Pavement Busters Guide

Why and How to Reduce the Amount of Land Paved for Roads and Parking Facilities

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by

Todd Litman
Victoria Transport Policy Institute

Abstract
This guide identifies ways to reduce the amount of land required for roads and parking facilities. It examines economic, social and environmental costs of pavement (also called impervious surfaces). These costs are often overlooked or undervalued in policy and project evaluation, which skews planning decisions to supply more road and parking area than optimal. It identifies current policies and planning practices that unintentionally increase road and parking requirements, and specific strategies for reducing pavement area. This analysis indicates that road and parking area can often be reduced significantly in ways that are cost effective and maintain accessibility.

Summarized in
More efficient management can often reduce the amount of land paved for roads and parking facilities.
“Form no longer follows function, fashion, or even finance; instead, form follows parking requirements.” — Donald Shoup

Introduction
The *landscape* (the earth’s surface) is a unique and valuable resource. It can be used in various ways, ranging from wildlands and farmlands, to buildings and transportation facilities. Public policies and planning practices affect how land is used, which can have significant economic, social and environmental impacts.

*Greenspace* (also called *openspace* or *natural environment*) refers to ecologically productive lands such as forests, deserts, farms, gardens and parks. The *built environment* refers to land developed for human activities (Rogers 2016; Romem 2016). This includes *impervious surfaces* (land covered by materials impenetrable to water, such as asphalt, concrete and brick), a major portion of which consists of transportation facilities. Roads and parking facilities typically cover 10-25% of urban land, and more than 50% in major commercial centers such as downtowns and commercial centers, as illustrated in Figure 1. Although such facilities are useful and necessary, they also impose significant economic, social and environmental costs.

**Figure 1** Impervious Surface Coverage (Arnold and Gibbons 1996)

Roads, parking facilities and sidewalks represent a major portion of urban land area.

Many current policies and planning practices are intended to maximize road and parking supply; they assume that more is better. This increases the amount of land devoted to transport facilities. Alternative approaches can significantly reduce road and parking pavement area, providing many benefits.

This guide identifies ways to reduce the amount of land paved for transportation facilities. It investigates various costs of paving land, describes ways to determine optimal road and parking supply, identifies current practices that unintentionally expand transport facility area beyond what is optimal, and identifies strategies for reducing road and parking facility pavement.
Measuring Pavement Area

Various studies have measured the amount of land covered by impervious surfaces such as roofs and pavement (Arnold and Gibbons 1996; Badger and Bui 2019; Elvidge, et al. 2007). More compact development tends to increase impervious surface area per acre but reduce it per capita. Taller, more compact buildings reduce land consumption. For example, a one-story house requires almost three times as much land as the same interior space provided in a three story townhouse, and six times as much as an apartment in a six-story building.

A typical residential street is 36 feet (12 meters) wide, with a 7-foot parking lane and 11-foot traffic lane. If houses average 100-foot street frontages, there is 1,800 square feet (sf) (180 square meters [sm]) of frontage street area. Figure 2 shows the relationship between per capita lane-miles (and therefore roadway area) and density in U.S. urban regions from the Federal Highway Administration’s Highway Statistics Report. This indicates that U.S. city roadway supply ranges from less than 2 to more than 16 lane-miles per 1,000 residents, with rates that decline with density. This is equivalent to 150 to 1,200 square feet of road space per capita (assuming lanes, including parking and curb areas, average 14-foot widths), with higher rates in sprawled areas and lower rates in compact cities.

**Figure 2** Urban Density Versus Roadway Supply (FHWA 2012, Table HM72)

This figure illustrates per capita road area. Each dot represents a U.S. urban region. Since the data measure traffic lanes but ignore parking lanes, it understates total urban road area.

This indicates that there are 150-1,200 square feet of road space per capita, with higher rates in sprawled urban regions and lower rates in more compact areas.

Figures 1 and 2 indicate the amount of land devoted to roads in various U.S. cities. The results indicate that the portion of land devoted to roadways declines with density, but per capita road area increases with density. Residents of sprawled cities such as Atlanta, Houston and Dallas require about three times as much roadway land as residents of compact cities such as New York, San Francisco and Chicago. Similar differences probably exist within urban regions, such as between central and urban fringe neighborhoods.

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1 For more information see the “Roadway Land Value” and “Parking Costs” chapters of Transportation Cost and Benefit Analysis at www.vtpi.org/tca.
Figure 2  Land Devoted To Streets (Meyer and Gomez-Ibanez 1983, p. 181)

As urban population density increases the portion of land devoted to streets increases while per capita road area declines.

A typical parking space is 8-10 feet (2.4-3.0 meters) wide and 18-20 feet (5.5-6.0 meter) deep, totaling 144-200 square feet (13-19 sm). Off-street parking requires driveways (connecting the parking lot to a road) and access lanes (for circulation within a parking lot), and so typically requires 300-400sf (28-37 sm) per space, allowing 100-150 spaces per acre (250-370 per hectare). Assuming there are two to four off-street parking spaces per capita, parking pavement totals about 1,000sf per capita ("Parking Costs," Litman 2009).

Figure 3  Maximum Passengers Per Lane-Hour By Urban Mode (ADB 2012)

The maximum number of passengers a 3.5-meter urban road lane can carry varies significantly by mode and load factor (passengers per vehicle).
Figures 3 and 4 illustrate the space requirements of various urban transport modes. Automobile travel requires much more travel and parking space than walking, bicycling and public transit travel. Actual space requirements can vary depending on road design, traffic conditions and vehicle load factors (passengers per vehicle).

**Figure 4: Space Required By Travel Mode**

![Space Required By Travel Mode](image)

Various studies have estimated the amount of land devoted to roads and parking facilities. Akbari, Rose and Taha (2003) used high-resolution orthophotos to estimate the area of various land-use types in Sacramento, California. They found that pavement covers about 35% of residential areas and 50–70% of non-residential areas. Table 2 summarizes the results.

**Table 2: Calculated Surface-Area Percentages** (Akbari, Rose and Taha 2003)

<table>
<thead>
<tr>
<th></th>
<th>Tree Cover</th>
<th>Barren Land</th>
<th>Grass</th>
<th>Roof</th>
<th>Road</th>
<th>Sidewalk</th>
<th>Parking</th>
<th>Miscellaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>14.7</td>
<td>10.2</td>
<td>24.5</td>
<td>19.4</td>
<td>12.7</td>
<td>8.0</td>
<td>4.9</td>
<td>5.6</td>
</tr>
<tr>
<td>Commercial/service</td>
<td>9.6</td>
<td>7.3</td>
<td>9.3</td>
<td>19.8</td>
<td>15.5</td>
<td>3.7</td>
<td>31.1</td>
<td>3.8</td>
</tr>
<tr>
<td>Industrial</td>
<td>8.1</td>
<td>19.7</td>
<td>6.0</td>
<td>23.4</td>
<td>7.3</td>
<td>1.3</td>
<td>20.0</td>
<td>14.3</td>
</tr>
<tr>
<td>Transport/communications</td>
<td>0.0</td>
<td>4.0</td>
<td>0.0</td>
<td>5.0</td>
<td>80.0</td>
<td>1.0</td>
<td>10.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Industrial and commercial</td>
<td>2.8</td>
<td>15.6</td>
<td>5.6</td>
<td>19.2</td>
<td>10.3</td>
<td>1.3</td>
<td>32.1</td>
<td>13.1</td>
</tr>
<tr>
<td>Mixed urban</td>
<td>26.8</td>
<td>2.1</td>
<td>7.1</td>
<td>23.7</td>
<td>17.6</td>
<td>4.5</td>
<td>9.5</td>
<td>8.7</td>
</tr>
</tbody>
</table>

*This table summarizes the surface area of various types of land uses in Sacramento, California.*

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Figure 6 illustrates the land devoted to streets and parking in Vancouver, BC. It shows that road rights-of-way total approximately 28% of total land in the city and 7% in the entire urban region. Nicoletti and Clark (2019) found that about 20% of the entire Vancouver region and 50% of the urbanized area is covered with impervious surfaces, and that tree canopy cover 54% for the entire Metro Vancouver land base and 32% of the land within the Urban Containment Boundary.

These figures illustrate the distribution of land uses in the City of Vancouver and the larger Vancouver metropolitan region. It shows that road rights-of-way total approximately 28% of total land in the city and 7% in the entire urban region.

Hoehne, et al. (2019) estimate that in 2017 the Phoenix, Arizona metropolitan region had 12.2 million parking spaces. They estimate that for every registered non-commercial vehicle there are 4.3 total parking spaces of which 1.3 are off-street residential spaces, 1.3 are off-street non-residential spaces, and 1.7 are on-street spaces. They estimate that roads and parking cover approximately 36% of the metro’s land area (10% parking and 26% roadway).

