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Pavement Buster's Guide

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

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by
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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
Todd Litman (2011), "Why and How to Reduce the Amount of Land Paved for Roads and Parking Facilities," *Environmental Practice*, Vol. 13, No. 1, March, pp. 38-46 (https://doi.org/10.1017/S1466046610000530); at www.vtpi.org/EP_Pav.pdf.

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More efficient management can 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 earth surface, or *landscape*, is a unique and valuable resource. It can be used in various ways, ranging from wildlands and farms to buildings and transportation facilities. Public policies and planning practices affect how land is used, which have many economic, social and environmental impacts. Some land uses provide greater community benefits than others, as summarized in Table 1. For example, people tend to benefit if their community has more natural lands, parks and farmlands that provide wildlife habitat, recreation, stormwater percolation, reduced heat island effects, beauty and environmental quality. Of all land uses, pavement tends to provide the least external benefits. As a result, most people benefit if their community can reduce pavement area, making more land is available for building and greenspace.

Table 1 **External Values Ranked** (McConnel and Walls 2005)

Community Benefits	Land Uses Ranked
Wildlife habitat	1. Unique wildlands (shorelines, old-growth forests, etc.).
Housing and business activity	2. Disturbed but functional wildlands
Recreation	3. Unique cultural sites.
Hydrologic (stormwater percolation)	4. Farmlands
Reduced heat island effect	5. Parks and gardens
Agricultural productivity and tourism	6. Lawns
Aesthetic (beauty) and improved mental health	7. Buildings
Reduces air and noise pollution	8. Pavement (sidewalks, roads and parking lots)

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

Many current policies and planning practices assume that it is desirable to maximize road and parking supply, which increases impervious surface area (Muller and Mitova 2023). However, there are often ways to meet travellers' needs with significantly less pavement. This can provide many benefits including improved walking conditions, reduced stormwater management costs and heat island effects, more urban greenspace, regional habitat preservation, reduced sprawl costs and improved urban design flexibility. Some of these strategies also reduce total vehicle traffic and associated costs.

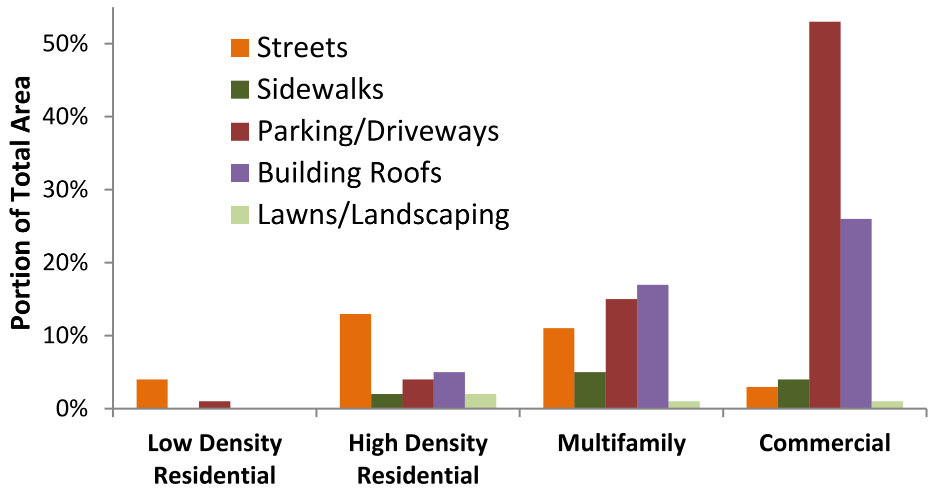
This analysis is affected by how these impacts are measured: the *potion* of land that is impervious tends to increase with development density is highest in central cities, but *per capita* impervious surface area tends to increase with sprawl and automobile dependency, and so tends to be greater in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

This guide identifies practical ways to reduce the amount of land paved for transportation facilities. It describes various costs of paving land, identifies 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. This information should be useful to public officials, property owners, facility designers, transportation professionals, environmental advocates and anyone who wants a more verdant, cost-effective and attractive community.

Measuring Pavement Area[1]

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; Litman 2024). More compact development tends to increase impervious surface area per acre but reduce it per capita. 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.

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



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

Denser areas tend to have more impervious surface area per acre of land but less per capita.

Designer and cartographer Katya Kisin produced a on-line map which shows virtually all parking lots in the U.S.

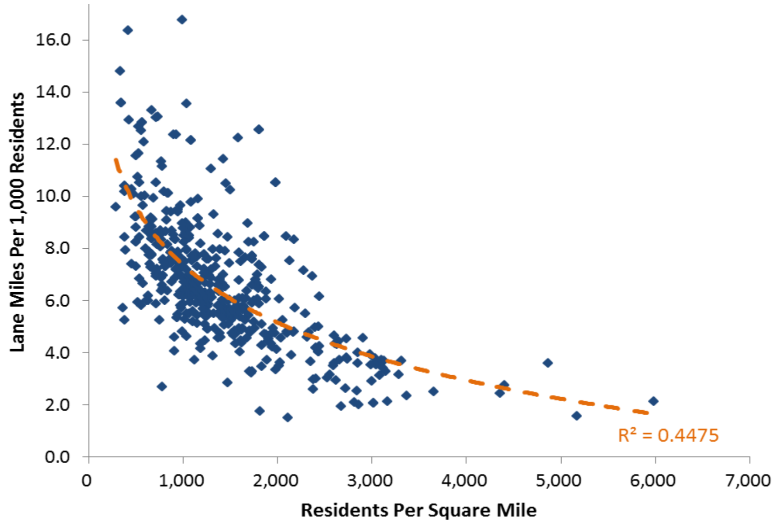
Figure 2 **Nashville Parking Lots** (Kisin 2022)

Katya Kisin's GIS mapping system shows all parking lots in the U.S. This image shows parking lots in Nashville, Tennessee (shown in black).

[1] For more information see the "Roadway Land Value" and "Parking Costs" chapters of *Transportation Cost and Benefit Analysis* at www.vtpi.org/tca.

A typical residential street is 36 feet (12 meters) wide, with a 7-foot parking lane and 11-foot traffic lane. Figure 2 shows the relationship between per capita lane-miles (and therefore roadway area) and density in U.S. urban regions based on data 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 average 14-feet), with higher rates in sprawled areas and lower rates in compact cities.

