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Evaluating Transportation Land Use Impacts

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

24 March 2016

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Abstract
This report examines ways that transportation decisions affect land use patterns, and the 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 report describes specific methods for evaluating these impacts in transport planning.

Originally published as
"Land Use Impact Costs of Transportation,"
World Transport Policy & Practice, Vol. 1, No. 4, 1995, pp. 9-16.

Contents

Introduction

Land use development patterns (also called *urban form*, *built environment*, *community design*, *spatial development*, and *urban geography*) refer to human use of the earth's surface, including the location, type and design of infrastructure such as roads and buildings. Land use patterns can have diverse economic, social and environmental impacts: some some require less impervious surface (buildings and pavement) per capita and so preserve more openspace (gardens, farmland and natural habitat), and some are more accessible and so reduce transportation costs to businesses and consumers.

Transportation planning decisions influence land use directly, by affecting the amount of land used for transport facilities, and indirectly, by affecting the location and design of development. For example, expanding urban highways increases pavement area, and encourages more dispersed, automobile-oriented development (sprawl), while walking, cycling and public transit improvements encourage compact, infill development (smart growth).

Planning Decision
(development practices, infrastructure investment, zoning, development fees, etc.)
↓
Urban Forum Patterns
(density, mix, connectivity, parking supply, etc.)
↓ ↓

Travel Behavior	**Land Use**
(amount and type of walking, cycling, public transit and automobile travel)	(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 transport planning decision, its impacts on urban form and travel behavior, and its ultimate economic, social and environmental impacts.

These relationships are complex. There may be several steps between a transport planning decision and its ultimate effects, and a particular planning deicison can have a variety of impacts and costs, as illustrated above. Table 1 summarizes these impacts.

Table 1 **Transport Planning Land Use Impacts and Costs**

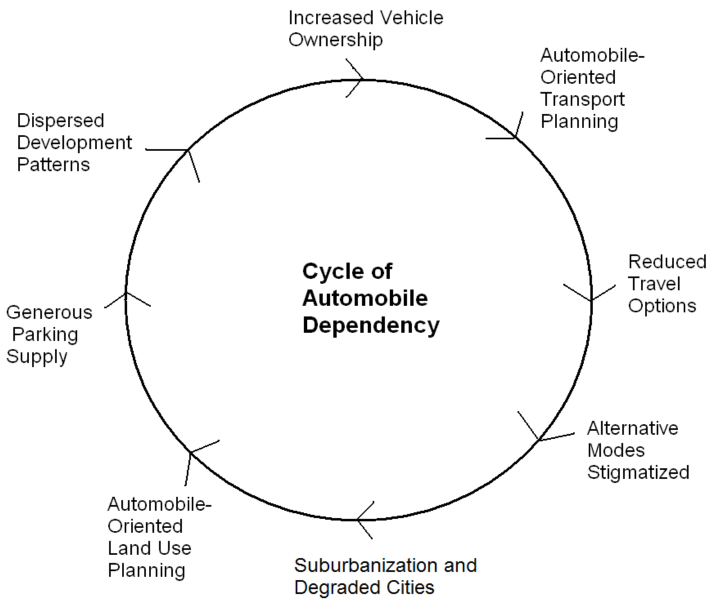
Increased Pavement Area	More Dispersed Development
• Reduced openspace (gardens, parks, farmlands and wildlife habitat). • Increased flooding and stormwater management costs. • Reduced groundwater recharge. • Aesthetic degradation.	• Reduced openspace (farmlands and wildlife habitat). • Longer travel distances, more total vehicle travel. • Reduced accessibility for non-drivers, which is inequitable (harms disadvantaged people). • Increased vehicle traffic and resulting external costs (congestion, accident risk, energy consumption, pollution emissions).

This table summarizes various land use impacts and costs from transport planning decisions.

Historical Context

During the last century, many transportation and land use planning practices reinforced a 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 ensure 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.

Smart growth can provide various economic, social and environmental benefits. 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.

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.

AIA (2005), *What Makes a Community Livable? Livability 101*, American Institute of Architects (www.aia.org); at www.aia.org/aiaucmp/groups/aia/documents/pdf/aias077949.pdf.

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); at www.epa.gov/dced/getting_to_sg2.htm.

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.

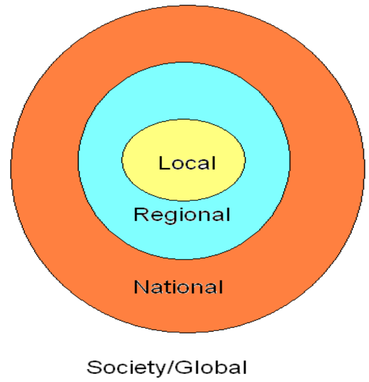
This table lists various types of land use impacts that may be affected by transport planning decisions. These impacts are described in more detail in this report.

- *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 with more condiseration to those that are more local.

Some analyses are concerned with impacts within a given area, measured per acre or square kilometer, while others are concerned with impacts per capita. For example, smart growth policies that encourage more compact, infill development tend to increase impervioius surface coverage (the portion of land covered with buildings or paved for roads and parking facilities) within existing urban areas, but tends to reduces per capita and total regional impervious surface area.

Most analysis is primarily concerned with net impacts to society rather than the effects of *self selection* (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 pattern 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 categorized 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).
- *Metropolitan region or metropolis* – a large urban region (generally more than 500,000 residents) that usually consists of one or two large cities, and various smaller cities and towns (called *suburbs*). This development pattern is considered a *polycentric*.
- *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.

Common Issues of Confusion in Land Use Evaluation

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. For example, when people claim that "more than a third of the land in cities is paved" or "urban housing is primarily highrise" they are usually referring to central business districts and possibly inner neighborhoods. Pavement area and highrise housing rates are much lower for an entire city or urban region.

Density refers to people, jobs or housing per unit of land area (acre, hectare, square-kilometer or -mile). *Density* can be measured *net* (only developable land, excluding roads, parks and utility rights-of-way) or *gross* (all land). Density is generally associated with other land use factors including centricity, mix, roadway connectivity, transport diversity (good walking, cycling and public transit service), and efficient parking management. Together these are called *compact development* or *urbanization*. Because density is relatively easy to measure, it is often used as an indicator of this set of factors.

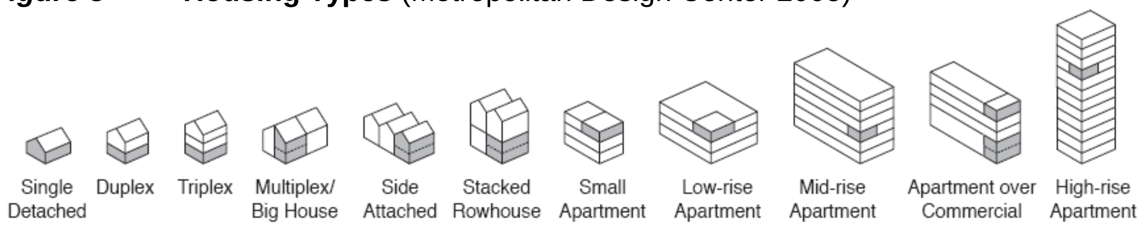
Analysis can vary depending on *scale, location and time*. For example, some studies evaluate land use factors (such as the relationships between density and annual vehicle travel) at the neighborhood level and others at the county or regional level. Smaller scale analysis tends to be more difficult but accurate.

Self-selection can affect land use patterns. For example, people who, due to necessity or preference, rely on alternative modes, tend to locate in more urban, multi-modal locations, so part of the differences in per capita automobile travel between urban and suburban locations may reflect self-selection. It would therefore be inappropriate to assume that an individual who shifts from a suburban to an urban location will change their travel patterns to reflect local averages: a car enthusiast who moves to a transit-oriented neighborhood may continue to drive and avoid using public transit.

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 often debates about different development patterns, generally termed *sprawl* and *smart growth* (Aurbach 2003; Litman 2003). Table 4 compares these patterns. There is often confusion about exactly how these patterns should be defined and measured. For example, some analyses only consider density, while others only consider population growth outside of existing cities, neither of which accurately reflects the full set of relevant factors.

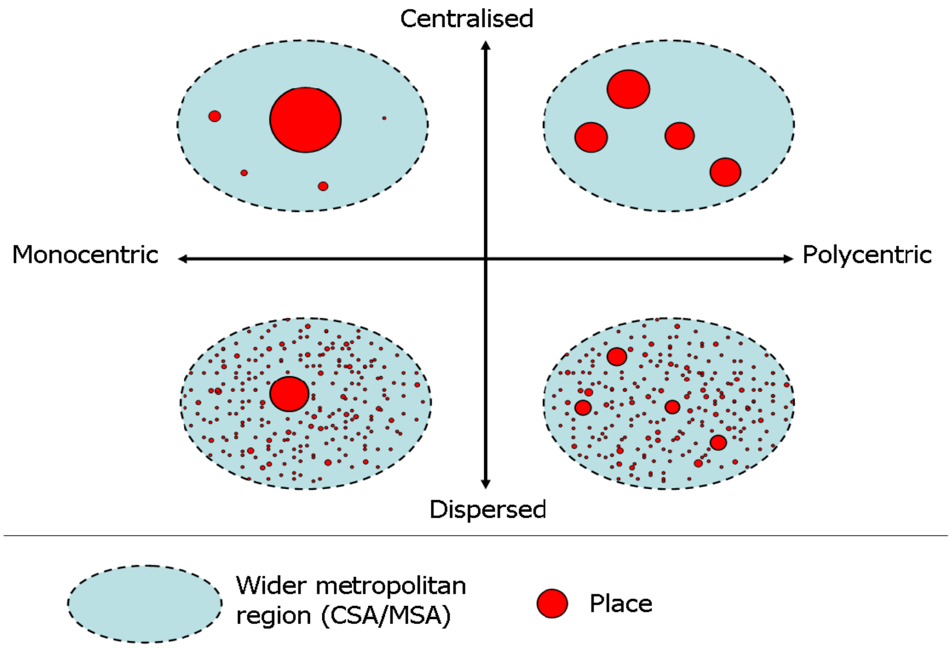
Table 4 **Comparing Sprawl and Smart Growth** (SGN 2011)

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, sidewalks, public parks, public facilities).

