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Evaluating Transportation Land Use Impacts

Considering the Impacts, Benefits and Costs of Different Land Use Development Patterns

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Suburban Residential

Urban Commercial Center

Abstract

This paper examines ways that transportation decisions affect land use patterns and resulting economic, social and environmental impacts. These include direct impacts on land used for transportation facilities, and indirect impacts caused by changes to land use development patterns. In particular, certain transportation planning decisions tend to increase *sprawl* (dispersed, urban-fringe, automobile-dependent development), while others support *smart growth* (more compact, infill, multi-modal development). These development patterns have various economic, social and environmental impacts. This paper describes specific methods for evaluating these impacts in transport planning.

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Introduction

Land use (also called *development*, *community design*, *urban form*, *spatial planning*, and *urban geography*) refers how the earth's surface is used, including to the location, type and design of human development. Land use patterns have diverse economic, social and environmental impacts. For example, some land use patterns are more *accessible* (they require less physical travel to reach common destinations) and have lower development costs; some are relatively more accessible for non-drivers and so benefit disadvantaged people; and some preserve more greenspace and therefore preserve ecological health.

Transportation planning decisions influence land use directly, by affecting the amount of land used for transport facilities, and indirectly, by affecting land use *accessibility* ("Accessibility," VTPI, 2005) and therefore development location and design, as indicated in Table 1. For example, expanding urban highways increases pavement area, and by improving automobile access to urban fringe areas, encourages more dispersed, automobile-oriented development (commonly called *sprawl*), while public transit improvements encourage more compact, infill development (called *smart growth*).

Table 1 **Examples of Transportation Planning Land Use Impacts**

Planning Decision	Direct Impacts	Indirect Impacts
Increased parking supply.	Increases pavement area.	Reduces density and encourages urban fringe development.
Expanded urban roads.	Increases pavement area. Degrades urban landscapes.	Encourages urban fringe development.
Transit improvements.	May require new facilities (rail lines, busways, stations, etc.)	Makes urban areas more accessible and attractive.
Road pricing.	Reduces need to expand roads and parking facilities.	Mixed, depending on overall effects on accessibility and livability.

This table describes examples of transportation land use impacts.

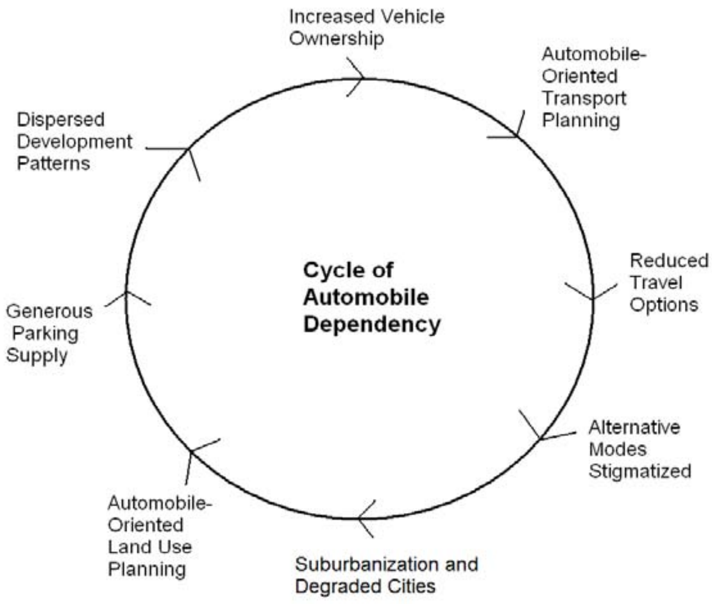
These relationships are sometime complex. There may be several steps between a particular transport planning decisions and its ultimate effects, as summarized below.

Planning Decision
(development practices, infrastructure investment, zoning, development fees, etc.)
↓
Urban Forum Patterns
(density, mix, connectivity, parking supply, etc.)
↓ ↓
Travel Behavior
(amount and type of walking, cycling, public transit and automobile travel)
Land Use
(Impervious surface coverage, greenspace, public service costs)
↓ ↓
Economic, Social and Environmental Impacts
(consumer costs, public service costs, physical fitness, crashes, pollution emissions, etc.)

There may be several steps between a planning decision, its impacts on urban form and travel behavior, and its ultimate economic, social and environmental impacts.

During the last century, many transportation and land use planning practices reinforced the cycle of increased automobile dependency and sprawl, as illustrated in Figure 1. This was generally unintended, reflecting a lack of consideration of the full impacts of these decisions. For example, when deciding how much parking to require for a particular type of land use, traffic engineers were probably not thinking about the additional sprawl that would result from a more generous standard, they simply wanted to insure motorist convenience. Similarly, planning decisions that affect roadway supply, transit service quality or roadway user fees often overlooked various land use impacts.

Figure 1 **Cycle of Automobile Dependency and Sprawl**



This figure illustrates the self-reinforcing cycle of increased automobile dependency and sprawl.

There is growing agreement among various planning professions that sprawl imposes a variety of economic, social and environmental costs on society compared with more smart growth. As a result, many professional organizations, jurisdictions and government agencies have adopted smart growth planning objectives, as summarized in the box on the next page. The disciplines of geography, urban economics, land use planning, landscape design, and environmental studies have long recognized these impacts, and the desirability of more integrated planning, but current transport planning often overlooks such impacts and objectives, particularly when evaluating relatively small, individual policies and projects, such as how much parking to require at a particular site or whether to expand a particular intersection.

Smart Growth Endorsements

Various professional, academic and government organizations have adopted Smart Growth principles and support its implementation. Below are a few examples.

AASHTO Center for Environmental Excellence (www.environment.transportation.org), American Association of State Highway and Transportation Officials. Promotes Smart Growth practices.

APA (2002), *Smart Growth Legislative Guidebook and User Manual: Model Statutes for Planning and the Management of Change*, American Planning Association (www.planning.org).

CITE (2004), *Canadian Guide to Promoting Sustainable Transportation Through Site Design*, Canadian Institute of Transportation Engineers (www.cite7.org).

Reid Ewing, Keith Bartholomew, Steve Winkelman, Jerry Walters and Don Chen (2007), *Growing Cooler: The Evidence on Urban Development and Climate Change*, Urban Land Institute and Smart Growth America (www.smartgrowthamerica.org/gcindex.html).

ITE (2003), *Smart Growth Transportation Guidelines*, Institute of Transport. Engineers (www.ite.org).

NALGEP (2004), *Smart Growth is Smart Business: Boosting the Bottom Line and Community Prosperity*, National Association of Local Government Environmental Professionals, (www.nalgep.org).

NAR (2004), *Creating Great Neighborhoods: Density in Your Community*, National Association of Realtors (www.realtor.org).

NEMO Project (www.canr.uconn.edu/ces/nemo) helps communities reduce impervious surface area and associated infrastructure and environmental costs.

SGN (2002 and 2004), *Getting To Smart Growth: 100 Policies for Implementation*, and *Getting to Smart Growth II: 100 More Policies for Implementation*, Smart Growth Network (www.smartgrowth.org) and International City/County Management Association (www.icma.org).

Land Use and Transportation Research Website (www.lutr.net), European Commission.

Smart Growth Leadership Institute (www.sgli.org) supported by the National Realtors Association (www.realtor.org) and Smart Growth America (www.smartgrowthamerica.org).

TRB (2009), *Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and CO2 Emissions*, Special Report 298, Transportation Research Board (www.trb.org); at http://onlinepubs.trb.org/Onlinepubs/sr/sr298prepub.pdf.

Urban Land Institute (www.uli.org) is a professional organization for developers which provides practical information on innovative development practices, including smart growth.

USEPA Smart Growth Website (www.epa.gov/smartgrowth) provides information on Smart Growth strategies to reduce environmental impacts.

Evaluation Framework

An *evaluation framework* specifies the basic structure of an analysis, including which impacts are considered and how they are measured and compared (Litman, 2001). A framework usually identifies:

- *Evaluation method*, such as cost-effectiveness, benefit-cost, lifecycle cost analysis, etc.
- *Evaluation criteria* are the factors and impacts considered in a particular analysis. Table 2 lists various land use impact evaluation criteria.

Table 2 **Land Use Impact Evaluation Criteria**

Economic	Social	Environmental
Value of land devoted to transportation facilities. Land use accessibility. Transportation costs. Property values. Crash damages. Costs to provide public services. Economic development and productivity. Stormwater management costs.	Relative accessibility for different groups of people – impacts on equity and opportunity. Community cohesion. Housing affordability. Cultural resources (e.g., heritage buildings). Traffic accidents. Public health (physical fitness). Aesthetic impacts.	Greenspace and wildlife habitat. Hydrologic impacts. Heat island effects. Energy consumption. Pollution emissions.

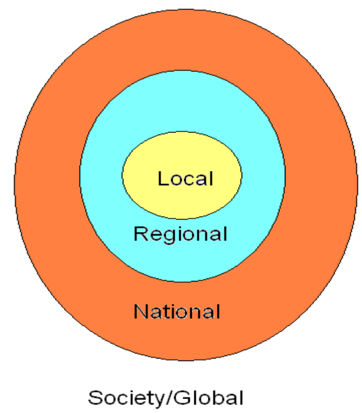
This table lists various types of land use impacts that may be affected by transport planning decisions. These impacts are described in more detail in this report.

- *Modeling techniques*, which predict how a policy change or program will affect travel behavior and land use patterns, and measure the incremental benefits and costs that result.
- *A Base Case* (also called *do nothing*), the conditions that would occur without the proposed policy or program.
- *Reference units*, such as costs per lane-mile, vehicle-mile, passenger-mile, incremental peak-period trip, etc.
- *Base year and discount rate*, which indicate how costs are adjusted to reflect the time value of money.
- *Perspective and scope*, such as the geographic range of impacts to consider.
- *Dealing with uncertainty*, such as whether sensitivity analysis or statistical tests will be used.
- *How results are presented*, so that the results of different evaluations are easy to compare.

Impacts are evaluated using a *with-and-without* test, which reflects the conditions that would occur with or without a particular policy or project. For example, the impacts of a roadway widening are the incremental changes that would occur if the project is implemented. This analysis requires defining the *base case*, the conditions that would otherwise occur if the proposed policy or project were not implemented.

Impacts can be evaluated from various perspectives, such as a particular geographic area, group, or time period. For example, residents of an area or group tend to evaluate policies based on their own benefits and costs, and may consider it desirable to externalize costs and exclude people they consider undesirable, but more comprehensive evaluation would consider these economic transfers (one person or group gains at another's expense) rather than net gains. It is usually best to consider *all* impacts, including those affecting other areas and times, although impacts to a particular group can be identified and highlighted.

Figure 2 **Analysis Perspectives**



Impacts may be evaluated from various perspectives and scales. Generally, all impacts should be considered, but some may be given special consideration.

Most analysis is primarily concerned with net impacts to society rather than the effects of *sorting* (the tendency of certain types of people to locate in certain areas). For example, it would generally be considered a benefit if a particular land use patterns increases accessibility and opportunity for disadvantaged people, and not a cost if that attracts disadvantaged people, and associated economic and medical problems to a particular area, because that is an economic transfer not a net cost (the total number of disadvantaged people does not increase, in fact, it may decline as more poor people are able to get jobs and mentally ill people are better able to access mental health services). However, policies that attract disadvantaged people to a particular area may seem undesirable to local residents and should be considered in equity analysis and as an impact that may require mitigation.

