5.14 Land Use Impacts

This chapter examines how transportation decisions affect land use patterns, and the economic, social and environmental impacts that result. It describes various external costs of low-density, automobile-oriented development, and benefits that can result from more resource-efficient land use patterns. More detailed information on this issue is available in the report, "Evaluating Transportation Land Use Impacts" (www.vtpi.org/landuse.pdf).

5.14.1 Chapter Index

5.14.2 Definitions

Land Use Impacts refers to effects transportation activities and facilities can have on land use patterns, that is, the location, design and use of landscape features such as cities, individual structures, farms, parks and wildlands. Land use patterns reflect various attributes, including the following:

- *Density* - the number of people, jobs or housing units in an area.
- *Mix* - whether different types of land uses are located in the same area.
- *Clustering* - whether related activities are located close together.
- *Roadway scale and connectivity* – the size of roads and city blocks.
- *Impervious surface coverage* – land that is covered by buildings and pavement.
- *Greenspace* – land devoted to lawns, gardens, parks, farms, woodlands, etc.
- *Accessibility* – the ease with which various types of people can reach goods, services and activities (including motorists, non-drivers, people with physical disabilities, etc.).

Of particular concern is the tendency of motorized modes to create *sprawl*, and the external costs that result.[1] Table 5.14.2-1 summarizes differences between *sprawl* and *smart growth* (more clustered land use patterns designed for diverse transportation).

Table 5.14.2-1 **Comparing Sprawl and Smart Growth**[2]

Attribute	Sprawl	Smart Growth
Density	Lower-density	Higher-density.
Growth pattern	Urban periphery (greenfield) development.	Infill (brownfield) development.
Land use mix	Homogeneous land uses.	Mixed land use.
Scale	Large scale. Larger buildings, blocks, and 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. Poorly suited for walking, cycling and transit.	Multi-modal. Supports walking, cycling and public transit.
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	Emphasizes the private realm (yards, shopping malls, private clubs).	Emphasizes the public realm (public streets, parks, walking facilities).

This table compares Sprawl and Smart Growth land use patterns.

[1] George Galster, et al. (2001), "Wrestling Sprawl to the Ground: Defining and Measuring an Elusive Concept," *Housing Policy Debate*, Vol. 12, Is. 4, Fannie Mae Foundation (www.fanniemaefoundation.org), pp. 681-717; at www.fanniemaefoundation.org/programs/hpd/pdf/HPD_1204_galster.pdf.

[2] Todd Litman (2006), *Evaluating Transportation Land Use Impacts*, VTPI (www.vtpi.org); at www.vtpi.org/landuse.pdf.

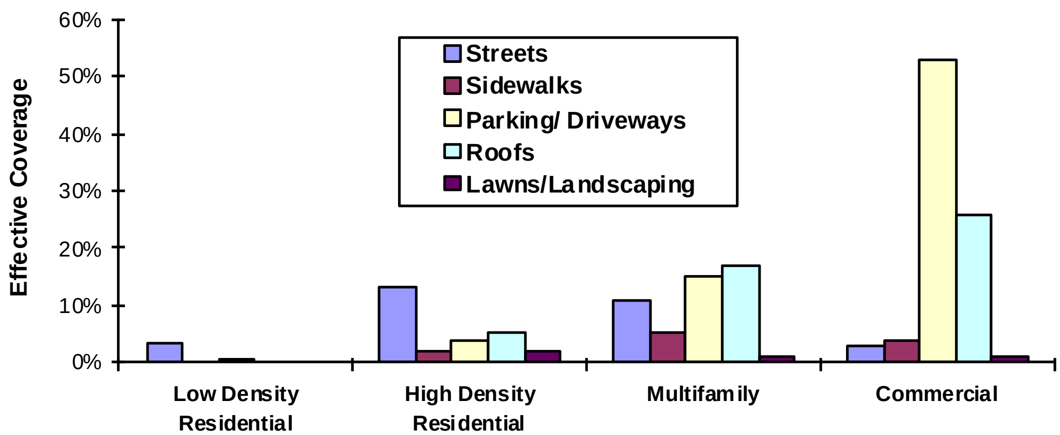
5.14.3 Discussion

This chapter discusses ways to evaluate the land use impacts of transportation decisions. There are two major factors to consider. The first factor concerns how specific policies and planning decisions affect land use, including both direct impacts of using land for transport facilities, and indirect impacts that result from changes in development type and location. These impacts vary by mode since automobile transport requires more space than other modes for travel and parking, and tends to encourage more dispersed land use patterns. The second factor concerns the economic, social and environmental impacts of these different land use patterns. Increased pavement and more dispersed land use development patterns impose various economic, social and environmental costs on society that are often not recognized in conventional transportation planning.

Direct Land Requirements

An estimated 20,000 square miles is devoted to road rights of way (about 0.7% of continental U.S.), and more than 13 thousand square miles of land is paved for roads (about 0.4% of continental U.S.).[3] Roads and parking cover a significant portion of land in urbanized areas, as indicated in Figure 5.14.3-1. Although impervious surface area increases with urban density, per capita coverage is greater in suburban conditions. For information on methods for measuring impervious area see Janke, Gulliver and Wilson.[4]

Figure 5.14.3-1 **Surface Coverage of Different Land Use Classes**[5]



Roads, parking facilities, sidewalks and the development that they bring to an area displace and damage natural greenspace. Although low-density residential development may have less percentage impervious surface, coverage per capita is usually greater.

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[3] Todd Litman (2000), *Transportation Land Valuation; Evaluating Policies and Practices that Affect the Amount of Land Devoted to Transportation Facilities*, VTPI (www.vtpi.org); at www.vtpi.org/land.pdf.

[4] Ben Janke, John S. Gulliver and Bruce N. Wilson (2011), *Development of Techniques to Quantify Effective Impervious Cover*, University of Minnesota (www.cts.umn.edu); at www.cts.umn.edu/Publications/ResearchReports/reportdetail.html?id=2058.

[5] City of Olympia (1995) *Impervious Surface Reduction Study*, City of Olympia Public Works (www.ci.olympia.wa.us), May 1995, p. 39.

Table 5.14.3-1 shows time-area analysis for various transport modes, for a 20-minute commute with 8 hours of parking. This indicates that automobile travel requires 30 to 100 times more space than other modes. Because motorists tend to travel farther per year than non-drivers (motorists travel on average about three times as far as nonmotorists), their total per capita land requirements for transportation are even greater.

Table 5.14.3-1 **Time-Area Requirements by Mode**[6]

Mode	Standing/ Parking	8 hr. Parking	Road Space	Per 20-minute Trip	Total (parking & 2 commutes)
	Sq. Ft.	*Sq. Ft.-Min.*	*Sq. Ft.*	*Sq. Ft.-Min.*	*Sq. Ft.-Min.*
Pedestrian	5	*0*	20	*400*	800
Bicycle	20	*9,600*	50	*1,000*	11,600
Bus	20	*0*	75	*1,500*	3,000
Automobile – 30 mph	400	*192,000*	1,500	*30,000*	252,000
Automobile – 60 mph	400	*192,000*	5,000	*100,000*	392,000

This table compares time-area requirements for parking and road space measured in square-foot-minutes (square feet times number of minutes) for 20-minute round-trip commutes by various modes.

In practice, automobile transport does not usually increase roadway land requirements by 30-100 times, even cities built before the automobile often had wide roads to accommodate wagon traffic and provide sunlight, but motor vehicles do tend to significantly increase the amount of land devoted to transport facilities. Newman and Kenworthy found that automobile dependent cities average about 7 meters of road length per capita, while less automobile-dependent cities average about 2.5 meters.[7] Parking supply follows a similar pattern. This indicates that automobile-oriented transportation increases transportation land requirements by 3 to 5 times. Put another way, 66% to 80% of the land devoted to roads and parking facilities in modern cities results from the greater space requirements of automobile transport.