Figure 3 **Urban Density Versus Roadway Supply** (FHWA 2012, Table HM72)

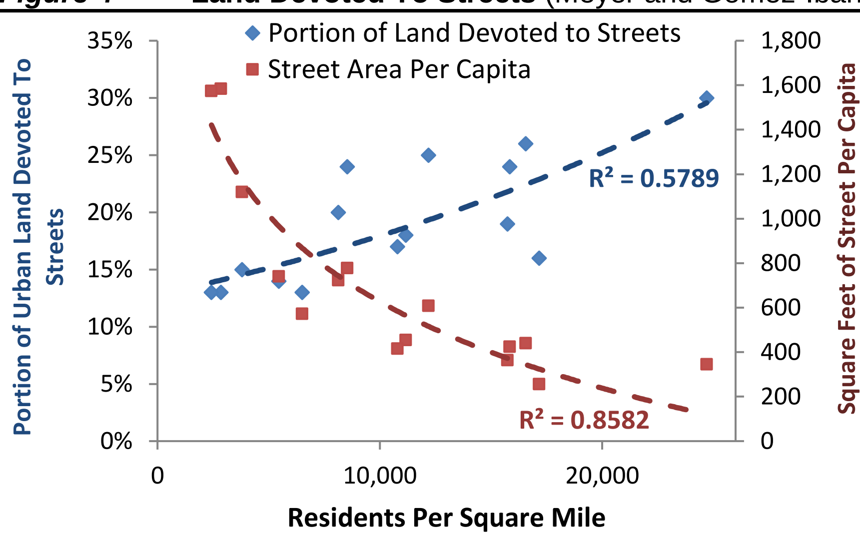


This figure illustrates per capita road area. Each dot represents a U.S. urban region. Since the data measure traffic lanes but ignore parking lanes, it understates total urban road area.

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 2 and 3 indicate the amount of land devoted to roads in various U.S. cities. These indicate that the portion of land devoted to roadways declines but per capita road area increases with density. Similar differences probably exist within urban regions, such as between central and urban fringe neighborhoods.

Figure 4 **Land Devoted To Streets** (Meyer and Gomez-Ibanez 1983, p. 181)

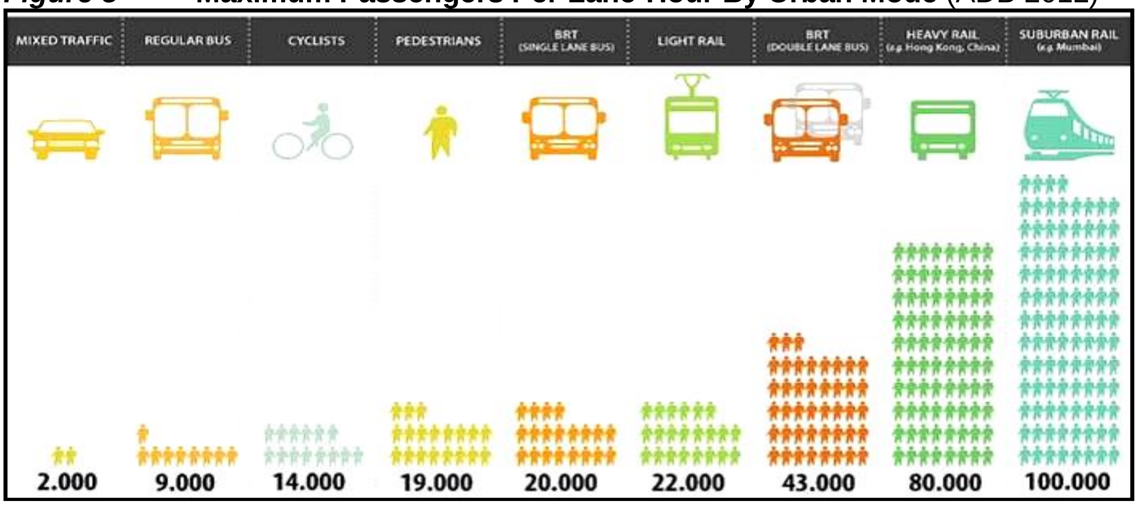


As urban population density increases the ***portion*** *of land devoted to streets increases while* ***per capita*** *road area declines.*

The study, "Urban Roadway in America: Amount, Extent, and Value," used satellite data to estimate that in the U.S. in 2016 urban land dedicated to roadways totalled approximately 58,000 km^2 (22,000 mi^2), averaging 0.06 hectares per household (about three times the average size of a new U.S. single-family house, and about half its average lot size), 3.2% of all PMSA census land area, and 21.7% of urbanized land, with a total estimated value of $4.1 trillion (Guerra, Duranton and Ma 2024). Applying cost–benefit analysis, the researchers concluded that U.S. cities devote an economically-excessive amount of urban land to road rights of way.

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).

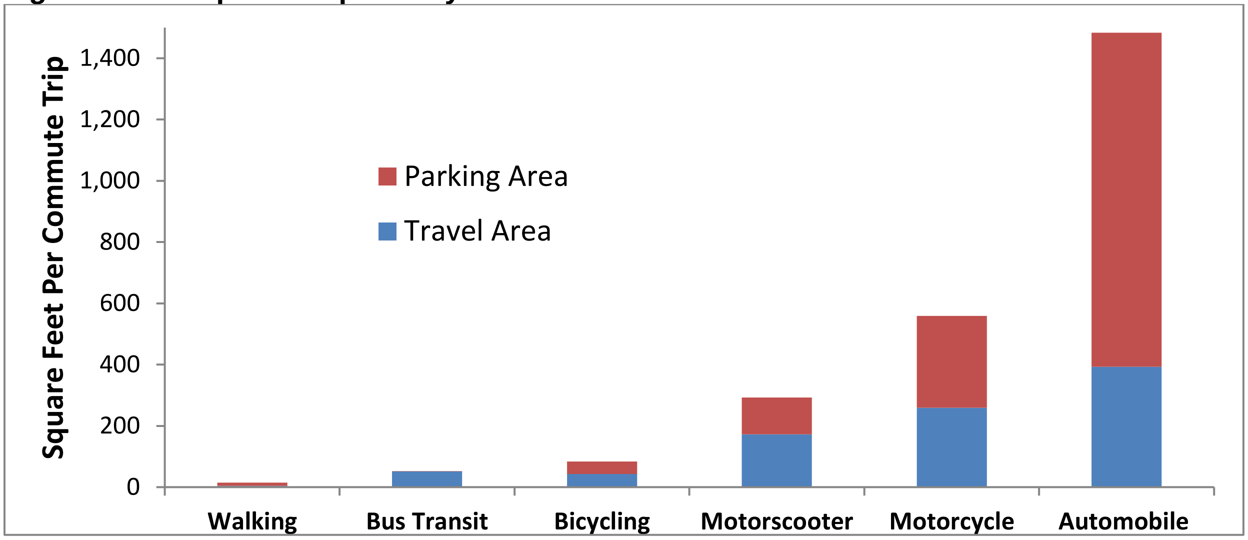
Figure 5 **Maximum Passengers Per Lane-Hour By Urban Mode** (ADB 2012)



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 4 and 5 illustrate typical road and parking space requirements of various transport modes. Space requirements per user can vary depending on road design, traffic conditions and vehicle load factors (passengers per vehicle) and travel distances. Because they are larger and faster, automobiles require far more space per passenger-trip than other modes, and since motorists tend to travel more annual miles than non-drivers, their total annual space requirements tend to be many times greater (Will, Cornet and Munshi 2020).