Land Use Categories

The earth's surface, called the *landscape*, is a unique and valuable resource. The landscape affects and is affected by most economic, social and environmental activities. Major land use categories are listed below.

Table 3 **Land Use Categories**

Built Environment	Openspace
• Residential (single- and multi-family housing) • Commercial (stores and offices) • Institutional (schools, public offices, etc.) • Industrial • Brownfields (old, unused and underused facilities) • Transportation facilities (roads, paths, parking lots, etc.)	• Parkland • Agricultural • Forests, chaparral, grasslands • Wildlands (undeveloped lands) • Shorelines

Land use patterns can be evaluated based on the following attributes:

- *Density* - the number of people, jobs or housing units in an area.
- *Clustering* - whether related destinations are located close together (e.g., commercial centers, residential clusters, urban villages, etc.).
- *Mix* - whether different land use types (commercial, residential, etc.) are located together.
- *Connectivity* – the number of connections within the street and path systems.
- *Impervious surface* – land covered by buildings and pavement, also called the *footprint*.
- *Greenspace* – the portion of land used for lawns, gardens, parks, farms, woodlands, etc. The *Green Area Factor* or *Green Area Ratio* (GAR) refers to the percentage of land that is greenspace.
- *Accessibility* – the ability to reach desired activities and destinations.
- *Nonmotorized accessibility* – the quality of walking and cycling conditions.

Land use attributes can be evaluated at various scales:

- *Site* – an individual parcel, building, facility or campus.
- *Street* – the buildings and facilities along a particular street or stretch of roadway.
- *Neighborhood or center* – a walkable area, typically less than one square mile.
- *Local* – a small geographic area, often consisting of several neighborhoods.
- *Municipal* – a town or city jurisdiction.
- *Region* – a geographic area where residents share services and employment options. A metropolitan region typically consists of one or more cities and various suburbs, smaller commercial centers, and surrounding semi-rural areas.

Geographic areas are often categories in the following ways:

- *Village* – Small urban settlement (generally less than 10,000 residents).
- *Town* – Medium size urban settlement (generally less than 50,000 residents).
- *City* – is a large settlement (generally more than 50,000 residents).
- *Metropolis* – a large city (generally more than 500,000 residents).
- *Urban* – relatively high density (10+ residents and 5+ housing units per acre), mixed-use development, multi-modal transportation system.
- *Suburban* – medium density (2-10 residents, 1-5 housing units per acre), segregated land uses, and an automobile-dependent transportation system.
- *Central business district* (CBD) – the main commercial center in a town or city.
- *Exurban* – low density (less than 2 residents or 1 housing unit per acre), mostly farms and undeveloped lands, located near enough to an urban area that residents often commute, shop and use services there.
- *Rural* – low density (less than 2 residents or 1 housing unit per acre), mostly farms and undeveloped lands, with a relatively independent identify and economy (i.e., residents do not usually commute, shop and use services in an urban area).

Land Use Terminology - Common Points of Confusion

The terms *city* and *urban* can refer to just a dense *central businss district* and its immediate residential neighborhoods, or a central city, or to an entire urban region, including suburbs.

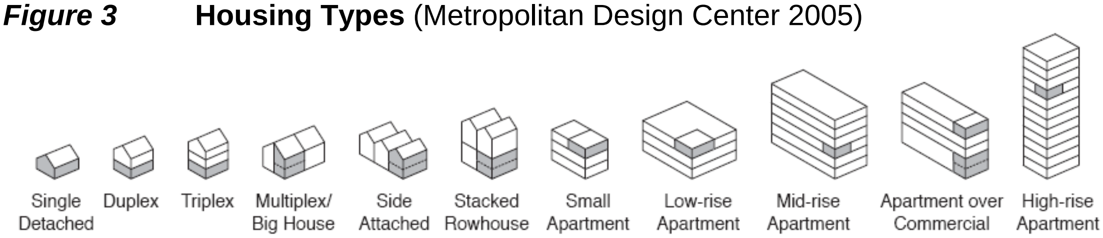
Density can be measured *net* (developable, private land only, excluding land used for roads, parks and other public services) or *gross* (all land).

Density can be measured based on *housing units, residents,* or *residents and employees*.

Housing can be categorized in various ways:

- *Small lot* – less than 7,000 square feet.
- *Medium lot* – 7,000 to 12,000 square feet.
- *Large lot* – more than 12,000 squre feet (0.3 acres)

Figure 3 **Housing Types** (Metropolitan Design Center 2005)



This illustrates various housing types.

There are growing debates about the impacts of *sprawl* compared with *Smart Growth* (Litman 2003). Table 4 compares these two development patterns.

Table 4 **Comparing Sprawl and Smart Growth** (Ewing, 1996; Galster, et al, 2001)

Attribute	Sprawl	Smart Growth
Density	Lower-density	Higher-density.
Growth pattern	Urban periphery (greenfield) development.	Infill (brownfield) development.
Activity Location	Commercial and institutional activities are dispersed.	Commercial and institutional activities are concentrated into centers and downtowns.
Land use mix	Homogeneous land uses.	Mixed land use.
Scale	Large scale. Larger buildings, blocks, wide roads. Less detail, since people experience the landscape at a distance, as motorists.	Human scale. Smaller buildings, blocks and roads, care to design details for pedestrians.
Transportation	Automobile-oriented transportation, poorly suited for walking, cycling and transit.	Multi-modal transportation that support walking, cycling and public transit use.
Street design	Streets designed to maximize motor vehicle traffic volume and speed.	Streets designed to accommodate a variety of activities. Traffic calming.
Planning process	Unplanned, with little coordination between jurisdictions and stakeholders.	Planned and coordinated between jurisdictions and stakeholders.
Public space	Emphasis on the private realm (yards, shopping malls, gated communities, private clubs).	Emphasis on the public realm (streetscapes, pedestrian environment, public parks, public facilities).

This table compares Sprawl and Smart Growth land use patterns.

Smart growth critics argue that lower-density, urban fringe development benefits consumers by increasing the supply and therefore reducing the price of large-lot housing. However, in recent years consumer demand for such housing has declined while demand for more compact, multi-modal housing has increased (Nelson 2006; Litman 2009).

How Transportation Planning Decisions Affect Land Use

Transportation planning decisions affect land use, both directly by determining which land is devoted to transport facilities such as roads, parking lots, and ports, and indirectly by affecting the relative accessibility and development costs in different locations (Moore and Throsnes 1994; Kelly 1994; Boarnet, Greenwald and McMillan 2008). In general, policies that reduce the generalized cost (financial costs, travel time, discomfort, risk) of automobile travel tend to increase total traffic and sprawl, while those that improve nonmotorized and transit travel tend to support Smart Growth, as summarized in Table 5.

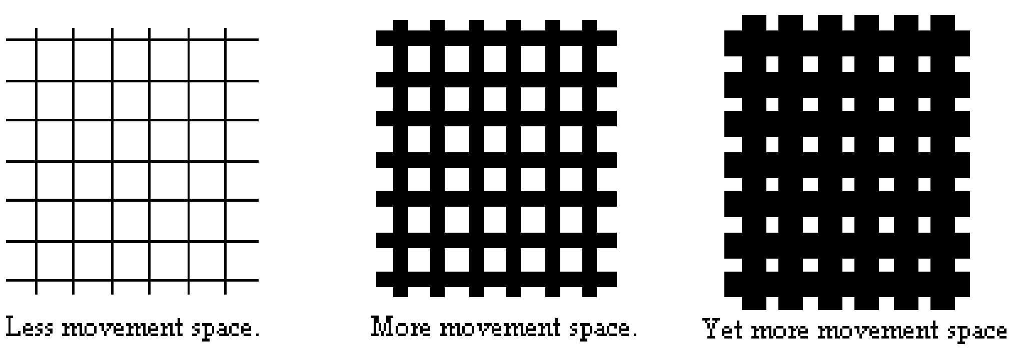
Table 5 **Transportation Policy and Program Land Use Impacts**

Encourages Sprawl	Encourages Smart Growth
Increased roadway capacity and speeds Generous minimum parking requirements. Free or subsidized parking. Low vehicle operating costs. Inferior public transit service. Poor walking and cycling conditions.	Reduced roadway capacity and speeds. Reduced parking supply. Parking pricing and management. Road pricing and distance-based vehicle fees. Transit service improvements and encouragement strategies. Pedestrian and cycling improvements. Traffic calming and traffic speed reductions. Access management and streetscape improvements.

Some types of transport planning decisions tend to support sprawl, others support Smart Growth.

Planning decisions often involve trade-offs between *mobility* (physical movement of people and goods) and *accessibility* (the ability to reach desired goods and activities). Incremental increases in road and parking capacity tend to create more dispersed land use patterns, increasing the amount of mobility required to achieve a given level of accessibility. This favors automobile travel and reduces the utility and efficiency of other transport modes, since large parking lots and wide streets create landscapes that are difficult for walking, and therefore for transit access. By increasing the amount of land required for a given amount of development, generous road and parking requirements favor urban fringe development, where land prices are lower. As a result, to some degree, automobile-dependency can be a self-fulfilling prophesy: practices to make driving more convenient make alternatives less convenient and increase automobile-oriented sprawl.

Figure 4 **Land Used for Roads and Parking**



Automobile transport requires relatively large amounts of land for roads and parking, which reduces the amount of land available for other activities. This tends to disperse destinations.

During much of the last century, many common planning practices, such as using roadway Level-of-Service to evaluate transportation system quality (as opposed to indicators that reflect multi-modal mobility or land use accessibility), and generous minimum parking requirements, unintentionally encouraged sprawl and automobile dependency. Many of these policies can be considered market distortions because they underprice vehicle travel ("Market Principles," VTPI, 2005). Smart Growth and TDM strategies can offset these trends, many of which are considered market reforms that increase economic efficiency.

It can be difficult to determine the exact land use impacts of a particular transport planning decision, particularly indirect, long-term impacts. Impacts are affected by factors such as the relative demand for different types of development, the degree to which a particular transportation project will improve accessibility and reduce costs, and how a transportation policy or project integrates with other factors. For example, if there is significant unmet demand for urban fringe development, expanding roadway capacity in that area will probably stimulate a significant amount of sprawl. Conversely, if there is significant unmet demand for transit-oriented development, improving transit service and implementing supportive land use policies (encouraging compact development around transit stations, improving area walking conditions, managing parking more efficiently, etc.) will probably stimulate Smart Growth. However, the exact impacts of a particular policy or project can be difficult to predict. Land use models can predict some but not all effects. Analysis therefore requires professional judgment.

Direct Impacts – Land Devoted To Transportation Facilities

This section investigates the amount of land devoted to transportation facilities. For more information see Arnold and Gibbons (1996), Delucchi (1996), Litman (2004c) and Manville and Shoup (2005).