The *Tool for Costing Sustainable Community Planning* was created to allow a user to estimate the major costs of community development, particularly those that change with different forms of development (e.g., linear infrastructure), and to compare alternative development scenarios.[8] It is geared towards estimating "planning-level" costs and revenues associated with the residential component of a development, although financial impacts of commercial and other types of development can be incorporated provided that infrastructure requirements are specified correctly.

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[6] Todd Litman (2001), *Evaluating Transportation Land Use Impacts*, VTPI (www.vtpi.org); at www.vtpi.org/landuse.pdf; based on Eric Bruun and Vukan Vuchic (1995), "The Time-Area Concept: Development, Meaning and Applications," *Transportation Research Record 1499*, TRB, pp. 95-104.

[7] Peter Newman and Jeff Kenworthy (1999), *Sustainability and Cities; Overcoming Automobile Dependence*, Island Press (www.islandpress.org), Table 3.9.

[8] CMHC (2006), *Tool For Costing Sustainable Community Planning*, Canadian Mortgage and Housing Corporation (www.cmhc-schl.gc.ca); at www.dcs.sala.ubc.ca/UPLOAD/RESOURCES/links/CMHC_CostingToolUserGuide.pdf.

Transportation Contribution Toward Sprawl

An important consideration in this discussion is the degree to which roads and vehicle use contribute to sprawl (dispersed, automobile-oriented land use development patterns). The conceptual measure of such impacts is the *with and without* test: the difference between that would occur with and without a certain policy or project.[9] Automobile use encourages sprawl by demanding large amounts of urban land for roads and parking, by degrading the urban environment, and by accommodating urban fringe development.[10] 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%.[11] Low-density land use, in turn, increases automobile use by dispersing destinations and reducing the viability of other travel modes.[12] 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 in this trend*."[13] Another popular 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...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."[14]

Table 5.14.3-2 describes how automobile use tends to result in sprawl.

Table 5.14.3-2 **Automobile Contributions Toward Sprawl**

Sprawl Attribute	Transportation Impacts
Density	Reduces density. Requires more land for roads and parking facilities.
Greenfield development	Allows urban fringe, greenfield development.
Dispersion	Allows more dispersed destinations.
Mix	Allows single-use development.
Scale	Requires large-scale roads and blocks.
Street design	Roads emphasize vehicle traffic flow, de-emphasize pedestrian activities.
Transportation options	Degrades walkability, reducing pedestrian and transit accessibility.

This table describes how automobile use contributes to various attributes of sprawl.

[9] C. van Kooten (1993), *Land Resource Economics and Sustainable Development*, UBC Press (www.ubcpress.ca).
[10] Dwight Young (1995), *Alternatives to Sprawl*, Lincoln Institute of Land Policy (www.lincolninst.edu).
[11] Nathaniel Baum-Snow (2007), "Did Highways Cause Suburbanization?," *Quarterly Journal of Economics*, Vol. 122, No. 2, pp. 775-805.
[12] Eric D. Kelley (1994), "The Transportation Land-Use Link," *Journal of Planning Literature*, 9/2, Nov. 1994, (http://jpl.sagepub.com/), p. 128-145; Todd Litman (2006), *Land Use Impacts on Transport*, VTPI (www.vtpi.org); at www.vtpi.org/landtravel.pdf.
[13] John Edwards (1982), *Transportation and Traffic Engineering Handbook*, Institute of Transportation Engineers/Prentice Hall (www.prenticehall.com), p. 401.
[14] Homberger, Kell and Perkings (1982), *Fundamentals of Traffic Engineering, 13 Edition*, Institute of Transportation Studies, UCB (www.its.berkeley.edu), p. 2-8.

Two arguments are used against treating sprawl as a transportation cost. One is that sprawl is a land use issue, not a transport issue.[15] However, transportation decisions affect land use – the two issues cannot be separated.[16] Another argument is that sprawl provides benefits that offset costs. But the benefits of sprawl are mostly private (internal); there appear to be few *external* benefits. The economically optimal level of sprawl consists of what consumers would choose in an efficient market. Some people argue that density causes social problems such as crime, poverty, and depression, but academic studies find no association between density and social problems when factors such as income and class are accounted for.[17] High population density per *room* (called "crowding") is associated with such problems, but not high density per *acre*.

Land Use Impact Costs

Various types of transportation land use impact externalities are described below.[18]

1. Environmental/Ecological Impacts

Biologically active areas such as wetlands, forests, farms, rangelands, gardens, and parks (collectively called *greenspace*) provide external environmental and social benefits, including wildlife habitat, air and water regeneration, social benefits of agricultural production and aesthetic benefits. These external benefits exist in addition to direct benefits to the landowner and are not reflected in the land's market value because they are enjoyed by society as a whole.[19] These benefits are reflected by increased value to adjacent real estate, improved local water quality, recreation and tourism; and in existence, option, and bequest values.[20]

Roads degrade environmental amenities and agricultural production directly by paving and clearing land, indirectly by encouraging increased development, sprawl and other disturbances, by severing and fragmenting habitat, and by introducing new species that compete with native plants and animals.[21] Sprawl tends to increase air pollution

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[15] Mark Delucchi (1997), *Annualized Social Cost of Motor-Vehicle Use in the U.S., 1990-1991*, Institute of Transportation Studies (www.uctc.net), UCD-ITS-RR-96-3 (1).

[16] Terry Moore and Paul Throsnes (1994), *The Transportation/Land Use Connection*, American Planning Assoc., Planning Advisory Service, Report 448/449 (www.planning.org).

[17] 1000 Friends of Oregon (1999), "The Debate Over Density: Do Four-Plexes Cause Cannibalism" *Landmark*, 1000 Friends of Oregon; at www.vtpi.org/1k_density.pdf; VTPI (2008) "Land Use Density and Clustering", *Online TDM Encyclopedia* (www.vtpi.org); at www.vtpi.org/tdm/tdm81.htm

[18] Also see Engin Isin and Ray Tomalty (1993), *Resettling Cities: Canadian Residential Intensification Initiatives*, Canadian Mortgage and Housing Corporation (www.cmhc-schl.gc.ca/en); Richard T.T. Forman, et al (2003), *Road Ecology: Science and Solutions*, Island Press (www.islandpress.com).

[19] Knaap and Nelson (1992), *The Regulated Landscape*, Lincoln Institute (www.lincolninst.edu), p. 126.

[20] Kopp and Smith (1993), *Valuing Natural Assets*, Resources for the Future (www.rff.org), pp. 10-19; Mohan Munasinghe and Jeffrey McNeely (1995), "Key Concepts and Terminology of Sustainable Development," *Defining and Measuring Sustainability*, World Bank (www.worldbank.org).

[21] Steven P. Brady and Jonathan L. Richardson (2017), Road Ecology: Shifting Gears Toward Evolutionary Perspectives, *Frontiers in Ecology and the Environment* (DOI: 10.1002/fee.1458); Committee for a Study on Transportation and a Sustainable Environment (1997), *Toward a Sustainable Future; Addressing the Long-Term Effects of Motor Vehicle Transportation on*

emissions compared with less automobile oriented communities.[22] If just 5% of a watershed is covered with impervious surfaces, such as roads and parking facilities, the water quality of streams is seriously degraded.[23] Paved surfaces have a "heat island" effect (increased local temperatures) which increases urban temperatures by 2-8° F in sunny conditions, increasing energy demand, smog and human discomfort.[24] These impacts tend to increase with sprawl.[25] Banzhaf and Jawahar identify the following benefits from preserving urban-fringe land development:[26]

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 damage from roads and traffic is well documented.[27] W. Roley states:

> "The net effect on wildlife of automobile-dependent urban sprawl is the fragmentation of habitat and the isolation of these fragments and their wildlife populations from one another. The gravest threat to the survival of wildlife in developed areas around the world is the reduction of both habitat and mobility of wildlife. The automobile, in other words, has become the greatest predator of wildlife."[28]

Roads cause various types of ecological damage, particularly when introduced to wilderness or semi-wilderness areas. These impacts tend to be complementary and

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Climate Change, Transportation Research Board (www.nas.edu/trb) Special Report 251, Chapter 4; USEPA (1999) *Indicators of the Environmental Impacts of Transportation*, Office of Policy and Planning, USEPA (www.itre.ncsu.edu/cte).