Figure 6 **Space Required by Travel Mode**[2]



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

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)

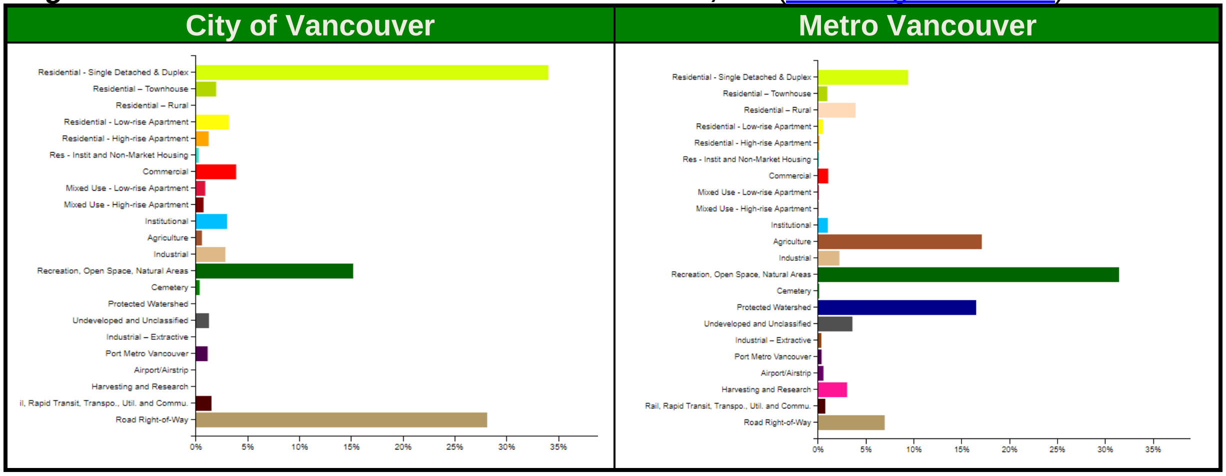
	Tree Cover	Barren Land	Grass	Roof	Road	Sidewalk	Parking	Miscellaneous
Residential	14.7	10.2	24.5	19.4	12.7	8.0	4.9	5.6
Commercial/service	9.6	7.3	9.3	19.8	15.5	3.7	31.1	3.8
Industrial	8.1	19.7	6.0	23.4	7.3	1.3	20.0	14.3
Transport/communications	0.0	4.0	0.0	5.0	80.0	1.0	10.0	0.0
Industrial and commercial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

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

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

[2] *Transport Land Requirements Spreadsheet* (www.vtpi.org/Transport_Land.xls), based on Eric Bruun and Vukan Vuchic (1995), “The Time-Area Concept: Development, Meaning and Applications,” *Transportation Research Record 1499*, TRB (www.trb.org), pp. 95-104.

Figure 7 **Land Use Distribution in Vancouver, BC** (Von Bergmann 2016)



This study found that road rights-of-way total approximately 28% of total land in the city of Vancouver and 7% in the Vancouver metropolitan region.

Hoehne, et al. (2019) estimate that in 2017 the Phoenix, Arizona metropolitan region had 12.2 million parking spaces. For each registered non-commercial vehicle there are 4.3 parking spaces of which 1.3 are off-street residential, 1.3 are off-street non-residential, 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. The table below summarizes the results. Parking spaces per capita declines 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 3 **Parking Spaces and Costs in Five U.S. Cities** (Scharnhorst 2018)

	New York	Philadelphia	Seattle	De 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.

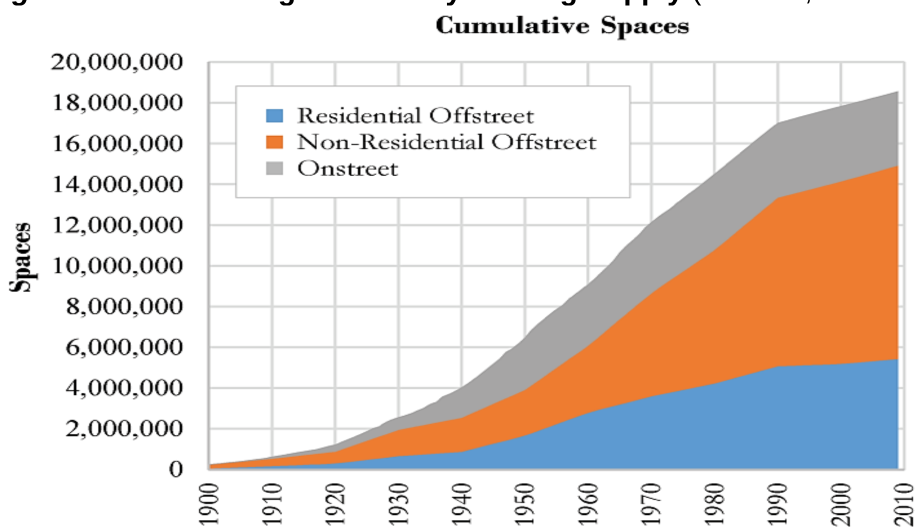
Table 4 **Estimated U.S. Parking Spaces** (Chester, Horvath and Madanat 2010)

Type	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
On-street	35	92	180	150	1,100
Surface	36	520	520	610	790
Structure	34	110	110	84	120
Total	105	730	820	840	2,000

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

Chester, et al. (2015) estimate that in Los Angeles County parking supply grew from nearly zero in 1900 to approximately 18.6 million designated parking spaces in 2010; approximately 3.3 spaces per automobile, including 1.0 residential, 1.7 nonresidential, and 0.6 on-street spaces, as illustrated below. 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 parking density (spaces per square mile) is greatest in the urban core, but suburban areas have greater parking supply growth. They conclude that abundant parking supply significantly increases vehicle ownership and use.

Figure 8 **Los Angeles County Parking Supply** (Chester, et al. 2015)

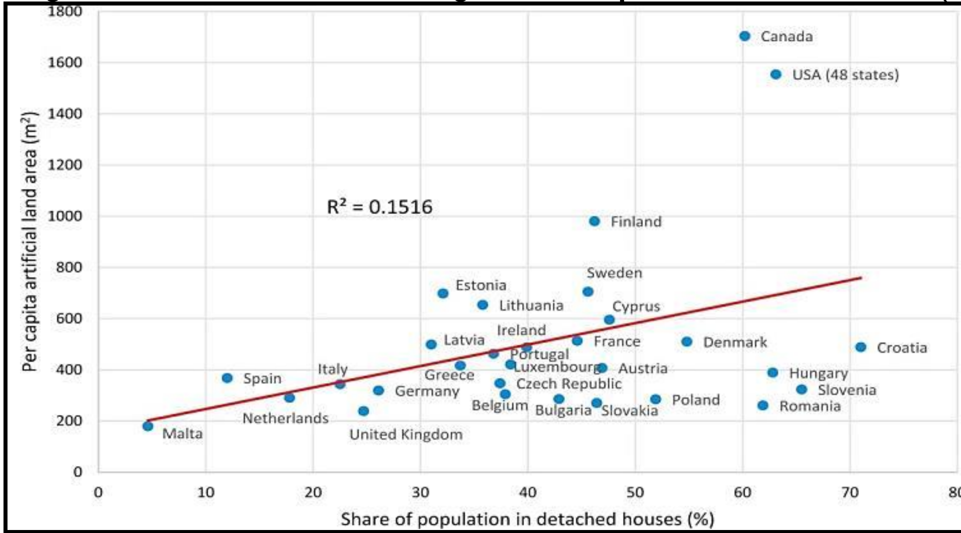


This figure illustrates the number of estimated parking spaces in Los Angeles County.