This table compares Sprawl and Smart Growth land use patterns.

Most metropolitan regions are polycentric, consisting of a central business district surrounded by smaller commercial centers, and a central city surrounded by smaller cities and towns. Sprawl refers to dispersed development in low-density, single-use, automobile-dependent development areas outside of any city or town; population growth in cities and towns outside existing cities is not necessarily sprawl if the development pattern reflects smart growth principles.

Figure 4 **Development Patterns** (Meijers and Burger 2009)



Most metropolitan regions are polycentric, with various business districts, cities and towns. Sprawl consists of dispersed, low-density, automobile-dependent development outside any urban area.

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 (Kelly 1994; Boarnet, Greenwald and McMillan 2008; OTREC 2009). 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.

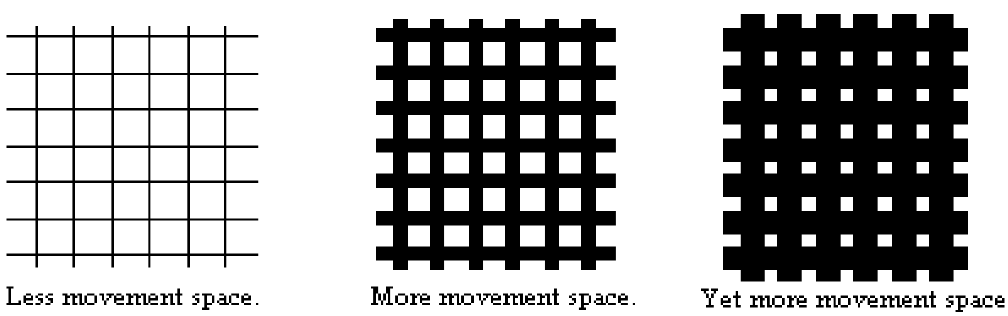
Table 5 **Transportation Policy and Program Land Use Impacts**

Encourages Sprawl	Encourages Smart Growth
Increased roadway capacity and speeds	Reduced roadway capacity and speeds.
Generous minimum parking requirements.	Reduced parking supply.
Free or subsidized parking.	Parking pricing and management.
Low vehicle operating costs.	Road pricing and distance-based vehicle fees.
Inferior public transit service.	Transit service improvements and encouragement strategies.
Poor walking and cycling conditions.	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 supply create more dispersed land use patterns, increasing the travel distances required to achieve a given level of accessibility. This favors automobile travel and reduces the utility and efficiency of other transport modes. By increasing the amount of land required for a given amount of development, higher road and parking requirements favor urban fringe development, where land prices are lower. As a result, automobile-oriented planning is self-fulfilling: practices to make driving more convenient make alternatives less convenient and increase automobile-oriented sprawl.

Figure 5 **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), Litman (2009 and 2011); Manville and Shoup (2005); and Woudsma, Litman and Weisbrod (2006).

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 2009). 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 has 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.

Amount Of Land Devoted to Transportation

Some studies have estimated the total amount of land devoted to transport facilities (Bruun 2014; Manville and Shoup 2005; Woudsma, Litman and Weisbrod 2006; Litman 2006d). Space requirements tend to increase with vehicle size and speed. For example, a vehicle traveling on an urban arterial at 30 miles-per-hour (mph) requires about 12 feet of lane width and 60 feet of lane length, or about 720 square feet in total, but at 60 mph this increases to 15 feet of lane width and 140 feet of length, or about 2,100 square feet in total. A bus requires about three times a much road space (measured as "passenger car equivalents") but typically carries 30-60 times as many passengers under urban-peak conditions. Private vehicles (bicycles and automobiles) also require parking when not used, ranging from about 20 square feet for a bicycle to 200-400 square feet for an automobile.

Table 6 **Space Required By Travel Mode**

Mode	Average Speed	Moving Area	Parking Area
	Miles/Hr	Sq. Feet	Sq. Feet
Walking	3	12	Not Appropriate
Bicycling	10	60	32
Motorcycle	30	720	150
Bus Transit	20	50	Not Appropriate
Solo Driving – Urban Arterial	30	720	300
Solo Driving - Highway	60	2,100	300

The space required to travel and park varies significantly by mode.

Various studies have investigated the amount of land used for parking facilities. Davis, et al. (2010) used detailed aerial photographs to estimate the number of surface parking spaces in Illinois, Indiana, Michigan, and Wisconsin. Parking lots were identified as paved and striped surfaces or where more than three cars were parked in an organized fashion, which excluded on-street and structured parking spaces, and residential parking spaces not in parking lots. They identified more than 43 million parking spaces in these four states, which averages approximately 2.5 to 3.0 off-street, non-residential parking spaces per vehicle. They estimate that these four states allocate 1260 km^2 of land to parking lots, with a lower bound estimate of 976 km^2 and an upper bound of 1,745 km^2. This accounts for approximately 4.97% of urban land, with a higher proportion of land devoted to parking in areas where urban sprawl is more prevalent.

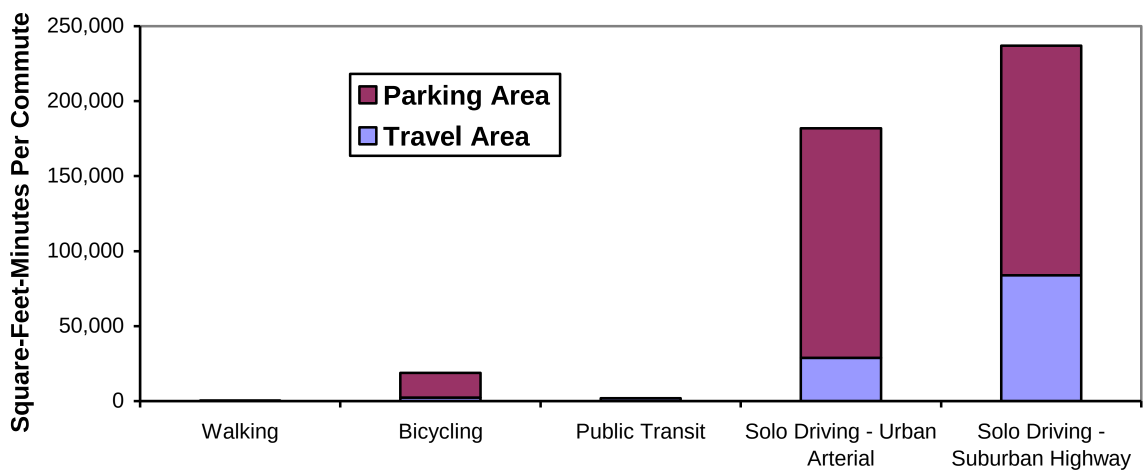
Chester, et al. (2015) estimate parking in Los Angeles County (CA) from 1900 to 2010 and how parking infrastructure evolves, affects urban form, and relates to changes in automobile travel. They estimate that since 1975 the ratio of residential off-street parking spaces to automobiles in is close to 1.0, with the greatest density of parking spaces is in the urban core, while most new growth in parking occurs outside of the core. In total, 14% of Los Angeles County's incorporated land is committed to parking. Pijanowski (2007) found approximately three non-residential off-street parking spaces per vehicle in Tippecanoe County, a typical rural county. Using GIS datasets, Hulme-Moir (2010) calculated that in Porirua, New Zealand, 24% of the central city district land area is parking facilities, compared to 7% green space and 4% recreation.

McCahill and Garrick (2012) compared 12 U.S. cities to evaluate the relationships between parking supply, population density and commute mode share. The findings suggest that on average each increase of 10 percentage points in the portion of commuters traveling by automobile is associated with an increase of more than 2,500 m2 of parking per 1,000 people and a decrease of 1,700 people/km2. Even for shorter trips within each city had much higher automobile mode share in cities with more parking supply. Analysis by Shin, Vuchic and Bruun (2009) indicates that automobile-oriented transport improvements tend to cause more dispersed, lower-denstiy development than high quality public transit.

An urban arterial traffic lane can typically accommodate about 1,000 peak-period vehicles. If the average urban automobile commuter drives 10 kilometers each way on a 3-meter wide lane, each requires 60 square meters of additional road space (3m width x 10,000m length x 2 daily commutes ÷ 1,000), plus two to four parking spaces (one at home, one at work, and a share at other destinations) that average 10 square meters for curb parking or 20 square meters for off-street parking. Each additional urban motorist therefore requires 80 to 140 square meters of land for additional road and parking space to avoid increasing traffic and parking congestion.