[22] USEPA (2001), *Improving Air Quality Through Land Use Activities - EPA Guidance*, Office of Transportation and Air Quality, USEPA (www.epa.gov).

[23] Richard Horner, et al (1996), "Watershed Determinates of Ecosystem Functioning," *Effects of Watershed Development and Management on Aquatic Ecosystems*, American Society of Civil Engineers (www.asce.org); Dana Beach (2002), *Coastal Sprawl: The Effects of Urban Design on Aquatic Ecosystems*, Pew Oceans Commission (www.pewoceans.org); Richard T.T. Forman, et al (2003), *Road Ecology: Science and Solutions*, Island Press (www.islandpress.com).

[24] US Environmental Protection Agency, *Heat Island Effect* (www.epa.gov/heatisld).

[25] Brian Stone, Jeremy J. Hess, Howard Frumkin (2010), "Urban Form and Extreme Heat Events," *Environmental Health Perspectives*; at http://ehp03.niehs.nih.gov/article/info:doi/10.1289/ehp.0901879.

[26] H. Spencer Banzhaf and Puja Jawahar (2005), *Public Benefits of Undeveloped Lands on Urban Outskirts: Non-Market Valuation Studies and their Role in Land Use Plans*, Resources for the Future (www.rff.org).

[27] See for example, van Bohemen (2004); Works Consultancy (1993), *Land Transportation Externalities*, Transit New Zealand (www.transit.govt.nz); Patricia White (2007), *Getting Up To Speed: A Conservationist's Guide to Wildlife and Highways*, Defenders of Wildlife (www.defenders.org).

[28] W. Roley (1993) "No Room To Road," *Earthword #4*, 1993, p. 35.

cumulative; although individually they may be minimized through mitigation efforts, their overall effects are still significant. Roads produce the following impacts:[29]

- *Roadkills*: Animals killed directly by motor vehicles. The Humane Society and Urban Wildlife Research Center estimate that more than 1 million large animals are killed annually on U.S. highways. Road kills are a major cause of death for many large mammals including several threatened species. Roadkills increase with traffic speeds and volumes.
- *Road Aversion and other Behavioral Modifications*: Roads affect animals' behavior and movement. For example, black bears cannot cross highways with guardrails. Other species become accustomed to roads and therefore more vulnerable to harmful human interactions.
- *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.
- *Exotic Species Introduction:* Roads spread exotic species of plants and animals that compete with native species. Some introduced plants thrive in disturbed habitats along new roads, and spread into native habitat. Preventing this spreading is expensive.
- *Pollution*: Road construction and use introduce noise, air and water pollutants.
- *Habitat Impacts*: Roads displace and disrupt habitat.
- *Impacts on Hydrology and Aquatic Habitats*: Road construction changes water quality and water quantity, stream channels, and groundwater.
- *Access to Humans*: This includes hunters, poachers, and irresponsible visitors.
- *Sprawl:* Increased road accessible stimulates development, stimulates demand for urban services, which stimulates more development, leading to a cycle of urbanization.

Researchers Richard Forman and Robert Deblinger studied the ecological effects of a four-lane highway through urban, suburban and rural areas, taking into account roadkill, habitat loss, traffic noise, barrier effects to wildlife, introduction of exotic species, water pollution and hydrologic impacts (such as changes in wetlands drainage).[30], with some effects being even more dispersed. Extrapolating these results the researchers calculated that roads influence approximately 20% of the continental United States. A study published by the Florida Department of Transportation estimated that the total value of ecosystem benefits (runoff prevention, carbon sequestration, pollination and other insect services, air quality, invasive species resistance, and aesthetics) of landscaping along state highway rights-of-way at half billion dollars per year.[31]

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[29] Reed Noss (2003), *Ecological Effects of Roads*, Road-Rip; Jennifer McMurtray (2003), *Conservation Minded Citizen's Guide To Transportation Planning*, Defenders of Wildlife (www.defenders.org).
[30] Richard Forman and Robert Deblinger (2000), "The Long Reach of Asphalt," *Conservation Biology*; Patricia White (2007), *Getting Up To Speed: A Conservationist's Guide to Wildlife and Highways*, Defenders of Wildlife (www.GettingUpToSpeed.org).
[31] George L. Harrison (2014), *Economic Impact of Ecosystem Services Provided by Ecologically Sustainable Roadside Right of Way Vegetation Management Practices*, University of Florida/IFAS for the Florida Department of Transportation (www.dot.state.fl.us); at http://tinyurl.com/ovmoezt.

Table 5.14.3-3 summarizes these benefits from various land uses categories. Urban areas and highway buffers provide relatively little benefits, and pavement provides virtually none. This indicates that roadways, and the increased urban expansion they often encourage, impose significant environmental costs.

Table 5.14.3-3 **External Environmental Benefits of Land Uses**[32]

	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	Medium	Low	Low	Low	Low	Low	None[f]
Pavement	None	None	None	None	None	None	None	None[f]

a. Ecological benefits include wildlife habitat, species preservation and support for ecological systems.
b. Recreation includes hunting, fishing, wildlife viewing, hiking, horse riding, bicycling, etc.
c. Includes preservation of cultural sites, harvesting traditional resources, and support for traditional activities.
d. External economic environmental benefits are economic benefits a piece of land provides people who do not own it, including economic benefits to a community of tourism, harvesting fish, wild plants and animals, and agriculture.
e. Economic value of wetlands, forests and urban greenspace is reflected in tourism and recreational expenditures, increased adjacent property values, water resources quality and availability, and fisheries.
f. Highway buffers and pavement provide social benefits but minimal environmental benefits.

Various techniques can be used to monetize the ecological values of openspace (undeveloped lands).[33] These values can be used to calculate external costs of policies and projects that change land use patterns, such as paving or preserving greenfields. Table 5.14.3-4 illustrates a generic cost structure. 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 external environmental benefits. For example, converting land from second-growth forest to pavement represent an environmental cost of $60,000 per hectare. Indirect impacts (such as traffic noise, pollution, and introduced species) to land within 50 meters of a road can be considered to impose half these costs.

Table 5.14.3-4 **Land Conversion Costs** (1994 CA$/hectare)[34]

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
Pristine 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

32 Peter Bein (1997), *Monetization of Environmental Impacts of Roads*, B.C. Ministry of Transportation (www.gov.bc.ca/tran).
33 H. Spencer Banzhaf and Puja Jawahar (2005).
34 Bein (1997).

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 external benefits.

2. Aesthetic Degradation and Loss of Cultural Sites

Roads and parking facilities, vehicle traffic, and low-density development often degrade landscape beauty in various ways.[35] Regional planner 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 and healthy landscapes is indicated by their importance in attracting tourism and increasing adjacent property values.[36] Car traffic and roadway expansion is a threat to the cultural heritage and tourist industry of Cairo, Egypt, and probably most other historic cities.[37] Landscape aesthetic degradation can be evaluated using surveys.[38] Visualization techniques can be used to evaluate the esthetic impact of roads and traffic.[39] Ratings generally became less favorable as road size increases.

The study, *Measuring the Economic Value of a City Park System*, describes numerous benefits from urban parks and openspace, and identifies the following as suitable for quantification: [40]

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

3. Social Impacts

Automobile-oriented transport tends to result in development patterns that are suboptimal for many social goals. Wide roads and heavy traffic degrade the public realm (public spaces where people naturally interact) and in other ways reduce community cohesion.[41] Appleyard reported a negative correlation between vehicle traffic volumes and measures

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[35] John Edwards (1982), "Environmental Considerations," *Transportation and Traffic Engineering Handbook*, Second Edition, ITE (www.ite.org), p. 396; Harvey Flad (1997), "Country Clutter; Visual Pollution and the Rural Landscape", *Annals*, AAPSS (www.aapss.org), 553, Sept. 1997, pp. 117-129.