Davis, et al. (2010) used detailed aerial photographs to count off-street surface parking spaces in Illinois, Indiana, Michigan, and Wisconsin. They did not count on-street and structured parking spaces, other than the top floor of structure with open roofs, or residential parking spaces not in parking lots. They identified more than 43 million parking spaces in these four states, averaging 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 km^2 of land, approximately 5% of urban land area.

Orsi (2021) used satellite and GIS data to measure per capita impervious surface areas for 30 European and North American cities. Figure 7 compares this with share of households in detached homes. This indicates that each one percent increase in the proportion of people living in detached houses is roughly associated with an 8m^2 increase in per capita artificial land (impervious surface) area.

Figure 9 **Detached Housing Versus Impervious Surface Area** (Orsi 2021)



Per capita impervious surface area tends to increase with the portion of detached houses. This factor is about five times higher in Canada and the USA than in European cities due to more compact development and lower rates of automobile ownership and use.

Millard-Ball (2021) developed an economic framework for optimizing street widths. He used tax parcel data to quantify the widths, land areas, and land value of streets in 20 large U.S. counties. He found that urban residential street rights-of-way average 55 ft. wide, far greater than the 16 ft. required for basic access, and this land has a total value of $959 billion. He concluded that reducing street width requirements could reduce the portion of urban land devoted to roads and increase the portion devoted to other uses, such as housing. Gössling, et al (2016) used high-resolution satellite images to analyze the amount of land devoted to transportation facilities in Freiburg, Germany. They found that the portion devoted to automobiles is greater, and the portion devoted to bicycling is smaller, than their mode shares. 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's city center, 24% of land is parking facilities, 7% to 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 5 **Average Land Consumption Per Automobile**

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

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

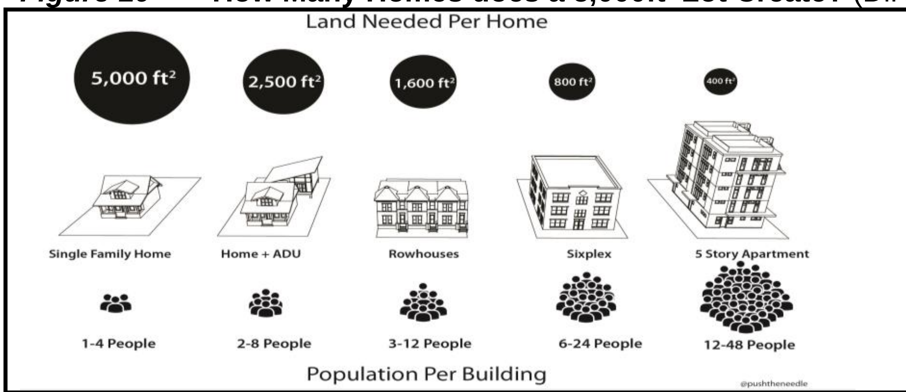
This suggests that motor vehicles typically require 800 to 4,000 square feet of land for roads and parking facilities, with lower rates in compact urban areas where roads are narrower and parking is shared, and higher rates in suburban and rural areas. As a result, per capita pavement area increases with vehicle ownership rates and declines with density. Although roads and parking facilities use a relatively small portion of total land area they are located in areas with high land values and competing uses. More efficient management can free up valuable land for other productive uses and provide other benefits.

Considering land, construction and operating costs, surface off-street parking spaces typically have $500 to $1,500 annualized value, and about twice that for structured parking (Litman 2009). Assuming there are three to six off-street parking spaces per vehicle, parking facility costs probably average $2,000 to $4,000 per vehicle-year, most of which is paid indirectly, through general taxes, housing costs and higher prices for other goods.

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 *potion* 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.

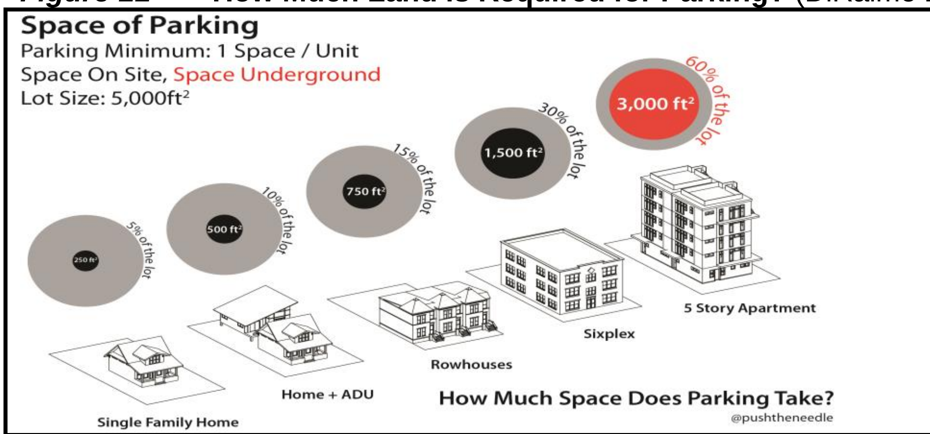
Figure 10 **How Many Homes does a 5,000ft² Lot Create?** (DiRaimo 2021)



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.

Figure 11 **How Much Land is Required for Parking?** (DiRaimo 2021)



The portion of land required for off-street parking increases with building density, although this can be reduced with underground parking or more efficient parking management.

The table below shows the land required for houses, roads and parking for three types of 1,800 square foot (sf) houses: car-free urban, car-owing urban, and suburban. It assumes three stories in cities and one story in suburbs; car-free urban households use a tenth of a vehicle through sharing and taxis, car-owning urban households own one vehicle and suburban households own two, parking facilities (including driveways) average 300 sf in cities and 400 sf in suburbs; and road space per vehicle averages 200 sf in cities and 1,000 in suburbs.

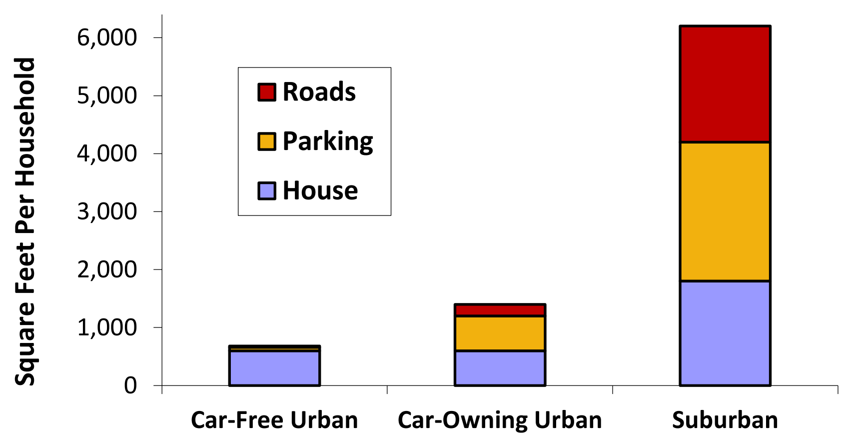
Table 6 **Impervious Surface Area Per Household**

	Car-Free Urban	Car-Owning Urban	Suburban
House – stories	3	3	1
House area (sf)	600	600	1,800
Vehicles per household	0.1	1	2
Parking spaces per vehicle	2	2	6
Area per parking space (sf)	300	300	400
Total parking space area (sf)	60	600	2,400
Road area per vehicle (sf)	20	200	2,000
Total	*680*	*1,400*	*6,200*

This table compares urban and suburban building, parking and road impervious surface area.