Scharnhorst (2018) developed comprehensive parking inventories and cost estimates for New York, Philadelphia, Seattle, Des Moines, and Jackson, Wyoming. Parking was categorized by type: on-street, off-street surface and off-street structured. Table 2 summarizes the results. Parking spaces per capita delines with density, parking supply per square mile increases with density, but the portion of parking that is structured increases with land prices, so supply is often greater where it is less visible.

| Table 2 Parking Spaces and Costs in Five U.S. Cities (Scharnhorst 2018) |
| --- | --- | --- | --- | --- |
| | New York | Philadelphia | Seattle | Des Moines | Jackson |
| Population | 8,537,673 | 1,567,872 | 704,352 | 215,472 | 10,529 |
| Parking Spaces | 1,965,377 | 2,172,896 | 1,596,289 | 1,613,659 | 100,119 |
| Spaces Per Capita | 0.2 | 1.4 | 2.3 | 7.5 | 9.5 |
| Spaces Per HH | 0.6 | 3.7 | 5.2 | 19.4 | 27.1 |
| Total Value | $20.55 billion | $17.46 billion | $35.79 billion | $6.42 billion | $711 million |
| Value Per HH | $6,570 | $29,974 | $117,677 | $77,165 | $192,138 |

Scharnhorst used various data sources to measure parking supply and costs in five cities.
McCahill and Garrick (2012) used data from 12 US cities to measure the relationships between travel activity and land consumption. They found that on average each 10 percentage point increase in automobile commute mode share is associated with an increase of more than 2.5 square meters of parking per capita, and a decrease of 1,700 people per square kilometer.

Chester, Horvath and Madanat (2010) estimate there are between 105 million and 2.0 billion on- and off-street parking spaces in the U.S., based on the five scenarios below, indicating between 0.5 to 8 parking spaces per vehicle, summarized below.

<table>
<thead>
<tr>
<th>Type</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
<th>Scenario 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-street</td>
<td>35</td>
<td>92</td>
<td>180</td>
<td>150</td>
<td>1,100</td>
</tr>
<tr>
<td>Surface</td>
<td>36</td>
<td>520</td>
<td>520</td>
<td>610</td>
<td>790</td>
</tr>
<tr>
<td>Structure</td>
<td>34</td>
<td>110</td>
<td>110</td>
<td>84</td>
<td>120</td>
</tr>
<tr>
<td>Total</td>
<td>105</td>
<td>730</td>
<td>820</td>
<td>840</td>
<td>2,000</td>
</tr>
</tbody>
</table>

*This table summarizes various estimates of U.S. parking spaces.*

Chester, et al. (2015) estimate Los Angeles County parking supply from 1900 to 2010, and studied how parking infrastructure affects urban form and relates to changes in automobile travel. They estimate that in 2010 there were 18.6 million designated parking spaces in the County, approximately 3.3 spaces per automobile, including 1.0 residential, 1.7 nonresidential, and 0.6 on-street spaces (Figure 6). In total, 14% of Los Angeles County’s incorporated land is devoted to parking, which is greater than roadway rights-of-way. They find that the urban core has the greatest density of parking spaces, but suburban areas have greater parking supply growth. They conclude that abundant parking supply increase vehicle ownership and use.

*Figure 6* Los Angeles County Parking Supply (Chester, et al. 2015)

This figure illustrates the number of estimated parking spaces in Los Angeles County.
Davis, et al. (2010) used detailed aerial photographs to count off-street surface parking spaces in Illinois, Indiana, Michigan, and Wisconsin. Parking spaces were identified as paved areas with painted stripes, or where more than three cars were parked in an organized fashion, which excluded on-street and structured parking spaces (other than the top floor if the structure has an open roof), 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 in these four states parking lots use 1,260 km² of land (lower bound 976 km² and upper bound 1,745 km²) approximately 5% of urban land, with higher proportions in more sprawled areas.

Zeng and Ramaswami (2020) analyzed how lifestyle and consumption patterns affect land consumption, and therefore the land savings of lifestyle changes such as reduced consumption of meat, clothing and motor vehicles. Gössling, et al (2016) used high-resolution satellite images to analyze the amount of land devoted to transportation facilities, and the portion of this land devoted to various modes, in four different districts in Freiburg, Germany. They found that they portion of land devoted to automobile transport is greater than its mode share, and the portion devoted to bicycling is less than its share of trips. Ebrahimian, Gulliver and Wilson (2015), measure “effective” impervious area (EIA), which refers to land areas that drain into storm sewers. 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.

The table below summarizes total estimated roadway and parking facility land consumption per U.S. urban automobile, based on previously described data sources. This indicates that, for automobile travel to be convenient a typical vehicle requires about 2,400 square feet of space. Where land is very expensive, some parking can be structured or underground, reducing land consumption, but in most situations these space requirements translate into land consumption.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square feet of road space per capita (Figure 2)</td>
<td>150</td>
<td>675</td>
<td>1,200</td>
</tr>
<tr>
<td>Square feet of road space per vehicle @ 0.8 vehicle per capita</td>
<td>188</td>
<td>844</td>
<td>1,500</td>
</tr>
<tr>
<td>Off-street parking spaces per vehicle</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Square feet per off-street parking space</td>
<td>300</td>
<td>350</td>
<td>400</td>
</tr>
<tr>
<td>Square feet parking per vehicle</td>
<td>600</td>
<td>1,500</td>
<td>2,400</td>
</tr>
<tr>
<td>Total road and parking square feet per vehicle</td>
<td>788</td>
<td>2,344</td>
<td>3,900</td>
</tr>
</tbody>
</table>

This table summarizes various factors that affect parking demand and optimal parking supply.

This suggests that an average urban vehicle requires 800 to 4,000 square feet of land for roads and parking facilities, which is about three times the land required for a house. As a result, per capita pavement area increases with vehicle ownership rates and declines with population density. Although roads and parking facilities represent a relatively small portion of total land area they are often located in areas with high land values and competing uses. More efficient management that reduces road and parking land requirements can free up valuable land for other productive uses and provide other benefits.
Factors Affecting Impervious Surface Area

This analysis can be used to understand how various development and transportation factors affect impervious surface area. This analysis is affected by how these impacts are measured: the portion of land that is impervious tends to increase with development density, and tends to be highest in central cities, but per capita impervious surface area tends to increase with sprawl and automobile dependency, and so tends to be greater in suburban and rural areas.

**Figure 7** How Many Homes does a 5,000ft² Lot Create? (DiRaimo 2021)

The amount of land required per housing unit, and the number of potential occupants per parcel, vary by an order of magnitude.

All are three-bedroom homes.

The table below calculates the building, road and parking area required for three housing types: car-free urban, car-owing urban, and suburban. It assumes that each house has 1,800 square feet (sf) of interior space, with three stories in cities and one story in suburbs; a car-free urban household uses a tenth of a vehicle through sharing and taxis, a car-owing urban household owns one vehicle, and a suburban household owns two; parking spaces (including driveways) average 300sf in cities and 400sf in suburbs; and road space per vehicle averages 200sf in cities and 1,000 in suburbs.

**Table 5** Impervious Surface Area Per Household

<table>
<thead>
<tr>
<th></th>
<th>Car-Free Urban</th>
<th>Car- Owning Urban</th>
<th>Suburban</th>
</tr>
</thead>
<tbody>
<tr>
<td>House – stories</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>House area (sf)</td>
<td>600</td>
<td>600</td>
<td>1,800</td>
</tr>
<tr>
<td>Vehicles per household</td>
<td>0.1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Parking spaces per vehicle</td>
<td>2</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Area per parking space (sf)</td>
<td>300</td>
<td>300</td>
<td>400</td>
</tr>
<tr>
<td>Total parking space area (sf)</td>
<td>60</td>
<td>600</td>
<td>2,400</td>
</tr>
<tr>
<td>Road area per vehicle (sf)</td>
<td>20</td>
<td>200</td>
<td>2,000</td>
</tr>
<tr>
<td>Total</td>
<td>680</td>
<td>1,400</td>
<td>6,200</td>
</tr>
</tbody>
</table>

This table compares urban and suburban building, parking and road impervious surface area.
The figure below illustrates the results. A typical two-car suburban household requires an estimated 6,200 square feet of impervious surface, 4,800 more than a one-car urban household and 5,520 more than a car-free urban household.

It is also interesting to compare impervious surface footprints with urban park area. According to the Trust for Public Land’s City Park Facts (TPL 2017), U.S. cities average 13 acres of public parks per 1,000 residents, or about 570sf per capita. This is comparable to per capita housing footprints, but less than the road and parking area typically required for one automobile. It is also interesting to compare the number of trees displaced by urban and suburban development. A healthy forest contains 40-100 significant trees per acre (SBC 2007). Since suburban development requires an additional 4,800-5,520sf of impervious surface, each suburban home displaces 5-12 more trees than an urban home.
The table below compares the total impervious area of these three housing types. Because suburban areas have far more land per household, they can accommodate the additional pavement that motor vehicles require and still have significant greenspace. Urban areas have less land per household so their greenspace declines significantly as vehicle ownership increases. For example, if urban households own just one vehicle which requires two 300sf parking spaces and 200sf of road space, nearly half of local land area is impervious. As a result, preserving urban greenspace requires limiting vehicle ownership and minimizing road and parking area per vehicle.