[36] Charles Fausold and Robert Lileiholm (1996), *The Economic Value of Open Space: A Review and Synthesis*, Lincoln Institute (www.lincolninst.edu).

[37] S.L. Cullinane and K.P.B. Cullinane (1995), "Increasing Car Ownership and Use in Egypt: The Straw that Breaks the Camel's Back?" *International Journal of Transport Economics*, Vol. 22, Feb., pp. 35-63.

[38] Anton C. Nelessen (1994), *Visions for a New American Dream*, Planners Press (www.planning.org).

[39] L. Huddart (1978), "Evaluation of the Visual Impacts of Rural Roads and Traffic," TRRL (www.trl.co.uk), Report #355.

[40] Peter Harnik and Ben Welle (2009), *Measuring the Economic Value of a City Park System*, The Trust for Public Land's Center for City Park Excellence (www.tpl.org); at www.tpl.org/sites/default/files/cloud.tpl.org/pubs/ccpe-econvalueparks-rpt.pdf.

[41] Todd Litman (2007), *Community Cohesion As A Transport Planning Objective*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/cohesion.pdf ; David Forkenbrock and Glen Weisbrod (2001), *Guidebook for Assessing the Social and Economic Effects of Transportation Projects*, NCHRP Report 456, TRB (www.trb.org); Kate Williams and Stephen Green (2001), *Literature Review of Public Space and Local Environments for the Cross Cutting Review*, Oxford Centre for Sustainable Development.

of neighborly interactions and activities, including number of friends and acquaintances residents had on their street, and the area they consider "home territory." He comments:

> "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."[42]

Various writers criticize the "placelessness" resulting when urban space is optimized for vehicle traffic.[43] Carlson argues, "*Automobile-based development has reduced opportunities for public life and magnified the polarization of our society by aggravating the geographical and time barriers between people with different incomes, and by making it more difficult for those who don't own cars to participate in life outside their communities."*[44] Sprawl is associated with reduced housing diversity, social alienation, reduced social interaction and exacerbated urban problems.[45] Studies indicate that respondents living in walkable neighborhoods were more likely to know their neighbors, participate politically, trust others, and be socially engaged.[46] Researchers comment,

> "A deeper issue than the functional problems caused by road widening and traffic buildup is the loss of sense of community in many districts. Sense of community traditionally evolves through easy foot access–people meet and talk on foot, which helps them develop contacts, friendships, trust, and commitment to their community. When everyone is in cars there can be no social contact between neighbors, and social contact is essential to developing commitment to neighborhood."[47]

Automobile oriented communities make non-drivers "location disadvantaged" due to their relatively poor access by other modes.[48] Various critics argue that automobile travel, urban scrawl, and middle-class flight to suburbs contribute to racial and income segregation, social conflict and degraded cities.[49] Long commutes increase the physical

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42 Donald Appleyard (1981), *Livable Streets*, University of California Press (www.ucpress.edu).

43 James Kunstler (1993), *The Geography of Nowhere*, Simon & Schuster, (www.simonsays.com).

44 Daniel Carlson, Lisa Wormser, and Cy Ulberg (1995), *At Road's End; Transportation and Land Use Choices for Communities*, Island Press (www.islandpress.org), p. 15.

45 Engin Isin and Ray Tomalty (1993), *Resettling Cities: Canadian Residential Intensification Initiatives*, Canadian Mortgage and Housing Corporation (www.cmhc-schl.gc.ca/en).

46 Kevin M. Leyden (2003), "Social Capital and the Built Environment: The Importance of Walkable Neighborhoods," *American Journal of Public Health*, Vol. 93, No. 9 (www.ajph.org), pp. 1546-1551.

47 Richard Untermann and Anne Vernez Moudon (1989), *Street Design; Reassessing the Safety, Sociability, and Economics of Streets*, University of Washington, (www.washington.edu).

48 Merle Mitchell (1994), "Links Between Transport Policy and Social Policy" in *Transport Policies for the New Millennium*, Ogden et al. editors, Monash University (www.monash.edu.au).

49 David Popenoe (1979), "Urban Sprawl: Some Neglected Sociological Consideration," *Sociology and Social Research*, Vol. 63, p. 255-268; Steven Cochrun (1994), "Understanding and Enhancing

separation between work and home, leading to reduced sensitivity concerning the impacts of business activities on nearby communities. A Lincoln Institute of Land Policy newsletter article describes the impacts of sprawl on the poor:

> "Land use patterns that put a premium on mobility actually disadvantage some segments of the population. Furthermore, a major cause of this poverty, in the opinion of many scholars and policymakers, is the gap between where these poor people live in central cities and where job growth is taking place in the suburbs. This transportation gap can be all but unbridgeable for low-wage workers who do not own cars, especially when public transit, where it exists, usually focuses on downtown and is often useless for conveying people to widely dispersed, suburban employment sites."[50]

Some critics argue that sprawl is socially beneficial. Hugh Stretton claims that lower density cities provide more per capita recreational land, ignoring the fact that preserving openspace requires *increased* densities.[51] He cites survey findings that suburban residents prefer their current housing over inner-city apartments, but does not consider alternative residential patterns that may satisfy residents at higher densities.

4. Public Service Costs

Sprawl tends to increase the costs of public services such as policing and emergency response, school busing, roads, water and sewage.[52] The relationship between land use patterns and public service costs are shown in Figure 5.14.3-2 and tables 5.14.3-5 through 5.14.3-7. Since most of these studies only consider a portion of all cost categories, the total incremental cost of sprawl is higher than indicated when all costs are also considered.

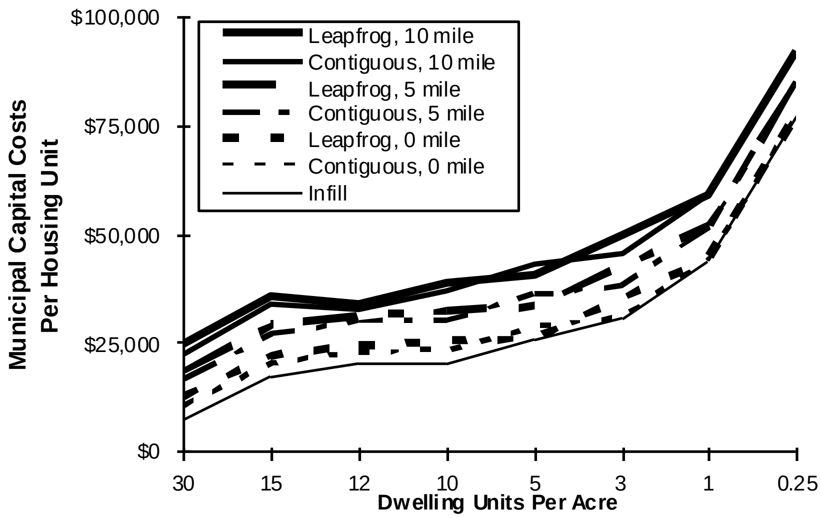
Neighborhood Sense of Community," *Journal of Planning Literature*, Vol. 9, No. 1, (http://jpl.sagepub.com), p. 92-99.

[50] Lincoln Institute (1994) "Restructuring our Car-Crazy Society," *Land Lines*, Lincoln Institute (www.lincolninst.org), March 1994, p. 2.

[51] Hugh Stretton (1994), "Transport and the Structure of Australian Cities" in *Transport Policies for the New Millennium*, Ogden et al. editors, Monash University (www.monash.edu.au).

[52] Pamela Blais (2010) "Perverse Cities: Hidden Subsidies, Wonky Policy, and Urban Sprawl", UBC Press (http://perversecities.ca); Todd Litman (2004), *Understanding Smart Growth Savings: What We Know About Public Infrastructure and Service Cost Savings, And How They are Misrepresented By Critics*, VTPI (www.vtpi.org); at www.vtpi.org/sg_save.pdf; Reid Ewing (1997), "Is Los Angeles-Style Sprawl Desirable?" in *Journal of the American Planning Association*, Vol. 63, No. 1, Winter, pp. 95-126.

