by car (ECOTEC, 1993). ▪ The most energy-efficient settlement in terms of transport is one with a resident population size of 25-100k or 250k plus (Banister, 1997).
2. Density
▪ Increasing densities reduce transport energy consumption (Newman and Kenworthy, 1989a and b). ▪ There is no clear relationship between the proportion of car trips and population density in the US (Gordon *et al.,* 1989a and b, 1991). ▪ As densities increase, modal split moves towards greater use of rail and bus (Banister *et al*., 1997). ▪ Compact cities may not necessarily be the answer to reducing energy consumption, due to effects of congestion; also decentralisation may reduce trip length (Breheny, 1997, 2001; Gordon and Richardson, 1997). ▪ Decentralised concentration is the most efficient urban form in reducing car travel (Jenks *et al.,* 1996). ▪ Density is the most important physical variable in determining transport energy consumption (Banister *et al.,* 1997). ▪ Higher densities may provide a necessary, but not sufficient condition for less travel (Owens, 1986). ▪ As people move from big, dense cities to small, less-dense towns they travel more by car, but the distances may be shorter (Hall, 1998b).
3. Jobs-housing balance and mixed use development
▪ Communities are balanced where the ratio of jobs to housing units lies in the range of 0.75 to 1.5 (Breheny, 1995). ▪ Local facility provision does not determine modal choice, personal and household characteristics are the determinants (Farthing *et al.,* 1997). ▪ Diversity of services and facilities in close proximity reduces distance travelled, alters modal split and people are prepared to travel further for higher-order services and facilities (Banister, 1996).
4. Location, accessibility and neighbourhood design
▪ Location of new housing development outside existing urban areas or close to the strategic transport network or as free-standing development, increases travel and influences mode split, and can lead to "stretch" commuting (Headicar and Curtis, 1998). ▪ Location is an important determinant of energy consumption and car dependency (Banister *et al.,* 1997). ▪ Development close to existing urban areas reduces self-containment and access to non-car owners (Headicar, 1996). ▪ Urban design quality: some anecdotal evidence in the US showing the differential impact of new urbanist *versus* cul-de-sac route networks on travel behaviour (Marshall, 2001 and 2005).

Wider socio-economic characteristics
▪ Increased household size, income and car ownership are associated with increased trip frequency (Hanson, 1982). ▪ Car ownership is associated with increased travel distance, proportion of car journeys and transport energy consumption (Naess and Sandberg, 1996). ▪ Dual-income households: the choice of new housing location is influenced by the location of two workplaces. The extent of "excess travel" and the reasons behind this phenomenon are not well researched. Travel time is more important than travel distance, and the role of the travel factor in the choice of a new home location seems to be important (Ma and Banister, 2006a) ▪ Attitude: some research in California, US as to the impact on travel behaviour, which suggests it may be a more important factor than land use and other socio-economic variables. Early research available from Surrey, UK (Hickman, 2005).

Source: Based on Banister, 2005.

Much of the existing empirical evidence is thus limited. Simple bivariate relationships (such as density and travel) are most often analysed; few research studies consider the wide range of likely urban form and socio-economic influences on travel, and nearly all are based on cross-sectional data, showing just one "snapshot" of results in time. Further research should hence include wide-ranging, detailed longitudinal analysis that allows the dynamic processes to be explored (and not only the net effects) by following decision processes over time. It should also be noted that in the 21st century there are "no" compact cities and "no" dispersed cities, as cities are hybrids of these forms, and are dynamic and constantly changing. The literature is now considered in more detail, structured around the four broad themes (Table 2).

2.2. Settlement size

Settlement size affects the range of jobs and services that can be supported. It also influences the quality of public transport that can be provided, and the length of trips. Diseconomies of scale may occur with the larger settlements (e.g. London, Birmingham and the larger conglomerations) where travel distances again increase, as labour market areas function regionally, and as specialisation in terms of certain jobs requires particular skills which are often scarce, and may thus be remotely located (Owens, 1986; ECOTEC, 1993).

- Empirical evidence from the UK National Travel Survey (NTS) suggests a clear correlation between increasing settlement size and decreasing travel distance (for all purposes). The average journey distance by car (and other modes) is lowest in conurbations and highest in rural areas, even if the variations in travel by car ownership (a proxy for income) are controlled for. Transport-related energy consumption (one measure of sustainable transport) is one-third lower than average in the metropolitan areas (excluding London) and more than one-third higher than average in the smallest settlements (Banister, 1997).
- Analysis of the changing patterns of commuting distance in the three largest cities in the UK shows how, over time (1971-81), different patterns have developed. In London, commuting distance increases linearly from the centre, as there is a strong pull from the central city. But in Birmingham there is a threshold at 7 km, after which the commuting distance levels off, and at 9 km from the city centre it falls as work places become more dispersed. In Manchester, the threshold is 5 km from the centre, but it remains constant over space. Changes in thresholds depend both on patterns of location, access to transport and the increasing complexity and

diversity of the job market that has to accommodate multi-worker households, shift workers and part-time workers (Spence and Frost, 1995). The most recent changes now being brought about, through opportunities provided by new ICT technologies for distance working and telecommuting, also need to be considered (Banister and Stead, 2004).

- At the more local level, some empirical evidence suggests that there is a link between travel patterns in new housing developments and the urban centre for the work journey, but not for other journey purposes. The conclusions (from a study of six new housing developments around Oxford in the UK) were that income differences between the new housing locations were not the primary source of variations in work-related car travel, but that location was also a key determinant (Curtis, 1995).
- Other evidence from major cities also points towards a linear relationship between distance from home to the centre and transport energy consumption (i.e. in London and Paris, and more recently in Perth, Australia). In London and Paris it was found that residents living at a distance of 15 km from the centre consumed more than twice the transport energy used by those living at 5 km from the centre (Mogridge, 1985). The figures for Perth were less dramatic, as those living 15 km from the centre consumed only 20% more transport energy than those living 5 km from the centre (Newman and Kenworthy, 1988).

The general conclusion reached here is that the larger metropolitan settlements are associated with low travel distance and transport energy consumption. In many studies, increasing distance from home to the urban centre is associated with increasing travel distance, an increasing proportion of car journeys and increasing transport energy consumption. The only exception is trip frequency, which does not appear to vary significantly according to the distance between home and the urban centre. The evidence is mixed, however, particularly when considering differing urban forms from the US: evidence from the ten largest urban areas in the US, for example, shows no easily identifiable relationship between urban population size and modal choice (Gordon *et al.,* 1989a and b, 1991).