The figure below illustrates these results. A typical two-car suburban household requires about 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.

Figure 12 **Impervious Surface Area Per Household**



Households that occupy compact homes (multiplexes, townhouses and low-rise apartments) in walkable urban neighborhoods require far less land for housing, parking and roads than if they lived in single-family houses in automobile-dependent suburbs where they own more vehicles and drive more miles.

It is also interesting to compare impervious surface area with urban greenspace. 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 impervious surface area of different locations. Because suburban areas have more land per household they can accommodate the additional pavement required by motor vehicles and still have significant greenspace. Urban areas have less land per capita 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 7 **Portion of Impervious Surface Area**

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

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 required by various options, and their environmental impacts. Similarly, planners seldom quantify the amount of habitat affected by transport and development planning decisions. For example, planning analysis seldom evaluates surface area, and environmentalists sometimes oppose infill development that displaces 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). Fitzgerald (2023) argues that many communities place excessive emphasis on urban trees to the detriment of other community goals such as affordable housing.

Factors Affecting Heat Island Effects

Heat island effects are the additional ambient temperatures caused by darker surfaces concentrated in urban areas. The following factors can affect this (UBC 2022; UNEP 2021):

- The portion of land devoted to dark surfaces such as roofing and pavement.
- Imprevious surface reflectivity (albedo). Ligher colors reduce heat gain.
- Greenspace and tree cover. More cover reduces heat gain.

For information and analysis tools see *Cool Planning for a Hotter World* (Litman 2022 and 2023) and the *Smart Surfaces Coalition* (https://smartsurfacescoalition.org).

Impervious Surface Costs

Paving land for roads and parking facilities imposes various direct and indirect costs:

- *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 4,500 sf 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).

- *Reduced walkability.* Leadbetter, et al. (2024) found that parking lots have significant negative impacts on walkability; their objective walkability score is half that of other road segments and 3.5 times lower than pedestrian and bicycle streets.

- *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* (www.heat.gov/pages/urban-heat-islands) Pavement, particularly dark-colored asphalt, absorbs and stores solar radiation which increases ambient temperatures. This increases urban summer temperatures 2-8° F, which increases energy demand, smog, discomfort (Gould 2022), and human mortality (Brochu, et al. 2022; Iungman, et al. 2023).

- *Increased vehicle travel and associated costs*. Road and parking expansions tend to increase 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, pollution emissions and illness (Garber, et al. 2025).

- *Displaces other road uses*. Road right of way devoted to automobile travel 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 and total transportation costs (Burchell, et al. 2005; Litman 2015).

- *Reduced housing affordability*. Local roads and residential parking costs increase development costs, which reduces housing affordability (Gabbe and Pierce 2016; Litman 2020).

- *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 (Ives, et al. 2015; White 2007).

- *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.

Reducing road and parking area frees up urban land for other productive uses (Pojani, et al. 2017). The table below rates the environmental values of various land uses. Openspaces, such as forests, farms and parks, provide wildlife habitat, groundwater recharge, farm productivity and beauty. Impervious surfaces, such as buildings, roads and parking, are ecologically sterile and so provide minimal environmental 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. These impacts can inequitable: public greenspace and tree cover tend to increase with income, leaving lower-income communities less comfortable and healthy (McDonald, et al. 2021).

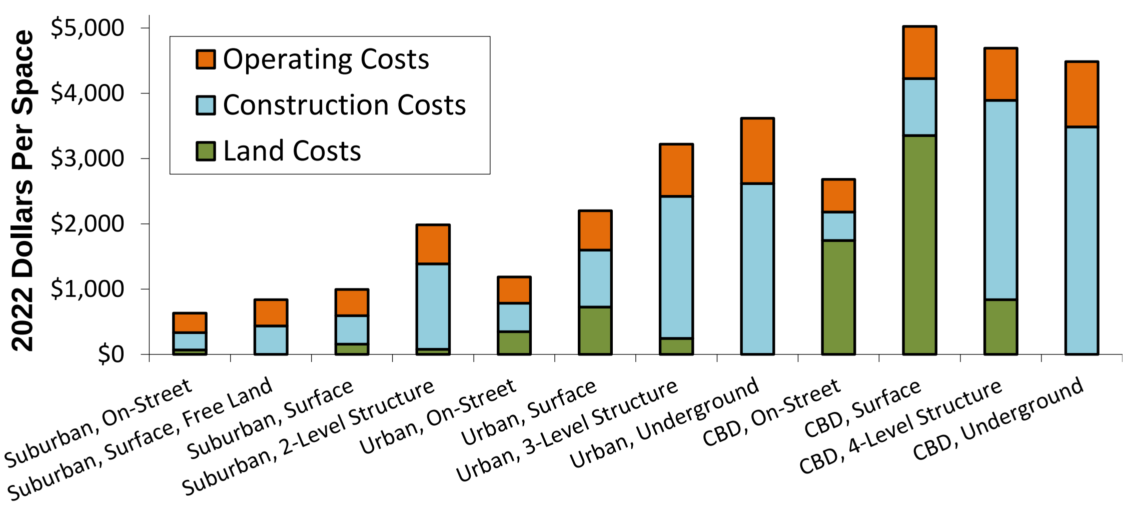
Table 8 **Land Use Environmental Values** (McConnell and Walls 2005)

Land Use	Environmental Values	
Undisturbed natural openspace	Wildlife habitat, groundwater recharge, beauty	Highest
Disturbed natural openspace	Wildlife habitat, groundwater recharge, beauty	
Farmlands	Agricultural productivity, beauty	
Urban parks	Wildlife habitat, groundwater recharge, beauty	
Xeriscape gardens and lawns	Wildlife habitat, food production, groundwater recharge, beauty	
Mono-crop Lawns	Beauty	
Gravel roads and pervious parking	Groundwater recharge	
Landscaped roads and parking	Wildlife habitat, beauty	
Buildings and pavement	Ecologically sterile	Lowest

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. The figure below illustrates typical annualized costs per parking space, excluding indirect and environmental costs.

Figure 13 **Typical Annualized Costs per Parking Space** (“Parking Costs” Litman 2009)



This figure illustrates typical costs per parking space.