Roads

Most roads have two to four lanes, each 10-14 feet wide, plus shoulders, sidewalks, drainage ditches and landscaping area, depending on conditions. Road rights-of-way (land legally devoted to roads) usually range from 24 to 64 feet wide. Most roads in developed countries are paved. In high density urban areas road pavement often fills the entire right-of-way, but in other areas there is often an unpaved shoulder that may be planted or left in its natural condition. The amount of land devoted to roads is affected by:

- Projected vehicle traffic demand (which determine the number of traffic lanes).
- Road design standards (which determine lane and shoulder widths, drainage and landscaping). Such standards are usually based on recommendations developed by professional organizations such as the Institute of Transportation Engineers (ITE) and the American Association of State Transportation and Highway Officials (AASHTO).
- On-street parking practices (whether streets have parking lanes).
- Additional design features, such as shoulders, sidewalks, ditches and landscaping.

Parking

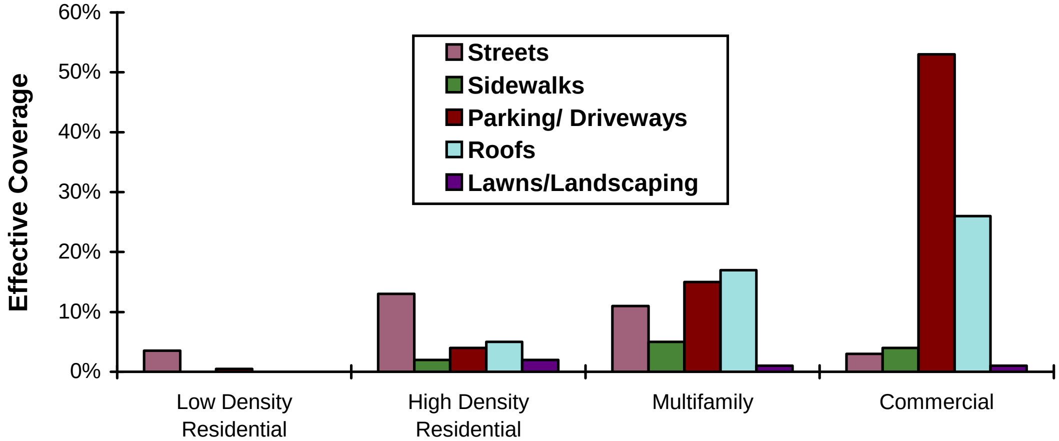
A parking space is typically 8-10 feet wide and 18-20 feet deep, totaling 144 to 200 square feet ("Parking Costs," Litman 2005a). Off-street parking requires about twice this amount (300+ square feet per space) for driveways and access lanes. Public policies affect the amount of land devoted to parking facilities. Most urban streets have one or two parking lanes that typically represent 20-30% of their width, and rural roads often have shoulders intended, in part, to provide parking. Some off-street parking facilities are provided by local governments, usually with direct or indirect subsidy (indirect subsidies include free land and property tax exemption). Most jurisdictions have zoning codes with minimum parking requirements. These minimum parking requirements are similar to a property tax to fund public parking facilities, although the owner captures any long-term capital gain if the property appreciates in value.

This suggests that there are two to three off-street parking spaces per vehicle (one residential and two non-residential), plus two urban on-street spaces. Estimates of the total number of on-street parking spaces are somewhat arbitrary since most suburban and rural roads have shoulders on which vehicles can park, but these locations have modest parking demand. The number of parking spaces per vehicle tends to be lower in urban areas where shared parking is common, and higher in suburban and rural areas where each destination its own parking lot. Structured parking reduces land requirements (a 3-story parking structure requires a third of the land used by a surface lot), and underground parking can be considered to use no additional land.

Total Amount Of Land Devoted to Transportation

Some studies have estimated the total amount of land devoted to transportation facilities (Kahn 2000; Manville and Shoup 2005; Woudsma, Litman and Weisbrod 2006). Figure 5 illustrates one analysis of urban impervious surface coverage. It suggests that 5-10% of suburban land, 20-30% of urban land, and 40-60% of commercial center land is devoted to roads and parking. This is the single largest category of impervious surface, covering twice as much land as the next category, building roofs.

Figure 5 **Surface Coverage** (Arnold and Gibbons 1996)



This figure illustrates land coverage in various urban conditions.

Table 6 shows time-area analysis applied to various transportation modes, measured in square-foot-minutes, for a 20-mile round-trip commute (10 miles each way) with 8 hours of parking (pedestrian travel has no parking requirements). In general, reducing the amount of land needed for transportation facilities reduces total impervious surface, allowing more land to be available for other productive uses such as housing, farms, parks and wildlands. Increased density tends to increase impervious surface per acre (or hectare) within a developed area, but reduces it per capita (Manville and Shoup 2005), and if the overall population is fixed, reduces total impervious surface. Urbanization therefore tends to increase land use impact intensity, but reduces per capita impacts.

Table 6 **Time-Area Requirements By Mode** (based on Bruun and Vuchic 1995)

Mode	Standing/ Parking	8 hr. Parking	Road Space	Speed	Per Mile	Per 10-Miles	Total
	Sq. Ft.	*Sq. Ft.-Min.*	*Sq. Ft.*	*MPH*	*Sq. Ft.-Min.*	*Sq. Ft.-Min.*	*Sq. Ft.-Min.*
Pedestrian	5	0	20	3	400	4,000	8,000
Bicycle	20	9,600	50	10	300	3,000	15,600
Bus	20	9,600	75	30	150	1,500	12,600
Automobile – slower	400	192,000	1,500	30	3,000	30,000	252,000
Automobile – faster	400	192,000	5,000	60	5,000	50,000	292,000

This table compares time-area requirements, measured in square-foot-minutes (square feet times the number of minutes) for a 20-mile round-trip commute with 8 hours of parking.

Indirect Impacts – How Transport Affects Land Use Development

As described earlier, automobile-oriented transport planning tends to support sprawl by increasing the amount of land required for development (particularly roads and parking facilities), by improving accessibility to urban-fringe locations, and by degrading urban environments, as summarized in the table below. Walking and transit improvements tend to have opposite effects, encouraging more compact, mixed, multi-modal development.

Table 7 **Automobile Transportation Land Use Impacts**

Land Use Factors	Impact
Impervious surface	Portion of land area that is paved for transportation facilities.
Density	Reduces density. Requires more land for roads and parking facilities.
Dispersion	Allows more dispersed urban-fringe destinations.
Mix	Allows single-use development where common services are unavailable in neighborhoods.
Scale	Requires large-scale roads and blocks.
Street design	Roads emphasize vehicle traffic flow, de-emphasize pedestrian activities.
Pedestrian travel	Degrades pedestrian environment by increasing air and noise pollution, and risk.

This table identifies how automobile-oriented transport planning supports sprawl.

One study calculates that, had the interstate highway system not been built, the aggregate population of 1950 geography central cities would have grown by 8% between 1950 and 1990 rather than declined, as observed, by 17% (Baum-Snow 2007). The tendency of automobile transportation to cause sprawl is widely acknowledged. The *Transportation and Traffic Engineering Handbook* states, "*Although there are other factors that play a role* [in urban sprawl], *reliance on the automobile has been most significant...* (Edwards, 1982, p. 401). Another transport engineering text states:

> "Automotive transportation allowed and encouraged radical changes in the form of cities and the use of land. Cheap land in the outer parts of cities and beyond became attractive to developers, much of it being converted from agricultural uses. Most of the new housing was in the form of single-family homes on generously sized lots. There is no reason to doubt that this trend will continue... Automobiles were easily able to serve such residential areas, while walking became more difficult, given the longer distances involved, and mass transportation found decreasing numbers of possible patrons per mile of route." (Homberger, Kell and Perkings 1982 p. 2-8)

It can be argued that sprawl is a land use issue rather than a transport issue, since it can be controlled by land use policies such as development restrictions and zoning codes. But such policies are often ineffective at controlling development (Knapp and Nelson, 1992). Few governments can establish and enforce effective land use controls where undeveloped land is easily accessible to urban areas. Impacts should be evaluated using a *with-and-without test*: the difference in development with and without a policy or project.

Sprawl impacts can be evaluated based on the amount of impervious surface (or *footprint*), the loss of openspace (particularly wildlands that provide ecological services such as wildlife habitat), and other disturbance activities, such as noise and dispersion of harmful chemicals which affect ecological integrity and agriculture activity.

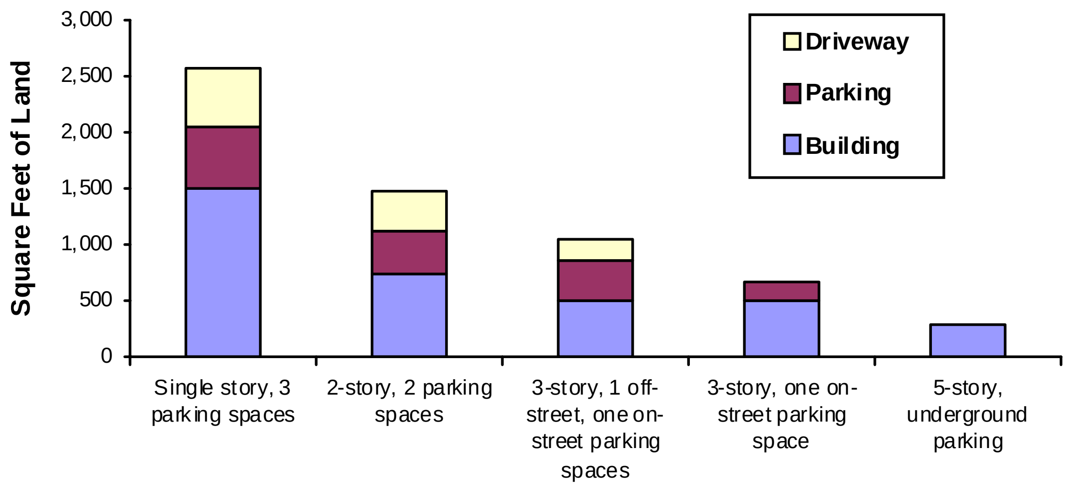
Table 8 **Development Footprint** (Square Feet)

Location	Building	Parking	Driveway	Total
1,250 sq. ft. Residential				
Sprawl, single story, 3 parking spaces.	1,500	540	540	*2,580*
Sprawl, 2-story, 2 parking spaces.	750	360	360	*1,470*
Urban, 3-story, 1 off-street, one on-street parking space.	500	360	180	*1,040*
Urban, 3-story, one on-street parking space.	500	180		*680*
Urban, 5-story, underground parking.	300			*300*
1,000 sq. ft. Commercial				
Sprawl, single story, 4 parking spaces.	1,200	720	720	*2,640*
Sprawl, 2-story, 2 parking spaces.	600	360	360	*1,320*
Urban, 3-story, 1 off-street, one on-street parking space.	400	360	180	*880*
Urban, 3-story, 1 on-street parking	400	180		*580*
Urban, 5-story, underground parking.	240			*240*

This table compares the footprint of sprawl and urban development. (Assumes gross footprint is 120% of net floor area, 180 sq. ft. per parking space, driveway area equals parking area.)

Table 8 and Figure 6 compare the footprints of different types of development. Sprawl uses two to four times as much land as medium-density urban development to provide the same amount of interior space. Even relatively modest changes in development style, from single-story suburban structures with maximum amount of parking to medium-density, 2-3 story buildings with more moderate parking supply can reduce land consumption by half. Urban fringe development impacts tend to be much larger than just the build footprint, including noise and introduced species. Residential development in an area can lead to restrictions on farming activities (called an *urban shadow*). A single large building in an otherwise natural area can reduce its aesthetic value.