Figure 5.14.3-2 **Residential Service Costs**[53]



This illustrates increased capital costs for lower density, non-contiguous development.

Table 5.14.3-5 **Household Annual Municipal Costs by Residential Densities**[54]

Costs	Rural Sprawl	Rural Cluster	Medium Density	High Density
Units/Acre	1:5	1:1	2.67:1	4.5:1
Schools	$4,526	$4,478	$3,252	$3,204
Roads	$154	$77	$53	$36
Utilities	$992	$497	$364	$336
Totals	$5,672	$5,052	$3,669	$3,576

Per household service costs increase due to sprawl. These are mostly external costs.

Table 5.14.3-6 **Estimated 25-Year Public Costs for Three Development Options**[55]

	Spread	Nodal	Central
Residents per Ha	66	98	152
Capital Costs (billion C$ 1995)	54.8	45.1	39.1
O&M Costs (billion C$ 1995)	14.3	11.8	10.1
Total Costs	*69.1*	*56.9*	*49.2*
Percent Savings over "Spread" option	n/a	17%	29%

This study found substantial public service cost savings for more compact development patterns.

53 James Frank (1989), *The Costs of Alternative Development Patterns*, Urban Land Institute (www.uli.org), summarized from p. 40.
54 Robert Smythe (1986), *Density-Related Public Costs*, American Farmland Trust (www.farmland.org); at www.farmlandinfo.org/sites/default/files/Density-Related_Public_Costs_1.pdf, based on prototypical community of 1,000 units housing 3,260 people, 1,200 students.
55 Pamela Blais (1995), *The Economics of Urban Form*, in Appendix E of *Greater Toronto*, Greater Toronto Area Task Force (Toronto).

Table 5.14.3-7 **Twin City Development Patterns Compared**[56]

	Sprawl (2.1 units/acre)	Smart Growth (5.5 units/acre)
Miles of local roads	3,396	1,201
Costs of local roads per unit	$7,420	$2,607
Other infrastructure costs per unit	$10,954	$5,206
Total infrastructure costs per unit	$18,374	$7,813

This study found substantial infrastructurecost savings for smart growth development patterns.

Some costs increase at very high densities due to congestion and high land costs, and decrease in rural areas where governments provide few services.[57] But sprawl encourages new residents with higher expectations to move to exurban areas, so local governments face pressure to provide urban services to low-density sites despite high unit costs.[58] Some communities use impact fees to internalize a portion of these costs, but in practice these seldom reflect full marginal costs.[59] Since these are fixed costs, they provide no incentive to use resources efficiently once development costs are paid. Total costs of sprawl are probably greater when commercial development costs are also included:

> "Because the home and the workplace are entirely separated from each other, often by a long auto trip, suburban living has grown to mean a complete, well-serviced, self-contained residential or bedroom community and a complete, well-serviced place of work such as an office park. In a sense we are building two communities where we used to have one, known as a town or city. Two communities cost more than one; there is not only the duplication of infrastructure but also of services, institutions and retail, not to mention parking and garaging large numbers of cars in both places."[60]

5. Increased Transportation Costs/Reduced Access

Sprawl creates less accessible land use patterns, which increases the amount of mobility required for a given level of accessibility and reduces transportation options, as discussed in Chapter 5.9 of this report. This increases per capita vehicle ownership and use, increasing total transportation costs, as summarized in the table below. Households in low-density suburbs generate almost two-thirds more per capita vehicle hours of travel than comparable households in urban areas, implying increased user and external costs.[61]

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[56] Center for Energy and Environment (1999), *Two Roads Diverge: Analyzing Growth Scenarios for the Twin Cities*, Minnesotans for an Energy-Efficient Economy (www.me3.org), p. 23.

[57] Robert Burchell, et al. (1998), *The Costs of Sprawl – Revisited*, TCRP Report 39, TRB (www.trb.org).

[58] Judy Davis, Arthur C. Nelson, and Kenneth Dueker (1994), "The New 'Burbs," *Journal of the American Planning Association*, Vo. 60, No. 1, (www.planning.org),Winter.

[59] City of Lancaster (1994), *Urban Structure Program*, (www.cityoflancasterca.org).

[60] Douglas Kelbaugh (1992), *Housing Affordability and Density*, Washington Department of Community Development (www.wa.gov), p. 17.

[61] Ewing, Haliyur and Page (1995), "Getting Around a Traditional City, a Suburban Planned Unit Development and Everything in Between," *Transport. Research Record 1466*, (www.trb.org), pp. 53-62.

Table 5.14.3-8 **Transportation Costs That Increase with Sprawl**

Internal Costs	External Costs
Transportation Time Vehicle Ownership Vehicle Operation Residential Parking Crash Damages	Non-Residential Parking Traffic Congestion Roadway Costs and Traffic Services Pollution Emissions Increased Impervious Surface/Reduced Greenspace Fuel Externalities Mobility For Non-drivers (chauffeuring and transit subsidies)

By increasing per capita vehicle ownership and mileage, sprawl tends to increase these costs.

Households in lower-density, automobile dependent communities spend significantly more on transport, on average, than otherwise comparable households in communities with more accessible land use and balanced transportation systems.[62] McCann found that households in automobile dependent communities devote more than 20% of household expenditures to transportation (over $8,500 annually), while those in communities with more diverse transportation systems spend less than 17% (under $5,500 annually).[63] Some critics argue that increased transport costs are offset by lower housing costs, but this is not necessarily true, automobile dependency can increase housing costs.[64]

Sprawled land use tends to increase the costs of providing basic mobility to people who are transportation disadvantaged. Motorists in automobile dependent communities must do more chauffeuring of non-drivers. Transit services and pedestrian facilities experience economies of scale: unit costs decline as the number of users increase, resulting in better facilities and services, and better integration with other components of the transportation system and land use activities. Communities must either provide less service or increase subsidies to maintain a given level of transportation options. Put another ways, a more balanced transport system increases the efficiency of alternative modes, improving the quality of service and cost effectiveness of providing adequate mobility for non-drivers.

6. Economic Productivity and Development

More accessible and resource efficient land use patterns can increase economic productivity and development. Increased density and clustering provides efficiencies of agglomeration, due to increased accessibility (the ability to reach desired activities and destinations), and interactions. It means, for example, that businesses can more easily interact and trade among themselves, that customers can find competitive goods and services, suppliers can easily provide inputs, and specialized workers can expect greater

[62] Peter Newman and Jeff Kenworthy (1999), *Sustainability and Cities; Overcoming Automobile Dependence*, Island Press (www.islandpress.org), pp. 111-117.
[63] Barbara McCann (2000), *Driven to Spend; The Impact of Sprawl on Household Transportation Expenses*, STPP (www.transact.org).
[64] Wenya Jia and Martin Wachs (1998), "Parking and Affordable Housing," *Access*, Vol. 13, Fall 1998 (www.uctc.net), pp. 22-25.

employment opportunities. Agglomeration benefits are why cities develop. Although agglomeration benefits are difficult to measure, they appear to be large.[65] Activities that involve interaction among numerous people, such as education, finance and creative industries, are particularly affected by agglomeration.

One published study found that doubling a county-level density index is associated with a 6% increase in state-level productivity.[66] This suggests that increasing the portion of urban land devoted to roads and parking and increased sprawl tend to reduce economic productivity, while TDM strategies that accommodate and encourage clustering tend to increase economic development.

Some people assume that near universal automobile ownership and telecommunications improvements have eliminated the value of proximity, but the evidence indicates otherwise. Although automobile transport allows activities to be more dispersed within an urban region, the economic importance of cities has increased, as indicated by the increasing portion of residents and businesses located in urban areas. The clustering of computer development in areas such as Silicon Valley indicates that even information-based industries benefit from proximity and agglomeration.