Bruun and Vuchic (1995) measure total space requirements by multiplying space and time. Figure 6 illustrates the total travel and parking space required for typical 20-minute commutes by various modes, measured in square-feet-minutes. Automobiles require much more space due to their size, speed and parking requirements.

Figure 6 **Space Required By Travel Mode**



Automobile travel requires far more space for travel and parking than other modes.

Table 7 illustrates this in a slightly different way: it shows the number of passengers that can be carried by various modes by a four-meter lane.

Table 7 **Typical Maximum Passengers Per 4-Meter Lane-Hour**

Arterial	Freeway	HOV	Bike Lane	Walkway	Arterial Bus Lane	Bus Rapid Transit	Rail Line
800-1,100	1,800-2,400	4,000-8,000	5,000-10,000	5,000-10,000	8,000-12,000	20,000-30,000	40,000-60,000

Roadway capacity varies by mode. (= 1,000 people)

In practice, automobile transport does not necessarily increase transport land requirements 15-100 times, since even cities built before the automobile often had wide roads to accommodate wagon traffic and provide sunlight. Under optimal conditions, (such as on a congested urban freeway) vehicles often follow much closer together than safety experts recommend, reducing road space requirements by 20-50% than this analysis indicates, but other conditions (such as inclement weather) require even greater space requirements than indicated. Newman and Kenworthy (1999, Table 3.9) found that automobile dependent cities average about 7 meters of road length per capita, while less automobile-dependent cities average about 2.5 meters, and parking supply follows a similar pattern. This indicates that automobile-oriented transportation increases facility land requirements 3 to 5 times. Put differently, 66% to 80% of the land devoted to roads and parking facilities in modern cities results from the greater space requirements of automobile transport.

In addition, motor vehicle traffic tends to reduce development density indirectly by increasing the need for sidewalk and building setbacks to avoid traffic noise and dust, so larger boulevards, highways shoulders and front lawns can be considered, in part, a land use cost of motor vehicle transport.

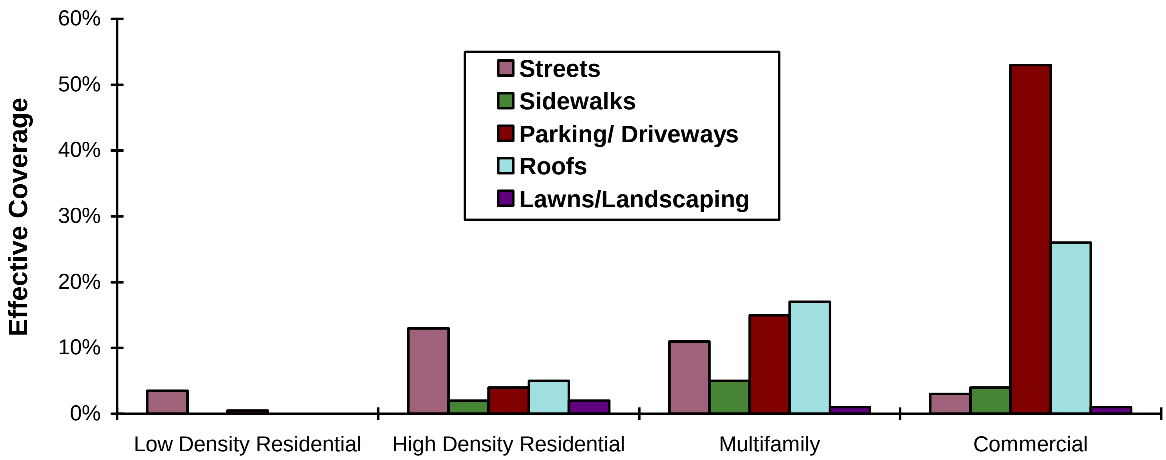
Although it is possible to build overhead highways and underground parking facilities that minimize land consumption, they are costly, and often exacerbate traffic problems by increasing local vehicle traffic. For example, each additional lane added to an urban center highway typically adds 5,000 additional vehicles a day to surface streets, increasing local traffic problems. In practice, even wealthy cities with aggressive highway building programs cannot accommodate unlimited automobile travel demand.

Compare this with other urban land uses. A typical urban resident uses about 100 square meters of land for a small-lot (400 sq. m.) single-family home with four residents, and less for multi-family housing (townhouses, condominiums and apartments). A typical employee needs about 10 square meters of office space or about 30 square meters for retail. This indicates that an automobile requires more land than a typical urban resident uses for housing, jobs and commercial activities. Automobiles more than double the amount of land required per capita.

This means that a square kilometer of urban land can accommodate up to 10,000 automobiles if completely paved for roads and parking facilities, assuming 100 square meters per vehicle, but this would leave no land for other purposes. If a neighborhood wants to devote just 20% of land to roads and parking facilities in order to leave significant space for homes, businesses, schools, parks and gardens, it can only accommodate about 2,000 vehicles per square kilometer.

Figure 7 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. Ebrahimian, Gulliver and Wilson (2015), develop a method for measuring "effective" impervious area (EIA), which refers to the portion of total impervious area that is hydraulically connected to the storm sewer system, as opposed to areas where stormwater runoff flows into local ground or surface water. For information on methods for measuring impervious surface area see Janke, Gulliver and Wilson (2011).

Figure 7 **Surface Coverage** (Arnold and Gibbons 1996)



This figure illustrates land coverage in various urban conditions.

Indirect Impacts – How Transport Affects Land Development

As previously described, automobile-oriented transport planning tends to cause more dispersed, automoible-oriented development (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 (Leo Tidd, et al. 2013). Walking and transit improvements tend to have opposite effects, encouraging more compact, mixed, multi-modal development.

Table 8 **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.

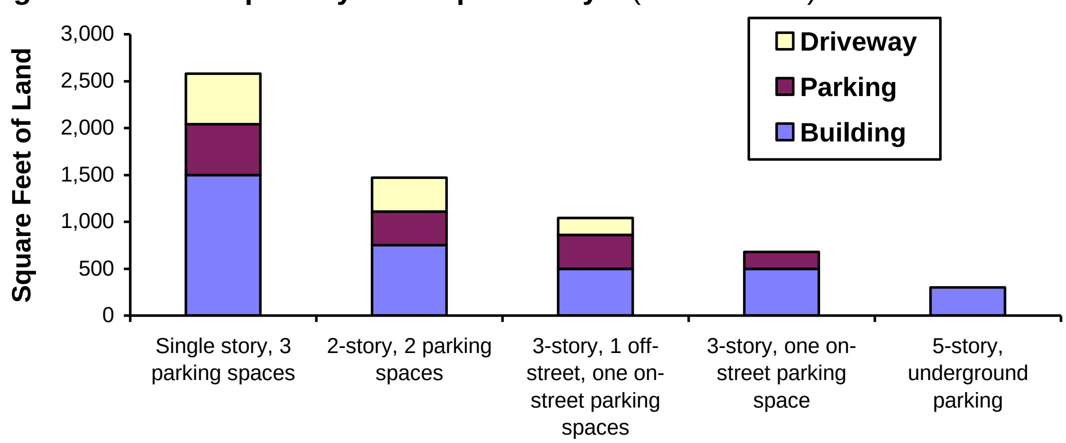
Table 9 **Development Footprint** (Square Feet)

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 9 and Figure 8 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 8 **Footprint by Development Style** (from Table 8)



The amount of land area required for a 1,250 sq. ft unit varies by development type.

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), Ewing and Hamidi 2014, and Litman (2004a).

Accessibility and Transportation Costs

People sometimes assume that by increasing development density smart growth increases traffic congestion (Melia, Parkhurst and Barton 2011), but this is not necessarily true. A study by the Arizona Department of Transportation found less traffic congestion on roads in more compact urban neighborhoods than in lower density suburban neighborhoods due to more mixed land use (particularly more retail in residential areas) which reduces trip lengths, more nonmotorized and public transport use, and a more connected street networks which substantially reduced vehicle travel on major roadways (Kuzmyak 2012). Analysis of the number of destinations that can be reached within a given travel time by mode (automobile and transit) and purpose (work and non-work trips) for about 30 US metropolitan areas indicates that increased proximity from more compact and centralized development is about ten times more influential than vehicle traffic speed on a metropolitan area's overall accessibility (Levine, et al. 2012).