Figure 6 **Footprint by Development Style** (from Table 8)



This figure illustrates the amount of land area required to provide 1,250 sq. ft of residential interior floor area with various types of development.

Costs and Benefits Of Different Land Use Patterns

This section identifies economic, social and environmental impacts affected by land use patterns, particularly the costs and benefits of sprawl and Smart Growth. For more discussion see Burchell, et al. (2002) and Litman (2004a).

Accessibility and Transportation Costs

Low-density, dispersed, automobile dependent land use patterns are less accessible, requiring more travel to reach activities (jobs, services, recreation, etc.), and reducing travel options (walking, cycling, public transit). This increases per capita transport costs, including internal costs (costs paid directly by consumers) and external costs (costs borne by society as a whole). Conversely, Smart Growth tends to reduce total transport costs.

Households in sprawled communities tend to spend significantly more money on transportation than otherwise comparable households in communities with more accessible, multi-modal land use patterns (Ewing, Pendall and Chen, 2002; Miller, 2003; USEPA, 2004; Litman, 2005b; CTOD, 2006). McCann (2000) found that households in automobile dependent areas devote more than 20% of household expenditures to transport (over $8,500 annually), while those in smart growth communities spend less than 17% (under $5,500 annually). She also found that vehicle expenditures provide little long-term economic value: $10,000 spent on motor vehicles provides just $910 in equity, compared with $4,730 for the same investment in housing.

Sprawl is particularly burdensome to lower-income households and non-drivers. In automobile-dependent locations, lower-income households devote a relatively large portion of their income to transportation, and nondrivers experience reduced accessibility and must be chauffeured by friends and family who drive. Because transit services and pedestrian facilities experience economies of scale (unit costs decline as use increases), sprawl reduces service quality and increases unit costs. This harms people with physical disabilities, as described by (Schneider and McClelland, 2005).

> Sprawling communities, automobile dependence, a lack of curb cuts on sidewalks, and strip mall stores separated from bus stops by oceans of parking: All form significant barriers to basic mobility for many people with disabilities. Worse, sprawl's rush to the suburbs is decaying the urban core, often the only place people with disabilities can find affordable housing. This raises significant safety issues for people with certain kinds of disabilities. It raises sizeable employment issues, too, as jobs move to the suburbs, where they are out of reach of people who cannot drive and lack access to good public transit… We need communities that are compact and equipped with readily accessible sidewalks, public transportation, and affordable housing. A community that works well for people with disabilities works extraordinarily well for everyone.

Described differently, Smart Growth tends to reduce transportation costs and improve mobility options for non-drivers. The relative higher costs of mobility for non-drivers is both an economic issue, because it increases costs to consumers and society, and a social equity issue, because it exacerbates inequities, as described later in this report.

Household Affordability

Land use patterns have various impacts on housing costs ("Affordability," VTPI, 2005). Sprawl reduces unit land costs (dollars per acre), and so reduces costs for larger-lot homes, while Smart Growth reduces land requirements per housing unit, reduces parking requirements, and expands housing types, but may require structured parking and increase other building costs. As a result, overall cost impacts depend on how the question is framed. For households that demand larger-lot single-family homes and generous parking supply (2+ parking spaces per housing unit), sprawl probably reduces housing costs, but for households with more flexible housing and parking preferences (they would consider a smaller-lot or multi-family home), Smart Growth often reduces housing costs. The overall value to consumers, therefore, depends on the degree of flexibility in housing preferences. Some research indicates that many suburban households would select more urban locations if they had security, quality public services (such as schools) and other social attributes currently associated with suburbs (Eppli and Tu, 2000; Litman, 2004a).

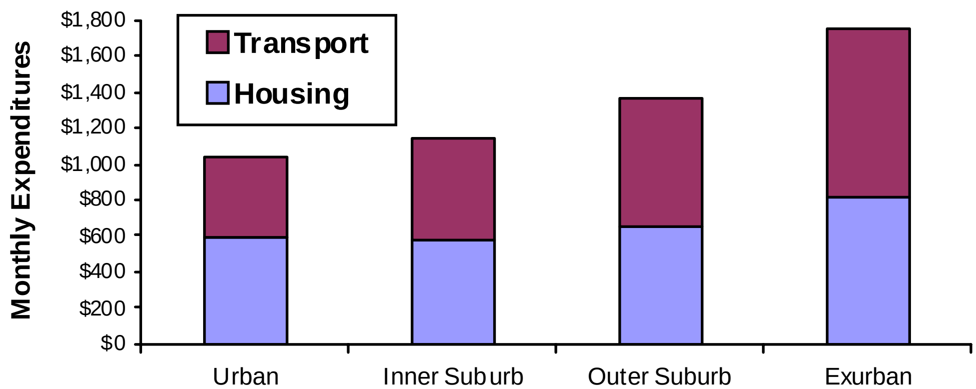
Table 9 **Smart Growth Housing Cost Impacts**

Reduces Affordability	Increases Affordability
• Urban growth boundaries reduce developable land supply, increasing unit land costs (dollars per acre). • Increases some building costs (structure parking, curbs, sidewalks, sound barriers, etc.).	• Increased density, reduced parking requirements and setback, reduces land requirements per housing unit. • More diverse, affordable housing options (secondary suites, apartments over shops, loft apartments). • Smart Growth market reforms provide financial savings for reduced parking demand and more compact development.

Many Smart Growth strategies can increase housing affordability.

Combined transportation and housing costs (an *Affordability Index*) are lowest on average in more urban locations (Lipman, 2006). The figure below illustrates these costs.

Figure 7 **Affordability Index** (CTOD, 2006)



Although housing costs vary little, transportation costs increase significantly in less urban areas.

Economic Productivity and Development

Land use patterns affect economic productivity and development ("Economic Development," VTPI, 2005). All else being equal, increased accessible and reduced transportation costs tend to increase economic productivity. Certain land use impacts affect specific industries. For example, resort communities benefit from environmental and cultural preservation that attracts visitors. To the degree that more accessible land use reduces consumers' vehicle expenses it tends to increase regional employment and business activity, as illustrated in Table 10 and Figure 8.

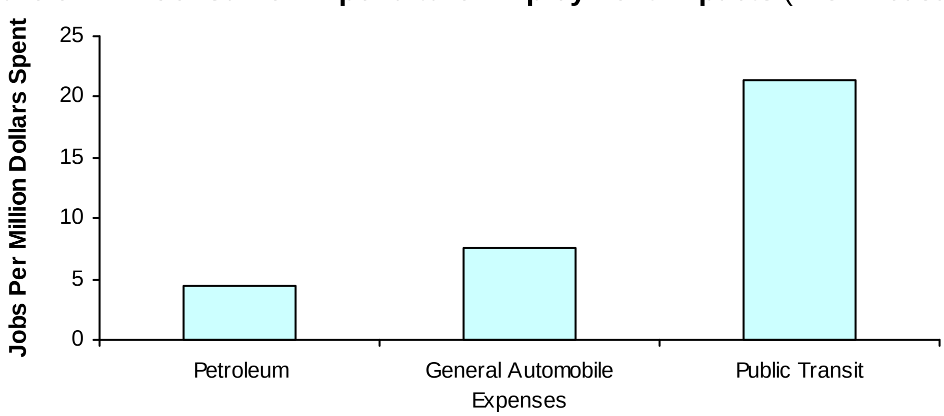
Table 10 **Economic Impacts Of $1 Million Expenditure** (Miller, Robison & Lahr, 1999)

Expenditure Category	Regional Income	Regional Jobs
Automobile Expenditures	$307,000	8.4
Non-automotive Consumer Expenditures	$526,000	17.0
Transit Expenditures	$1,200,000	62.2

This table shows economic impacts of consumer expenditures in Texas.

Many economic activities experience *agglomeration efficiencies*, that is, they are more efficient when located close together, allowing more interaction, trade and cooperation. Activities such as education, finance and creative industries are particularly affected by agglomeration. According to Bettencourt, et al. (2007), many properties have power law functions of city size that fall into distinct classes: innovation and wealth creation have increasing returns, infrastructure displays scale economies, and the pace of social life also seems to increase with city population size. Although agglomeration benefits are difficult to measure, they appear to be large (Anas, Arnott and Small 1997; Lee 1999; Muro and Puentes 2004; Graham 2007). One published study found that doubling county-level density index is associated with a 6% increase in state-level productivity (Haughwout 2000; also see discussion in Muro and Puentes 2004). More accessible, compact, mixed, connected land use patterns tend to increase employment, economic productivity, land values and tax revenues (IEDC 2006).

Figure 8 **Consumer Expenditure Employment Impacts** (B.C. Treasury Board, 1997)

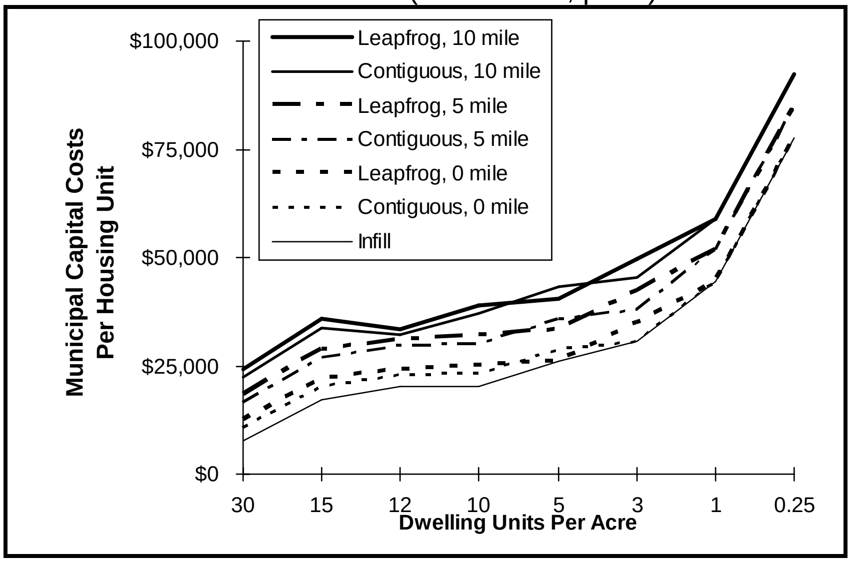


This figure illustrates the number of regional jobs created by various consumer expenditures.

Infrastructure and Public Service Costs

Sprawl tends to increase infrastructure and public service costs (Smyth 1986; Burchell, et al. 2002; CEE 1999; Muro and Puentes 2004; Litman 2004a; CMHC 2006; IBI 2008). Figure 9 illustrates how capital costs increase with development dispersion.

Figure 9 **Residential Service Costs** (Frank 1989, p. 40)



Public infrastructure costs are far higher for lower density, dispersed development.

Burchell and Mukherji (2003) found that sprawl increases local road lane-miles 10%, annual public service costs about 10%, and housing costs about 8%, increasing total costs an average of $13,000 per dwelling unit. Table 11 summarizes public costs (utilities, government services and transportation infrastructure) for three possible development patterns in the Toronto region, showing significant potential savings with more compact development. The study indicates that transportation costs and pollution also decline.