Discussion Summary

Table 5.14.3-9 describes how transportation facilities, automobile-oriented (low-density, dispersed, urban-fringe) development, and motor vehicle traffic contribute to various land use costs. For example, policy or planning decision increases the amount of land devoted to roads and parking facilities tend to reduce the environmental and aesthetic benefits of the greenspace lost.

Of course, different people may value these impacts differently. For example, some people may be most concerned if transportation facilities displace wildlife habitat, others about threats to cultural sites such as cemeteries and battlefields, loss of area farmlands or reduced sidewalk space that reduces neighborhood interactions. The point is that most people value landscape features that may be threatened by the construction of transportation facilities (road, bridges, parking lots, airports, etc.), urban sprawl and increased motor vehicle traffic.

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[65] Alex Anas, Richard Arnott and Kenneth Small (1997), *Urban Spatial Structure*, University of California Transportation Center (www.uctc.net), No. 357.
[66] Andrew F. Haughwout (2000), "The Paradox of Infrastructure Investment," *Brookings Review*, (www.brookings.edu), Summer 2000, pp. 40-43.

Table 5.14.3-9 **Costs Associated With Various Land Use Impacts**

External Costs	Transportation Facilities	Automobile-Oriented Development	Motor Vehicle Traffic
Environmental degradation	Pavement replaces greenspace.	Reduces greenspace.	Harm wildlife, distributes invader species.
Aesthetic degradation and loss of cultural sites	Pavement replaces attractive natural and human-made features.	Development replaces natural and human-made landscape features.	Motor vehicle traffic tends to be noisy and unattractive.
Social impacts.	Wide roads and large parking lots degrade the public realm, reducing community cohesion.	Mixed.	High traffic roads are not conducive to some types of community interactions.
Public service costs	Increases some public service costs (e.g., road maintenance)	Tends to significantly increase public service costs.	Vehicle traffic requires public services (policing, emergency, lighting, etc.)
Increased transportation costs/reduced access	Wide roads and large parking lots are not conducive to walking, and therefore transit.	Reduced accessibility by dispersing destinations and reducing transportation options.	High traffic roads are not conducive to walking and therefore transit.
Economic productivity and development	Land devoted to transport facilities is unavailable for other productive uses.	Reduces efficiencies of accessibility and agglomeration.	Money spent on vehicles and fuel has low economic multipliers.

This table describes economic costs resulting from motor vehicle land use impacts.

Because these impacts are indirect, with several steps between a decision and its ultimate effects, land use impact costs can be difficult to incorporate into a planning process. The following approaches can be used, depending on context and needs.

1. *Qualitative benefits of smart growth.* Describe the benefits that tend to result from transport planning decisions that help create more compact, multi-modal communities, such as improved walking conditions, improving public transit service, and implementing parking management to reduce parking supply.

2. *Qualitative costs of sprawl.* Describe the costs that tend to result from transport planning decisions that stimulate automobile traffic, reduce travel options, and create more dispersed, urban-fringe development, such as widening roadways, increasing parking supply, and reducing funding for alternative modes.

3. *Qualitative analysis with respect to planning objectives.* Evaluate planning decisions can based on the degree that they support or contradict strategic land use development objectives such as greenspace preservation and urban redevelopment.

4. *Quantitative costs of transport facilities*. Calculate the incremental economic, social and environmental costs that result from transportation facilities, such as reduced openspace, stormwater management costs, and barrier effects. Assign a "shadow price" (a dollar value representing external costs) to each acre of land paved.

5. *Quantitative costs of transport activity*. Calculate the incremental economic, social and environmental costs that result from planning decisions that increase motor vehicle

traffic and therefore stimulate sprawl. Assign a "shadow price" to each induced vehicle-mile resulting from urban fringe highway expansion or free parking.

Environmental and Social Benefits?
A 1978 report argues that highways provide external environmental and social benefits, including reduced pollution, 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.[67] Few of these claimed (but unsubstantiated) benefits seem reasonable based on current knowledge and sensibilities, and some seem outright silly. Typical quotations from the report include:

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 Vegetation: *"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."*

[67] Hays Gamble and Thomas Davinroy (1978), *Beneficial Effects Associated with Freeway Construction*, Transportation Research Board (www.trb.org), Report 193.

5.14.4 Estimates:

All values are in U.S. dollars unless otherwise indicated.

1. Environmental Impacts

Some studies have valued open space.[68] The box below ranks of these values. Impervious surfaces such as buildings, parking lots and roadways generally provide the least environmental benefits. 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[69]	
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 5.14.4-1 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 5.14.4-1 **Puget Sound Openspace Values[70]**

	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.

[68] Carolina Tagliafierro, et al. (2013), "Landscape Economic Valuation By Integrating Landscape Ecology Into Landscape Economics," *Environmental Science & Policy*, Vol. 32, pp. 26-36; www.sciencedirect.com/science/article/pii/S1462901112002286.
[69] Virginia McConnell and Margaret Walls (2005), *The Value of Open Space: Evidence from Studies of Nonmarket Benefits*, Resources for the Future (www.rff.org); at http://bit.ly/1SjCvfI.
[70] Matt Chadsey, Zachary Christin, and Angela Fletcher (2015), *Open Space Valuation for Central Puget Sound*, Earth Economics (www.eartheconomics.org); at http://bit.ly/1WLJ1NK.

- A 2008 European study recommends a "Nature and Landscape" cost of 0.004 Euro per interurban vehicle kilometer ($0.007 2007 USD per vehicle mile) for cars and 0.015 ($0.021) for trucks,[71] based on damage compensation costs.

- A major Swiss government transporation cost study included analysis of road and railroad infrastructure habitat loss and fragmentation.[72] 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 by roads 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.

- Austroads estimates the costs of various transportation land use impacts including social and water, biodiversity, and nature and landscape degradation.[73]

- One major study estimates the annualized environmental costs of paving land for roadways as shown in Table 5.14.4-2. Assuming an overall average value of $4,500 U.S. per acre (the middle of the range), or approximately $5,000 per lane-mile (assuming 12-foot lane width), this equals about 3.2¢ per VMT, assuming 200,000 annual vehicle miles per lane mile.[74] This represents a lower bound estimate because it does not include indirect environmental degradation from induced development.

Table 5.14.4-2 **Annual External Environmental Cost of Paving Land**[75]

Land Use Type	1997 Canadian $ Per Hectare	2007 US $ Per Acre
Wetlands	$30,000	$11,055
Urban Greenspace	$24,000	$8,849
2nd Growth Forest	$18,000	$6,631
Farmland	$12,000	$4,425
Road Buffer	$6,000	$2,206

This table indicates estimated annual environmental cost of paving various types of land.

71 M. Maibach, et al. (2008), *Handbook on Estimation of External Cost in the Transport Sector*, CE Delft (www.ce.nl), Table 48; at http://bit.ly/1T7Ub0n.

72 Swiss ARE (2005), *External Costs of Traffic in Nature and Landscape*, report for *The External Cost of Transport In Switzerland*, Swiss Federal Office of Spatial Development (www.are.admin.ch); at www.are.admin.ch/themen/verkehr/00252/00472/index.html?lang=en.

73 Caroline Evans, et al. (2015), *Updating Environmental Externalities Unit Values*, Austroads (www.austroads.com.au); at www.onlinepublications.austroads.com.au/items/AP-T285-14.

74 3.9 million miles of U.S. public roads carry about 2,300 million vehicle miles of travel, about 600,000 annual vmt per road mile, or about 200,000 vmt per lane mile, assuming 3 average lanes per road.

75 Peter Bein (1997), *Monetization of Environmental Impacts of Roads*, B.C. Ministry of Transportation and Highways, p. 3-28.

Given that induced sprawl impacts a much larger area than the area directly paved for roadways, 3¢ per VMT is used as the base value.