Optimal Road and Parking Supply

According to planning theory, optimal road and parking supply is the amount required to serve user demands with the least costs to users (delay, risk and user fees), governments (roadway construction and operating expenses), and society (congestion delay, crash and pollution costs). 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 and parking supply is the amount that could be financed if travelers had diverse mobility options (walking, bicycling, ridesharing, driving, transit, telework, etc.) and paid all facility costs through user fees.

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. Planners generally assume that when it comes to road and parking supply, more is better; they lack a vocabulary for determining what amount is enough or too much. This results 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 their costs.

Several common planning practices encourage goverments to expand roads beyond what is necessary or optimal. Most transportation agencies were originally highway agencies, and many of their planning and funding practices retain that mission; they assume that their goal is to maximize vehicle travel speed and capacity, evaluate transport system performance based on vehicle traffic conditions and have more funding available for highways than for other modes.

The study, *Road Capacity as a Fundamental Determinant of Vehicle Travel* (Millard-Ball and Rosen 2025) found that population and road supply growth affects total vehicle travel more than income and fuel prices, so road capacity analysis predicts regional vehicle travel about as well as complex travel demand models. The researchers point out that road supply does not just affect traffic speeds, it also impacts automobile accessibility, pedestrian connectivity, land development, transit service feasibility, and household residential and employment location decisions. Since per capita vehicle travel peaked early in the Twenty First Century. road capacity rather than income has emerged as a dominant factor affecting vehicle travel. This implies that roadway planning and funding decisions significantly affect future travel activity.

Typical North American communities have three to six off-street parking spaces per vehicle, including many government-mandated spaces that are seldom or never used (Bunt & Assoc. 2024; Litman 2024; Scharnhorst 2018). Volker and Thigpen (2024) found that more than 75% of Sacramento, CA households have enough off-street parking to park all their vehicles, and combining off-street and on-street parking those households have an average of 1.6 more spaces than vehicles. This oversupply is particularly severe in areas with transportation or parking management policies (Galdes and Schor 2022; Spack and Finkelstein 2014).

Various planning practices contribute to parking oversupply (Shill 2020; Shoup 1999a). Parking standards are based on demand surveys that were mostly performed in suburban areas with unpriced parking. They are calculated for 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). These practices result in more parking than needed at most times and location , particularly where land use is mixed, there are good travel options, or where transport and parking management strategies are implemented (Shoup 2005). 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 shows that many parking lots never fill.

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 spaces declines.

Table 9 **Parking Spaces Required for 100-Employees**

Spaces	Conditions	Land Prices	Overflow Options	Management
100	Auto-dependent	Low	Few	One unpriced space per employee.
80	Auto-dependent	Moderate	Few	Employees share 80 unpriced spaces, assuming most days at least 20% are offsite.
60	Suburban commercial	Moderate	Some	Employees share unpriced spaces and have a Commute Trip Reduction (CTR) program.
50	Suburban commercial	Moderate	Some	Employees share spaces, have a CTR program, and $40 per month parking fee or cash out.
40	Suburban commercial	High	Many	Employees share spaces, have a CTR program, and $80 per month parking fee or cash out.
20	Urban commercial	High	Many	Employees share spaces, a CTR program, and $120 per month parking fee or cash out
10	Central business district	High	Many	Employees share spaces with a $120 per month parking fee or cash out.
0	Central business district	High	Many	Employees rent parking from nearby commercial operators.

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

Table 10 summarizes various planning distortions that result in economically excessive road and parking supply. Although many of these distortions may individually seem modest and reasonable, their impacts are cumulative and synergistic (total impacts are greater than the sum of individual impacts), resulting in far more road and parking supply than is optimal. Many experts now recommend planning reforms. For example, the Institute of Transportation Engineers International President recently advocated eliminating minimum parking requirements and other parking planning reforms (Belmore 2019), and the *Parking Reform Network* (https://parkingreform.org) is a professional organization supporting policy changes.

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.

Table 10 **Road and Parking Planning Distortions and Corrections** (Litman 2017)

Distortions	Corrections
Most demand studies are performed at single-use, suburban sites where parking is unpriced, resulting in standards that are excessive in other conditions.	Perform more research to determine how geographic, demographic and management factors affect transport and parking demand.
Standards are seldom adjusted to reflect geographic, demographic and economic factors that affect demand.	Apply more accurate standards that reflect specific conditions.
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.	Apply more accurate standards that reflect specific conditions.
Standards are often designed to accommodate the greatest demand a site may ever encounter over the facility's lifespan, although this is usually excessive.	Apply more accurate standards, with contingency-based solutions available to address future changes in demand.
Generous minimum standards result in abundant parking supply, which discourages owners from charging for parking, creating a self-fulfilling prophesy.	Apply more accurate parking standards and parking management solutions before expanding parking supply.
Governments often provide subsidized parking, which discourages businesses from charging for parking at their sites.	Price public parking efficiently.
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.	Apply "least cost planning," so management strategies receive equal support as capacity expansion.
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.	Use comprehensive evaluation which takes into account all economic, social and environmental impacts.
Generous standards were created when land costs were lower and there was less concern about traffic impacts and sprawl.	Adjust planning practices to reflect changes in land values and planning objectives.
Current planning practices tend to be automobile-oriented.	Apply more multi-modal planning.

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

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) analyzed the relationship between parking pricing, policies, parking supply, and parking demand in the Bay Area. It found that most locations analyzed have significant amounts of unused parking even during the peak periods. Although there are shortages at some times and locations, there is usually significant unused parking supply in lots and structures nearby. 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.

Studies indicate that conventional parking requirements are nearly twice what is needed in compact, Smart Growth neighborhoods (Schneider, Handy and Shafizadeh 2014). A detailed study, *Travel Demand Management: An Analysis of the Effectiveness of TDM Plans in Reducing Traffic and Parking*, found that office buildings that implemented TDM plans generate, on average, 34% to 37% less traffic and need 17% to 24% fewer on-site parking spaces than Institute of Transportation Engineers' predicted rates (Spack and Finkelstein 2014). Fairfax County has ambitious vehicle trip reduction goals. The study, *Don't Underestimate Your Property: Forecasting Trips and Managing Density over the Long Term*, found that 13 residential and commercial developments with TDM programs actually generate 63% fewer trips than trip generation models predict, more than double the targets (Galdes and Schor 2022). 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 that analyze the market distortions that result in an economically excessive amount of land being devoted to transportation facilities only consider one or two factors, such as excessive road width standards, excessive parking minimums in zoning codes, and underpricing of parking facilities. More comprehensive analysis is likely to identify even greater oversupply.

Explanations for Excessive Road and Parking Supply

There are several reasons that decision-makers may favor excessive road and parking supply.

- Many decision-makers are unaware of full road and parking facility costs, and so fail to consider the full savings and benefits of pavement-reduction policies.
- 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.

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 Area

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

Use Structured Instead of Surface Parking

Structured parking facilities use less land and require less pavement per space than surface lots (Croeser, et al. 2022). A two-story garage uses half as much and a four-story garage uses a quarter as much land per parking space, and underground parking uses virtually no incremental land. Surface parking tends to be more convenient for drivers, particularly for larger vehicles, but structured parking protects vehicles from extreme weather.