The literature on population size and travel behaviour is hence not fully developed, and there is much scope for further research, particularly in view of the current development growth agenda and discussion in the UK on Sustainable Communities[2] (ODPM, 2003). A further piece in the jigsaw is the growth in long-distance journeys, particularly for commuting. Most trips do not use much energy as they are locally based, and perhaps carried out on public transport or by foot and cycle. From a limited small-scale household survey, it was estimated that 84% of car trips used less than the average amount of energy per trip (15.1 MJ per trip). About 24% of motorised trips used 78% of the total energy (Banister *et al.*, 1997). Such evidence again suggests that sustainable transport strategies ought to be placed within the wider regional context, to be based on journey to work and city-region areas, and to be closely developed and integrated with the wider growth agenda.

2.3. Density

Development density is measured in terms of population, residential and employment density. The argument here is that higher population densities should widen the range of opportunities for the development of local contact networks, and that activities can be undertaken without using motorised travel (ECOTEC, 1993). Higher population densities can also widen the range of local services and facilities that are provided, and this can as well reduce the need to travel long distances. By concentrating on public transport orientated development – where pyramids of development density are orientated around public transport nodes – public transport patronage can be supported, urban form become less car dependent, urban sprawl confined, and there is a greater opportunity to cycle and walk (Crane, 1996). These are all essential ingredients of the sustainable and fair city in transport terms.

- Although it is difficult to take full account of short walk trips, as the data sources are sparse, it does seem that in the UK about 1 000 trips are made on average per person per year. Lower densities (1-5 persons per hectare) result in a slightly higher number of trips (+6%), and higher densities (over 50 persons per hectare) have slightly lower numbers of trips (-7%). But it is probably in the higher-density areas that there may be under-recording of short trips, particularly if they form part of a trip tour (or trip chain). These types of activity are common in urban areas where services and facilities are located in close proximity to each other (Banister, 1997).
- With increasing population density, the proportion of trips by car decreases, whilst the proportion of trips by public transport and walking both increase. Car trips account for 72% of journeys in low-density areas (less than one person per hectare) but only 51% of trips in high-density areas (more than 50 persons per hectare). There is a fourfold difference in public transport trips and almost a twofold difference in walk trips between very low-density areas and very high-density areas (UK-NTS data). There are many other variables apart from density that influence these figures, but the pattern still exists if socio-economic variables are controlled for (ECOTEC, 1993).
- European evidence promotes the links between urban density, quality of life and car trips. For example, in Vienna (Gielge, 2004), developments in the city centre permit much higher densities than in the suburbs. A ratio of 3 to 1 is used (similar to those quoted for London in chapter 1), but the greater density is not promoted at the expense of open space, but through the construction of more flats rather than single family homes. Gielge suggests that the densities obtained in European cities balance jobs, housing and social integration, even though the levels of public funding of infrastructure do not vary by location.
- The links between residential density and travel are less distinct, except at the metropolitan scale (Ewing, 1997). For small-scale cities, as size and density decreases the links become weaker. This weakening relationship has been linked to the decentralisation process and the decline in household size over time, with more housing units for the same population. There would need to be substantial increases in population density to make any real differences, as the counter factors of smaller households would diminish the effectiveness of density increases (Breheny, 2001).
- A controversial but widely cited study of energy use in cities around the world found that population density, job density and city centre dominance control petroleum use (Newman and Kenworthy, 1989 and 1999). For example, there is a strong increase in petroleum consumption when population density falls below 29 persons per hectare, and the conclusion is drawn that cities need to develop with strong centres and intensively-used suburbs. The analysis has been criticised for the quality of data used, the type of methods employed and the interpretation of the output, particularly on the causality inferred. Although the original research used data for 1980, it has been updated to 1990, where the patterns were found to be even more pronounced. In all cities, it seems that there has been an increase in the use of the car over the decade, as measured by vehicle-kilometres of travel per person. There has also been an increase in the use of public transport, but only in certain cities (e.g. Zurich and Singapore), and even here the increase has been modest. It is not clear whether this increase in public transport use has come from car users, or from existing users of public transport, or from walking and cycling. Even in cities where public transport investment has been substantial and where reductions in the use of the car might be expected, this has not taken place. Action has to be more comprehensive than merely the promotion of public transport.
- Evidence from the US suggests that there is no clear relationship between the proportion of car trips for work journeys and population density (Gordon *et al*., 1989a and b). It is suggested

that "co-location" of firms and households can reduce journey times, and decentralisation can reduce city centre congestion. A comparison of auto commuting trip times from the 1985 American Housing Survey, with data from the 1980 Census, for the 20 largest metropolitan areas in the US suggests that average trip times either fell by a statistically significant amount or remained the same. The explanation in the US has been that it is simply the market operating spontaneously through the relocation of firms and households, which helps achieve the balance of keeping commuting times within tolerable limits, even though commuting distances may have increased substantially. This alternative view may be explained by the definition of population density in terms of workplace locations rather than the conventional residential location; also that much of the research is based on studies of suburban sprawl in California – a very different urban form to that found in Europe.

There is therefore a substantial body of research that, on balance, demonstrates a link between population density and many measures of travel patterns – mode, distance and travel time. The only exception is that there is little variation in journey frequency by population density (Richardson and Gordon, 2001). Conversely, there has been little recent research concerning the relationships between employment density and travel patterns. The recent debate includes considerations of the new urbanism and urban renaissance, where the concern is not over density alone, but over the quality and design of the urban environment as a whole (Handy, 2002). Within the wider urban environment, density has an important role to play, but this role is enhanced when combined with other factors, such as mixed uses, safe and secure places, community, open space, green space and quality of development.

Again, the research field can and should be further developed, with detailed empirical analysis focused on, for example, alternative development forms, the role of density, potential synergies with population size and other variables, longitudinal change, adaptive change, or the potential adverse impacts of sprawl. Wider factors could be covered, such as attitudinal reasons for co-location of homes and workplaces, and the impact of recent ICT developments (for example, in terms of whether telecommuting for two or three days a week actually reduces overall travel-to-work distance, or whether it allows people to locate even further away from their workplaces). Also much of the evidence seems quite old and needs updating.

2.4. Jobs-housing balance and mixed-use development

The jobs-housing balance and the mixing of land uses are also perceived to affect the physical separation of activities and hence travel demand, particularly in recent times through the outsourcing of less specialised employment (Owens, 1986). This is commonly measured using job ratio – this is the ratio of jobs in the area to workers resident in that area. The evidence here, much of which is US-based, is variable, as even if there is a balance between workers and jobs, there is no guarantee that local workers will take local jobs. A balanced community is viewed as having a ratio of jobs to housing units within the range of 0.75 to 1.5. More generally, mixed-use developments should help reinforce denser neighbourhoods through the provision of more small shops and other facilities, but again, availability does not necessarily mean greater use. In terms of fairness this issue is important, as it may be those without access to a car who make most use of local jobs and facilities.