2. Aesthetic Degradation and Loss of Cultural Sites

Transportation aesthetic costs have rarely been monetized. Segal estimates that a 3/4 mile stretch of Boston's Fitzgerald Expressway reduced downtown property values by as much as $600 million in current dollars by blocking waterfront views.[76] This averages $1.30 to $2.30 per vehicle trip over the Expressway. This is an extreme case, but indicates that aesthetic degradation from roads probably costs billions of dollars a year in reduced property values and other losses. Aesthetic costs probably rank with other minor environmental costs such as the barrier effect, water pollution and waste disposal, so a comparable estimate of 0.5¢ per vehicle mile seems appropriate.

3. Social Costs

We have found no estimates of this group of costs. They are probably significant in total, and comparable to environmental impact costs, so an estimate of 3¢ is used.

4. Increased Public Service Costs

Assuming that sprawl induces 50% of households to choose one step lower density in Table 5.14.3-5, half the average incremental annual municipal cost increases ([($5,672-$5,052)+ ($5,052-$3,669)+($3,669-$3,576)] x 0.5 = $350), divided by 15,100 annual vehicle miles per household,[77] indicates this external cost averages $0.023 per mile, or about $0.03 in 2007 dollars.

5. Increased Transportation Costs.

Sprawled land use increases both users and external transport costs, but few studies attempt to quantify it. One approach is to use estimates of vehicle ownership and use at different residential densities to calculate expected use travel costs per household. Applying an estimate developed by John Holtzclaw to the density values in Table 5.14-1, costs can be calculated using user cost values from Chapter 3.1.[78]

Assuming that sprawl causes 50% of households to choose a residence one step lower density in this table, the three incremental increases in vehicle costs are averaged and divided by two. Divided by 15,100 average annual miles this cost averages 12¢ per mile, as shown in Table 4.14.4-2. If this is considered entirely a future cost then this value should be depreciated, but if it is a current cost (which seems appropriate where sprawl is both a current and future problem) no depreciation is needed.

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76 Segal (1981), *The Economic Benefits of Depressing an Urban Expressway*.

77 USDOT (1992), *National Personal Transportation Survey* (www.dot.gov).

78 These estimates understate total sprawl costs because they use a constant transit accessibility index of 10, a factor that typically increases with density, and because the estimate of $0.10 per mile of external costs is low, as will be discussed in Chapter 4. It also fails to incorporate user time and accident risk costs, which probably increase with sprawl.

6. Economic Productivity and Development

We have found no estimates of this group of costs. They are probably significant but for the purpose of this analysis no value is assigned to this cost.

Table 5.14.4-2 **Annual Household Auto Costs Under Four Densities**[79]

units/acre	1:5	1:1	2.67:1	4.5:1
Auto/Household	3.4	2.3	1.77	1.6
VMT/Household	28,822	18,603	15,100	13,233
Auto Ownership Costs ($/year)	$11,669	$7,894	$6,075	$5,491
Auto Operating Costs ($0.134/mile)	$5,098	$3,291	$2,670	$2,340
External Costs ($0.10/mile)	$3,804	$2,455	$1,993	$1,746
Total Costs	$20,571	$13,640	$10,738	$9,578
Incremental cost of reduced density	$6,931	$2,905	$1,160	N/A
Average of incremental costs	($6,931 + $2,905 + $1,160) ÷ 3 = $3,666			
Average incremental cost per household	$3666x 0.5 = $1,833			
Average cost per vehicle mile	$1833/ 15,100 = 0.121			

This illustrates the additional automobile costs resulting from lower density land use patterns.

One study found that households in automobile-oriented sprawled regions spend more than $8,500 annually on transport, while those in communities with more efficient land use spend less than $5,500 annually, an average incremental cost of 15¢ per vehicle-mile.[80] This indicates the costs of transport and land use decisions that increase automobile dependency and sprawl. Assuming that vehicle use causes about 40% of sprawl, this results in a working value of 6.2¢ per vehicle-mile or about $0.07 in 2007 dollars.

5.14.5 Variability

These costs are associated with driving that contributes to the construction of roads, especially outside of urban areas, or that result in low-density urban expansion. Ideally, this cost should be assessed specifically for each situation. Thus, sprawl costs would be higher in communities where sprawl impacts are greater, and for specific trips that accommodate and encourage urban expansion and low-density development. Although most of this cost is assigned to automobile use, some transit services also contribute to sprawl, indicated by the portion of riders who access bus and trains by car.

5.14.6 Equity and Efficiency Issues

These are external costs, and so tend to be inequitable and inefficient. Land use changes, such as increased impervious surface and less accessible, more automobile-oriented development patterns, can have multiple, durable impacts. Dispersed, automobile-oriented land use patterns tends to be harmful to disadvantaged people because it reduces their accessibility and mobility options and increases their transportation costs.

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[79] John Holtzclaw (1994), *Using Residential Patterns and Transit to Decrease Auto Dependence and Costs*, National Resources Defense Council (www.nrdc.org). Vehicle ownership and annual mileage data from *National Personal Transportation Survey: Summary of Travel Trends*, USDOT, 1992, p. 12, 18.

[80] Barbara McCann (2000), *Driven to Spend; The Impact of Sprawl on Household Transportation Expenses*, STPP (www.transact.org).

5.14.7 Conclusions

Transportation decisions affect land use patterns. Motor vehicles require relatively large amounts of land for roads and parking facilities, and encourage dispersed development. These land use changes tend to impose various economic, social and environmental costs. Although these impacts are difficult to quantified, they appear to be quite large in total, comparable in magnitude to other transport external costs such as crash damanges and pollution. Reduced road requirements and less dispersed development patterns could benefit society by preserving greenspace, reducing public service costs, increasing accessibility and improving aesthetics, which could provide total benefits worth hundreds of dollars annually per capita. This is not to say that automobile use and low-density land use offer no benefits, but most of these benefits are internal, enjoyed by drivers and landowners, while these costs are mostly external. Society must therefore be able to account for these incremental external costs in transport planning.

These impacts are difficult to monetize, in part because it is difficult to predict how a particular transport planning decision changes land use patterns, and in part because many of the economic, social and environmental impacts that result are themselves difficult to monetize. Critics challenge some of this analysis, arguing for example, that some costs of sprawl are exaggerated or that benefits offset these costs.[81] However, such criticism tends to focus on just one or two impacts, and does not change the overall conclusion that sprawl imposes significant external costs.

There are few existing monetized estimates of these costs. Estimates described above can be used, acknowledging that these results are preliminary and more research is needed. The cost charged to vehicle use should take into account two additional factors. First, automobile use is not necessarily the only cause of sprawl; other influences such as zoning policies are also influential. Second, not all communities consider sprawl a problem. For these reasons, automobile use is only considered responsible for half of these costs, calculated to be 8.3¢ per vehicle mile as indicated in Table 5.14.7-1.

Table 5.14.7-1 **Land Use Impact Cost Estimate** (2007 dollars per vehicle mile)[82]

Cost Category	Estimate (Cents/Veh. Mile)
Environmental	3¢
Aesthetic & Cultural	0.5¢
Social	3¢
Municipal	3¢
Transportation	7¢
Total Sprawl Cost	*16.5¢*
Automobile Sprawl Costs (Total reduced 50% for other contributing factors)	8.3¢

This table summarizes estimated land use impact costs associated with motor vehicle use.

[81] Todd Litman (2007), *Evaluating Criticism of Smart Growth*, VTPI (www.vtpi.org); at www.vtpi.org/sgcritics.pdf

[82] This estimate is admittedly one of the most uncertain and controversial in this report. See Chapter 4 for information on a survey that supports this conclusion and the magnitude of this estimate.

These costs are charged to urban driving and telework, because they encourage low-density land use. Rural driving is charged at half this rate on the assumption that it contributes less to sprawl. Ridesharing, public transit, bicycling, and walking decrease roadway requirements and encourage higher densities, so impose no land use impact costs, although a sprawl cost should be assigned to some commuter rail services.