Structured parking typically costs $20,000 to $40,000 extra per space, and parking facilities typically accommodate 100-150 spaces per acre so considering just financial costs, structured parking becomes cost effective when land prices exceed three to four million dollars per acre. Indirect and non-market values, such as stormwater management costs, heat island effects, and the value of greenspace can justify structured parking at lower land costs.

Smart Growth Development Policies

Smart Growth (also called *New Urbanism* or *location-efficient development*) is a general term for policies and planning practices that result in more compact, mixed-use, multi-modal communities, as opposed to sprawl. Major differences between these two land use patterns are compared in the table below.

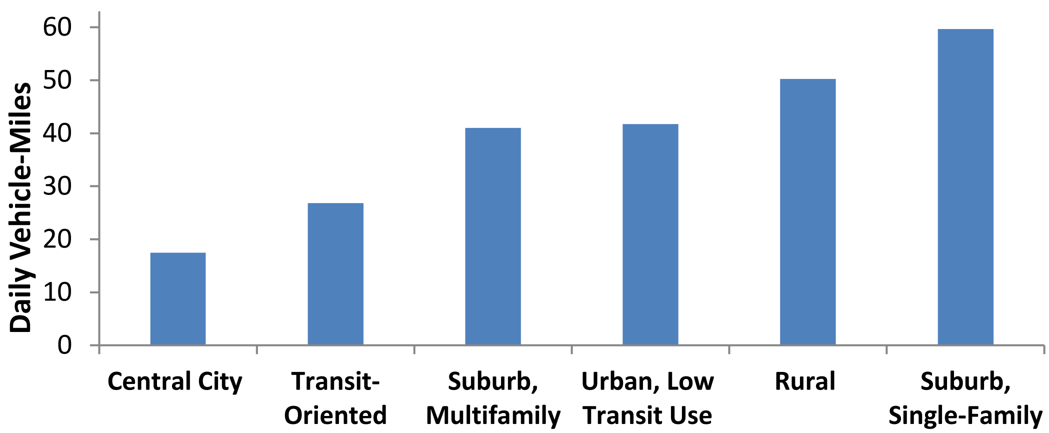
Table 11 **Comparing Smart Growth and Sprawl** ("Smart Growth," VTPI 2007)

	Smart Growth	Sprawl
Density	Compact development.	Lower-density, dispersed activities.
Growth pattern	Infill (brownfield) development.	Urban periphery (greenfield) development.
Land use mix	Mixed land use.	Homogeneous (segregated) land uses.
Scale	Human scale. Smaller buildings, blocks and roads. More detail since people experience the landscape up close, as pedestrians.	Large scale. Larger buildings, blocks, wide roads. Less detail, since people experience the landscape at a distance, as motorists.
Public services (shops, schools, parks)	Local, distributed, smaller. Accommodates walking access.	Regional, consolidated, larger. Requires automobile access.
Transport	Multi-modal transportation and land use patterns that support walking, cycling and public transit.	Automobile-oriented transportation and land use patterns, poorly suited for walking, cycling and transit.
Connectivity	More connected roads, sidewalks and paths, allowing relatively direct travel by nonmotorized as well as motorized modes.	Hierarchical road network with numerous loops and dead-end streets, and unconnected sidewalks and paths, with many barriers to nonmotorized travel.
Street design	Streets designed to accommodate a variety of activities. Traffic calming.	Streets designed to maximize motor vehicle traffic volume and speed.
Planning process	Planned and coordinated between jurisdictions and stakeholders.	Unplanned, with little coordination between jurisdictions and stakeholders.
Public space	Emphasis on the public realm (parks and recreation facilities, sidewalks).	Emphasis on the private realm (yards, shopping malls, gated communities, private clubs).

This table compares Smart Growth with sprawl development patterns.

Smart Growth tends to increase the portion of land that is paved within developed areas but reduces total per capita impervious surface area, typically by an order of magnitude. It encourages narrower streets and smaller parking lots, more structured parking, and more compact building types such as multi-story townhouses, multifamily, and mixed-use buildings. It supports and is supported by transport and parking management which reduces travel distances and increases the portion of destinations that are easily reached by non-auto modes, reduces vehicle ownership and use, and allows more shared parking. People who live and work in Smart Growth 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 (CAPCOA 2021; Litman 2005). The following figure illustrates these effects.

Figure 14 **Household VMT by Neighborhood Type** (Salon 2014)



Per capita daily vehicle-miles vary significantly within urban regions.

This development pattern can provide many benefits, as summarized below.

Table 12 **Smart Growth Benefits by Category** (Ewing and Hamidi 2015; Litman 2015)

Economic	Social	Environmental
• Openspace preservation increases agricultural and recreation industry productivity. • Reduced costs of providing public infrastructure and services. • Improved accessibility reduces vehicle travel and associated costs to households, businesses and governments. • Agglomeration efficiencies, which increase economic productivity. • Reduced vehicle and fuel spending reduces export exchange burdens.	• Increased accessibility and improved mobility options increase opportunities for physically, economically and socially disadvantaged people. • Reduced traffic casualties (injuries and deaths). • Improved public fitness and health. • Increased community cohesion (positive interactions among neighbors). • Reduced chauffeuring burdens.	• Openspace preservation maintains wildlife habitat and other ecological functions. • Reduces surface and groundwater disruptions, maintains water quality, and reduces stormwater management costs. • Reduces per capita energy consumption and pollution emissions. • Reduces heat island effects.

By reducing per capita land consumption, improving accessibility and reducing automobile travel, Smart Growth tends to provide various economic, social and environmental benefits.

Favor Space-Efficient Travel Modes
Walking, bicycling, ridesharing and public transit require less land for roads and parking than automobile travel. *Transportation Demand Management* (TDM) strategies can favor these modes and discourage automobile ownership and use, as summarized in the table below.

Table 13 **Transportation Demand Management Strategies** (VTPI 2007)

Improved Transport Options	Incentives to Shift Mode	Land Use Management	Policies and Programs
Walking and bicycling improvements Bike/transit integration Carsharing Guaranteed ride home Park & ride facilities Ridesharing Shuttle services Alternative work schedules (flextime) Telework Traffic calming Transit improvements	Efficient parking pricing Efficient road pricing Walking and bicycling encouragement Congestion pricing Distance-based pricing Commuter financial incentives Fuel tax increases High occupant vehicle (hov) priority Pay-as-you-drive insurance Vehicle restrictions	New urbanism Smart growth Transit oriented development (tod) Car-free districts Location efficient development Streetscaping Complete streets policies Street reclaiming	Access management Campus transport management Commute trip reduction Freight transport management Marketing programs School trip management Special event management Tourist transport management Transport market reforms

Various strategies can favor space-efficient modes, reducing road and parking area.

Green Roofs
The International Green Roof Association (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 Street Width Requirements
Many jurisdictions require wide residential streets that can be reduced with better design and traffic management, and reduced parking area (CTV 2023; Guo, et al. 2012). Municipal zoning codes and development policies can be changed to reflect New Urbanist design principles.