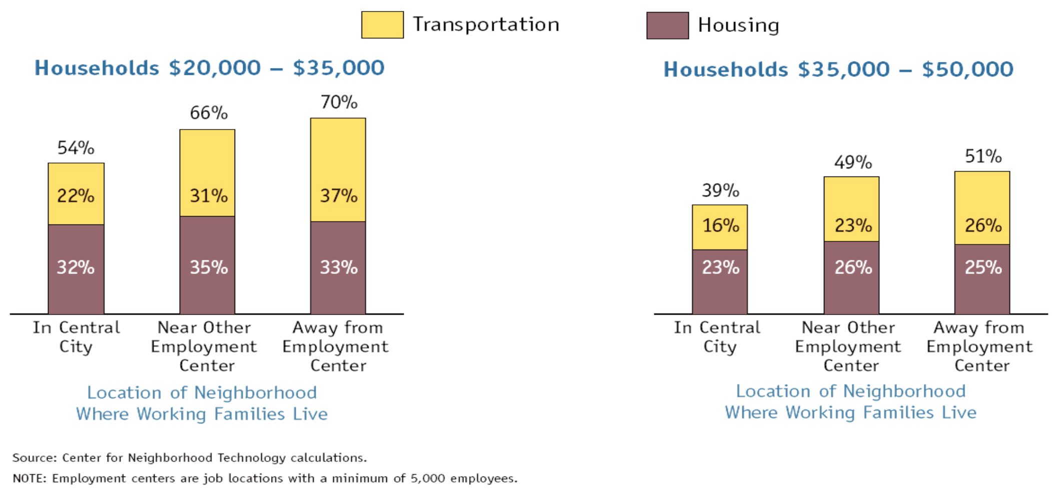
Residents of smart growth communities tend to own fewer vehicles, drive less and rely more on alternative modes which reduces total transport costs, including *internal* costs (borne directly by users) and *external* costs (borne by other people) (Miller 2003; USEPA 2004; Litman 2005). The magnitude of these savings depends on specific conditions and the scope of analysis. Smart growth community residents typically own 10-30% fewer vehicles and drive 20-40% fewer annual miles than in automobile-dependent communities. Although fuel prices, insurance premiums. parking fees and transit subsidies tend to be higher in urbanized areas, residents generally have substantial net consumer savings (CNT 2010). Similarly, road and parking facilities tend to have higher unit costs (per space or lane-mile), but this is generally offset by fewer parking spaces and lane-miles per capita, resulting in lower total infrastructure costs (Woudsma, Litman and Weisbrod 2006).

The *Housing + Transportation Index* (*H+T Index*) calculates the combined housing and transportation expenditures for various locations in 337 U.S. metropolitan regions (CNT 2008). It indicates that households in more compact neighborhoods enjoy combined housing and transport cost savings that average from $1,580 annually in lower-priced markets such as Little Rock up to $3,850 annually in higher-priced markets such as Boston (CNT 2010). For a typical household this is equivalent to a 10-20% increase in pre-tax income. 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), and because vehicles tend to depreciate much more than housing, housing expenditures provide greater long-term value: after a decade, $10,000 spent on housing is worth $4,730 compared with just $910 from the same investment on motor vehicles.

In addition to these direct transportation cost savings, smart growth can provide indirect savings and financial benefits. For example, smart growth policies include parking requirement reductions which can typically saves $500 to $1,500 annually per parking space reduced, and cashing out employee parking subsidies (employees who commute by alternative modes receive the cash value of the parking space they do not use), which typically provides $400 to $1,000 annually in additional employee benefits.

Smart growth is particularly beneficial to physically, economically and socially disadvantaged people who tend to be constrained in their ability to drive. Smart growth improves nondrivers overall accessibility and reduces the portion of lower-income household budgets devoted to transportation, as illustrated in figure 9.

Figure 9 **Share of Income Spent on Housing and Transport** (Lipman 2006)



The portion of income devoted to combined housing and transportation by lower and moderate income households is much lower for residents of more central locations.

Because transit services and pedestrian facilities experience economies of scale (unit costs decline as use increases), smart growth tends to increase service quality and reduce unit costs. Conversely, sprawl harms people with physical disabilities by reducing their mobility and accessibility options, 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.

Household Affordability

Land use patterns affect 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. Sprawl reduces housing costs for households that demand larger-lot single-family homes and generous parking supply, but Smart Growth reduces housing costs for households with more flexible housing and parking preferences (they would consider a smaller-lot or multi-family home). Research indicates that many households would choose 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).

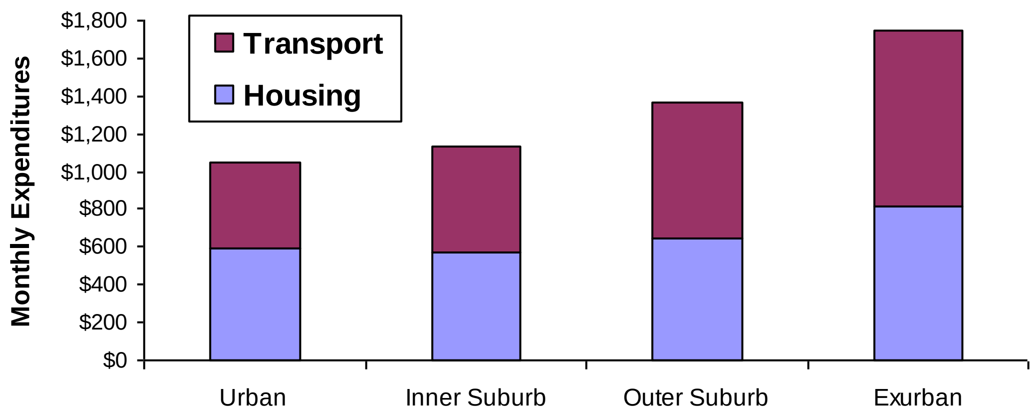
Table 10 **Smart Growth Housing Cost Impacts**

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 (Ewing and Hamidi 2014; Lipman 2006). Lower-income households that live in sprawled locations face financial risks due to their high transportation costs. The figure below illustrates these costs (Dodson and Sipe 2006).

Figure 10 **Affordability Index** (CTOD 2006)

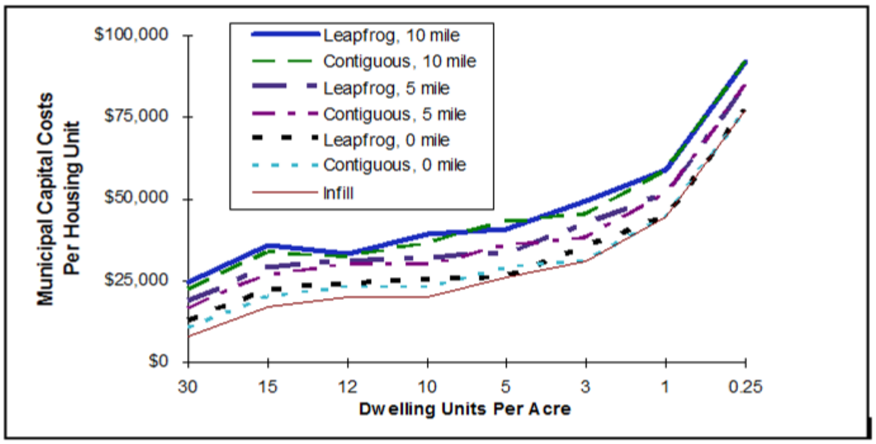


Although housing costs vary little, transportation costs increase significantly in less urban areas.

Infrastructure and Public Service Costs

Increasing density tends to increase the cost efficiency of providing public infrastructure and services by reducing road and utility line lengths, and travel distances required for services such as garbage collection and emergency response (Blais 2010; Burchell, et al. 2002; IBI 2008; Muro and Puentes 2004; Stantec 2013). As a result, the per capita costs of providing a given level of services tends to decline with more compact, mixed and connected development. Computer models can calculate development costs in specific situations (CMHC 2008; SGA and RCLCO 2015a & b; Utah's Governor's Office 2003), although these generally focus capital costs and often overlook other public service costs that increase with sprawl, such as emergency response and school busing. Figure 11 illustrates how capital costs increase with development dispersion.

Figure 11 **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. A major study for Halifax, Nova Scotia (Stantec 2013) found that more compact development, which increased the portion of new housing located in existing urban centers from 25% to 50% reduced infrastructure and transporta costs by about 10%, and helped achieve other social and environmental objectives including improved public fitness and health, and reduced pollution emissions. Table 11 indicates that more compact development can provide significat savings to utilities, government services and transportation infrastructure in the Toronto region.

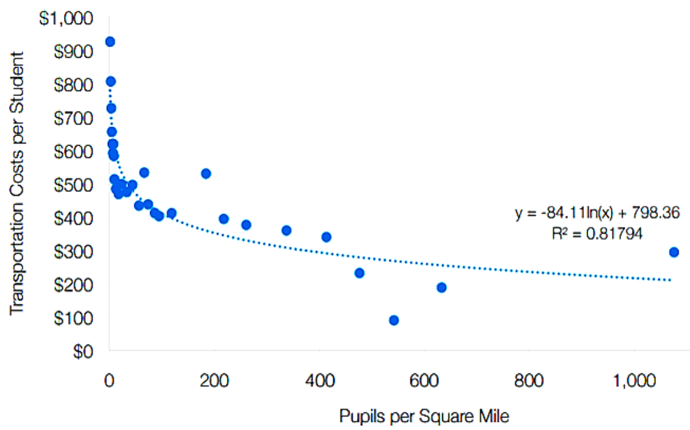
Table 11 **Public Costs of Three Development Options** (Blais 1995)

	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.

More compact development could save Calgary, Canada about a third in capital costs and 14% in operating costs for roads, transit services, water and wastewater, emergency response, recreation services and schools (IBI 2008). A Charlotte, North Carolina study found that lower density neighborhoods with disconnected streets require four times the number of fire stations at four times the cost compared with more compact and connected neighborhoods (CDOT 2012). A study for the City of Madison, Wisconsin (SGA and RCLCO 2015a) found that annual net fiscal impacts (incremental tax revenues minus incremental local government and school district costs) are $6.8 million net revenue ($203 per capita and $4,534 per acre), compared with $4.4 million ($185 per capita and $1,286 per acre) for the low density scenario. A similar study for West Des Moines, Iowa predicts that, to accommodate 9,275 new housing units, compact development designed to maximize neighborhood walkability would generate a total annual net fiscal impact of $11.2 million ($417 per capita and $17,820 per acre), about 50% more than the $7.5 million ($243 per capita and $2,700 per acre) generated by the least dense scenario (SGA and RCLCO 2015b). Figure 12 illustrates how school transportation costs tend to decline with increased population, due to reductions in the need to provide school bus services.