**Table 6** Portion of Impervious Surface Area

<table>
<thead>
<tr>
<th></th>
<th>Car-Free Urban</th>
<th>Car-Owning Urban</th>
<th>Suburban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (household/acre)</td>
<td>15</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>Total land per household (sf)</td>
<td>2,904</td>
<td>2,904</td>
<td>10,890</td>
</tr>
<tr>
<td>Impervious surface per household (sf)</td>
<td>680</td>
<td>1,400</td>
<td>6,200</td>
</tr>
<tr>
<td>Portion of land that is impervious</td>
<td>23%</td>
<td>48%</td>
<td>57%</td>
</tr>
<tr>
<td>Remaining greenspace</td>
<td>2,240</td>
<td>1,504</td>
<td>4,690</td>
</tr>
<tr>
<td>Portion of land that can be greenspace</td>
<td>77%</td>
<td>52%</td>
<td>43%</td>
</tr>
</tbody>
</table>

This table compares urban and suburban impervious surface areas. Urban areas have little land per household and so need to limit vehicle ownership in order to preserve local greenspace.

This analysis indicates that per capita impervious surface area tends to decline with density, with reduced automobile ownership and use, and with policies that minimize road and parking supply per vehicle. Overall, sprawled, automobile-oriented development typically displaces 5-10 times as much greenspace per capita as urban infill.

These impacts are generally ignored. When purchasing a home or vehicle, or making travel decisions, consumers seldom consider the amount of impervious surface area that will be required by various options, and their environmental impacts. Similarly, planners seldom quantify the amount of habitat preserved by policies that reduce automobile ownership and encourage infill rather than sprawled development. Smart Growth advocates of more compact, multi-modal development seldom report the environmental benefits that result from reduced impervious surface area; in fact, infill development is frequently opposed for displacing urban trees, although such losses are far smaller than would occur if the same amount of development occurs in sprawled, automobile-dependent locations (Litman 2019).
Impervious Surface Costs

Paving land for roads and parking facilities imposes various direct and indirect costs, as described below. Current planning practices often overlook some of these costs, which skews decisions toward economically excessive pavement area. As a result, pavement reduction often provides greater benefits than commonly recognized.

- **Land.** Land devoted to roads and parking facilities has opportunity costs; it could be used for other productive purposes including building, farming and openspace (van Essan, et al. 2004). Urban roads and parking facilities tend to be located in areas with high land values, such as commercial centers and resort communities, so their land costs tend to be high. Assuming that each vehicle requires 4,500sf of land for roads and parking, and the price of this land averages $1-3 million per acre, this is about $10,000-30,000 per vehicle, or $1,000 to $2,000 annualized value (Franco 2020; Hoehne, et al. 2019; Litman 2003; Scharnhorst 2018).

- **Facility costs.** Roads and parking facility construction and operating costs are estimated to total about $1,000 to $4,000 annually per motor vehicle (Litman 2009; Franco 2020).

- **Hydrologic impacts.** Impervious surfaces prevent groundwater percolation which increases stormwater management costs and reduces groundwater recharge (CNT 2020; Jacob and Lopez 2009). Blum, et al. (2020), found that each 1% increase in pavement area increases nearby waterway flooding by 3.3%. Water quality degrades significantly if impervious surface covers more than 5% of a watershed (Horner, et al. 1996).

- **Water Pollution.** Paved surfaces collect and concentrate water pollutants such as phosphorous, nitrogen and suspended solid (Jacob and Lopez 2009).

- **Heat island effects.** Pavement, particularly dark-colored asphalt, absorbs and stores solar radiation, which increases ambient temperatures. As a result, urban areas are 2-8° F hotter in summer, which increases energy demand, smog and discomfort (USEPA 2011).

- **Increased vehicle travel and associated costs.** Increased parking and roadway capacity tends to increase per capita vehicle ownership and use, and degrade other travel options (McCahill and Garrick 2012; Shoup 2005). This increases various costs, including traffic congestion, consumer costs, accidents, energy consumption and pollution emissions.

- **Displaces other road uses.** Road rights of way devoted to automobile traffic is unavailable for other modes or uses, such as sidewalk cafes and play areas (TA 2021).

- **Sprawl costs.** Expanding road and parking area encourages more dispersed, automobile-dependent development patterns, which increases the costs of providing public services (water, sewage, garbage, emergency response, school), increases total transportation costs, and imposes environmental costs (Burchell, et al. 2005; Litman 2006).

- **Reduced housing affordability.** Local roads and residential parking costs are borne through development costs and property taxes, so increasing these costs tends to reduce housing affordability (Gabbe and Pierce 2016; Jia and Wachs 1998).

- **Displaced openspace and habitat.** Undeveloped land, farmland and greenspace provide various environmental and aesthetic benefits, including wildlife habitat, groundwater recharge, air and noise pollution reduction, and reduced ambient temperatures (White 2007). Many urban areas contain important wildlife habitats and species (Ives, et al. 2015).

- **Energy and pollution.** Road and parking facility construction and operation cause significant energy consumption and pollution (Chester, Horvath and Madanat 2010).
Aesthetic degradation. Larger roads and parking facilities tend to reduce adjacent property values because they are unattractive and noisy (Nelessen 1994).

Table 7 rates the environmental values of various land uses. Openspaces, such as forests, farms and parks, provide wildlife habitat, groundwater recharge, agricultural productivity and beauty. Impervious surfaces, such as buildings, roads and parking, are ecologically sterile and so provide the least benefit. Shifts to higher environmental values, such as from buildings and pavement to lawns, or from mono-cropped lawns to xeriscape (native plant) gardens (Ponsford 2020), tends to increase wildlife habitat and groundwater recharge, and reduce urban heat island effects.

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Environmental Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undisturbed natural opespace</td>
<td>Wildlife habitat, groundwater recharge, beauty</td>
</tr>
<tr>
<td>Disturbed natural opespace</td>
<td>Wildlife habitat, groundwater recharge, beauty</td>
</tr>
<tr>
<td>Farmlands</td>
<td>Agricultural productivity, beauty</td>
</tr>
<tr>
<td>Urban parks</td>
<td>Wildlife habitat, groundwater recharge, beauty</td>
</tr>
<tr>
<td>Xeriscape gardens and lawns</td>
<td>Wildlife habitat, food production, groundwater recharge, beauty</td>
</tr>
<tr>
<td>Mono-crop Lawns</td>
<td>Beauty</td>
</tr>
<tr>
<td>Gravel roads and pervious parking</td>
<td>Groundwater recharge</td>
</tr>
<tr>
<td>Landscaped roads and parking</td>
<td>Wildlife habitat, beauty</td>
</tr>
<tr>
<td>Buildings and pavement</td>
<td>Ecologically sterile</td>
</tr>
</tbody>
</table>

Land uses vary in their environmental values.

Most consumers never purchase parking spaces or roadways as a separate item (they are usually bundled with building space or provided by governments and businesses) and so they have little idea of their costs. Figure 10 illustrates typical annualized costs per parking space, excluding indirect and environmental costs.

**Figure 10** Typical Annualized Costs per Parking Space (“Parking Costs” Litman, 2009)

This figure illustrates typical annualized costs per parking space.
Optimal Road and Parking Supply

According to planning theory, optimal road and parking supply is the minimum amount required to serve user needs in the most cost-effective way. For example, optimal road and parking supply is the amount that serves motorists’ travel demands with the least costs to users (delay, risk and user fees), governments (roadway construction and operating expenses), and society (congestion delay, accident and pollution costs imposed on other people). Road and parking planning decisions, such as the number and width of traffic lanes, and the size of parking facilities, should consider all impacts (benefits and costs) and options (including management solutions instead of expanding supply), and support strategic planning objectives such as a community’s desire to support compact development and resource-efficient mobility. Comprehensive analysis of costs and options is called least cost planning.

According to market theory, optimal road and parking supply is the amount consumers would purchase if markets responded to their demands (called consumer sovereignty) and they directly paid all costs (“Market Principles,” VTPI 2007; Litman 2017). For example, optimal road supply is the amount that could be financed if travelers had diverse mobility options (walking, cycling, ridesharing, driving, transit, telework, etc) and paid all roadway costs through user fees. Similarly, optimal parking supply is the amount consumers would purchase if they had diverse transport and parking options and paid fees that reflect parking facility marginal costs.

Current road and parking planning practices seldom reflect these principles: they often ignore significant costs, overlook some options, contradict strategic goals, and underprice facility use. This result in economically excessive road and parking supply: larger roads and parking lots than needed, and more than travellers would choose if users paid directly for using these facilities.