- Evidence from the US finds only weak links between job ratio and travel (Ewing, 1997). For example, in a national investigation of the effect of the various land-use characteristics (including the balance of homes and jobs) on trip generation, it was found that there is no statistically significant relationship between the balance of homes and jobs and journey frequency. More locally, in a study of commuting patterns in the San Francisco Bay Area, only a weak, negative relationship between job ratio and the proportion of journeys undertaken by foot and cycle was found, and where there were many more jobs than houses, the proportion of journeys by foot or cycle falls. Policy could balance housing and jobs so that walking and cycling are encouraged.

- A study in the Los Angeles region questioned the relevance of job ratio on travel patterns and presented the results of a commuting study to show that job ratio has a statistically significant, but relatively small, influence on commuting time (Giuliano and Small, 1993). The conclusion reached was that attempts to alter the metropolitan structure of land use are likely to have small impacts on commuting patterns, even if jobs and housing became more balanced.
- In the UK, the jobs and housing balance has gained less attention, with the exception of research based upon the New Towns. These settlements were originally designed to be self-contained and balanced (Breheny, 1995). The evidence shows that Mark I New Towns retained their self-containment over the 1960s, although this declined in the 1970s and 1980s. Compared to other settlements, the New Towns performed well in self-containment terms. The newer generation of New Towns has also showed relatively good levels of self-containment.
- Jobs-housing balance has been studied in France (Aguilera and Mignot, 2004), where commuting patterns in seven cities were examined. Some cities seemed to have large suburban subcentres close to the centre, whilst others had outlying subcentres along the main transport axes. They classified cities as centralised according to whether more than 60% of jobs are located in the centre (Marseilles, St Etienne and Dijon), or deconcentrated according to whether they had only 40% of jobs in the centre (Paris, Lyon, Bordeaux and Grenoble). The changes over time (1990-99) point towards a substantial increase in the distance between homes and workplaces for both types of subcentres.
- The limited evidence on the provision of local services and facilities in new residential developments suggests that it reduces average trip distances but does not significantly affect the proportion of journeys by foot. Proximity to neighbourhood facilities is positively associated with average distance, after taking into account the effects of various socio-economic differences of the areas studied (Farthing *et al.*, 1997). It has also been shown that the provision of local facilities is associated with increased use in terms of journey frequency (weaker) and of reducing trip length (stronger).

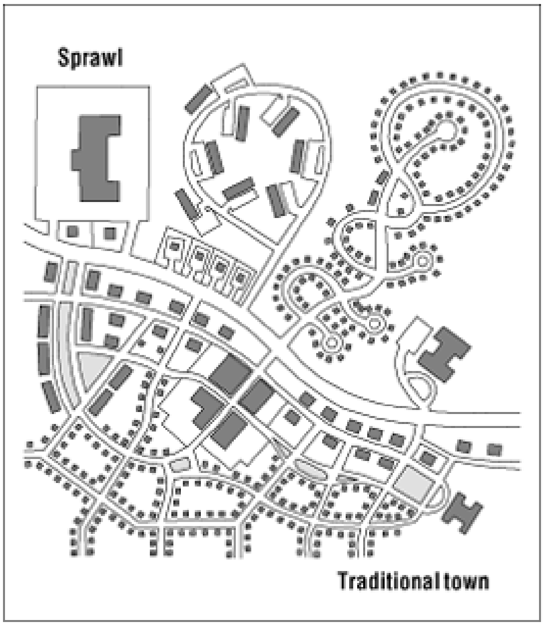
2.5. Location, accessibility and neighbourhood design

The proximity to transport networks – highway, public transport and walking and cycling– also influences travel patterns and, consequently, transport energy consumption. Better access to major transport networks, particularly road and rail networks, increases travel speeds and extends the distance which can be covered in a fixed time. So major transport networks are a powerful influence on the dispersal of development, but local neighbourhood design may also have an impact, for example, in improving pedestrian and cycle permeability, and in helping to concentrate development (Hickman, 2005).

- Short distances from home to the highway network, particularly free-flowing strategic routes, appear to increase travel distances (through increased speeds) and can contribute to a high proportion of long-distance "stretch" commuting trips (Calthorpe, 1993). Routes in the southeast of the UK, such as the M25, M40 and M3, are a powerful influence on the dispersal of development (Hickman and Banister, 2005).

- Distance from home to the nearest bus stop and railway station affects the modal share. The proportion of car journeys increases and the proportion of non-motorised journeys decreases with increasing distance from the nearest bus stop. US research shows how the proportion of rail journeys decreases with increasing distance from the railway station. Residents living within 150 metres of a railway station in California typically use rail for approximately 30% of all journeys (Cervero, 1994). Residents living at a distance of around 900 metres from the nearest railway station are likely to make only about half the number of rail journeys made by residents living within 150 m of a railway station. Similar findings are available from Surrey, UK (Hickman, 2005).
- Evidence in London provides an indication of the distances that people are prepared to walk to underground stations. Although individuals obviously differ, the aggregate story is that "acceptable" distances range from about 800 metres for residential properties to about 500 m for commercial properties. However, care is needed with the use of such broad thresholds (Banister *et al.,* 2004).
- It is important to understand that individuals (whether pedestrians, cyclists, public transport users and/or car drivers) are very different in terms of their personal characteristics. Gender and (dis)ability differences, in particular, are often overlooked. Traditionally, transport policy has been heavily geared towards the male, car-based commuter without any understanding of the needs of other members of society. To make greater use of public transport requires both the distances to the facility to be within walking distance (or reasonable cycle-and-ride or park-and-ride distance) and the quality of the service provided to be acceptable. There should be a clear recognition of all types of social diversity and resistance to generalisation (Social Exclusion Unit, 2002).
- In the Netherlands, the ABC location policy sets the conditions as to where businesses can locate in order to control mobility. The mobility characteristics of the business have to match the accessibility characteristics of the area where it wishes to locate. There have been difficulties with the implementation of the policy. For example, businesses complain about the lack of "A" locations which are accessible by public transport, and that they are reserved for people-intensive uses such as offices. As a consequence, development sites are often categorised as "B" type to maximise opportunities for development and reduce the mobility constraints (Priemus and Maat, 1998).
- Local design issues provide a classic example of the dilemmas that need to be addressed to reconcile transport concerns with those of sustainable urban development. There seem to be substantial benefits, in terms of land use, from switching away from grid transport networks in cities to loops and cul-de-sacs, as the amount of usable land increases from 64% with a grid system to 76% in a cul-de-sac system (Grammenos and Tasker Brown, 2000). This possibility is attractive from the developers' perspective. From the transport planning perspective, it also reduces the problems of "rat runs" or shortcuts through residential areas and it succeeds in reducing traffic speeds through design. But there are disadvantages, as a traditional grid network provides greater accessibility, a wider choice of routes and better potential for public transport. A grid network is estimated to reduce motorised traffic and increase walking and cycling usage when compared to cul-de-sac networks, using both US and UK-based research (Boarnet and Crane, 1999). The new urbanism movement in the US and much of good urban design practice in the UK now encourage traditional grid street networks (Marshall, 2005). Figure 1 provides the classic comparison between suburban sprawl and traditional neighbourhood development.