Table 11 **Public Costs of Three Development Options** (Blais 1995)

	Central	Nodal	Spread
Residents per Ha	152	98	66
Capital Costs (billion C$1995)	39.1	45.1	54.8
O&M Costs (billion C$1995)	10.1	11.8	14.3
Total Costs	*49.2*	*56.9*	*69.1*
Percent Savings over "Spread" option	*40%*	*16%*	*NA*

More spread development substantially increases public service costs.

None of the studies considers total public service costs affected by land use patterns. Some only consider capital costs, others only local government expenses. Few studies include additional costs for school busing, emergency response costs, or services provided by private utilities or businesses.

Rural residents traditionally accepted lower levels of public services such as roads (often unpaved), emergency response (often voluntary), and parks (often few). Sprawl encourages residents accustomed to urban services to locate in exurban areas and demand more services. Impact fees are used to internalize incremental public costs but are seldom adequate (Sorensen and Esseks, 1998). As a result, households in older urban areas tend to subsidize suburban residents' public costs (Guhathakurta 1998). Lancaster, California established development impact fees that reflect the infrastructure costs of a particular location, calculated by a civil engineering firm (New Rules 2002). A typical new house is charged $5,500 if located near the city and $10,800 if located a mile away. Since this fee structure was implemented, virtually all new development has located close to the city.

Table 12 **Public Services Capital Costs, Billions** (IBI 2008)

	Dispersed	Compact	Difference
Roadways	$17.6	$11.2	$6.4 (-36%)
Transit	$6.8	6.2	0.6 (-9%)
Water and Wastewater	$5.5	$2.5	$3.0 (-54)
Fire Stations	$0.5	$0.3	$0.2 (-46%)
Recreation Centers	$1.1	$0.9	$0.2 (-19%)
Schools	$3.0	$2.2	$0.8 (-27%)
Totals	$34.5	$23.3	$11.2 (-33%)

Public services infrastructure costs tend to be higher for more dispersed development.

The City of Calgary *Plan-it* program compared the costs of providing infrastructure and public services to more compact and dispersed development patterns. The study found that the more compact land use saves about a third in capital and operating costs for roads, transit services, water and wastewater, emergency response, recreation services and schools, as summarized in tables 12 and 13.

Table 13 **Public Services Operating Costs, Annual Billions** (IBI 2008)

	Dispersed	Compact	Difference
Roadways	$0.23	$0.19	$0.04 (-18%)
Transit	$0.30	$0.30	$0.00 (0%)
Water and Wastewater	$0.06	$0.03	$0.03 (-55%)
Fire Stations	$0.28	$0.23	$0.05 (-18%)
Recreation Centers	$0.23	$0.19	$0.04 (-18%)
Totals	$0.99	$0.86	$0.13 (-14%)

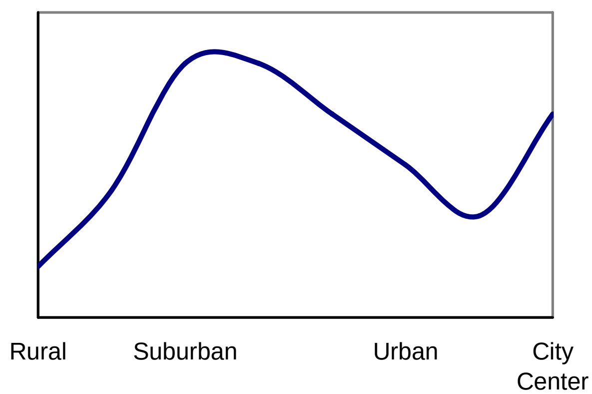
Public services operating costs tend to be higher for more dispersed development.

The relationships between density and public costs are, of course, complex. Actual costs depend on the specific location and types of services provided. There are also costs associated with increased density, including increased congestion and friction between activities, special costs for infill development, and often higher design standards. Ewing (1997) concludes that coats are:

- Lowest in rural areas where households provide their own services.
- Increase in suburban areas where services are provided to dispersed development
- Decline with clustering, as densities increase from low to moderate.
- Are lowest for infill redevelopment in areas with adequate infrastructure capacity.
- Increase at very high densities due to congestion and high land costs.

Figure 10 illustrates this pattern. Much of the public savings in rural areas are actually costs shifted from public to private budgets or reductions in service quality. Rural residents actually spend more in total on these services (SC, 1999), although the costs do not show up in public utility budgets. Cost reductions associated with increased density are true resource cost savings, reflecting reductions in total costs per unit.

Figure 10 **Land Use Impacts on Public Service Costs**

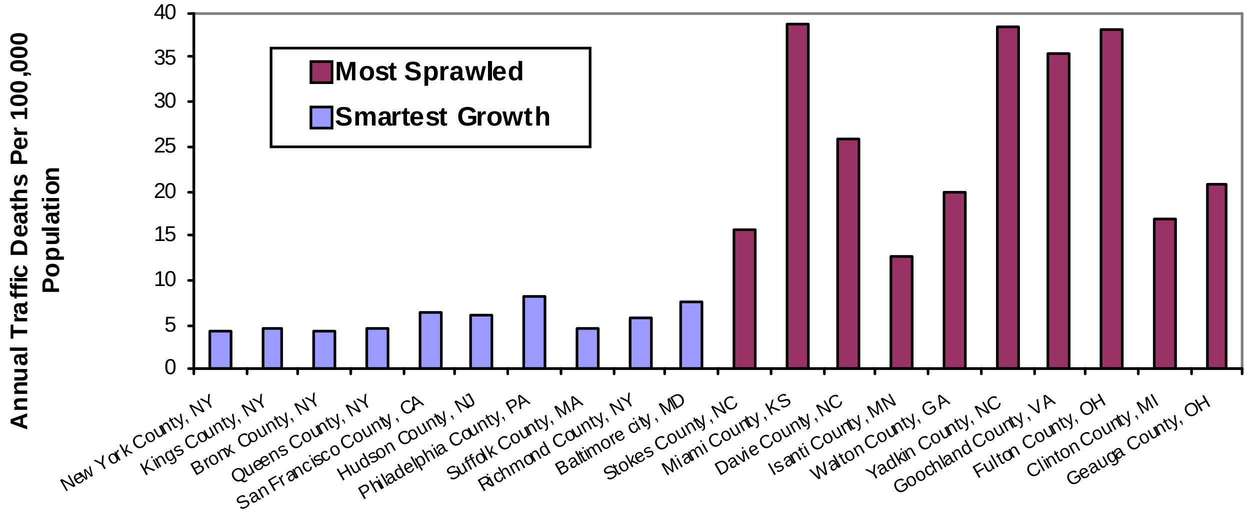


Costs are low in rural areas where public services are minimal, increase in suburban areas as more services are supplied, decline with more compact development, and increase at high densities.

Safety and Health

Land use patterns affect public safety and health (Frank, Kavage and Litman 2006; Boarnet, Greenwald and McMillan 2008). Although increased density tends to increase crash rates per vehicle-mile, it tends to reduce per capita vehicle travel and traffic speeds, which reduces crash severity and per capita traffic fatalities, as illustrated below. Urban residents have lower total violent death rates, including traffic injuries and homicide, than suburban residents (Lucy 2002).

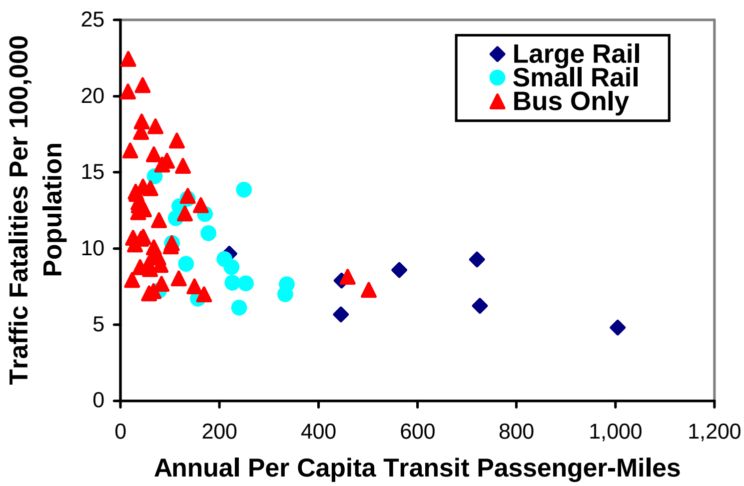
Figure 11 **Traffic Death Rate** (Ewing, Schieber and Zegeer, 2003)



The least sprawled US communities have far lower fatality rates than the most sprawled communities.

Similarly, traffic fatality rates tend to decline with increased per capita transit ridership, probably reflecting the effects of transit-oriented development on travel (Figure 12).

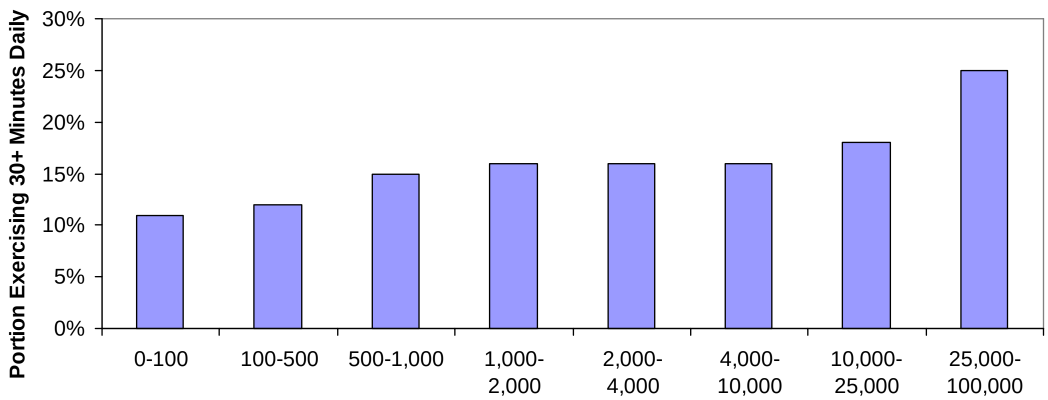
Figure 12 **U.S. Traffic Deaths** (Litman, 2004b)



Per capita traffic fatalities (including automobile occupants, transit occupants and pedestrians) declines with increased transit ridership.

The American Academy of Pediatrics (2009) argues that conventional, sprawled community design is unhealthy, particularly for children, because it discourages physical activity. Research by Lawton (2001), Khattak and Rodriguez (2003), and Gehling (illustrated in the Figure 13) indicate that residents of more urban, walkable communities are more likely to achieve recommended levels of physical activity than residents of more automobile-oriented, sprawled communities. For more discussion see Litman, 2005b.