Various planning practices contribute to parking oversupply (Litman 2006; Shoup 1999a). Parking standards are based on demand surveys that were mostly performed in suburban areas with unpriced parking. Parking standards are based on an 85th occupancy rate (a parking facility is considered full if 85% of spaces are occupied) using an 85th percentile demand curves, (85 out of 100 sites will have unoccupied parking spaces even during peak periods), and a 10th design hour (parking facilities are sized to fill only ten hours per year). As a result these standards results in economically excessive supply than actually needed at most destinations, particularly where land use is mixed, there are good travel options, or where transport and parking management strategies are implemented.

The optimal number of parking spaces can vary significantly depending on location and management practices. As locations become more multi-modal, land prices increase, there are more options for overflow parking nearby, and parking is more efficiently managed, the optimal number of parking spaces declines.
Table 8 Parking Spaces Required for 100-Employees

<table>
<thead>
<tr>
<th>Parking Spaces</th>
<th>Conditions</th>
<th>Land Prices</th>
<th>Overflow Options</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>Auto-dependent</td>
<td>Low</td>
<td>Few</td>
<td>Each employee assigned a free personal space</td>
</tr>
<tr>
<td>80</td>
<td>Auto-dependent</td>
<td>Moderate</td>
<td>Few</td>
<td>Employees share free spaces, assuming that most times 20% are on leave, working offsite or commuting by non-auto modes.</td>
</tr>
<tr>
<td>60</td>
<td>Suburban commercial</td>
<td>Moderate</td>
<td>Some</td>
<td>Employees share free spaces and have a Commute Trip Reduciton program that encourages non-auto commuting</td>
</tr>
<tr>
<td>50</td>
<td>Suburban commercial</td>
<td>Moderate</td>
<td>Some</td>
<td>Employees share spaces and have a Commute Trip Reduciton program, with a $40 per month parking fee or cash out</td>
</tr>
<tr>
<td>40</td>
<td>Suburban commercial</td>
<td>High</td>
<td>Many</td>
<td>Employees share spaces and have a Commute Trip Reduciton program, with a $80 per month parking fee or cash out</td>
</tr>
<tr>
<td>20</td>
<td>Urban commercial</td>
<td>High</td>
<td>Many</td>
<td>Employees share spaces and have a Commute Trip Reduciton program, with a $120 per month parking fee or cash out</td>
</tr>
<tr>
<td>10</td>
<td>Central business district</td>
<td>High</td>
<td>Many</td>
<td>Employees share spaces with a $120 per month parking fee or cash out</td>
</tr>
<tr>
<td>0</td>
<td>Central business district</td>
<td>High</td>
<td>Many</td>
<td>Employees rent parking from commercial operators</td>
</tr>
</tbody>
</table>

The optimal number of parking spaces varies depending on location and management practices.

As a result of these practices many parking facilities are underutilized (Shoup 2005; Kuzmyak, et al, 2003). To illustrate this, Strong Towns sponsors an annual Black Friday Parking contest in which participants submit photos of underutilized shopping mall parking lots taken during the Friday after Thanksgiving, which is considered the busiest shopping day of the year, and therefore the peak parking demands. This indicates that many parking lots never fill.

Table 5 summarizes various factors that result in economically excessive road and parking supply. Although individual distortions may seem modest and reasonable, their impacts are cumulative and synergistic (total impacts are greater than the sum of individual impacts), resulting in economically excessive road and parking supply. Many experts now recommend parking planning reforms. For example, the Institute of Transportation Engineers International President recently advocated eliminating minimum parking requirements and other parking planning reforms (Belmore 2019).
Table 9  Road and Parking Planning Distortions and Corrections (Litman 2017)

<table>
<thead>
<tr>
<th>Distortions</th>
<th>Corrections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most demand studies are performed at single-use, suburban sites where parking is unpriced, resulting in standards that are excessive in other conditions.</td>
<td>Perform more research to determine how geographic, demographic and management factors affect transport and parking demand.</td>
</tr>
<tr>
<td>Standards are seldom adjusted to reflect geographic, demographic and economic factors that affect demand.</td>
<td>Apply more accurate standards that reflect specific conditions.</td>
</tr>
<tr>
<td>Standards are often based on an 85% percentile demand curve, the 10th or 20th annual design hour, and 85-90% occupancy, resulting in excessive supply at most sites and times.</td>
<td>Apply more accurate standards that reflect specific conditions.</td>
</tr>
<tr>
<td>Standards are often designed to accommodate the greatest demand a site may ever encounter over the facility’s lifespan, although this is usually excessive.</td>
<td>Apply more accurate standards, with contingency-based solutions available to address future changes in demand.</td>
</tr>
<tr>
<td>Generous minimum standards result in abundant parking supply, which discourages owners from charging for parking, creating a self-fulfilling prophesy.</td>
<td>Apply more accurate parking standards and parking management solutions before expanding parking supply.</td>
</tr>
<tr>
<td>Governments often provide subsidized parking, which discourages businesses from charging for parking at their sites.</td>
<td>Price public parking efficiently.</td>
</tr>
<tr>
<td>Road and parking facility funding often cannot be used for management programs, even if such programs are more cost effective and provide greater total benefits.</td>
<td>Apply “least cost planning,” so management strategies receive equal support as capacity expansion.</td>
</tr>
<tr>
<td>Evaluation often overlooks some costs of paving land for transport facilities, such as opportunity costs (if the land is owned), stormwater management and environmental impacts.</td>
<td>Use comprehensive evaluation which takes into account all economic, social and environmental impacts.</td>
</tr>
<tr>
<td>Generous standards were created when land costs were lower and there was less concern about traffic impacts and sprawl.</td>
<td>Adjust planning practices to reflect changes in land values and planning objectives.</td>
</tr>
<tr>
<td>Current planning practices tend to be automobile-oriented.</td>
<td>Apply more multi-modal planning.</td>
</tr>
</tbody>
</table>

This table summarizes various planning and market distortions that result in economically-excessive road and parking requirements, and how they can be corrected.

Schneider, Handy and Shafizadeh (2014) find that Smart Growth community residents own fewer vehicles and generate about half as many trips per capita as standard models predict, and recommend adjustment factors for predicting vehicle trips in compact, multi-modal areas. Similarly, Ewing, et al. (2011) and Tian, et al. (2015) find that mixed-use development generate fewer vehicle trips that standard models predict and recommend appropriate model adjustment methods. Millard-Ball (2015) points out that many “new” trips predicted by traffic models are actually trips that would occur elsewhere if a new development is not constructed, and so recommends new methods for calculating infill development trip generation.

The Right Size Parking Project (www.rightsizeparking.org) developed practical tools for accurately calculating parking demand, taking into account geographic and economic factors. It found that parking demand per unit declines with increased transit proximity, local population and employment density, and parking price (the amount that residents must pay extra, if any,
for a parking space), and increases with rents, unit size and number of bedrooms. The resulting model can be used to determine the parking supply needed in a particular development.

The San Francisco Bay Area Value Pricing Pilot Project (http://regionalparking.mtc.ca.gov) uses case studies, academic research, policy analysis and data analysis to address the relationship between parking pricing, policies, parking supply, and parking demand in cities around the Bay Area. It found that most study locations have significant amounts of unused parking, even during the peak periods. Most of the study locations have significant amounts of unused parking, even during the peak periods. Although there is excess demand on some streets at some times, there are almost always significant amounts of unused parking in lots and structures within a few blocks. Parking requirements fail to respond to factors affecting demand. Households that are younger or lower income and who have good walk/bike and transit access have lower automobile ownership rates. High parking requirements make housing less affordable. There is little analysis of the costs and alternatives of transit project parking structures. In some cases, housing would provide more transit ridership and revenue than parking structures.

A parking demand study at suburban office sites in southern California found that conventional standards are nearly twice what is needed, and this oversupply will increase if commute trip reduction efforts are successful (Willson 1995). Parking surveys in 26 Seattle neighborhoods found that most had only 40-70% peak-period occupancy (Seattle 2000). Comparing two automobile-oriented suburban areas in Nashville, Tennessee, Allen and Benfield (2003) found that a combination of improved roadway connectivity, better transit access, and modest density increases can reduce per capita VMT 25%, and impervious surface 35%.

Similarly, current planning practices result in economically-excessive roadway supply (Banerjee and Welle 2016). Road use is unpriced, and transportation agencies have dedicated funds that, in many cases may only be used for roads. Alternative standards can significantly reduce roadway requirements (Homberger 1996), sometimes called road diets or lane diets (Karim 2015). For example, Eugene, Oregon planners found that local road rights-of-way could be reduced 16-20% over standard practices without reducing performance (West and Lowe 1997). Noble prizewinning economist William Vickrey estimated that the current road system is a quarter to a third overbuilt compared with what is optimal, due to inefficient pricing (Hau 2000, footnote #1).