Figure 1. **Suburban sprawl versus traditional development**



Source: Duany and Plater-Zyberk, 1992.

There needs to be a reconciliation between the desires of pedestrians for short, direct routes, including access to public transport, and those of the car driver, which are also for short direct routes. The difference is one of scale and speed, with the pedestrian wanting a memorable experience, pleasure (sociability and walkability), but also safety, perhaps with separation from cars. The car driver, in general, also wants separation from pedestrians, but is more interested in ease of navigation around towns (including issues such as legibility and signposting), low levels of congestion and availability of parking (Marshall, 2005). At times, it is where these two sets of different requirements coincide that accidents take place, as best illustrated at road junctions, where pedestrians may want to cross and car drivers may want to turn (Berman, 1996). Table 3 provides a list of eleven aspects of neo-traditional development that are important considerations in the determination of behavioural change and in determining the quality of the environment. Such understanding is important for both sustainability at the local level, and to ensure that neighbourhood living is inclusive.

There is a need for a real shift in the way streets and urban spaces are imagined and designed. Walking, cycling and public transport become the prime focus of design efforts, with the needs of the car relegated as appropriate. There is much useful experience to draw on here, particularly from countries such as Germany and the Netherlands. Innovative solutions are on offer, where the usual "taken for granted" assumptions are removed, with reduced needs for signage, and different emphases placed on shared space and pedestrian-car interactions, often with dramatically successful and popular results (Southworth and Ben-Joseph, 1997). Friesland in the Netherlands provides an interesting example. Such experiments can offer UK policymakers very useful lessons and best practice models (Marshall, 2005).

Table 3. **Determinants of local quality**

1. Mixed use core within walking distance for residents.
2. Local employment and civic centres.
3. A range of housing types for different income levels.
4. Higher housing densities and smaller lots than those found in suburbs.
5. District architecture based on the local vernacular.
6. Creation of a sense of community.
7. Creation of a sense of tradition.
8. Common open spaces.
9. Streets that are social spaces as well as a transport facility.
10. Narrow streets with side walks and alleys running behind homes.
11. Grid street patterns that provide multiple paths for drivers and pedestrians.

Source: Berman, 1996.

Parking provision also affects local accessibility. In the short term, parking policies have a direct impact on modal choice, whilst in the longer term location policies have a continuing effect on transport demand, in terms of the numbers of trips, mode choice and trip lengths. Trip frequency and modal choice are both influenced by parking availability. As the availability of residential car parking increases, the average number of trips per person decreases (Kitamura *et al*., 1997). It is suggested that residents with more parking spaces make fewer, longer car-based journeys, whilst residents with fewer parking spaces make more journeys, but these tend to be short and less car-based. However, as with much of the empirical evidence, the issue of causality is not proven.

- Maximum parking standards have been set rather than minimum levels, so that there is no basis for commuted payments for on-site parking provision but such payments can still be sought for park-and-ride or on-street parking controls. In the UK, the maximum levels for food retailing are now one space per 14 m^2 (above a threshold of 1000 m^2), and one space per 20 m^2 for non-food retail above the same threshold. For B1 uses (including offices), the standard is one space per 30 m^2 (above a threshold of 1500 m^2) and 1.5 spaces per dwelling for residential parking. Work Place Parking Levies (WPPL) are being considered by some local authorities (e.g. Nottingham) as a means to raise revenues for public transport investment (e.g. trams), but they are also being resisted by businesses, who see WPPL as a tax that is not related to congestion (Banister, 2002).
- Car parking is enormously important to local authorities as it is a major source of revenue and determines the attractiveness (for some) of the town centre. There does not seem to have been a definitive study that demonstrates whether or not a strong parking policy, applied over a period of time with appropriate accompanying measures (e.g. on public transport priority), enhances the economy and environment of the town centre or reduces it. There are arguments in both directions.

Complementary measures are also important. "Complementary" is defined in a broad sense to include individual measures that reinforce those existing and those measures that are used in combination and involve actions in both transport and planning. In addition to traditional packages of measures in the transport sector (e.g. pedestrian and cycling priorities, traffic management and demand management, public transport priority and park-and-ride), there is a range of alternatives to promote sustainable development through complementary actions:

- Company transport plans (some local authorities and businesses have been in the lead in introducing these as part of their sustainable urban development strategy);
- Travel awareness campaigns and provision of quality information;
- School travel provision and accessibility to other facilities (e.g. hospitals and day care centres), particularly for those with no car available;
- Corporate policies which have an effect on travel decisions – just-in-time deliveries and the length of freight supply chains, specialisation with high consequent levels of transport intensity, rationalisation and closure of local facilities with increased travel distances, and company relocation policies from central to peripheral locations.

Park-and-ride is an interesting example of a transport and planning solution to a city centre problem, namely, congestion and a deterioration of environmental quality. On its own, it may have limited value, but this value is greatly enhanced if it is seen as part of a traffic reduction strategy to limit car parking and give priority to public transport in the town centre (Banister, 2005).

2.6. Conclusions

Underlying much of this debate and the empirical evidence is a lack of up-to-date detailed analysis. Much of the thinking has been constrained by convention, with protagonists either being seen to favour intervention through planning and other controls, technological fixes, or much greater freedom for the market to operate. As usual, the reality is more complex and requires a combination of approaches, not just one based on an over-simplification of trends on the ground. The approaches used may be synergistic, or may not be compatible and lead to counter-intuitive results. Effective policy packaging is thus critical. The literature on urban form, planning and sustainability also needs to be considered alongside wider fields – such as that covering traffic demand management, "soft factors", city competitiveness, and social inclusion– if progress towards the sustainable city is to be achieved.