Parking Management
Parking management includes various strategies that encourage more efficient use of parking facilities, as listed below, 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 14 **Parking Management Strategies** (Litman 2013; Willson 2015)

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

This table summarizes the parking management strategies. It indicates the typical reduction in the amount of parking required at a destination.

Current parking mandates can often be reduced in response to the factors listed below.

Table 15 **Parking Adjustment Factors** (Litman 2013; Rowe, et al. 2013)

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

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

Some strategies are particularly effective at reducing pavement area. Parking can be provided in land-efficient structures rather than surface parking (Croeser, et al. 2022), and parking facilities can be shared, so fewer spaces are needed. 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 and high operating costs. 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.

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 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.
- Use car stackers and mechanical garages, as illustrated below.

Figure 15 **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 (Cortright 2021; Yencha 2022).
- *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 and Road Space Reallocation
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.

Road space reallocation changes roadway design to favor space-efficient mode, such as walking, bicycling and public transit, over automobile travel and parking. This can be justified on fairness grounds, to better balance the allocation of public resources between users, and to encourage more efficient travel (De Gruyter, Zahraee and Young 2022) The *Streetspace Allocation Option Generation Tool* (https://ifpedestrians.org/roadoptions/public), developed for the European Union's *MORE* (Multi-modal Optimization of Roadspace in Europe) helps redesign, reallocate, or regulate streetspace to meet specific community policy goals, including accommodating various modes, minimizing pollution emissions and supporting local economic development.

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 (Bebinger 2022; CNT 2020; Mukhija and Shoup 2006; Rodriguez-Valencia and Ortiz-Ramirez 2021; *Smart Surfaces Coalition,* https://smartsurfacescoalition.org; Yakubu 2024):

- 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 (Bebinger 2022).
- 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) and on-site peculation to reduce surface runoff (Stiffler 2012).
- Use ribbon or "Hollywood" driveways, which are two strips of pavement instead of a full lane, as illustrated below. This reduces paved area by about half.

Figure 16 **Permeable Blocks and Hollywood Drives**

Permeable pavement blocks allow grass to grow and water to drain into the ground.

Ribbon or "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 16 summarizes potential pavement reduction strategies identified in this guide.

Table 16 **Pavement Reduction Strategies**

Management Strategy	Description
Structured rather than surface parking facilities	Use structured and underground instead of surface parking. This is typically cost effective when land prices exceed about $3 million per acre.
Favor space-efficient travel modes	Apply transportation demand management strategies to favor space-efficient modes that reduce the amount of land required for roads and parking facilities.
Educate decision-makers	Educate decision-makers concerning the costs of excessive road and parking supply, distortions in current planning practices, and pavement reduction strategies.
Parking management	Implement parking management policies and programs that encourage more efficient use of parking facilities by sharing, pricing and use of off-site parking facilities.
Efficient pricing	Charge users directly for using roads and parking facilities. Cash out and unbundle currently free parking.
Smart Growth	Encourage more compact, mixed, multi-modal development, which encourages sharing of parking facilities and use of alternative modes.
Overflow plans	Develop plans to manage traffic and parking during occasional peaks and special events.
Use existing facilities more efficiently	Increase parking supply by using otherwise wasted space, smaller stalls, car stackers and valet parking.
Parking tax reform	Various tax policy changes that support parking management objectives.
Structured and underground parking	Use structured and underground parking facilities rather than surface lots in order to reduce impervious surface area and increase development density.
Infill and brownfield redevelopment	Encourage redevelopment of existing urban areas rather than expansion into greenfields.
Streetscaping	Improve roadway design, including traffic calming and road diets.
Shared rights of way	Encourage government agencies and utilities to share rights of way among various utilities and other land uses.
Parking facility design	Improved parking facility design and operations to support parking management objectives and reduce harmful impacts.
Better pavements	Use pervious and reflective pavements which reduce environmental impacts.

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

These strategies vary in the range of benefits they provide. For example, improving road and parking facility design with on-site percolation, permeable pavements and reflective materials can reduce stormwater management costs and heat island effects, but does not reduce sprawl or traffic impacts. Some parking management strategies, such as parking facility sharing, can reduce the total amount of land paved for parking facilities, and others, such as more efficient parking pricing and commute trip reduction programs, can reduce per capita vehicle ownership and use, and therefore traffic problems.

Many of these impacts will vary depending on how they are measured. For example, more compact urban development tends to have more impervious surface per unit of land (per acre or hectare) but less impervious surface per capita. More compact housing types reduces impervious surface per housing unit, and therefore per capita.

Table 17 summarizes these effects.

Table 17 **Benefit Analysis**

Management Strategy	Stormwater Mgt. Savings	Heat Island	Habitat Preservation	Reduced Sprawl	Reduced Traffic
Structured parking facilities	✓	✓	✓	✓	
Compact infill	More local, less total impervious surface area.			✓	✓
Favor space-efficient modes	More local, less total impacts (e.g., more sidewalk pavement).			✓	✓
Educate decision-makers				✓	✓
More accurate & flexible standards	✓	✓	✓	✓	✓
Parking management	✓	✓	✓	✓	✓
Efficient pricing				✓	✓
Smart Growth	More local, less total impervious surface area.			✓	✓
Overflow plans	✓	✓	✓	✓	✓
Use facilities more efficiently	✓	✓	✓	✓	✓
Parking tax reform	✓	✓	✓	✓	✓
Structured & Underground Parking	✓	✓	✓	✓	✓
Infill & brownfield redevelopment	More local, less total impervious surface area.			✓	✓
Streetscaping	✓	✓	✓	✓	✓
Shared rights of way					
Improve facility design	✓	✓			
Pervious and reflective pavements	✓	✓			

This table indicates the benefits provided by various impervious surface reduction strategies. Some increase impervious surface within the urban area but reduce per capita and total impacts, preserving regional openspace and reducing sprawl-related costs. Some also reduce total vehicle travel and traffic costs.

This analysis suggests that pavement management plans should reflect the following priorities:

1. Encourage compact development that minimizes per capita impervious surface area.
2. Reduce total automobile ownership and use. Favor space-efficient modes (walking, bicycling, micromodes and public transit) over automobile travel.
3. Use structured rather than suface parking, so less land is used per parking space.
4. Use narrower roadways with more greenspace, and bury roads were appropriate.
5. Incorporate greenspace into roads and parking facilities, particularly tree cover.
6. Use on-site stormwater water percolation, such as bio swales.
7. Use pervious pavements to allow groundwater recharge and more reflective pavement materials to reduce heat island effects.

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. 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 (Fortuna 2024).

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 uncertainly 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 public infrastructure costs, free up land for other productive uses, reduce stormwater management and heat island costs, create more livable communities, increase land use accessibility, encourage more efficient travel behavior, and more equitably allocation public resources. Higher development densities tend to increase the portion of impervious surface area per acre, but reduces it per captia, so compact development supports most pavement busting goals. 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 parking minimums
- 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 50^{th} 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.

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