Most studies indicating economically excessive land devoted to transportation facilities only consider one or two distortions, such as unpricing, biased investment practices or excessive zoning requirements. More comprehensive analysis is likely to identify even greater oversupply.
Explanations for Excessive Road and Parking Supply

It is important to consider the reasons that decision-makers often favor excessive road and parking supply.

- Many decision-makers are unaware of full road and parking facility costs. For example, one survey found that employers estimated their parking costs at just $13 per month although actual costs were many times higher (COMSIS 1994).

- Transportation agencies are primarily concerned with traffic movement, parking spillover problems, regulatory simplicity, and fiscal impacts. They are less concerned with other impacts and objectives, indirect costs, and planning objectives outside their responsibility.

- A certain amount of road and parking supply can be justified for basic access. Even non-drivers may value having paved roads and parking at their property, to facilitate access and increase property values. Only supply beyond what is needed for basic access (for example, a second traffic lane) may need to be tested based on individual users’ willingness to pay (“Roadway Land Value,” Litman 2009).

- Road and parking reduction strategies often seem difficult to implement. As a result, they are often considered solutions of last resort, to be implemented only in special conditions where road and parking facility expansion is particularly difficult.

- Generous road and parking supply are assumed to prevent congestion, insure emergency access, and prevent problems such as spillover impacts and enforcement requirements.

- Convenient vehicle access is considered important to businesses, and therefore for local economic development. Parking regulations, metered parking, and parking enforcement are frustrating to users and unpopular.

- From an administrative perspective it seems easiest and fairest to apply rigid standards rather than more flexible policies that may be challenged. Professional organizations provide recommended minimal standards but fewer resources for flexible requirements.

- Minimum parking requirements impose no direct cost on governments. Increasing parking requirements is cheaper than providing public parking facilities. Incorporating parking into building costs appears equitable, since businesses can pass such costs on to customers.

- Automobile ownership and use have grown steadily over the last century, and roads and parking facilities are durable and can be difficult to expand. It may therefore seem sensible oversupply parking to accommodate possible increases in future demand.

- Transportation agencies generally lack incentives to reduce land requirements by sharing rights of way with other utilities (Feitelson and Papay 1999).

These factors help explain why decision-makers often favor excessive road and parking capacity. However, most of these issues can be addressed with cost-effective strategies described in this guide. For example, mobility management strategies can reduce traffic congestion problems without increasing roadway supply (for example, by encouraging cycling, ridesharing, public transit, flextime and telework), and improved parking enforcement can help avoid parking spillover problems. New pricing methods significantly reduce transaction costs, increasing the feasibility of efficient road and parking pricing. Increasing concerns about economic, social and environmental impacts justifies more emphasis on management solutions.
An important issue in this analysis is the ease of adjusting road and parking supply if needed in the future. Excessive standards are often justified on grounds that additional supply may be needed sometime and is cheaper to provide during initial construction than later. Once land is paved there is often little consideration of converting it to other uses.

Expanding roads and parking facilities tends to be costly, particularly in established urban areas. However, alternatives are often cost effective, such as management strategies that encourage peak-period travelers to use more efficient modes (ridesharing, public transit, telework, etc.). These often provide significant additional benefits, including facility cost savings, consumer cost savings, improved mobility for non-drivers, increased safety, energy conservation and pollution emission reductions. The availability of these management strategies reduces the need to oversupply urban roadways.

Land used for roads and parking facilities is often treated as a sunk cost, with no opportunity value recognized. However, virtually all land has alternative potential uses, either to be rented or sold for monetary gain, or converted to greenspace (landscaping, farms or forests) for environmental benefits. It therefore makes sense to reduce the amount of land paved for roads and parking facilities whenever alternative uses could provide greater benefits (Lee 1999).

This suggests that optimal road and parking supply is significantly less than what results from current planning practices (Litman, 2017):

- More accurate planning, which adjusts minimum parking requirements to reflect specific geographic and demographic factors, and allows cost effective management strategies such as sharing and use of off-site parking for to accommodate occasional peaks, can typically reduce parking supply by 10-30% compared with current practices.

- Efficient pricing, including cost-based road and parking fees (users directly pay all road and parking facility costs), parking cash out (non-drivers receive the cash equivalent of parking subsidies), and unbundling (parking facilities are sold or rented separately from building space) typically reduces peak-period traffic and parking demand about 20%.

- Least-cost planning, which applies the most cost-effective transportation improvement options, typically reduces peak-period traffic and parking demand by 10-30%.

- More flexible, contingency-based planning allows reduced road and parking supply, since cost-effective management strategies can be deployed if needed in the future.

Of course, the degree of road and parking oversupply varies depending on specific circumstances. In rural areas, most roads and parking facility pavement may be justified for the sake of basic access, and because paving land for roads and parking facilities imposes modest costs. In urban areas there are more transport options and expanding roads and parking facilities tend to impose greater costs, so greater reductions may be justified.
Strategies to Reduce Road and Parking Requirements

The following strategies can reduce the amount of land paved for roads and parking. For more information see NEMO; Litman (2013); Steuteville (2015); UTTIPEC (2010) and Willson (2015).

Allow and Encourage Compact Urban Infill Development

Compared with sprawled development infill (building in existing urban areas) tends to require less pavement and displace less habitat. Secondary suites, townhouses, apartments and housing-over-commercial are compact housing types that reduce the amount of land used for a given amount of building space. Parking lots and low-density shopping malls are appropriate locations for infill development (Romem and Garcia 2020). Many jurisdicitions forbid or discourage development of such housing.

Favor Space-Efficient Travel Modes

Walking, bicycling, ridesharing and public transit require less land for roads and parking than automobile travel. Many policies, called Transportation Demand Management (TDM) or Mobility Management can favor these modes and discourage automobile ownership and use, as summarized in Table 10. These can include more investments in sidewalks and crosswalks, bicycle facilities, and public transit services, plus efficient road and parking pricing, increased fuel prices, and tax policy reforms.

<table>
<thead>
<tr>
<th>Improved Transport Options</th>
<th>Incentives to Shift Mode</th>
<th>Land Use Management</th>
<th>Policies and Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative Work Schedules (flextime)</td>
<td>Bicycle and Pedestrian Encouragement</td>
<td>Car-Free Districts</td>
<td>Access Management</td>
</tr>
<tr>
<td>Bicycle Improvements</td>
<td>Congestion Pricing</td>
<td>Compact Land Use</td>
<td>Campus Transport Management</td>
</tr>
<tr>
<td>Bike/Transit Integration</td>
<td>Distance-Based Pricing</td>
<td>Location Efficient Development</td>
<td>Commute Trip Reduction</td>
</tr>
<tr>
<td>Carsharing</td>
<td>Commuter Financial Incentives</td>
<td>New Urbanism</td>
<td>Freight Transport Management</td>
</tr>
<tr>
<td>Guaranteed Ride Home</td>
<td>Fuel Tax Increases</td>
<td>Smart Growth</td>
<td>Marketing Programs</td>
</tr>
<tr>
<td>Park &amp; Ride</td>
<td>High Occupant Vehicle (HOV) Priority</td>
<td>Transit Oriented Development (TOD)</td>
<td>School Trip Management</td>
</tr>
<tr>
<td>Pedestrian Improvements</td>
<td>Pay-As-You-Drive Insurance</td>
<td>Street Reclaiming</td>
<td>Special Event Management</td>
</tr>
<tr>
<td>Ridesharing</td>
<td>Parking Pricing</td>
<td></td>
<td>Tourist Transport Management</td>
</tr>
<tr>
<td>Shuttle Services</td>
<td>Road Pricing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Telework</td>
<td>Vehicle Restrictions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic Calming</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transit Improvements</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mobility management includes numerous strategies that affect vehicle travel behavior.

Green Roofs

The International Green Roof Association ([www.igra-world.com](http://www.igra-world.com)) shares information on methods to create buildings that reduce stormwater runoff, reduce heat island effects and improve beauty through green roof technologies, such as planting lawns and gardens on roofs, and recovering stormwater.
Educate Decision Makers
Educate decision-makers concerning the full costs of generous road and parking capacity, biases in current planning practices that favor oversupply, and alternative strategies that can help reduce paved area.

Reduce and More Accurate Parking Requirement
As described earlier, current road and parking supply standards tend to be economically excessive and can often be reduced due to geographic, demographic and management factors, such as listed in Table 11.