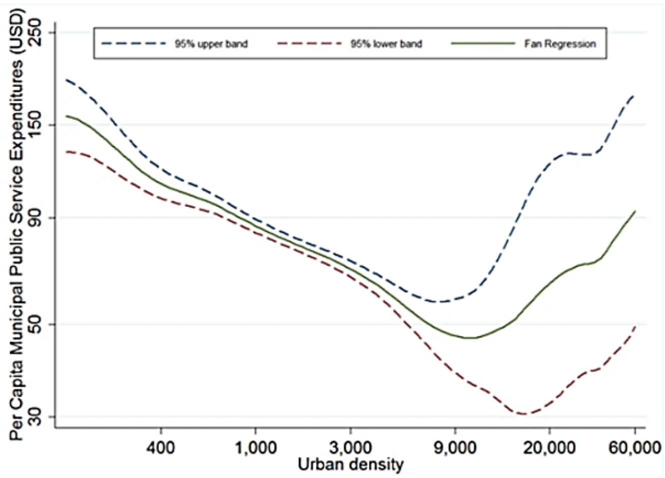
Figure 12 **Transportation Costs Per Student** (SGA 2015, p. 11)



Wisconsin Department of Public Instruction data show that school transport costs are high for low-density development (under 50 school pupils per square mile) and decline with density.

The same pattern is found in developing countries. Detailed analysis of 2,500 Spanish municipal budgets found that lower-density development increases per capita local service costs (Rico and Solé-Ollé 2013). They found that municipalities with less than 25 residents per acre, each 1% increase in urban land area per capita increases municipal costs by 0.11%. Of this, 21% is for basic infrastructure, 17% for culture and sport programs, 13% for housing and community development, 12% for community facilities, 12% for general administration, and 6% due to increased local policing costs. Analyzing per capita municipal spending on public services in 8,600 municipalities of Brazil, Chile, Ecuador and Mexico, de Duren and Compeán (2015) found that municipal service efficiencies are optimized at about 90 residents per hectare, which jusitifies densification policies, particularly in medium-sized cities of developing countries (Figure 13).

Figure 13 **Municipal Service Costs By Urban Density** (de Duren and Compeán 2015)



All else being equal, the annual costs of providing public water, sewage, garbage collection by municipal governments in Brazil, Chile, Ecuador, and Mexico range from more than $150 in very low density areas to about $50 per capita.

Using data from three U.S. case studies, the study, *Smart Growth & Conventional Suburban Development: Which Costs More?* (Ford 2010) found that more compact residential development can reduce infrastructure costs by 30-50% compared with conventional suburban development. *Building Better Budgets: A National Examination of the Fiscal Benefits of Smart Growth Development* (SGA 2013) found that Smart Growth development costs one-third less for upfront infrastructure costs and saves an average of 10% of ongoing public services costs.

Rural residents traditionally accepted lower public service quality 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, most new development 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 Calgary *Plan-it* program compared infrastructure and public service costs of compact and dispersed development patterns. More compact development saves about a third in capital costs and 14% in 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 Millions** (IBI 2008)

	Dispersed	Compact	Difference
Roadways	$230	$190	$40 (-18%)
Transit	$300	$300	$0 (0%)
Water and Wastewater	$60	$30	$30 (-55%)
Fire Stations	$280	$230	$50 (-18%)
Recreation Centers	$230	$190	$40 (-18%)
Totals	*$990*	*$860*	*$130 (-14%)*

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

The City of Calgary (2016) applies development fees based on detailed and transparent accounting of the costs of providing public infrastructure and services (water, sewage, roads, etc.). The resulting fees are significantly higher in sprawled locations to reflect the higher costs of serving those areas. Fees range from $2,593 per multi-unit unit and $6,267 for per single family home in urban areas up to $422,073 to $464,777 per hectare (about $45,000 for a quarter-acre lot) in suburban locations.

The Utah's Governor's Office (2003), developed the *Municipal Infrastructure Planning and Cost Model User's Manual* (MIPCOM), a spreadsheet model that estimates infrastructure construction and operation for new development, and how development density and location affect these costs. These costs include:

- *Regional infrastructure*, including regional roads, transit, and water supply facilities.
- *Subregional (off-site) infrastructure*, including water and waste water treatment facilities and distribution networks, storm drain lines and basins, and minor arterial roads.
- *On-site infrastructure*, including local roads, water transmission lines, sewer transmission lines, dry utilities (telephone, electric, etc.), and storm drains.

Analyzing per capita municipal spending on public services in 8,600 municipalities of Brazil, Chile, Ecuador and Mexico, de Duren and Compeán (2015) found that municipal service efficiencies are optimized at densities close to 9,000 residents per square kilometre (90 residents per hectare), of which 85% of municipalities are below. They conclude that this justifies policies that encourage densification, particularly in medium-sized cities of developing countries, which are currently absorbing most of the world's urban population growth.

The MIPCOM analysis indicates that development impact fees should typically be discounted 20% for infill development. A study by the City of Charlotte, North Carolina found that a fire station in a low-density neighborhood with disconnected streets serves one-quarter the number of households and at four times the cost of an otherwise identical fire station in a less spread-out and more connected neighborhood (CDOT 2012).

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

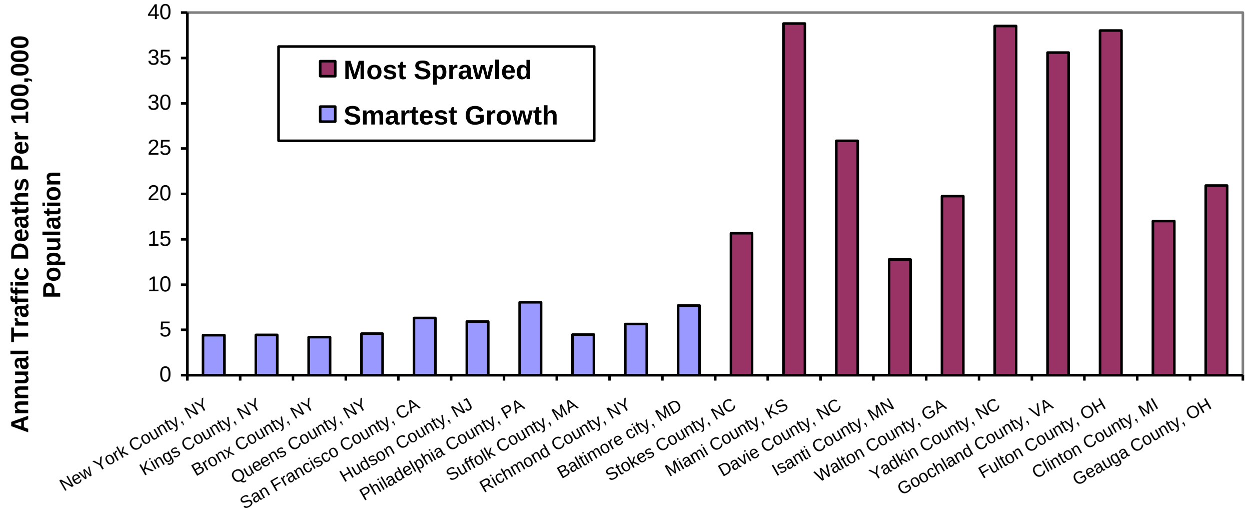
- Lowest in rural areas where households provide their own services.
- Increase in suburban areas where services are provided to dispersed development
- Decline with clustering, as densities increase from low to moderate.
- Are lowest for infill redevelopment in areas with adequate infrastructure capacity.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

Much of the public savings in rural areas are actually costs shifted from public to private budgets, or reduced service quality. Rural households devote a larger portion of their budgets to utilities and public services (8.1%) than average (7.2%), and large city residents spend least (6.6%-6.8%), but the higher costs in rural areas do not show up in public budgets (BLS 2013). Cost reductions associated with increased density are true efficiency gains (lower costs to provide a given level of service) rather than cost shifts.

Safety and Health

Land use patterns affect public safety and health (Boarnet, Greenwald and McMillan 2008; Ewing and Hamidi 2014). 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).

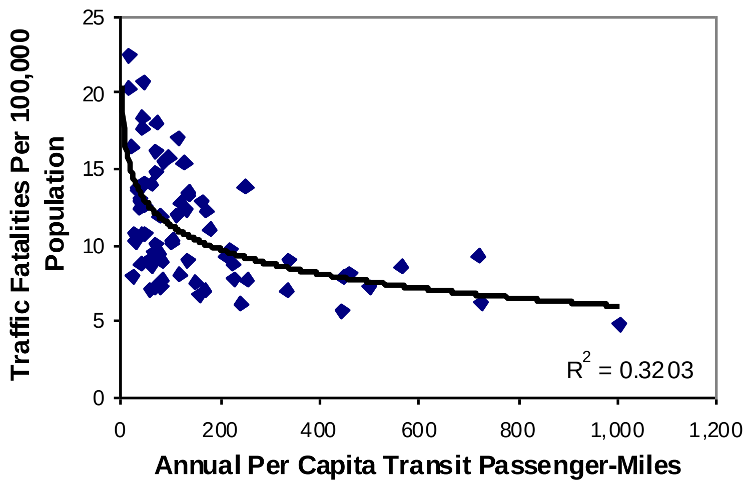
Figure 12 **Traffic Death Rate** (Ewing, Schieber and Zegeer 2003)



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 13).