Different researchers have examined the issue of energy use in transport at a variety of levels. Some favour regional and city-wide approaches, others more detailed studies which examine commuting movements and patterns of suburbanisation. It should, however, be remembered that commuting only accounts for about 20% of all trips and that the growth in travel demand is now taking place in the non-work-based activities, in particular for social, shopping and recreational purposes.

The debate is important to current development aspirations in the UK, particularly in terms of the development of Sustainable Communities (ODPM, 2003). Decisions affecting cities take place at all levels. At the national level, planning policies can influence the location of new development in relation to existing towns, cities and other infrastructure. Regional and city-wide policies can influence the size and shape of new development and the type of land use: whether it is used for housing, commercial and industrial purposes, or a combination of these in a mixed-use development, where clustering and concentration may take place. At the local and neighbourhood levels, planning policies can be used to influence the density and layout of development, together with accommodating local concerns over the quality of design and the local environment, such as that promoted by Breheny and Rookwood (1993).

The evidence in the US and Europe agrees that the built environment is more important than socio-economic factors in predicting trip lengths, but that socio-economic characteristics are more important in predicting trip frequencies and modal choice. When looking at vehicle distance travelled (a combination of trip lengths, frequencies and modes), the built environment again comes out as being the key determinant (Stead, 2001). Land-use strategies have the potential to reduce vehicle travel by bringing activities closer to the home location and thereby reducing the length of trips. Even though there may be decreases in trip lengths, there may also be a tendency to increase frequency of trips, thereby reducing the net effects. A third possibility is the preferences and attitudes of people, and these factors may be more important than both the built environment and socio-economic factors in predicting travel behaviour (Hanson, 1982).

The characteristics of the built environment also may not always determine individuals' travel patterns, but individuals will choose to live in particular locations because they want to adopt a particular lifestyle – a type of reverse causality. There is some evidence of this in Europe, where people are beginning to choose where to live on the basis of the lifestyle they want, which in turn is partly dependent on their travel patterns and mode preferences, for example, in car-free communities. Again, these arguments provide a rich background against which to examine the impact that transport has had on the built environment and the way in which our cities are becoming either more or less sustainable.

Despite the empirical difficulties and the lack of robust research evidence, it is possible to come to some conclusions. In terms of the particular influences that transport has on land use and urban form, there are clear influences on trip length, speed and mode choice. There is less impact on the frequency of travel. Conversely, development patterns and form may influence travel behaviour. Higher-density development is more likely to be clustered around a public transport network, whilst extensive highway networks enable commercial strip "edge city" development and low-density urban sprawl to dominate.

There is a series of strategic issues that must be addressed if sustainable land use with transport is to be achieved nationally and regionally. Cities are changing from centres of work to multifunctional centres, including leisure, education, government and retirement, all located close together. Patterns of dispersal and decentralisation are important, as are the possibilities for recentralisation, with densification and new forms of urban living. It is here that issues relating to urban design, in terms of innovation and quality, need to be considered as part of the sustainable and inclusive city. Cities are no longer just the centres of wealth creation, but need to address concerns over the quality of the environment, including equity issues, access to open space, low crime rates, safe and secure living, clean air, affordable housing and access to services and facilities.

Much of the evidence presented here refers to the city as a whole or to the city in its regional context. Recent interest is now switching away from the city centre, where many innovative policies have been implemented to encourage recentralisation and new urban living, towards the outskirts which are characterised by suburban development and urban sprawl.

3. URBAN SPRAWL

"The suburb as a residential place is as old as civilisation. However suburbanisation as a process involving the systematic growth of fringe areas at a pace more rapid than the core cities occurred first in the US and Britain, where it can be dated from about 1815 (Jackson, 1985, p. 130, quoted in Batty, 2005)."

In the EU, there is considerable concern over the growth in urban sprawl, not just in cities expanding into their hinterlands, but in growth along the main arterial routes between cities. Where restraint policies have been used (e.g. Greenbelts in the UK), there is evidence of leapfrogging as development "jumps" across the constrained areas to new sites even further away. The basic argument made in the EU is that densities are already high and space is limited (CEC, 2004). This means that policies should seek to strengthen the patterns of concentration and not promote dispersed development. Such a strategy has environmental and social benefits, and can help achieve sustainable urban development. With respect to transport, this means that trip lengths can be kept to a minimum and that high-quality public transport can be provided. Much of the EU Transport White Paper (CEC, 2001) is directed at substantially raising the costs of travel and in promoting public transport so that a substantial modal shift can take place. Urban sprawl[3] is seen as being an inefficient use of land, as environmental and social costs are not taken account of in the operation of the land market. It is also seen to lead to a greater consumption of resources, in supporting the more dispersed distribution of population, and in providing a lack of diversity (chapter 2).

But even in Europe there has been a history of centralisation followed by decentralisation. The historical pattern of development for small towns was linked by the transport network, and this led to growth by absorption with the same small towns and network still in existence. Peripheral subcentres then developed, based on local public transport, to reduce the commuting to the centre. Some of these subcentres were also new towns (UK) or dormitory towns (France), and these were situated on the main road and rail axes. Polycentric developments were more common in the Netherlands and Italy, based around the historic towns, but expansion and infill has continued to place pressures on all cities and regions as movements have become more circumferential rather than radial. Most recently, there has been a reurbanisation process as people have moved back into the cities.

Considerable research efforts, within the recent 5th Framework EU programme of research on "Cities of Tomorrow", have developed some of these themes within this debate – three will be mentioned here (Marshall and Banister, 2006).

TRANSPLUS – focused on the institutional and organisational relationships between transport, land use and sustainability within EU cities. There was a strong case made for the inclusion of wider urban functional regions that surround individual cities and clusters of cities, as markets and labour catchment areas extend way beyond city boundaries. For smaller cities it was concluded that the monocentric urban form is more sustainable than a polycentric one, but with the larger cities more complex urban forms emerged as being more sustainable. It should be noted that sustainability related to the transport and land-use dimensions, with the aim of reducing car dependence and promoting the use of public transport and soft modes of transport (walking and cycling). The more complex polycentric urban forms include multi-centred cities (e.g. London, Berlin and Paris), metropolitan clusters (e.g. Greater Manchester and Merseyside, the Ruhr, and Milan-Turin), and ring clusters (e.g. Randstad). In each case the different dimensions of sustainability can be identified, both in the physical transport and land-use contexts, as well as in the necessary institutional and organisational structures required (Sessa, 2006).