Table 11 Parking Adjustment Factors (Litman 2013; Rowe, et al. 2013)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Description</th>
<th>Typical Adjustments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographic Location</td>
<td>Vehicle ownership and use rates in an area.</td>
<td>Requirements should reflect variations identified in census and travel survey data.</td>
</tr>
<tr>
<td>Density</td>
<td>Number of residents, employees or housing units per acre/hectare.</td>
<td>Increased density tends to reduce per capita vehicle ownership and use.</td>
</tr>
<tr>
<td>Land Use Mix</td>
<td>Range of land uses located within convenient walking distance.</td>
<td>Increased mix tends to reduce per capita vehicle ownership and use.</td>
</tr>
<tr>
<td>Transit Accessibility</td>
<td>Nearby transit service frequency and quality.</td>
<td>Improved transit accessibility tends to reduce per capita vehicle ownership and use.</td>
</tr>
<tr>
<td>Carsharing</td>
<td>Whether a carsharing service is located nearby.</td>
<td>Carshare service availability tends to reduce per capita vehicle ownership and use.</td>
</tr>
<tr>
<td>Walkability</td>
<td>Walking environment quality.</td>
<td>Improved walkability reduces vehicle traffic and allows more sharing of parking facilities.</td>
</tr>
<tr>
<td>Demographics</td>
<td>Age and physical ability of residents or commuters.</td>
<td>Demand tends to decline for young (under 30) elderly (over 65) and disabled people.</td>
</tr>
<tr>
<td>Income</td>
<td>Resident or commuter incomes.</td>
<td>Lower incomes reduce demand (SPUR, 1998).</td>
</tr>
<tr>
<td>Pricing</td>
<td>Road and parking pricing, unbundling and cashing out.</td>
<td>Efficient pricing tends to reduce vehicle ownership and use.</td>
</tr>
<tr>
<td>Parking &amp; Mobility Mangt.</td>
<td>Parking and mobility management programs are implemented at a site.</td>
<td>Efficient pricing tends to reduce vehicle ownership and use.</td>
</tr>
<tr>
<td>Design Hour</td>
<td>Annual hours a facility may fill.</td>
<td>Higher values allow reduced supply.</td>
</tr>
<tr>
<td>Facility design</td>
<td>The type of facility design applied.</td>
<td>Improved design sometimes allows roadway dimensions to be reduced.</td>
</tr>
<tr>
<td>Contingency-Based Planning</td>
<td>Development of a plan of actions to address future problems.</td>
<td>Having a plan allows reduced supply.</td>
</tr>
</tbody>
</table>

This table summarizes various factors that affect parking demand and optimal parking supply.

Reduce Residential Street Width Requirements
Most jurisdictions require wide residential streets. This practice is not justified for safety or by consumer demands, since many households would not choose to pay for on-street parking if it were unbundled, and so represents a hidden subsidy of automobile ownership and use (Guo, et al. 2012). Reducing minimum residential street widths in municipal zoning codes and development policies allows developers to build new urbanist communities with narrower streets and less parking.
Parking Management

Parking management includes various strategies that encourage more efficient use of parking facilities, as listed in Table 12, some of which are also mobility management strategies (they reduce total vehicle travel). Mobility and parking management can be implemented instead of road and parking facility expansion whenever overall cost effective, considering all impacts. For example, governments should implement mobility management whenever it is cheaper than expanding roads, and businesses should implement parking management when cheaper than adding parking supply. This requires supportive policies, including comprehensive analysis (which considers all benefits of management solutions), flexible funding (so money can be used for mobility management programs rather than facility expansion), and flexible road and parking requirements.

Table 12 Parking Management Strategies (Litman 2013; Willson 2015)

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Description</th>
<th>Typical Reductions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shared Parking</td>
<td>Parking spaces serve multiple users and destinations.</td>
<td>10-30%</td>
</tr>
<tr>
<td>Parking Regulations</td>
<td>Regulations favor higher-value uses such as service vehicles, deliveries, customers, quick errands, and people with special needs.</td>
<td>10-30%</td>
</tr>
<tr>
<td>More Accurate and Flexible Standards</td>
<td>Adjust parking standards to more accurately reflect demand in a particular situation.</td>
<td>10-30%</td>
</tr>
<tr>
<td>Parking Maximums</td>
<td>Establish maximum parking standards.</td>
<td>10-30%</td>
</tr>
<tr>
<td>Remote Parking</td>
<td>Provide off-site or urban fringe parking facilities.</td>
<td>10-30%</td>
</tr>
<tr>
<td>Smart Growth</td>
<td>Encourage more compact, mixed, multi-modal development to allow more parking sharing and use of alternative modes.</td>
<td>10-30%</td>
</tr>
<tr>
<td>Walking and Cycling Improvements</td>
<td>Improve walking and cycling conditions to expand the range of destinations serviced by a parking facility.</td>
<td>5-15%</td>
</tr>
<tr>
<td>Increase Capacity of Existing Facilities</td>
<td>Increase parking supply by using otherwise wasted space, smaller stalls, car stackers and valet parking.</td>
<td>5-15%</td>
</tr>
<tr>
<td>Mobility Management</td>
<td>Encourage more efficient travel patterns, including changes in mode, timing, destination and vehicle trip frequency.</td>
<td>10-30%</td>
</tr>
<tr>
<td>Parking Pricing</td>
<td>Charge motorists directly and efficiently for using parking facilities.</td>
<td>10-30%</td>
</tr>
<tr>
<td>Improve Pricing Methods</td>
<td>Use better charging techniques to make pricing more convenient and cost effective.</td>
<td>Varies</td>
</tr>
<tr>
<td>Financial Incentives</td>
<td>Provide financial incentives to shift mode such as parking cash out.</td>
<td>10-30%</td>
</tr>
<tr>
<td>Unbundle Parking</td>
<td>Rent or sell parking facilities separately from building space.</td>
<td>10-30%</td>
</tr>
<tr>
<td>Parking Tax Reform</td>
<td>Change tax policies to support parking management objectives.</td>
<td>5-15%</td>
</tr>
<tr>
<td>Bicycle Facilities</td>
<td>Provide bicycle storage and changing facilities.</td>
<td>5-15%</td>
</tr>
<tr>
<td>Improve User Information and Marketing</td>
<td>Provide convenient and accurate information on parking availability and price, using maps, signs, websites and apps.</td>
<td>5-15%</td>
</tr>
<tr>
<td>Improve Enforcement</td>
<td>Insure that parking regulation enforcement is efficient and fair.</td>
<td>Varies</td>
</tr>
<tr>
<td>Transportation Management Associations</td>
<td>Establish member-controlled organizations that provide transport and parking management services in a particular area.</td>
<td>Varies</td>
</tr>
<tr>
<td>Overflow Parking Plans</td>
<td>Establish plans to manage occasional peak parking demands.</td>
<td>Varies</td>
</tr>
<tr>
<td>Address Spillover Problems</td>
<td>Use management, enforcement and pricing to address spillover problems.</td>
<td>Varies</td>
</tr>
<tr>
<td>Parking Facility Design and Operation</td>
<td>Improve parking facility design and operations to help solve problems and support parking management.</td>
<td>Varies</td>
</tr>
</tbody>
</table>

This table summarizes the parking management strategies. It indicates the typical reduction in the amount of parking required at a destination.
Some parking management strategies are particularly effective at reducing pavement area. Sharing parking facilities is particularly effective at reducing parking requirements ("Shared Parking," VTPI 2007). This can be done in several ways:

- **Shared Rather Than Reserved Spaces.** Motorists share parking spaces, rather than being assigned a reserved space. For example, 100 employees can usually share 60-80 parking spaces, since at any particular time some are away or using alternative commute modes.

- **Share Parking Among Destinations.** Parking can be shared among multiple destinations. For example, office buildings can share parking with restaurants and theaters since office demand peaks during weekdays while restaurant and theater demand peaks evenings.

- **Public Parking Facilities.** Public parking, including on-street, municipal off-street, and commercial (for profit) facilities generally serve multiple destinations. Converting from free, single-use to paid, public parking allows more efficient, shared use.

- **In Lieu Fees.** "In lieu fees" mean that developers help fund public parking facilities instead of providing private facilities serving a single destination (Shoup, 1999b). This tends to be more cost effective and efficient. It can be mandated or optional.

With more efficient management and improved travel options, some parking facilities can be converted to other uses. For example, one study found that surface parking lots around rail transit stations could be profitably developed into mixed-use, pedestrian friendly, transit-oriented developments, which would help to meet the demand for affordable housing near transit, and provide a variety of benefits including increased tax revenues and reduced per capita vehicle travel (CNT 2006). Some communities limit parking supply, typically in commercial centers with high quality transit. Imposing a parking limit encourages better utilization of existing facilities, forces businesses to encourage their employees and customers to use alternative travel modes, and allows more parking to be priced.

**Efficient Road and Parking Pricing**
Charging users directly for using roads and parking facilities, with higher fees under peak conditions, encourages more efficient use, reducing supply. Efficient road pricing typically reduce peak traffic by 10-30%, and even more if part of a comprehensive mobility management program (Boarnet, et al. 2014). Cost-recovery parking pricing (fees set to pay for parking facilities), **parking cash-out** (non-drivers receive the cash equivalent of parking subsidies) and **unbundling** (parking rented separately from building space) typically reduce parking demand by 10-30% (Spears, Boarnet and Handy 2014), and shifting from annual or monthly to daily parking fees reduces automobile commuting about 8% (Rosenfeld 2018). These reductions allow pavement area to be reduced.