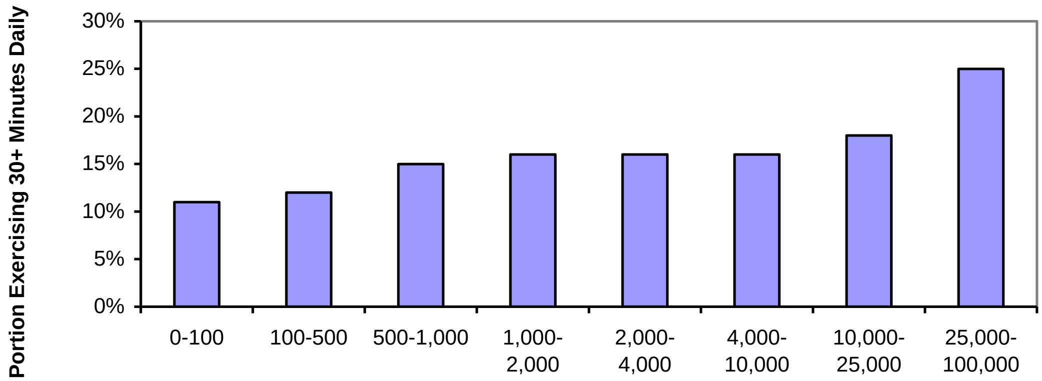
Figure 13 **U.S. Traffic Deaths** (Litman, 2004b)



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 14) 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, 2005.

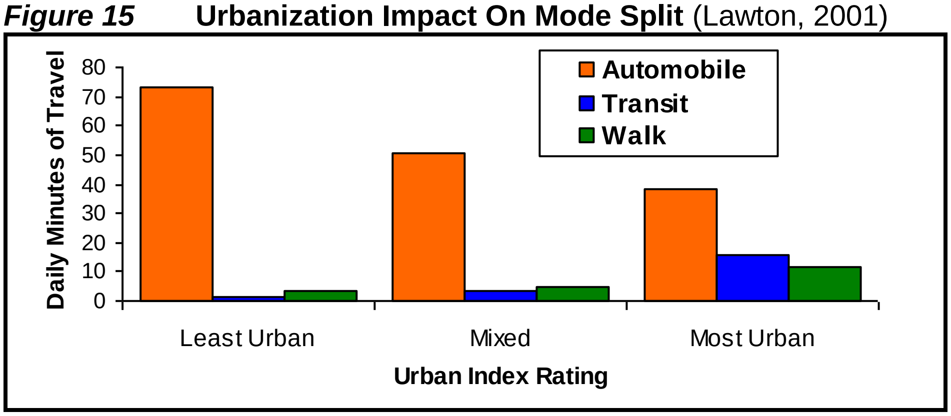
Figure 14 **Portion of Population Walking & Cycling 30+ Minutes Daily** (Unpublished Analysis of 2001 NHTS by William Gehling)



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 15 **Urbanization Impact On Mode Split** (Lawton, 2001)



Ewing, Frank, and Kreutzer (2006) identify a variety of specific ways that land use patterns can affect public health. Forsyth, Slotterback and Krizek (2010) discuss how Health Impact Assessments (HIAs) can be used to evaluate the public health impacts of specific planning decisions.

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.

Economic Productivity and Development

Land use patterns affect economic productivity and development. All else being equal, greater accessible and lower transport costs increase economic productivity (Donovan and Munro 2013; Litman 2010b). More accessible land use that reduces consumers' vehicle and fuel expenditures tends to increase regional employment and business activity, as illustrated in Table 14.

Table 14 **Regional Economic Impacts Of $1 Million Expenditure** (MRL 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, particularly finance, education and creative industries, experience *agglomeration efficiencies*; they are more efficient when located close together, because this facilitates interaction, trade and cooperation (Bettencourt, et al. 2007). Although difficult to measure these impacts appear to be large (Anas, Arnott and Small 1997; Lee 1999; Muro and Puentes 2004; Graham 2007; Sohn and Moudon 2008). More accessible, compact, mixed, connected land use patterns tend to increase employment, economic productivity, land values and tax revenues (IEDC 2006). 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), although Gordon (2012) emphasizes that land use density is a surrogate for complex relationship networks that are only partly geographic.

Meijers and Burger (2009) found that metropolitan region labor productivity declines with population dispersion (a higher proportion of residents live outside urban centres), and generally increases with polycentric development (multiple business districts, cities and towns within a metropolitan region, rather than a single large central business district and central city). This suggests that in growing regions, suburbanization is not economically harmful if new cities and towns reflect smart growth principles, but dispersed, automobile-dependent sprawl reduces economic productivity. This suggests that regional rail transit systems with transit oriented development around stations tends to support regional economic development by encouraging efficient polycentric land use development patterns.

More compact development, including reductions in the amount of land required for transport facilities such as roads and parking, frees up land for other productive uses, including businesses, housing, farmlands, and recreation. The box on the following page describes how this can increase regional economic productivity.

Transportation Policy Impacts On Farm Productivity
This example describes how transport land use impacts can affect agricultural productivity.

The Netherlands and Southern California (Los Angeles, Ventura, Orange, and eastern Riverside and San Bernardino counties) are similar in area (~ 16 thousand square miles) and population (~16 million residents). Both have significant agricultural potential. The Netherlands produces more than $40 billion annually in agricultural products. Farming was once major industry in Southern California, but it is now minor, accounting for less than a billion dollars in direct economic productivity.

Several factors account for this differences, including topography (much of Southern California is hilly), water supply (Los Angeles has less) and economic policy (agricultural industry is well supported by the Dutch government), but a major factor is land use policy, which in turn is affected by transport policy. The Netherlands encourages compact development, with minimal per capita land consumption for housing, parking and roads, which leaves more land for farming.

The following table compares the amount of land required for 16 million residents with multi-modal and automobile-oriented transport systems. Automobile dependency encourages larger building footprints, more surface parking and roads.

Typical Land Consumption Per Capita (Square Feet)

	Multi-Modal	Auto-Oriented
Housing (1,200 sq. ft. interior space per capita)	(Three stories) 400	(One-story) 1,200
Parking (300 sq. ft. per space)	(2 spaces) 600	(6 spaces) 1,800
Roads (15 foot right-of-way width per lane)[1]	(30 lane-feet) 450	(100 lane-feet) 1,500
Impervious surface per capita (sq. ft)	1,450	4,500
Total impervious surface (sq. miles)	832	2,582
Portion of 16 thousand sq. miles	5%	16%

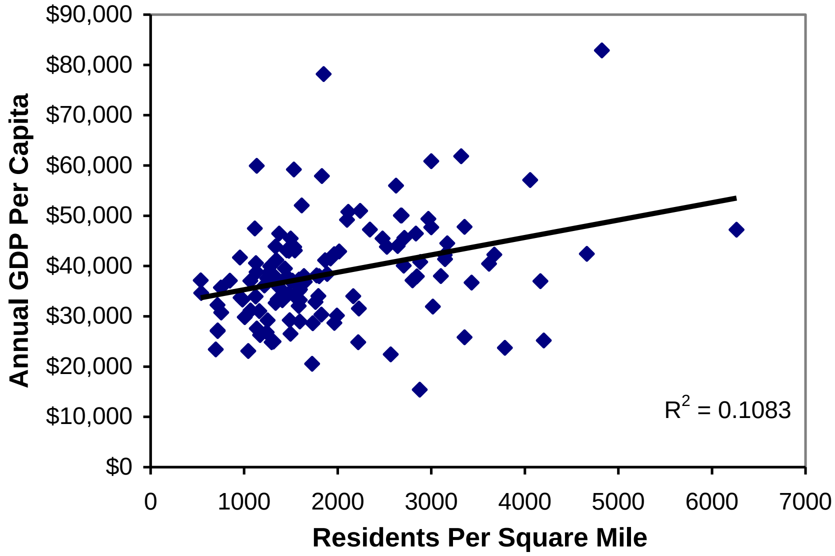
In the multi-modal community residents consume about 5% of the land base for buildings, parking and roads, compared with 16% in automobile-oriented areas, leaving about 11% more land available for productive uses such as agricultural. Of course, actual impacts depend on factors, including other land uses (such as residential lawns, parks and industrial facilities) and the quality of land displaced. Urban development often occurs on agricultural lands (valleys and deltas) which reduces farm production.

This example illustrates how transportation policies can significantly affect per capita land consumption, which can have significant economic impacts. This indicates that transportation policies that encourage more compact development and reduce the amount of land required for roads and parking facilities can increase the productivity of farming or other land-intensive industries.

[1] *Federal Highway Statistics*, Table 71 (www.fhwa.dot.gov/policyinformation/statistics/2008/hm71.cfm) provides data on road miles in various cities, suggesting that per capita lane-miles range from about 30 in multi-modal communities up to about 100 in

Per capita GDP tends to increase with population density, as illustrated in Figure 16. This probably reflects a combination of improved accessibility, transportation cost savings, agglomeration efficiencies and infrastructure cost savings that result from more accessible, compact development.