PROPOLIS – adopted a more formal modelling approach (three models were used: MEPLAN, TRANUS and the Dortmund Model) to examine a common reference scenario and a set of different alternative futures in seven EU cities (Helsinki, Dortmund, Inverness, Naples, Vicenza, Bilbao and Brussels). Indicator analysis was then used to measure the levels of sustainability (economic, social and environmental) for each of the policy options tested. In all cities the equity and accessibility indicators deteriorated, and it is only in Helsinki, Naples and Brussels that the health index improves. But this improvement mainly resulted from the assumption that old polluting vehicles would disappear over the modelled period (2001-21). The deterioration in both the environmental and social dimensions is attributed to city growth, sprawl and growth in car traffic.

In their policy analysis, it was concluded that individual interventions were not effective. A combination of increased car operating costs and public transport improvements (cheaper and faster), together with supporting land-use policies [concentration of new housing and development at public transport accessible (rail) locations] could have environmental and social benefits (a reduction of 17% in CO_2 emissions and a 10% reduction in traffic accidents), as well as transport benefits, including modal shift and reductions in trip frequencies and lengths. The figures given here relate to Dortmund (Table 4).

Table 4. **The Dortmund combined scenario for 2021**

	Difference to Reference Scenario for 2021						
	Trips	**Mean trip length (kms)**	**Per cent public transport trips**	**Per cent car trips**	**Car-kms per capita**	**Car owner-ship**	**CO_2 emissions per capita**
Car operating costs +75%	-2.78	-14.77	+6.49	-3.61	-20.98	-6.24	-18.89
Public transport times -5%	0	+0.02	+1.15	-0.06	-0.12	-0.05	-0.04
Public transport fares -50%	+0.75	+2.49	+11.84	-0.42	-0.68	+1.95	+1.62
Development at rail stations	+0.01	-1.43	+1.01	-0.01	-0.46	+0.01	-0.35
Total – individual additive	-2.02	-13.69	+20.19	-4.10	-21.32	-4.33	-17.66
Total – combined	-1.93	-11.56	+27.45	-4.96	-23.28	-3.81	-17.61
Difference	+0.09	+2.13	+7.26	-0.86	-1.96	+0.52	+0.05

Source: Based on Lautso and Wegener (2006).

The differences (percentages) for each policy relates to the policy scenario (2021) as compared with the reference scenario (2021), individually and in combination. So one total assumes additivity and the other allows for potential synergies. Positive synergies are found for public transport trips and the percentage using the car, together with car-km per capita (Table 4: light grey). Negative effects are reported for the number of trips, mean trip lengths, car ownership and CO_2 per capita emissions

(Table 4: dark grey), but even here there are substantial reductions on the reference scenario. Across all seven cities, the same magnitude of change was found, with a 15-20% reduction in CO_2 emissions and an 8-17% reduction in traffic accidents, as compared with the reference scenario. Accessibility to the city centre was improved through the reductions in travel time, and the socio-economic benefits ranged between €1 000 and €3 000 per inhabitant (net present values).

SCATTER – develops an interesting debate on urban sprawl, as it is suggested that the implementation of a high-quality regional public transport system can initially induce a shift from car to public transport, leading to shorter road travel times and reductions in fuel consumption and emissions. But, in the longer term, this high-quality public transport system encourages a renewal of urban sprawl through the acceleration of out migration, leading to longer trips, more fuel consumption and increases in emissions. Through simulation, single and combined policy measures were tested to explore their impacts on urban sprawl. The most effective combination was a mixture of congestion charging, reductions in public transport fares in the city centre and a tax on suburban residential developments and on offices poorly served by public transport.

It is important to draw a distinction between suburbs and sprawl. Ewing *et al.* (2002) define four dimensions in their index of sprawl, including low-density development, segregated land uses, the lack of significant centres and poor street accessibility. These are all very specific characteristics identified in chapter 2, but many suburbs in the EU have medium levels of density (Table 1 gives the figures for London), mixed land uses with major and minor centres and good street accessibility. They even match up well to Galster *et al.*'s (2001) more demanding eight dimensions of sprawl – density, continuity, concentration, clustering, centrality, nuclearity, mixed uses and proximity. Note that these measures and others (e.g. Tsai, 2005) are all physical measures of sprawl and their outcomes, and they do not analyse the underlying causes of sprawl. There are clear priorities within the EU, based on the management of land assets and a system of national and local plans that manage urban growth, to prevent urban sprawl. There is a strong emphasis on the re-use of existing developed land and infill, rather than taking more greenfield land.

The SCATTER project reinforced the negative aspects of urban sprawl (Batty *et al.*, 2003) through its focus on the unpleasant aesthetics (monotony), and the efficiency of urban form as more infrastructure is required, with wasteful commuting and a loss of land (ecological impacts). There was also discussion of its impacts on spatial segregation with a lack of social interaction, "white flight" and "ghetto-isation" of areas leading to social exclusion and unrest (as seen recently in Paris and elsewhere in urban France, where more than 10 000 cars were symbolically burned). The ecological impacts in terms of land and energy consumption are also increasing, with space consumed per capita more than doubling in the EU over the last 50 years as cities have grown (Chapter 1 and Hartog, 2005).

Several important issues are raised by these three projects that relate to urban form and sprawl.

1. The study area needs to be extended beyond the geographical limits of the city to include the labour market catchment area.
2. It is not just in cities that sprawl is taking place, but also along corridors between cities and a process of city clustering is taking place that may lead to coalescence.
3. There is a debate over whether high-quality infrastructure (road and rail) encourages longer-distance commuting (probably true), but also faster commuting to maintain a constant travel time (Chapter 4).

4. Individual policy interventions do not seem to be effective, and it is only with combined approaches that measurable benefits can be obtained – in terms of reductions in trip lengths, greater use of public transport, less fuel use and lower emissions.
5. There are many different types of urban form that can generate new patterns of land use and travel, including monocentric (mixed use) cities and polycentric (clusters, rings and linear or "beads on a string") cities that have a range of critical size, density, mixed use and other characteristics (chapter 2).
6. Most of the studies reviewed here look at different EU cities at one point in time rather than one city over a series of time points. The dynamics of city development, its urban form and structure should provide a focus for analysis, so that the process of change can be understood and so that the benefits of different types of urban form can be "locked in".
7. Empirical evidence suggests that trip lengths for all purposes are increasing rather than reducing, but that travel times remain constant. This means that faster modes (car and rail) are becoming more important, whilst slower modes (bus, cycle and walking) are becoming less attractive. But does this also mean that cities are becoming less or more efficient in terms of their economic growth potential, and in terms of their environmental "footprint" and social inclusiveness?

4. CONCLUSIONS

> "*…the structure of the modern spatial economy, where the central city is now just one of many nodes within a complex sea of urbanisation whose pricing and market structure almost defy understanding* (Krugman, 1993, quoted in Batty, 2005, p. 387)."