Older road and parking pricing methods had high transaction costs, including inconvenience to motorists who were required to use specific change, and high labor costs for collecting money. Newer, electronic pricing methods are more convenient, accurate, flexible, and cost effective. They can accommodate various payment methods (coins, bills, credit and debit cards, mobile telephone and the Internet), eliminate the need for toll booths, incorporate multiple rates and discounts, automatically vary rates by day and time, charge only for the amount of time parked, and are convenient to use. Newer systems also produce printed receipts and record data for auditing, which prevents fraud.
Smart Growth Development Policies

Smart Growth (also called location-efficient development) is a general term for policies and planning practices that result in more efficient land use development by creating more compact, mixed-use, multi-modal communities. Smart Growth is an alternative to urban sprawl. Major differences between these two land use patterns are compared in Table 13. New Urbanism refers to Smart Growth applied at the neighborhood or local scale. Access management is a term used by transportation engineers for improved integration between land use and roadway planning, which tend to support Smart Growth.

<table>
<thead>
<tr>
<th>Table 13 Comparing Smart Growth and Sprawl (“Smart Growth,” VTPI 2007)</th>
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</thead>
<tbody>
<tr>
<td><strong>Smart Growth</strong></td>
</tr>
<tr>
<td>Density</td>
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<tr>
<td>Growth pattern</td>
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<tr>
<td>Land use mix</td>
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<tr>
<td>Scale</td>
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<td>Public services (shops, schools, parks)</td>
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<tr>
<td>Transport</td>
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<td>Connectivity</td>
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<tr>
<td>Street design</td>
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<tr>
<td>Planning process</td>
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<tr>
<td>Public space</td>
</tr>
</tbody>
</table>

This table compares Smart Growth with sprawl development patterns.

Smart Growth and New Urbanism can reduce per capita pavement area in several ways (although they may increase pavement per acre due to increased density). They emphasize more compact development patterns and building designs, including narrower streets, multi-story structures and structured parking. They support and are supported by transport and parking management. They increase transport options (particularly walking, cycling and public transit access). Residents and employees in such areas tend to own 10-20% fewer cars and make 20-40% fewer vehicle trips than in more automobile-dependent areas, allowing road and parking supply to be reduced (Litman 2005).
Smart Growth policy reforms encourage more compact, mixed, multi-modal land use development (Litman 2007). They can provide many benefits including infrastructure cost savings, improved housing affordability, reduce transportation problems, increased livability, and economic development. These include (SGN 2002 and 2004):

- More comprehensive planning – develop local and regional planning programs, and tools for evaluating land use impacts and options.
- Location-based fees – restructure development fees, taxes and utility charges to reflect the lower cost of providing public services in more accessible locations.
- Smart public facility location and design – locate and design public facilities (government offices, schools, recreation centers, etc.) so they are accessible by multiple-modes and reflect other Smart Growth objectives.
- Reform zoning codes – reduce minimum parking and setback requirements, and increased density and mix.
- Encourage urban redevelopment – develop policies and programs that favor infill redevelopment over new, greenfield development.
- Growth controls and openspace preservation – develop policies and programs that limit growth outside of existing urban areas and preserve openspace.
- More neutral transport funding – reduce dedicated funds for roads and parking facilities, and apply least-cost planning for solving transportation problems.
- Educate decision-makers – sponsor workshops and training programs for planners, development professionals, public officials and the general public concerning the benefits of Smart Growth and tools for achieving land use planning objectives.

**Overflow Plans**

Excessive parking requirements are often justified to meet occasional peak demands. Parking supply can often be reduced if facility managers and transportation agencies establish overflow parking plans and special event transport management plans, which indicate how occasional peak demands will be managed. This may include use of off-site parking, special shuttle services, user information, and incentives for employees to use alternative modes during peak periods.

**Use Parking Facilities More Efficiently**

The number of vehicles that can be parked in a facility can be increased in various ways:

- Use currently wasted areas (corners, edges, undeveloped land, etc.). This can be particularly appropriate for small car spaces, motorcycle and bicycle parking.
- Where there is adequate street width, change from parallel to angled on-street parking.
- Allow existing parking facilities with low utilization rates to be reduced in size.
- Maximize the number of on-street parking spaces, for example, by using a curb lane for parking rather than traffic during off-peak periods.
- Reduce parking space size. Commuter and residential parking spaces can be somewhat smaller than shorter-term uses which have more entering and exiting activity. A portion of
spaces can be sized for compact vehicles, motorcycles and bicycles. Motorcycles can be allowed to share parking spaces.

- Allow *tandem parking* (one vehicle parked in front of another, so the first must be moved for the second to exit) to count toward minimum residential parking requirements.
- Use car stackers and mechanical garages, as illustrated in Figure 11.
- Use valet parking, particularly during busy periods. This can increase parking capacity by 20-40% compared with users parking their vehicles. Commercial lots often have attendants park vehicles during busy periods, but not off-peak.
- Remove or consolidate non-operating vehicles, equipment, material and junk stored in parking facilities, particularly in prime locations.

*Figure 11  Carstackers*

*Carstackers allow more vehicles to be stored in a given area.*

**Parking Tax Reform**

*Parking tax reform* includes various tax policies that support parking management (Cortright 2021; PCW 2002; Litman 2007):

- *Per-space levies.* This is a special tax imposed on parking facilities, such as a $30 annual tax on each non-residential parking space. If applied specifically to employee parking it is called a *workplace parking levy*.
- *Free parking levy.* This is a special tax imposed on unpriced parking, for example, a $50 annual tax per space provided free to employees. This is a variation on per-space levies designed to discourage unpriced parking.
- *Stormwater management fees.* This is a utility fee based on impervious surface area to fund stormwater management services, such as a $15 annual fee per 1,000 square feet of pavement, or a $5 annual fee per parking space (Minneapolis 2005; Cortright 2021).
- *Car-free tax discounts.* This is a property tax discount provided to households that do not own an automobile, reflecting their lower roadway and traffic service costs they impose. For example, if municipal roadway expenditures average $200 annually per vehicle, a tax discount up to this amount could be provided to households that do not own a car.
Structured and Underground Parking
Structured and underground parking reduces land required per space compared with surface parking. A 4-story parking structure uses only about a quarter as much land per space as a surface parking lot, and underground parking requires almost no additional land. Although more costly to build (typically $10,000 to $30,000 more per space), this saves land costs, allows increased development density and greater design flexibility. Structured parking is generally cost effective when land prices exceed about $2 million per acre, considering just construction costs, and less if other planning objectives, such as accessibility and aesthetics, are also considered.

Infill and Brownfield Redevelopment
Many communities have older neighborhoods and brownfields (contaminated industrial lands) suitable for redevelopment. Redeveloping these areas instead of greenfields (currently undeveloped lands) avoids increasing impervious surface (www.epa.gov/brownfields). A variety of public policies and programs can help encourage this, including targeted cleanup, to favorable tax policies and public support of redevelopment projects in blighted areas.

Streetscaping
Streetscaping refers to roadway design intended to create safer, more multi-modal and attractive roadways. It can include changes to the road cross section, traffic management, sidewalk conditions, landscaping, street furniture (utility poles, benches, garbage cans, etc.), building fronts and materials specifications, which may include use of more permeable surfaces. It often involves traffic calming and road diets which reduce lane widths and the number of traffic lanes.

Encourage Shared ROW
There may be opportunities for more sharing rights-of-way between roads and other utilities that are overlooked because agencies have insufficient resources and incentives for coordinated planning and sharing (Feitelson and Papay, 1999). It may be helpful to develop more coordinated utility planning which specify how roadway rights-of-way can be used by other agencies.

Neighborhood Parks
Cities can expand public parks, particularly in dense neighborhoods that have limited greenspace. To optimize wellbeing and reduce heat-island effects, at least 20% of urban land area should be devoted to parks. Data from the Gallup-Healthways Wellbeing Index (WBI) indicates that the portion of urban land devoted to parks, and the quality of local parks, tends significantly affects residents’ wellbeing (Larson, Jennings and Cloutier 2016). For example, Athens, Greece is developing neighborhood pocket parks in order to increase livability and reduce heat island effects (Kyvrikosaios 2021).
Improve Facility Design

Various design features can reduce road and parking facility environmental impacts (Childs 1998; CNT 2020; Mukhija and Shoup 2006; Toronto 2007; Vancouver 2002):

- Use on-site stormwater storage and percolation, with natural wetlands for filtering.
- Maximize greenspace, particularly shade trees along roadways and in parking lots.
- Cover parking lots with awnings. Some parking lots charge extra for covered areas. Parking lot awnings are perfect locations for solar panels.
- Use lighter materials, such as concrete rather than asphalt, to reduce solar gain.
- Design and maintain parking facilities to be attractive and safe.
- Use transport facility land efficiently. Sell air rights above roads and parking lots. Incorporate ground-floor retail into parking structures, to create more attractive and lively streetscapes.
- Use paving permeable pavement (Figure 11) and pervious cement (cement, rock and fiber without fine particles) to reduce surface runoff (Booth and Leavitt 1999; Stiffler 2012).
- Use “Hollywood” driveways, which are two strips of pavement instead of a full lane (Figure 12). This reduces paved area by about half.