Figure 16 **Per Capita GDP and Urban Density** (BTS 2006 and BEA 2006)



Productivity tends to increase with population density. (Each dot is a U.S. urban region.)

Social Inclusion

Social inclusion (also called *economic opportunity* or *economic mobility*) 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.

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. Research by Ewing and Hamidi (2014) indicates that more compact development significantly increases economic opportunities for disadvantaged residents, and for every 10% increase in an index score, there is a 4.1% increase in the probability that a child born to a family in the bottom quintile of the national income distribution reaches the top quintile of the national income distribution by age 30.

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.

Freeman (2001) analyzed data from a cross-sectional survey of adults in Atlanta, Boston, and Los Angeles concerning their social interactions. The analysis indicates that, although the rate of neighborhood social tie formation was unrelated to land use density alone, it was significantly and substantially related to the degree to which residents of a neighborhood relied on their automobiles. Similarly, Leyden (2003) found that people living in walkable, mixed-use neighborhoods have higher levels of social capital compared with those living in car-oriented suburbs. Walkable neighborhood residents were more likely to know their neighbors, participate politically, trust others and be socially engaged, suggesting that polices and projects that support walking and public transit use, and increase land use mix, tend to increase community cohesion.

Environmental and Ecological 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 (Hawkes 2016), and parks (collectively called *greenspace* or *openspace*) provide external benefits, including wildlife habitat, air and water quality, and beauty (Brabec 1992; 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 of openspace preservation:

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.

Ecological value refers to the contribution land makes toward various environmental functions such as wildlife habitat, and surface and groundwater recharge. Roads and parking facilities have *hydrologic impacts* (changes to surface and groundwater flows) that tend to concentrate stormwater, increase flooding, scouring and siltation, and reduce dry season supply, and create barriers to fish (Litman 2005). These impose both economic and ecological costs. Paved surfaces create *heat islands*, causing ambient summer temperatures to rise 2-8° F in urban areas, which increases energy demand, smog, human discomfort and health problems (Stone, Hess, Frumkin 2010; USEPA 2011).

Transportation policies and projects are ecologically harmful if they disturb or divide habitat, convert natural habitat to gardens, farms or lawns, or increase impervious surface area. Parks, gardens, farms and lawns generally provide moderate to minimal wildlife habitat, particularly for larger animals, and although they allow surface and groundwater recharge, this often carries significant pollution loads from fertilizers, pesticides and other sources. From an ecological perspective, pavement is generally least beneficial land use since it provides no habitat, prevents groundwater recharge, increases stormwater management costs, and tends to concentrate water pollution.

As a result, transport policies provide ecological benefits to the degree that they help reduce wildlife habitat fragmentation, preserves wildlife habitat, discourages lower-density development, or reduces impervious surface. This analysis depends on how impacts are measured: higher density urban development tends to have poorer ecological effects within a given area (measured per acre or square mile) but have better effects per capita (Arnold and Gibbons 1996; USEPA 2006).

Some studies have valued open space (EDRG 2007; McConnel and Walls 2005; Tagliafierro, et al. 2013). The box below ranks of these values. Impervious surfaces such as buildings, parking lots and roadways generally provide the least environmental benefits, and they increase stormwater management costs and heat island effects (higher ambient temperatures from sunlight). These negative impacts can be reduced somewhat with design features such as rooftop gardens, street trees and pervious pavements, but this does not eliminate the value of open space preservation.

External Values Ranked (McConnel and Walls 2005)

1. Shorelands and wetlands such as lake and marshes.
2. Unique natural and cultural lands such as forests, deserts and heritage sites
3. Farmlands
4. Parks and gardens
5. Lawns
6. Impervious surfaces (buildings, parking lots and roads)

Some land use types, such as shorelines, unique natural and cultural lands, and high value farmlands, provide significant external benefits that justify their preservation.

Table 15 summarizes one estimate of various economic, social and environmental values of openspace in Washington State's Puget Sound region. Many are indirect, and so tend to be undervalued by stakeholders. For example, area residents may be unaware that openspace reduces disaster risks, maintains water quality and supports local industries.

Table 15 **Puget Sound Openspace Values** (Chadsey, Christin and Fletcher 2015)

	Low Range		High Range	
	Total (m)	Per Acre	Total (m)	Per Acre
Aesthetic (perceived beauty and higher property values)	$2,294	$655	$9,510	$2,717
Air quality protection	$422	$121	$529	$151
Food production (farm and aquaculture)	$13	$4	$86	$25
Shelter (wildlife habitat)	$74	$21	$111	$32
Water quality and percolation	$63	$18	$1,925	$550
Health (exercise and mental health)	$41	$12	$50	$14
Play (outdoor recreation and related industries)	$2,633	$752	$4,133	$1,181
Disaster mitigation (e.g., flood protection)	$1,860	$532	$4,194	$1,199
Raw materials (lumber, stone, etc.)	$23	$7	$155	$44
Waste and pollution transformation	$4,034	$1,153	$4,569	$1,306
Totals	*$11,458*	*$3,274*	*$25,264*	*$7,219*

This study indicates that openspace provides diverse economic, social and environmental benefits.

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.

Forman and 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.

Jacob and Lopez (2009) calculated how land use development density affects stormwater runoff volumes, and the amount of phosphorous, nitrogen and suspended solid water pollution. They found that these impacts increase per acre but declined per capita. For a constant or given population, higher density development tends to dramatically reduce loadings compared with diffuse suburban densities. Their model showed that doubling standard suburban densities [from 3-5 up to 8 dwelling units per acre can usually achieve more contaminant loading reductions than many traditional stormwater best management practices (BMPs), and that higher densities such as those associated with transit-oriented development outperform almost all traditional BMPs in reduced loadings per capita.

A major Swiss government research program on transporation costs included a study of habitat loss and fragmentation caused by road and railroad infrastructure (Swiss ARE 2005). The calculated external cost throughout Switzerland totaled 765 million Swiss Francs (CHFs) in 2000, of which habitat loss comprises CHF 179-337 million/year and habitat fragmentation CHF 264-746 million/year. Around 86% is caused and the rest by rail infrastructure. This is calculated to aveage:

1.2 centimes per vehicle-km for automobiles
0.7 centimes per passenger-km for rail transport
2.6 centimes per vehicle-km for trucks
3.4 centimes per vehicle-km for heavy articulated vehicles
1.2 centimes per tonne-km for rail freight transport.

Table 16 shows one evaluation of environmental benefits provided by selected land uses.

Table 16 **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; Mehaffy, Cowan and Urge-Vorsatz 2009), 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.

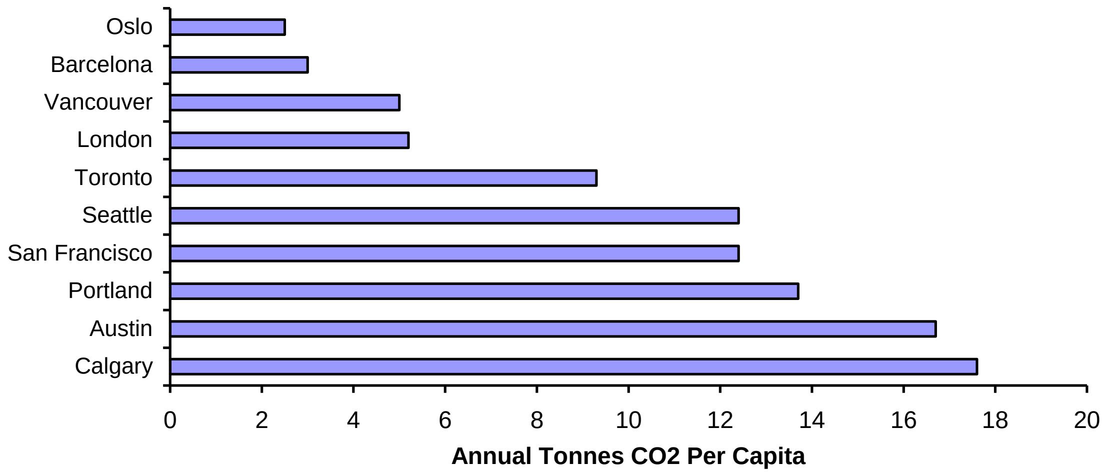
- *Street connectivity* (the degree to which streets connect to each other, rather than having deadends or large blocks) affects accessibility, including the amount of travel required to reach destinations and the relative speed and convenience of cycling and walking.

- *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, 2005; 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. Figure 17 compares per capita emissions between various cities.

Figure 17 **Climate Change Emissions By City** (Vancouver 2008)



Per capita energy consumption and climate change emissions vary significantly depending on a city's transportation and land use patterns.

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 17 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 17 **Smart Growth Consumer Impacts** (Litman 2010a)

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

There is often debate about the desirability of development patterns, generally termed *sprawl* and *smart growth* (Aurbach 2003; Litman 2003). Critics argue that sprawl imposes numerous economic, social and environmental costs, and that smart growth development is desirable. Smart growth critics argue that sprawl provides benefits that offset these costs, and meets consumer demands (Cox 2001; see box below).

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.