These cost values can be assigned to policy and planning decisions that increase vehicle travel or create more automobile-dependent, sprawled land use. Conversely, decisions that reduce motor vehicle traffic, reduce the amount of land paved for transport facilities, and encourage more clustered, accessible land development, can be considered to provide savings of this magnitude. For example, if two pollution reduction strategies are being considered, one that reduces per-mile vehicle emission rates (such as stricter emission standards) and the other reduces total vehicle mileage (such as improved transit services), the option that reduces total vehicle mileage can be considered to provide additional benefits to society by supporting more efficient land use development.

This methodology is admittedly crude. Because of the uncertainty and variability of these costs, it may be inappropriate to apply these cost values to some types of evaluation. Critics may argue that a particular transportation activity or decisions does not contribute to inefficient land uses, that there is no practical way to assign costs to such impacts and these values are arbitrary, that automobile dependency and sprawl provide external benefits that offset external costs, or that any problems resulting from inefficient land use patterns should be managed directly, through land use planning, rather than as a cost of transportation activities or planning decisions (as discussed in Chapter 8 of this report).

This is a "burden of proof" issue: it is difficult to prove that vehicle travel imposes land use costs of exactly this magnitude, but it would be equally difficult to prove that vehicle traffic does not impose such costs. As a result, the application of land use impact costs to transport evaluation depends on the values, perspectives and ideology of those involved. If decision-makers prefer to assign lower-range costs to motor vehicle use they will tend to place the burden of proof on the claim that such costs exist. If decision-makers prefer to assign higher-range costs to motor vehicle use, they will tend to place the burden of proof on the claim that such costs *do not* exist.

The suitability of these estimates can be tested by asking experts or stakeholders to rank various costs (or "problems"), such as traffic risk, air pollution, noise pollution and sprawl. If some of these impacts are monetized, others can be monetized based on their relative value. Such a survey, described in Chapter 6, indicated that the magnitude of land use impacts estimated here is consistent with public opinion.

Table 5.14.7-2 Estimate **Land Use Impact Costs** (2007 U.S. Dollars per Vehicle Mile)

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.0830	0.0830	0.0415	0.0664
Compact Car	0.0830	0.0830	0.0415	0.0664
Electric Car	0.0830	0.0830	0.0415	0.0664
Van/Light Truck	0.0830	0.0830	0.0415	0.0664
Rideshare Passenger	0.0000	0.0000	0.0000	0.0000
Diesel Bus	0.0000	0.0000	0.0000	0.0000
Electric Bus/Trolley	0.0000	0.0000	0.0000	0.0000
Motorcycle	0.0830	0.0830	0.0415	0.0664
Bicycle	0.0000	0.0000	0.0000	0.0000
Walk	0.0000	0.0000	0.0000	0.0000
Telework	0.0830	0.0830	0.0415	0.0664

Automobile Cost Range

This is currently a difficult cost to estimate due to limited research and data. The minimum estimate is based on just the increased municipal costs associated with sprawl. The maximum estimate reflects the higher range of each cost.

Minimum	Maximum
$0.02	$0.20

5.14.8 Information Resources

Information on transport land use impact evaluation is available from the following sources.

American Forests (www.americanforests.org) provides analysis tools for evaluating forest values and impacts, including the *CITYgreen* software program that analyses ecosystem services and calculates dollar benefits of forests under specific circumstances.

Chester Arnold and James Gibbons (1996), "Impervious Surface Coverage: The Emergence of a Key Environmental Indicator," *American Planning Association Journal*, Vol. 62, No. 2, Spring, pp. 243-258; at http://nemo.uconn.edu/publications/tech_papers/IS_keyEnvironmental_Ind.pdf.

H. Spencer Banzhaf and Puja Jawahar (2005), *Public Benefits of Undeveloped Lands on Urban Outskirts: Non-Market Valuation Studies and their Role in Land Use Plans*, Resources for the Future (www.rff.org).

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E. Brabec (1992), *The Value of Preserving Open Land*, Technical Information Series Vol. 1, No. 2, Scenic America (www.scenic.org).

Steven P. Brady and Jonathan L. Richardson (2017), Road Ecology: Shifting Gears Toward Evolutionary Perspectives, *Frontiers in Ecology and the Environment* (DOI: 10.1002/fee.1458).

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Robert Burchell, Anthony Downs, Barbara McCann and Sahan Mukherji (2005), *Sprawl Costs: Economic Impacts of Unchecked Development*, Island Press (www.islandpress.org).

Center for Watershed Protection (www.cwp.org).

CMHC (2006), *Tool For Costing Sustainable Community Planning*, Canadian Mortgage and Housing Corporation (www.cmhc-schl.gc.ca); at www.toolkit.bc.ca/sites/default/files/CMHC_CostingToolUserGuide.pdf.

Community Impact Assessment Website (www.ciatrans.net), sponsored by the U.S. Federal Highway Administration, provides information on methods for evaluating the impacts of transportation projects and programs on communities.

CTE (2008), *Improved Methods For Assessing Social, Cultural, And Economic Effects Of Transportation Projects*, NCHRP Project 08-36, Task 66, Transportation Research Board (www.trb.org), Center for Transportation and the Environment, AASHTO; at www.statewideplanning.org/_resources/234_NCHRP-8-36-66.pdf.

Environmental Impacts of Roads (www.environmentalscience.org/roads).

Environmental Valuation Reference Inventory (www.evri.ca) is a searchable storehouse of empirical studies on the economic value of environmental benefits and human health effects.

Caroline Evans, et al. (2015), *Updating Environmental Externalities Unit Values*, Austroads (www.austroads.com.au); at www.onlinepublications.austroads.com.au/items/AP-T285-14.

David Forkenbrock and Glen Weisbrod (2001), *Guidebook for Assessing the Social and Economic Effects of Transportation Projects*, NCHRP Report 456, TRB (www.trb.org); at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_456-a.pdf and http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_456-b.pdf.

Richard T.T. Forman, et al (2003), *Road Ecology: Science and Solutions*, Island Press (www.islandpress.com).

Green Roads (www.transportation.gov/utc/greenroads-sustainability-counts).

Stefan Grudemo, Pernilla Ivehammar and Jessica Sandström (2002), *Calculation Model For Encroachment Costs Of Infrastructure Investments*, Swedish National Road and Transport Research Institute (www.vti.se); at www.vti.se/nordic/3-03mapp/pdf/page27.pdf.

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Louis Berger Inc. (1998), *Guidance for Estimating the Indirect Effects of Proposed Transportation Projects*, NCHRP Report 403, TRB (www.trb.org); and (2001), *Guidance for Assessing Indirect and Cumulative Impacts of Transportation Projects in North Carolina*, North Carolina DOT (www.ncdot.org/~research).

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Todd Litman (2004), *Pavement Busters Guide*, VTPI (www.vtpi.org); at www.vtpi.org/pavbust.pdf.

Todd Litman (2005), *Transportation Land Valuation; Evaluating Policies and Practices that Affect the Amount of Land Devoted to Transportation Facilities*, VTPI (www.vtpi.org); at www.vtpi.org/land.pdf.

Todd Litman (2007), *Evaluating Criticism of Smart Growth*, VTPI (www.vtpi.org); at www.vtpi.org/sgcritics.pdf.

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Todd Litman (2004), *Understanding Smart Growth Savings: What We Know About Public Infrastructure and Service Cost Savings, And How They are Misrepresented By Critics*, VTPI (www.vtpi.org); at www.vtpi.org/sg_save.pdf.

Todd Litman (2005), *Land Use Impacts on Transport*, VTPI (www.vtpi.org); at www.vtpi.org/landtravel.pdf.

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M. Maibach, et al. (2008), *Handbook on Estimation of External Cost in the Transport Sector*, CE Delft (www.ce.nl); at http://ec.europa.eu/transport/costs/handbook/doc/2008_01_15_handbook_external_cost_en.pdf

Virginia McConnell and Margaret Walls (2005), *The Value of Open Space: Evidence from Studies of Nonmarket Benefits*, Resources of the Future (www.rff.org); at www.rff.org/rff/documents/rff-report-open%20spaces.pdf.

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