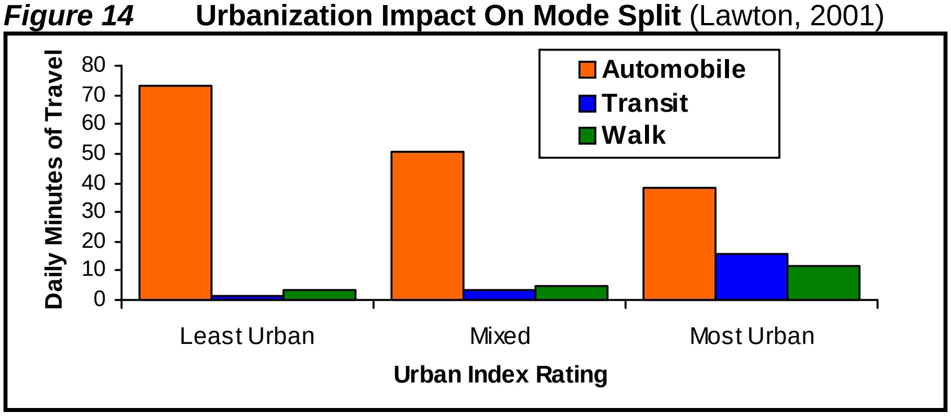
Figure 13 **Portion of Population Walking & Cycling 30+ Minutes Daily** (Unpublished Analysis of 2001 NHTS by William Gehling)



The portion of people who exercise sufficiently by active transport increases with density.

Lawton also found that increased urbanization (increased land use density, mix and roadway connectivity) increases minutes of nonmotorized travel, illustrated below.

Figure 14 **Urbanization Impact On Mode Split** (Lawton, 2001)



Frank, et al (2006) developed a *walkability index* that reflects the quality of walking conditions, taking into account residential density, street connectivity, land use mix and retail floor area ratio (the ratio of retail building floor area divided by retail land area). In King County, Washington a 5% increase in this index is associated with a 32.1% increase in time spent in active transport (walking and cycling), a 0.23 point reduction in body mass index, a 6.5% reduction in VMT, and similar reductions in air pollution emissions.

Social Inclusion

Social inclusion refers to the social and economic opportunities for people who are physically, economically and socially disadvantaged. This is both an efficiency and an equity issue, because people excluded from social and economic opportunities suffer directly, and are less productive, more dependent on social programs, and more likely to be involved in criminal and self-destructive behavior. Social inclusion therefore provides multiple benefits, including increased social equity, economic development, public cost savings, and reduced crime.

The term *social inclusion* is seldom used in North America. Planners here are more likely to say that it is important to provide *basic mobility*, which refers to transport for goods, services and activities that have high social value, such as health care, essential shopping, education and employment ("Basic Mobility," VTPI, 2005).

Sprawl tends to reduce social inclusion and increase the costs of providing basic mobility (Sanches and Brenman, 2007). Described more positively, by improving accessibility and affordable travel options (walking, cycling, ridesharing and public transit) Smart Growth tends to improve accessibility for disadvantaged people, improving their productivity and opportunities.

Community Cohesion

Community cohesion (also called *social capital*) refers to the quality of relationships among people in a community, as indicated by the frequency of positive interactions, the number of neighborhood friends and acquaintances, and their sense of community connections, particularly among people of different economic classes and social backgrounds (Forkenbrock and Weisbrod, 2001, pp. 97-106; Litman, 2007; CTE, 2008).

Land use patterns affect community cohesion in various ways. Suburban locations are often considered highly livable because they are physically segregated from disruptive activities, traffic, poverty and crime. However, the automobile travel they generate tends to reduce community cohesion overall, by increasing vehicle traffic impacts through neighborhoods, degrade walking and cycling conditions, and reducing opportunities for neighborhood interaction. Many suburban neighborhoods lack sidewalks, neighborhoods shops and other public places where neighbors naturally congregate. Researcher Donald Appleyard (1981) reported a negative correlation between vehicle traffic and measures of neighborly interactions, including number of friends and acquaintances residents had on their street, and the area they consider "home territory." He comments (1981, p. 35):

> "The activities in which people engage or desire to engage in may affect their vulnerability to traffic impact. So many of these activities have been suppressed that we sometimes forget they exist...Children wanting to play, and people talking, sitting, strolling, jogging, cycling, gardening, or working at home and on auto maintenance are all vulnerable to interruption [by traffic]...One of the most significant and discussed aspects of street life is the amount and quality of neighboring. Its interruption or 'severance' has been identified as one of the primary measures of transportation impact in Britain."

Many households prefer lower-density, suburban neighborhoods, but this partly reflects social attributes such as security, quality schools and prestige, rather than unique physical attributes, such as larger lawns (NAHB, 1999). This suggests that some households would choose Smart Growth locations if they had such amenities. Demand for New Urbanist communities, loft apartments and urban infill is strong where they offer personal security, school quality and prestige comparable to suburbs. Eppli and Tu (2000) found that New Urbanist community homes sold for an average of $20,189 more than otherwise comparable homes in more conventional communities, an 11% increase in value. Heart and Biringer (2000) calculate that 43% of homebuyers who currently choose rural and suburban locations are good candidates for higher density, traditional neighborhood developments.

This suggests that, although urban neighborhoods often have more social problems than suburban neighborhoods, urbanization does not *cause* social problems. Rather, these problems reflect the tendency of automobile dependent suburbs to offload social problems onto more accessible, multi-modal urban neighborhoods. Total regional social problems are likely to decline if Smart Growth can improve overall social inclusion in a region, helping disadvantaged people access education and employment.

Environmental Impacts

Road and sprawl environmental impacts are widely recognized by land use planners and ecologists (Noonan 1996; Flad 1997; Forman, et al 2003; White 2007). Ecologically active lands such as wetlands, forests, farms, and parks (collectively called *greenspace* or *openspace*) provide external benefits, including wildlife habitat, air and water quality, and beauty (Brabec 1992; Quammen 1996; Kauffman 2001; Ewing and Kostyack 2005). These external benefits exist in addition to direct benefits to landowners and are not reflected in land's market value (Knaap and Nelson 1992, p. 126). Some of these benefits result from the contribution that an ecological system makes toward market goods, such as fishery production or water quality. Other values are reflected in the tendency of greenspace to increase nearby property values and tourism, and in existence, option, and bequest values (Kopp and Smith 1993; Munasinghe and McNeely 1995; Sherer 2006). Banzhaf and Jawahar (2005) identify the following benefits from preserving undeveloped urban fringe lands:

1. Protecting groundwater.
2. Protecting wildlife habitat.
3. Preserving natural places.
4. Providing local food.
5. Keeping farming as a way of life.
6. Preserving rural character.
7. Preserving scenic quality.
8. Slowing development.
9. Providing public access.

A number of studies indicate that proximity to high traffic roads reduces residential property values due to noise and air pollution effects, while proximity to greenspace tendst to increase property values. Kang and Cervero (2008) studied how the Cheong Gye Cheon (CGC) project in Seoul, Korea, which involved converting a freeway into an urban park, affected property values. They found that freeway proximity reduced residential property values and increased non-residential property values, and that both residential non-residential properties within 500 meter were generally worth more when the freeway was replaced by an urban stream/linearpark. While proximity to freeway on-ramps was valued by residential properties, this benefit was offset by nuisance effects of noise, dust, fumes, and visual blight for residences within several kms of the structure.

Roads and parking facilities have *hydrologic impacts*, which refers to changes in the natural surface and groundwater flows (Litman, 2005). This concentrates stormwater, which increases flooding, scouring and siltation, and reduces surface and groundwater recharge which lowers dry season flows, and creates barriers to fish. These impose both economic costs and ecological costs. Paved surfaces have *heat island* effects, causing ambient summer temperatures to rise 2-8° F in urban areas (Stutz, 1995, USEPA, 1992). These higher temperatures increase energy demand, smog and human discomfort. Although per acre impacts tend to increase with density, impacts per capita tend to decline (Arnold and Gibbons, 1996; USEPA, 2006).

Researchers Richard Forman and Robert Deblinger (2000) studied the ecological effects of a 25-kilometer stretch of four-lane highway through urban, suburban and rural areas, taking into account roadkills, habitat loss, traffic noise, barrier effects to wildlife, introduction of exotic species, water pollution and hydrologic impacts (such as changes in wetlands drainage). They found that the road-effect zone averages 600 meters wide, with some effects being even more dispersed. Extrapolating these results the researchers calculated that roads influence approximately 20% of continental United States.

Reed Noss (1995), Havlick (2002), and Forman, et al (2003) identify various types of ecological damages caused by roads, listed below. Forman, et al (2003, p. 136) identifies road density thresholds (maximum road-miles per square mile) for various habitats.

- *Roadkills*: Animals killed directly by motor vehicles. More than 1 million large animals are killed annually on U.S. highways, representing more than 8% of all reported crashes (Hughes and Saremi, 1995). Roadkills increase with traffic speeds and volumes. Road kills are a major cause of death for many large mammals, including several threatened species.
- *Road Aversion and other Behavioral Modifications*: Some animals have an aversion to roads, which may affect their behavior and movement patterns. For example, black bears cannot cross highways with guardrails. Other species, on the other hand, become accustomed to roads, and are therefore more vulnerable to harmful interactions with humans.
- *Population Fragmentation and Isolation*: By forming a barrier to species movement, roads prevent interaction and cross breeding between population groups of the same species. This reduces population health and genetic viability.
- *Pollution*: Road construction and use introduce a variety of noise, air and water pollutants.
- *Habitat Impacts*: This includes loss of habitat, invasion of exotic species, and other effects.
- *Impacts on Hydrology and Aquatic Habitats*: Road construction alters watersheds through changes in water quality and water quantity, stream channels, and groundwater.
- *Access to Humans*: This includes hunters, poachers, and irresponsible visitors.

Some land use impacts, such as loss of wetlands and threats to endangered species, receive considerable attention and affect transport decisions. But it is impossible to address each impact individually. Doing so implies that only a few types of land use impacts are significant. A better approach is to apply a general model for assessing the value of any type of land. Various valuation techniques can be used to estimate the overall external environmental value of different land use categories and specific sites (Johansson 1987; Kopp and Smith 1993). The Urban Forest Effects (UFORE) Model developed by the U.S. Forest Service (www.fs.fed.us/ne/syracuse/About/about.htm) can be used to define and quantify various forest functions and values of urban trees air pollution, greenhouse gases and global warming, and building energy use.

Table 14 shows one evaluation of environmental benefits provided by selected land uses.

Table 14 **Environmental Benefits By Land Use Category** (Bein, 1997)

	Air Quality	Water Quality	Eco-logic[a]	Flood Control	Recrea-tion[b]	Aes-thetic	Cul-tural[c]	Eco-nomic[d]
Wetlands	High	High	High	High	High	High	High	High
Pristine Wildlands	High	High	High	Varies	High	High	High	Varies[e]
Urban Greenspace	High	High	Medium	Medium	High	High	High	Varies[e]
2nd Growth Forest	High	High	Medium	High	High	Varies	Medium	Medium
Farmland	Medium	Medium	Low	Medium	Low	Varies	Medium	Varies
Pasture/Range	Low	Medium	Low	Low	Low	Varies	Medium	Low
Mixed Urban	Low	Low	Low	Low	Varies	Varies	Varies	High
Highway Buffer	Low	High	Low	Low	Low	Low	Low	Low
Pavement	None	None	None	None	None	None	None	Varies

Notes
a. Include wildlife habitat, species preservation and support for ecological systems.
b. Includes hunting, fishing, wildlife viewing, hiking, horse riding, bicycling, etc.
c. Includes preservation of culturally significant sites, and traditional activities such as harvesting resources.
d. Includes economic benefits to people who do not own the land, such as tourism, fishing and hunting.
e. Reflected in tourism and recreational expenditures, increased adjacent property values, water resources quality and availability, and fisheries.