This quote taken from Batty summarises the difficulties of understanding and researching the spatial dynamics of urban growth and the view that there are many different types of processes at work, relating to historical accident, physical determinism, natural advantage, comparative advantage and randomness (Batty, 2005, pp. 19-22). It is in the suburbs that growth is taking place. The London example (Table 1) has over 60% of the population in the outer area and this accounts for 80% of the land area, at an average density of about one-third that of the central area. The modal shares in the two types of location also reflect this difference in density. In the inner area (20% of the land area), walking and cycling account for about 44% of all trips, with public transport and the car accounting for 34% and 22%, respectively, of all internal trips. The corresponding figures for outer London are 25% walking and cycling, 20% public transport and 55% car. It should be noted that these figures are all for 2001 and relate to internal trips within each area type. Trips between the two area types are 5% cycle and walk, 35% public transport and 60% car, and those between area trips amount to 15% of the total.

A considerable amount of empirical research has been carried out to establish relationships between travel and urban form, but much of this work is now dated, and most has used cross-sectional data. As noted above, it is important to also explore data for cities collected over several points in time, to establish the dynamics of city development and travel patterns. In recent research, Ma and Banister (2007) have extended the standard excess commuting[4] measure to capture the concept of commuting potential (measured as the difference between the maximum and minimum commuting trips), and to relate it to urban form through a series of simulation exercises. The main finding was that decentralisation of urban spatial structure can lead to either an increase or a decrease in average commuting distance. Such analysis can be used to benchmark commuting efficiency for a particular city over time. It is important to include the key socioeconomic variables as well as the urban form variables used in the simulation (Crane and Chatman, 2003).

When a similar approach was applied to the Seoul Metropolitan Area (1990-2000), it was found that commuting distance increased over time and that the maximum commuting distance also increased over time, but that the minimum commuting distance was stable or decreasing according to the different occupation categories used (Ma and Banister, 2006). When the same analysis was carried out for travel time, a very different picture emerged. Actual travel times reduce over time in Seoul (from 42.1 minutes in 1990; to 35.2 minutes in 1995; to 34.3 minutes in 2000), with similar levels of reduction being observed in both the maximum and minimum levels. A similar pattern is produced by occupation, with a greater level of travel time reduction by the work journey being measured from 1990-95 than from 1995-2000. Over a period of extensive city decentralisation, commuters have been more concerned with increasing their travel speeds rather than in reducing their travel distances. So the spatial processes of decentralisation (distance) have been countered by the economic processes of faster travel, resulting in a net reduction in travel time for the journey to work.

The complexity of cities and urban form would suggest that the mismatch between homes and workplaces can be explained by a mixture of physical and socio-economic factors, but that it is difficult (if not impossible) to isolate the exact effects of each. The role of interventions (planning and fiscal policies) should be aimed at reducing the minimum commuting trips, if the city is to operate both efficiently and sustainably. Conversely, any increase in the levels of the maximum commuting trip suggests that this is in an unsustainable direction for the city's journey-to-work patterns. In all cases, it suggests that homes and workplaces should be located close together, whether it is in the centre, the periphery or in between.

Trying to unravel the complexities of the interrelationships between travel, urban form and sustainable development is difficult. Underlying the discussion is the requirement to have some vision of the city in its desired form – it should be viable (economic justification), have vitality (inclusive and fair), and it should be healthy (high quality of life and environmental quality). Transport provides an essential element in city vitality, viability and health (Banister, 2005). The focus of this paper has been very much on how to reduce travel distances, as this physical element relates to the built environment and it is the variable that seems to be increasing over time. Other travel variables used, such as trip frequency and mode, relate more to the socio-economic characteristics of the individual. But even here (and with distance), there are strong interaction effects between the physical and social factors. This is most evident in the measurement of travel time that combines the physical (distance) with the social (choice of mode and hence speed).

The EU vision is based on maintaining the quality of urban life, urban planning and sustainable development, where mixed uses, high densities and good environmental conditions are seen as being central to both improving economic performance and the vitality of cities (CEC, 1990 and 2004). More compact settlements are seen to provide environmental and social benefits, in that they provide better access and encourage the use of healthy modes. There is less land consumption and closer levels of proximity, which in turn leads to less social segregation. Provided that quality open space is protected, there are also possibilities for local recreation. When all these factors are combined with sympathetic neighbourhood design, high-quality and inclusive city environments can be produced. However, that quality can be reduced through less space per home and a higher unit cost of housing. Environmental quality may also be reduced through higher levels of congestion and pollution, again reducing the attractiveness of these locations – this is the risk of unintended consequences (Crane and Schweitzer, 2003). The EU response here is that all these issues can be addressed through urban planning, and that land is a scarce resource which cannot and should not be left to market forces to decide on its highest value in use.

NOTES

1. The industrial revolution started in England in 1709, when Abraham Darby first smelted iron with coal at Coalbrookdale in Shropshire. But it was really Manchester that started industrialisation, with the manufacture of cotton in the 1800s (Hall, 1998a, p. 310) – it became the first and greatest industrial city in the world.

2. The Sustainable Communities Plan is seeking to deliver a much-increased supply of new housing in London and the South East by 2016. In four growth areas – the Thames Gateway, Ashford, Milton Keynes/South Midlands and London-Stansted-Cambridge-Peterborough– an additional 200 000 homes are planned above levels in current regional planning guidance. A complementary strategy is planned for the Midlands and the North, including the “Northern Way” and various Housing Renewal Pathfinder strategies, the latter of which are focused on developing the most deprived communities in the UK. The success of these growth plans is critically reliant on transport (and other) infrastructure investments.

3. Urban sprawl is defined as low-density (below 30 persons per hectare – see section 2.3), and uncoordinated urban growth, with spatially segregated land uses – this is a modified version of the definition used in the SCATTER project (Gayda, 2006).

4. Excess commuting is the difference between the actual average commuting trip distance or time and the minimum average commuting trip distance or time, and it is a measure of travel efficiency. The extended excess commuting measure takes the maximum average commuting trip so that the commuting potential within a given city’s urban form can be calculated.