Figure 12 Permeable Blocks and Hollywood Drives

Permeable pavement blocks allow grass to grow and water to drain into the ground. “Hollywood” driveways only pave two strips.

The city of Toronto (2007) developed parking facility design guidelines that include:
- Generous landscaped areas with trees and good quality soil.
- Enhance pedestrian and cycling infrastructure.
- Manage stormwater on-site.
- Reduce the urban heat island effect.
- Use sustainable materials and technologies.
Summary
Table 14 summarizes potential pavement reduction strategies identified in this guide.

<table>
<thead>
<tr>
<th>Management Strategy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compact Infill</td>
<td>Allow and encourage more compact housing types (townhouses and apartments) within existing urban areas.</td>
</tr>
<tr>
<td>Favor space-efficient modes</td>
<td>Apply transportation demand management strategies to favor walking, bicycling, ridesharing and public transit over private automobile travel, in order to reduce the amount of land required for roads and parking facilities.</td>
</tr>
<tr>
<td>Educate decision-makers</td>
<td>Educate decision-makers concerning the costs of excessive road and parking supply, distortions in current planning practices, and alternative options that result in more efficient use of available road and parking capacity.</td>
</tr>
<tr>
<td>More accurate and flexible standards</td>
<td>Adjust road and parking standards to more accurately reflect demand, taking into account various geographic, demographic and management factors.</td>
</tr>
<tr>
<td>Parking management</td>
<td>Implement parking management policies and programs that encourage more efficient use of parking facilities by sharing, pricing and use of off-site parking facilities.</td>
</tr>
<tr>
<td>Efficient pricing</td>
<td>Charge users directly for using roads and parking facilities. Cash out and unbundle currently free parking.</td>
</tr>
<tr>
<td>Smart Growth</td>
<td>Encourage more compact, mixed, multi-modal development, which encourages sharing of parking facilities and use of alternative modes.</td>
</tr>
<tr>
<td>Overflow plans</td>
<td>Develop plans which indicate how parking and traffic will be managed during occasional peaks and special events.</td>
</tr>
<tr>
<td>Use existing facilities more efficiently</td>
<td>Increase parking supply by using otherwise wasted space, smaller stalls, car stackers and valet parking.</td>
</tr>
<tr>
<td>Parking tax reform</td>
<td>Various tax policy changes that support parking management objectives.</td>
</tr>
<tr>
<td>Structured and Underground Parking</td>
<td>Use structured and underground parking facilities rather than surface lots in order to reduce impervious surface area and increase development density.</td>
</tr>
<tr>
<td>Infill and brownfield redevelopment</td>
<td>Encourage redevelopment of existing urban areas rather than expansion into greenfields.</td>
</tr>
<tr>
<td>Streetscaping</td>
<td>Improve roadway design, including traffic calming and road diets.</td>
</tr>
<tr>
<td>Shared rights of way</td>
<td>Encourage government agencies and utilities to share rights of way among various utilities and other land uses.</td>
</tr>
<tr>
<td>Parking facility design and operations</td>
<td>Improved parking facility design and operations to help solve problems and achieve parking management objectives.</td>
</tr>
</tbody>
</table>

This table summarizes the parking management strategies described in this report.
Building Institutional Support

Many of the pavement reduction strategies described in this guide involve changing current practices and organizational structures. It is important to build institutional support for such reforms (“Institutional Reforms,” VTPI, 2007). This often involves changing the way problems are defined and solutions evaluated (Barter 2014). Proponents should highlight the multiple benefits of these reforms, for example, pointing out that many pavement reduction strategies also help reduce traffic congestion, accidents and pollution emissions.

Most transportation agencies where created to build roads and are not well structured to support alternatives. Many transportation planning and funding practices are biased toward road and parking capacity expansion, away from demand management alternatives. It is important to educate practitioners and decision-makers concerning new planning and management techniques that can support more efficient use of road and parking facilities and allow pavement area to be reduced.

Least-cost planning is a resource planning method that gives demand management equal consideration as capacity expansion, and chooses the most cost effective option, taking into account all impacts (costs and benefits). This tends to support transport and parking management, because they tend to be more cost effective than facility expansion.

Transportation Management Associations (TMAs) coordinate transport activities in a particular area, such as a commercial or employment center, which is more effective than smaller, individual programs managed by individual employers (VTPI 2007). They can provide parking brokerage services, allowing parking facilities to be used more efficiently through sharing and renting. This provides a framework for implementing mobility management and parking management policies and programs.

Contingency-based planning is a strategy that deals with uncertainty by identifying specific responses to possible future conditions. Contingency-based planning can help support many of the pavement reduction strategies described in this guide. A contingency-based plan typically consists of various if-then statements that define the solutions to be deployed if certain problems occur: if parking supply proves to be inadequate then we will implement certain strategies, and if those prove to be insufficient then we will implement an additional set of strategies. For example, a contingency-based parking plan might initially allow developers to build fewer parking spaces than required by conventional standards, with a list of solutions that will be implemented if that proves inadequate and motorists experience significant problems finding parking or neighbors experience parking spillover problems. These might include various parking management strategies (such as programs to encourage employees to use alternative modes, arrangements to share parking facilities with nearby buildings, and increased regulation and pricing of onsite parking), improved enforcement if needed to address any spillover problems, and additional capacity (some land might be reserved for future parking lots, or a potential budget identified to build a parking structure), if needed.
Conclusions
There are economic, social and environmental reasons to reduce the amount of land paved for roads and parking; it can reduce facility costs, free up land for other productive uses, reduce stormwater management and heat island costs, create more livable communities, increase land use accessibility, and encourage more efficient travel behavior. Per capita impervious area tends to decline, but the portion of land devoted to impervious surface tends to increase, with development density and with vehicle ownership rates. Impervious surface reduction efforts become more cost effective and beneficial with increased land costs, density, and environmental concerns.

Current planning practices often result in economically excessive road and parking supply. Many zoning codes and development practices are based on outdated assumptions and inadequate information. Evaluation practices ignore many impervious surface costs. Funding is often dedicated to roads and parking facilities, and cannot be used for alternative solutions even if they are more cost effective and beneficial overall. Transportation policies favor automobile travel over other modes. Many decision-makers are unaware of these problems and so continue to apply wasteful policies that contradict other planning objectives.

There are many cost-effective ways to use road and parking facilities more efficiently, reducing pavement requirements. These include:

- More accurate and flexible standards
- Mobility management programs
- Parking management programs
- Efficient pricing
- Smart Growth policies
- Use existing facilities more efficiently
- Infill and Brownfield Redevelopment
- Streetscaping

These strategies tend to be most effective when implemented as an integrated program. Parking supply reductions of 10-30% are often justified by simply applying more accurate and flexible standards, for example, by reducing parking requirements in more accessible locations with multi-modal transportation systems, where on-street parking is available, or by using a 50th percentile demand curve. Additional 10-30% reductions are often justified if cost-effective management strategies are implemented, such as sharing parking facilities and relying on off-site facilities to meet occasional peak parking demands. Further 10-30% reductions are usually justified by efficient pricing, including cost recovery road tolls and parking fees, parking cash out, and parking unbundling. Mobility and parking management can be used to reduce minimum road and parking requirements, avoid the need to expand road and parking facilities, or even to reduce existing supply to help achieve other objectives, such as freeing up land for other uses, and reducing environmental impacts.

These strategies face various obstacles. Institutional reforms, least-cost planning, and supporting organizations such as transportation management associations can help facilitate implementation of the strategies described in this guide.
References and Resources


American Forests (www.americanforests.org) provides tools for tree and forest protection.


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

NEMO Project ([www.nemo.uconn.edu](http://www.nemo.uconn.edu)) addresses impervious surface impacts.


Parking Reform Network ([https://parkingreform.org](https://parkingreform.org)) is a professional organization that advocates for more efficient and equitable parking policies.

consist of compilation of related documents that provide practical information on various parking management strategies, suitable for use by planners and developers. These include:

- **Parking Solutions** (130 pages). Six documents that describe modern approaches to parking management.
- **Shared Parking** (133 pages). More than thirty documents concerning shared parking, parking in-lieu fees, parking requirement reductions and exemptions, and downtown parking requirements.
- **Green Parking Lot Design** (66 pages). Three documents that describe ways to improve parking lot environmental performance through landscaping, stormwater management and alternative surfaces.
- **Permeable Pavement and Bicycle Parking** (38 pages). Five documents concerning the use of permeable parking lot pavement materials, and five documents concerning bicycle parking.

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