Energy Consumption and Pollution Emissions

Smart Growth tends to reduce per capita energy consumption and pollution emissions, by reducing per capita vehicle travel and supporting other energy conservation strategies such as shared building walls and district heating (USEPA 2002; Mindali, Raveh and Salomon 2004; Ewing, et al. 2007; Glaeser and Kahn 2008), although it can increase exposure to local emissions such as carbon monoxide, particulates and noise. The following land use factors can affect energy consumption and emissions:

- *Density* (the number of people and businesses in a given area) and *clustering* (common destinations located close together) affects the distances that people must travel, and the potential of transit, walking and cycling.
- *Land use mix* (the diversity of land uses in an area) affects trip distances and the feasibility of nonmotorized transportation.
- *Major activity centers* (locate employment, retail and public services close together in walkable commercial centers) increases the feasibility of transit use and allows people to make personal and business errands without driving.
- *Parking management* (flexible minimum parking requirements, shared parking, priced parking and regulations to encourage efficient use of parking facilities) affects the relative price and convenience of driving, and affects land use density, accessibility and walkability.
- *Street connectivity* (the degree to which streets connect to each other, rather than having deadends or large blocks) affects accessibility, including the amount of travel required to reach destinations and the relative speed and convenience of cycling and walking.
- *Transit Oriented Development* (locating high-density development around transit stations) makes transit relatively more convenient, and can be a catalyst for other land-use changes.
- *Pedestrian Accessibility* and traffic calming affect the relative speed, convenience and safety of nonmotorized transportation.

Although individually each of these factors has relatively modest travel impacts, residents of traditional communities that incorporate most or all of these factors tend to drive 20-40% less than otherwise comparable residents of automobile-dependent communities (Litman, 2005b; Norman, MacLean and Kennedy 2006). A USEPA study (2004) found that regardless of population density, transportation system design features such as greater street connectivity, a more pedestrian-friendly environment, shorter route options, and more extensive transit service tend to reduce per-capita vehicle travel, pollution emissions, congestion delays and traffic accidents.

Aesthetic Impacts
Roads and traffic also reduce natural environmental beauty and cause urban blight (Hoyle and Knowles, 1992; Passonneau, 1996). The *Transportation and Traffic Engineering Handbook*, (Edwards, 1982, p. 396), the USDOT's *Environmental Assessment Notebook* (USDOE, 1997, p. 29-4) all cite visual aesthetic degradation as major negative impacts of roads. William Shore argues that an automobile oriented urban area is inherently ugly because retail businesses must "shout" at passing motorists with raucous signs, because so much of the land must be used for automobile parking, and because the settlement pattern has no clear form.

The value of attractive landscapes is indicated by their importance in attracting tourism and increasing adjacent property values. Segal estimates that a 3/4 mile stretch of Boston's Fitzgerald Expressway reduced downtown property values by the equivalent of $600 million by blocking waterfront views (Segal, 1981). Amortized, this cost averages $1.30 to $2.30 per expressway vehicle trip. This is an extreme case, but indicates that aesthetic degradation from roads may impose significant aesthetic costs. Public and professional surveys can be used to evaluate such aesthetic impacts on the landscape (Huddart, 1978). When such techniques were used in a survey visual quality ratings consistently declined as the size of the road construction increased.

In a study by Professor Wolf (2002), consumers were shown photos of retail streets with and without trees to residents in various US cities and asked how much they would pay various items at each location. Participants indicated that they were willing to pay nearly 12% more to shop on treed streets than on treeless ones. They perceived shops on tree-lined streets as better maintained, having a more pleasant atmosphere, and as likely having higher quality products. Participants also indicated that they were willing to travel farther to those shops (expanding the customer pool) and to pay more for parking.

The study, *Measuring the Economic Value of a City Park System* (Harnik and Welle 2009) describes numerous benefits from urban parks and openspace, and identifies the following as suitable for quantification:

- Increased property values
- Tourism value
- Direct use value
- Public fitness and health value
- Community cohesion value
- Reducing urban stormwater management costs
- Reduced air pollution

Cultural Preservation
Transportation facilities and sprawl sometimes threaten unique cultural resources, such as historic buildings, sacred land areas, neighborhood parks, older neighborhoods and towns, and traditional building styles. By reducing per capita land requirements and providing greater design flexibility, Smart Growth can avoid or reduce these impacts, allowing cultural preservation. Smart Growth also supports urban redevelopment, which helps preserve existing towns and cities, and urban neighborhoods.

Consumer and Economic Impacts

Critics argue that smart growth harms consumers and the economy by reducing housing options and restricting automobile travel. Table 15 evaluates the consumer and economic efficiency impacts of various smart growth strategies. Most of these strategies directly benefit the people affected by improving their housing and transport options and increasing efficiency. Many strategies correct existing market distortions that reduce housing and transportation options.

Table 15 **Smart Growth Consumer Impacts** (Litman 2009)

Strategy	Examples	Consumer Impacts	Economic Impacts
More integrated transport and land use planning	Better sidewalks and bikelanes around schools. Commercial development concentrated along transit routes.	Most consumers benefit from improved accessibility and transport options.	Tends to reflect good planning and increase overall efficiency.
Location-efficient development	More affordable housing located in accessible areas.	Benefits lower-income residents who choose such housing.	Responds to consumer demand and increases efficiency.
More flexible zoning codes	Allow more compact and mixed development.	Benefits consumers who prefer more compact, affordable housing options.	Responds to consumer demands and increases efficiency.
Reduced and more flexible parking requirements.	Reduced parking requirements in response to geographic, demographic and management factors (more sharing and pricing of parking)	Benefits consumers who prefer more compact, affordable housing options, particularly those who own fewer than average cars.	Responds to consumer demands and increases efficiency. Can provide significant savings and benefits.
Growth control	Urban growth boundaries that limit urban fringe development.	Harms consumers who demand large-lot housing where supply is inadequate.	Increases automobile-dependency and associated costs.
Transportation funding shifts	Reduced funding for roadway expansion and increased funding for walking and cycling facilities and public transit service improvements.	People who prefer alternative modes benefit directly. Motorists may have less capacity, but can benefit from reduced chauffeuring requirements, and reduced congestion if better alternatives cause mode shifts.	Can increase efficiency if there is demand for alternative modes and if mode shifting reduces problems such as congestion and accidents.

Most smart growth strategies directly benefit consumers and increase economic efficiency.

Two strategies may harm some consumers. Growth controls can prevent some consumers who want large-lot homes from obtaining the housing option they prefer, if there is a significant shorting of supply. However, there is currently an oversupply of such housing across North America and no indication that shortages will develop in the future (Leinberger 2008). Similarly, shifting funding from highways to other modes can harm motorists who care nothing about other travel options, if the investments are inefficient and so do nothing to reduce congestion or accident risk, but if such investments are efficient even people who continue driving may benefit overall.

Optimal Level of Sprawl

This analysis indicates that lower-density, urban-fringe development imposes various economic, social and environmental costs, including many costs that are external and not effectively considered in conventional planning. These are market distortions that result in economically excessive levels of sprawl and automobile use (Litman, 2001; Lewyn, 2005). Some critics argue that sprawl provides benefits that offset these costs, but they generally underestimate costs and miss-classify internal benefits as external (Litman, 2003). A variety of market reforms would be needed to determine the level of urban fringe development that is truly optimal. Implementing them would increase economic efficiency and equity ("Smart Growth Market Reforms," VTPI, 2005).

Environmental and Social Benefits?
A 1978 report by Gamble and Davinroy argues that highways provide environmental and social benefits. Here are typical quotations from the report:

Aesthetics: *"The freeway can provide open space, reduce or replace displeasing land uses, enhance visual quality through design standards and controls, reduce headlight glare, and reduce noise."* and "*Regarding the visual quality of the highway and highway structures, freeways may create a sculptural form of art in their own right. Some authors note that the undulating ribbons of pavement possessing both internal and external harmony are a basic tool of spatial expression."*

Wildlife: *"Freeway rights-of-way may be beneficial to wildlife in both rural and urban environments..."*

Wetlands: *"The intersection of an aquifer by a highway cut may interrupt the natural flow of groundwater and thus may draw down an aquifer, improving the characteristics of the land immediately adjacent to the highway."*

Native plants: *"Roadside rights-of-way can be among the last places where native plants can grow."*

Neighborhood Benefits: *"Highways, if they are concentrated along the boundary of the neighborhood, can promote neighborhood stability."* and *"Old housing of low quality occupied by poor people often serves as a reason for the destruction of that housing for freeway rights of way."*

Social Benefits: *"Highways can increase the frequency of contact among individuals..."* and *"Good highways facilitate church attendance."*

Recreation: "*Freeways cutting across, through, under, and around the cities afford an excellent opportunity for innovations in recreation planning and design."*

Additional claimed environmental benefits include improved air quality, energy savings, and reduce traffic noise. Urban benefits include removal of blighted housing and slums, support of mass transit, reduced accidents, greater safety for pedestrians – particularly school children, improved community values, civic pride, increased social contacts between diverse social groups, increased upward social mobility, in-migration of better educated families, and increased housing opportunities for racial minorities. Land use benefits include suburban growth, decentralization, industrial parks, shopping malls, commercial development at freeway interchanges, and drive-in businesses.

Evaluation Techniques

It would be inaccurate to say that current transport planning totally ignores land use impacts. Many projects undergo extensive review to identify, and if possible mitigate, negative impacts (FHWA, 1999; Forkenbrock and Weisbrod, 2001). However, current planning practices have several weaknesses:

- Little or not analysis is performed for many transportation decisions. For example, no environmental analysis is required when minimum parking requirements are raised.
- Many impacts are outside the scope of standard analysis. For example, impacts on accessibility, community cohesion and housing affordability are often overlooked.
- Environmental analysis tends to focus on special, individual values and impacts, such as risks to a unique environmental or cultural resource. Damage to more common habitats or features are often given little consideration even if cumulative impacts are large.
- Land use impacts are generally only evaluated during project planning. There is seldom review of existing policies and facilities. For example, there is no system to convert existing, underutilized roads and parking facilities back to greenspace.

As described earlier, comprehensive evolution of land use requires several steps, as summarized in the table below. The following pages describe techniques for evaluating land use impacts in transportation planning. For more information see Litman, 2001. These techniques are not mutually exclusive, they can be applied in combinations as appropriate.

Table 16 **Steps Between A Decision And Its Ultimate Effects**

	Physical Effects	Impacts
1. Direct impacts of transportation facilities	Amount of land paved for transportation facilities	• Greenspace preservation • Stormwater management costs • Heat Island effect • Transportation facility land values. • Development costs and affordability • Adjacent property values • Aesthetics
2. Changes in development patterns	Location, density and mix of development (degree of sprawl or Smart Growth).	• Greenspace preservation • Public service costs
3. Land use accessibility and transport diversity	Dispersion of common destinations, and quality of travel options.	• Changes in per capita vehicle travel • Equity and opportunity • Area property values
4. Quality of public realm	Quality of sidewalk environment, and other places where people often interact.	• Quality of community cohesion • Certain economic activities
5. Travel activity	Per capita motor vehicle ownership and use.	• Consumer transportation costs • Accidents • Energy and pollution impacts • Physical fitness and public health

There may be several steps between a transport planning decision and some of its ultimate effects.