This debate often depends on how sprawl and smart growth are defined and measured. For example, critics often define smart growth as "high density development" or "population growth in existing cities," although smart growth includes other factors, and allows development in new cities and towns, provided it reflects smart growth principles.

Changing consumers appear to be increasing demand for smart growth (Nelson 2006; Litman 2010a). Market research indicates that an increasing portion of households want good accessibility (indicated by shorter commutes), land use mix (indicated by nearby shops and services), and diverse transport options (indicated by good walking conditions and public transit services) and will often choose small-lot and attached homes with these features. Demographic and economic trends are increasing smart growth demand, causing a shortage of such housing. Demand for sprawl housing is declining, resulting in oversupply and reduced value.

Various studies, described in this report, indicates that lower-density, urban-fringe development imposes various economic, social and environmental costs. Many of these costs tend to be overlooked or undervalued in the planning process, and are seldom incorporated into pricing, which results in economically excessive levels of sprawl and automobile use (Litman, 2001; Lewyn, 2005). An efficient land market would therefore require the following features to determine the optimal level of sprawl:

- Improved housing options, including more affordable housing developed in accessible, smart growth areas.
- Policies that favor compact development to achieve agglomeration efficiencies and cost savings.
- Development and utility fees, and taxes that reflect the lower costs of providing public services in more accessible, compact locations, so smart growth residents would save money.
- Improved public services (particularly schools and public safety) in smart growth communities.
- Land use policies that protect environmental amenties, including encouragement of more compact development and openspace protection.

These policies would test the true level of consumer demand for large-lot, urban fringe housing. Although some households would probably still choose such housing, even if faced with better and more affordable alternatives, it is likely that a significant portion of the market would shift to smarter growth locations, reducing the need for additional sprawl.

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 18 **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.

Table 19 **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 2010a). 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 20 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 20 **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 21 summarizes these costs.

Table 21 **External Environmental Costs Calculation Example**

Land Use Impact	Hectares	Cost Per Hectare (From Table 14)	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 22 **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 23. This gives each objective equal weight.

Table 23 **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 24. 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 24 **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

Measuring Sprawl (Ewing and Hamidi 2014)

The report, *Measuring Sprawl* assigned a Sprawl Index score to 221 metropolitan areas and 994 counties in the U.S. according to four primary factors: *density* (people and jobs per square mile), *mix* (whether neighborhoods had a mix of homes, jobs and services), *centricity* (the strength of activity centers and downtowns) and *roadway connectivity* (the density of connections in the roadway network). The index averages 100, meaning that scores lower than 100 indicate more sprawl and scores higher than 100 indicate smart growth. The table below summarizes the study's key results.

Table 25 **Summary of Sprawl Outcomes** (Ewing and Hamidi 2014)

Outcome	Relationship to Sprawl	Impact of 10% Index Score
Housing affordability	Positive and significant	1.1% increase in housing costs relative to income.
Transportation affordability	Negative and significant	3.5% decrease in transportation costs relative to income
Upward mobility (probability a child born in the bottom income quintile reaches the top quintile by age 30)	Negative and significant	4.1% increase
Average household vehicle ownership	Positive and significant	0.6% decline
Percentage of commuters walking to Work	Negative and significant	3.9% increase
Percentage of commuters using public transit	Negative and significant	11.5% increase
Average journey-to-work drive time	Positive and significant	0.5% decline
Traffic crash rate per 100,000 population	Negative and significant	
Injury crash rate per 100,000 population	Negative and significant	
Fatal crash rate per 100,000 population	Positive and significant	15% decline
Body mass index	Positive and significant	
Obesity	Positive and significant	
Any physical activity	Positive and significant	
Diagnosed high blood pressure	Positive and significant	
Diagnosed heart disease	Not significant	
Diagnosed diabetes	Positive and significant	
Average life expectancy	Negative and significant	0.4% increase

This table summarizes various impacts of sprawl based on a comprehensive study.

Municipal Fisical Impact Analysis (SGA and RCLCO 2015)

The report, *Fiscal Implications Of Development Patterns A Model For Municipal Analysis*, provides an analysis tool to help municipalities understand the financial performance of development patterns, and how to improve this performance. It estimates the incremental costs of roads, water/wastewater, stormwater management, fire protection, school transport and solid waste collection, and compares that with the incremental revenues of new development. The report, *Fiscal Implications of Development Patters – Madison, WI* (SGA 2015) applies the model to a specific city.

Making the Land Use Connection

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 26 summarizes its analysis results.

Table 26 **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.

Sprawl Index Analysis

Researchers Reid Ewing and Shima Hamidi (2014) used sophisticated statistical analysis and extensive data sets to measure how various aspects of sprawl affect motor vehicle ownership, travel activity, and resulting health and safety, economic and environmental outcomes, as described in their report, *Measuring Sprawl 2014*. They assigned a Sprawl Index (although, since it increases with smart growth attributes, it is better to think of it as a Compactness Index) score to 221 U.S. metropolitan areas and 994 counties based on four primary factors: *density* (people and jobs per square mile), *mix* (whether neighborhoods had a mix of homes, jobs and services), roadway *connectivity* (the density of road network connections), and *centricity* (the portion of jobs in major activity centers). Table 27 summarizes key results.

Table 27 **Impacts of More Compact Development** (Ewing and Hamidi 2014)

Outcome	Relationship to Compactness	Impact of 10% Score Increase
Average household vehicle ownership	Negative and significant	0.6% decline
Vehicle miles traveled	Negative	7.8% to 9.5% decline
Walking commute mode share	Positive and significant	3.9% increase
Public transit commute mode share	Positive and significant	11.5% increase
Average journey-to-work drive time	Negative and significant	0.5% decline
Traffic crashes per 100,000 population	Positive and significant	0.4% increase
Injury crash rate per 100,000 pop.	Positive and significant	0.6% increase
Fatal crash rate per 100,000 population	Negative and significant	13.8% decline
Body mass index	Negative and significant	0.4% decline
Obesity	Negative and significant	3.6% decline
Any physical activity	Not significant	0.2% increase
Diagnosed high blood pressure	Negative and significant	1.7% decline
Diagnosed heart disease	Negative and significant	3.2% decline
Diagnosed diabetes	Negative and significant	1.7% decline
Average life expectancy	Positive and significant	0.4% increase
Upward mobility (probability a child born in a bottom-income-quintile family reaches the top quintile by age 30)	Positive and significant	4.1% increase
Transportation affordability	Positive and significant	3.5% decrease in transport costs relative to income
Housing affordability	Negative and significant	1.1% increase in housing costs relative to income.

This table summarizes economic, health and environmental impacts from compact development.

These results validate previous research indicating that more compact development reduces motor vehicle travel and associated costs. This disaggregated analysis of sprawl factors is useful because it is possible to have dense sprawl (for example, dispersed high-rise development in an automobile-dependent area) and rural smart growth (development concentrated in villages with commonly used services within walking distance of most households, connected to larger urban centers with convenient public transit services). This expands the range of policy tools that can be used to increase transport system efficiency, for example, even if a city cannot increase development density it may be able to increase mix, road connectivity, and the quality of resource-efficient travel modes (walking, cycling and public transport).

*ASSET (**www.asset-eu.org**)*

ASSET (**AS**sessing **SE**nsitiveness to **T**ransport) is a new European Community funded project which aims to develop the scientific and methodological capabilities to implement European policies aiming at balancing the protection of environmentally Sensitive Areas (SA) with the provision of an efficient transport system. Although the concept of sensitive areas has been repeatedly evoked in the context of EU transport policies, there is to date no scientific and no political agreement on a definition, nor is there an agreed approach to address the specific concerns associated to transport related SA (TSA).

The first part of the project defines a set of sensitiveness criteria to identify TSA and apply these in a mapping of TSAs across the EU, allowing for the identification and prioritisation of critical sustainability issues geared to the development of the Trans-European Transport Networks (TEN-T). The second part of the project concentrates on analysing policy instruments with regard to their applicability to different categories of TSA and the identification of adequate policy packages with a focus on market-based instruments. The proposed methodology and the policy instruments will be assessed in detail in 10 case studies covering (i) mountainous areas, (ii) urban/metropolitan areas, (iii) natural/protected areas, and (iv) coastal areas, as well as different modes, types of traffic and geographical situations. Finally, policy and operational guidelines for TSA will be developed, notably building on the cross site evaluation of the case studies.
The project involves a consortium of 11 partners in 9 countries, thus covering all relevant disciplines (natural scientists, economists, transport policy, social policy experts) and a wide geographical scope in Europe.

Evaluating The Fiscal Impacts Of Development (www.costofsprawl.org)

The New Hampshire *Cost of Sprawl Impact Model* is designed as a decision-support tool for New Hampshire's dedicated local and regional planners, to provide a mechanism to evaluate the financial impact on local governments related to new development.

Vision California - Charting Our Future (www.visioncalifornia.org).

Vision California uses the new *Rapid Fire Model*, a user-friendly spreadsheet tool that evaluates regional and statewide land use and transportation scenarios, including various combinations of land use density, mix, building types and transport policies, and predicts their impacts on vehicle travel, pollution emissions, water use, building energy use, transportation fuel use, land consumption, and public infrastructure costs. All assumptions are clearly identified and can be easily modified.

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

Table 26 **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.

Acknowledgements

Thanks to David Morley for his sharp editing.

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