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LIST OF PARTICIPANTS

Prof. Martin WACHS **Chairman**
Director
Transportation, Space, and Technology Program
Rand Corporation
1776 Main Street
P.O. Box 2138
SANTA MONICA, Ca. 90407
USA

Prof. Elizabeth DEAKIN **Rapporteur**
University of California at Berkeley
Director, UC Transportation Center
Co-Director, Center for Global Metropolitan Studies
2614 Dwight Way, 2d Floor.
BERKELEY, Ca. 94720-17282
USA

Prof. David BANISTER **Rapporteur**
Professor of Transport Planning
University College London
22 Gordon Street
GB-LONDON, WC1H 0QB
United Kingdom

Dr. Gilles DURANTON **Rapporteur**
Associate Professor
University of Toronto
Department of Economics
150 St. George Street
TORONTO, Ontario
Canada M5S 3G7

Dr. Matthew E. KAHN **Rapporteur**
Associate Professor of Economics
Tufts University
Fletcher School
MEDFORD, Ma. 02155
USA

Prof. Alex ANAS
Professor of Economics
405 Fronczak Hall
State University of New York at Buffalo
AMHERST, NY 14260
USA

Dr. Jon-Terje BEKKEN
Chief Research Economist
Institute of Transport Economics (TOI)
Department of Passenger Transport
Postboks 6110 Etterstad
N-0602 OSLO
Norway

Prof. Yossi BERECHMAN
CN Chair in Transportation and International Logistics
Henry Angus Building, Room #462
Sauder School of Business
2053 Main Mall,
University of British Columbia
VANCOUVER, BC V6T 1Z2
Canada

Prof. Marcial ECHENIQUE
University of Cambridge
Head, Department of Architecture
1-5 Scroope Terrace
GB-CAMBRIDGE, CB2 1PX
United Kingdom

Dr. Larry FRANK
Associate Professor and Bombardier Chair
School of Community and Regional Planning
University of British Columbia
West Mall Annex
1633 West Mall
VANCOUVER
Canada V6T 1Z2

Dr. Karen FRICK
Lecturer and Visiting Scholar, UC Transportation Center
University of California, Berkeley
Dept. of City and Regional Planning
228 Wurster Hall
BERKELEY, Ca. 94720-1782
USA

Prof. Jonathan GIFFORD
Professor of Public Policy
Director, Transportation Policy, Operations and Logistics Master's Program
George Mason School of Public Policy
3401 Fairfax Drive
MS 3B1
ARLINGTON, Va. 22201
USA

Dr. Aaron GOLUB
University of California, Berkeley
Lecturer and Visiting Scholar, UC Transportation Center
2614 Dwight Way, 2d Floor
BERKELEY, Ca. 94720-1782
USA

Dr. Eleni KOPANEZOU
Head, Clean Transport Unit
DG Energy and Transport
CE/EC
rue de la Loi 200
B-1049 BRUXELLES
Belgium

Dr. Kevin J. KRIZEK
Assistant Professor
Urban and Regional Planning Program
Humphrey Institute of Public Affairs
University of Minnesota
301 19th Ave. S.
MINNEAPOLIS, Mn. 55455
USA

Dr. Lewison LEM
Visiting Scholar
University of California Transportation Center
2614 Dwight Way, 2d Floor
BERKELEY, Ca. 94720-1782
USA

Dr. Kang-Rae MA
Research Fellow
University of the West of England
Centre for Transport and Society
Faculty of the Built Environment
Frenchay Campus, Coldharbour Lane
GB-BRISTOL BS16 1QY
United Kingdom

Dr. Jean-Loup MADRE
Director
Department of Transport Economy and Sociology
INRETS
2 av. du Général Malleret Joinville
F-94114 ARCUEIL Cédex
France

Prof. Arthur C. NELSON
Associate Director of the Metropolitian Institute
Director of Graduate Studies in Urban Affairs and Planning
Virginia Polytechnic Institute and State University
Washington-Alexandria Center
1021 Prince Street, Ste 200
ALEXANDRIA, Va. 22301
USA

Mr. Robert PAASWELL
Director
University Transportation Research Center
The City College of New York
138th Street & Convent Avenue
Marshak 917
NEW YORK, NY 10031
USA

Dr. Karina M. PALLAGST
Program Coordinator and Visiting Scholar
University of California, Berkeley
Institute of Urban and Regional Development
316 Wurster Hall # 1870
Berkeley, Ca. 94720-1870
USA

Prof. André de PALMA
Université de Cergy-Pontoise
THEMA
33 Boulevard du Port
F-95011 CERGY-PONTOISE
France

Prof. Rémy PRUD'HOMME
Université Paris XII Val de Marne
6, rue des Haudriettes
F-75003 PARIS
France

Prof. John QUIGLEY
Department of Economics
Evans Hall #3880
University of California
BERKELEY, Ca. 94720-3880
USA

Prof. William SATARIANO
Professor of Epidemiology and Community Health
University of California, Berkeley
102 Haviland Hall
BERKELEY, Ca.
USA

Prof. Quing SHEN
Dept. of Urban Studies and Planning
University of Maryland
Room 1215, Building 145
College Park
MARYLAND, Md. 20742
USA

Prof. Kenneth SMALL
Department of Economics
University of California, Irvine
3151 Social Science Plaza
IRVINE, Ca. 92697-5100
USA

Prof. Nigel SPENCE
University of London
Queen Mary
Department of Geography
Mile End Road
GB-LONDON E1 4NS
United Kingdom

Prof. Antonis STATHOPOULOS
National Technical University of Athens (NTUA)
Director, Railways & Transport Laboratory
Department of Transportation, Planning and Engineering
5, Iroon Polytechniou Str.
Zographou Campus
GR-15773 ZOGRAFOU (Athens)
Greece

Prof. Dr. Wendelin STRUBELT
Vice-President
Federal Office for Building and Regional Planning
Deichmanns Aue 31-37
D-53179 BONN
Germany

Prof. Matthew TURNER
Associate Professor
Department of Economics
University of Toronto
150 St. George Street
TORONTO, On.
Canada M5S 3G7

OECD/ECMT SECRETARIAT

JOINT OECD/ECMT TRANSPORT RESEARCH CENTRE

Dr. Andreas KOPP
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TRANSPORT, URBAN FORM AND ECONOMIC GROWTH

Containing sprawl is a major preoccupation of many urban planners, who view sprawl as responsible for driving up environmental costs and congestion. Nevertheless, many economists see benefits to sprawl, allowing households access to larger and cheaper properties. Some see the cycle of creation and destruction of firms and places of employment as fundamental to economic growth, with "slash and burn" development inevitably increasing sprawl. All acknowledge that there are market failures associated with this kind of development and with sprawl more generally. But intervention to contain such development can have costs that go beyond the factors normally considered in land use planning.

The Round Table examined the costs and benefits of sprawl, shedding light on the linkages between urban form and economic growth, and explored the tradeoffs involved in trying to contain sprawl. Discussions were based on papers prepared by Elizabeth Deakin (UC Berkeley), Matthew Kahn (Tufts University), Gilles Duranton (University of Toronto) and David Banister (University College London).

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