Comprehensive Project Analysis

One approach is to improve existing evaluation practices is to expand the range of land use impacts considered in planning ("Comprehensive Transport Planning," VTPI, 2005). This gives more consideration to the land use impacts identified in this report. Each impact can be described, and as much as possible quantified and monetized. Below is a list of impacts to consider and potential indicators.

Land Use Impact Checklist

Impact	Examples of Indicators
Economic	
Land value	Amount of land used for transportation facilities and its estimated value.
Land use accessibility	Number of public services and jobs within 30-minute travel time.
Transportation costs	Household expenditures on transportation.
Crash damages	Number of traffic crashes, injuries and deaths. Economic value of crash damages.
Public service costs	Costs of providing public services, including roads, utilities, garbage collection, emergency response, school transportation, etc.
Economic development	Economic productivity, employment, business activity, property values and tax revenues. Costs to governments and businesses, and agglomeration efficiencies.
Stormwater management	Costs of providing stormwater management.
Others	
Social	
Equity of opportunity	Relative level of accessibility and transport affordability for disadvantaged people (e.g., non-drivers and low income people) relative to more advantaged people.
Community cohesion	Quality of public realm (sidewalks, streets, parks, etc.), and frequenty of positive interactions among community residents.
Housing affordability	Amount of affordable housing available or planned.
Cultural resources	Preserviation of heritage buildings, historic sites, etc.
Public health	*Traffic safety* (per capita injuries and deaths), *physical fitness* (portion of the population that achieves minimal levels of daily physical activity) and *pollution exposure* (portion of population exposed to unacceptable levels of pollutants).
Aesthetic impacts.	Aesthetic quality of the landscape.
Others	
Environmental	
Impervious surface	Amount of land paved for transport facilities, and resulting hydrologic impacts and heat island effects.
Openspace preservation	Quantity and quality of greenspace (farms, forests, parks, etc.) and wildlife habitat.
Energy consumption and pollution emissions	Per capita energy consumption and emissions of air, water and noise pollution.
Others	

This table lists various land use impacts often resulting from transportation planning decisions.

Monetized Impact Evaluation

It is often possible to *monetize* (measure in monetary units) nonmarket impacts such as aesthetics and safety, so they can be incorporated in economic analysis along with market impacts (Banzhaf and Jawahar 2005; Litman 2005a). Such values can be used to calculate the external benefits provided by greenspace, and therefore the costs of developing or paving such land (TPL 2007). These include environmental and aesthetic benefits to nearby residents (reflected in 5-20% increase in nearby property values and tax revenues) and avoided public service costs (compared with the land being developed), additional farmland productivity, improved air and water quality, and support for certain businesses (such as tourism and fisheries).

Table 17 illustrates a generic cost structure. For each hectare of land converted from its current use (left column) to another use (top row), the dollar value in the intersection cell indicates the change in external environmental benefits. For example, converting land from second-growth forest to pavement hass an environmental cost valued at $60,000 per hectare. Indirect impacts (traffic noise, pollution, introduced species) to land within 500 meters of a road can be considered to impose half these cost.

Table 17 **Land Conversion Costs** (1994 CA$/hectare; Bein, 1997)

Land Use Categories	Wetlands	Pristine Wildland/ Urban Greenspace	Second Growth	Pasture/ Farmland	Settlement / Buffer	Pavement
Wetlands	0	-20,000	-40,000	-60,000	-80,000	-100,000
Wildland/Urban Greenspace	20,000	0	-20,000	-40,000	-60,000	-80,000
Second Growth Forest	40,000	20,000	0	-20,000	-40,000	-60,000
Pasture/Farmland	60,000	40,000	20,000	0	-20,000	-40,000
Settlement / Buffer	80,000	60,000	40,000	20,000	0	-20,000
Pavement	100,000	80,000	60,000	40,000	20,000	0

Using this table: For each hectare of land converted from its current use (left column) to another use (top row), the dollar amount in the intersection cell indicates the change in environmental value.

For example, a proposed road project requires paving 20 hectares of farmland and 10 acres of second growth forest, will lead to development on 10 hectares of second growth forest, and will cause noise and pollution impacts to 5 hectares of wetland, 20 hectares of second growth forest and 30 hectares of farmland. Table 18 summarizes these costs.

Table 18 **External Environmental Costs Calculation Example**

Land Use Impact	Hectares	Cost Per Hectare (From Table 13)	Half Cost for Indirect Impacts	Totals
Farmland to Pavement	20	$40,000	--	$800,000
Second Growth Forest to Pavement	10	$60,000	--	$600,000
Second Growth Forest to Settlement	10	$40,000	--	$400,000
Wetland noise and pollution	5	$80,000	x 0.5	$200,000
Second Growth noise and pollution	20	$40,000	x 0.5	$400,000
Farmland noise and pollution	30	$20,000	x 0.5	$300,000
Totals	*95*		--	*$2,700,000*

This table illustrates an example of calculating the environmental costs of a roadway project.

Planning Objectives

Another method, called *Multiple Accounts Evaluation*, is to rate and compare options relative to specific planning objectives, as illustrated in the tables below. Ratings can be developed by technical experts, a public survey or an advisory committee.

Table 19 **Evaluation Matrix Example**

	Improved Accessibility	Reduced Crashes	Improved Mobility for Non-drivers	Reduced Pollution Emissions
Option 1	High	High	Medium	High
Option 2	Medium	Very Harmful	High	Medium
Option 3	High	Medium	High	Low
Option 4	Low	High	Harmful	High

Each option is evaluated according to how well it helps achieve each objective.

A more quantitative system can be used. For example, each option can be rated from 5 (best) to -5 (worst) for each objective. These ratings are then summed to create total points for each project, as illustrated in Table 20. This gives each objective equal weight.

Table 20 **Evaluation Matrix Example – With Point Ratings**

	Improved Accessibility	Reduced Crashes	Improved Mobility for Non-drivers	Reduced Pollution Emissions	Total Points
Option 1	4	4	3	4	*16*
Option 2	3	-4	5	3	*7*
Option 3	5	3	4	1	*13*
Option 4	2	4	-3	5	*8*

Each option is evaluated according to how well it helps achieve each objective.

The objectives can be weighted, as shown in Table 21. The weight factors are multiplied times each rating, which are summed to give weighted total points. This approach begins to converge with standard Benefit-Cost analysis if points are considered to represent dollar values.

Table 21 **Evaluation Matrix Example – With Weighted Points**

	Improved Accessibility	Reduced Crashes	Improved Mobility for Non-drivers	Reduced Pollution Emissions	Total Points
Weight	*5*	*4*	*2*	*5*	
Option 1	4 (20)	4 (16)	3 (6)	4 (20)	*62*
Option 2	3 (15)	-4 (-16)	5 (10)	3 (15)	*24*
Option 3	5 (25)	3 (12)	4 (16)	1 (5)	*50*
Option 4	2 (10)	4 (16)	-3 (-6)	5 (25)	*40*

Each option is evaluated according to each objective, and each objective is assigned a weight. These are multiplied (values in parenthesis) and summed to obtain total points for each option.

Examples and Case Studies

Many communities have implemented planning studies which evaluate the impacts of various transportation and land use policies. The DVRPC (2008) is a good example. Table 22 summarizes its analysis results.

Table 22 **Indicator Recentralization Trend Sprawl**

	Recentralization	Trend	Sprawl
Core Cities Population	1,880,000	1,690,000	1,100,000
Core Cities Employment	948,000	844,000	595,000
Vehicles	3,530,000	3,600,000	3,910,000
Average Vehicles per Household	1.5	1.5	1.7
Percent Households in Core and Developed Communities	67.6%	61.3%	45.7%
Percent of Jobs within Core Cities	30.1%	26.8%	18.9%
New Acres of Development from 2005 to 2035	5,800	169,000	478,000
Percent of Region Developed	39.4%	46.1%	58.8%
Average Acres per Household	0.28	0.34	0.45
Change in the Number Households with Transit Access	190,000	92,400	(159,000)
Change in the Number of Jobs with Transit Access	257,000	192,000	(83,500)
Annual Vehicle Miles Traveled (billions of VMT)	47.0	48.7	50.0
Annual Vehicle Hours Traveled (billions of VHT)	1.53	1.59	1.64
Annual VMT per Capita	7,650	7,920	8,120
Annual VHT per Capita	248	258	266
Annual Vehicle Trips (billions)	7.60	7.80	8.29
Annual Crashes	62,400	64,600	66,600
Average Peak Period Roadway Speed (mph)	30.2	29.7	28.6
Annual Vehicle Hours of Delay (millions)	124	144	171
Annual Hours of Delay per Capita	23.8	27.7	32.9
Annual Transit Trips (millions of unlinked trips)	4187	367.9	256.7
Annual Pedestrian Trips (millions)	590.4	554.3	465.0
Residential & Transport Energy Use Per Household (m BTUs)	331	339	349
Residential & Transport CO_2 Emissions per Capita (tons)	8.1	8.3	8.5
Annual Household Automobile & Utility Expenses (2008 $)	$ 14,770	$ 15,070	$16,060
Infrastructure Costs per New Housing Unit (2008 $s)	$ 28,600	$ 37,400	$ 53,300
Jobs Added to Environmental Justice Communities	79,400	17,300	(151,000)

This analysis indicates that smart growth development can provide the following benefits:

- Openspace (farm and woodlands) preservation.
- Reduced per capita automobile travel resulting in reduced traffic congestion delay, energy consumption, pollution emissions and traffic accidents.
- Increased portion of household and jobs with access to public transportation.
- Increased walking and cycling activity.
- Reduced utility and transportation costs.
- More jobs located in economically disadvanted communities.

Conclusions

Transportation planning decisions can have many direct and indirect land use impacts. These impacts are often significant and should be considered when evaluating a particular policy or project. Conventional transport planning often overlooks some of these impacts, particularly when evaluating a single policy or project.

The relationships between transportation and land use are complex. Comprehensive analysis of transportation land use impacts includes consideration of:

- Impacts of lands used for transportation facilities.
- Impacts on the location, type and cost of development.
- Impacts on accessibility and travel options.
- Impacts on travel behavior.

Table 23 lists various types of impacts to consider. Many of these categories have various subcategories.

Table 23 **Transport Land Use Impacts**

Economic	Social	Environmental
Value of land devoted to transportation facilities	Equity and opportunity	Greenspace and wildlife habitat
Land use accessibility	Community cohesion	Hydrologic impacts
Transportation costs	Housing affordability	Heat island effects
Property values	Cultural resources	Energy consumption
Crash damages	Public fitness and health	Pollution emissions
Costs to provide public services	Aesthetic impacts	
Economic development		
Stormwater management costs		

This table lists various types of land use impacts that should be considered in transport planning.

More comprehensive analysis of these impacts can help integrate transportation and land use planning, resulting in transport decisions that better support land use objectives, and land use decisions that support transport objectives. For example, it can help planners determine which congestion reduction strategies support strategic community development objectives, and therefore help reduce infrastructure costs, improve accessibility for non-drivers and preserve openspace.

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