

Victoria Transport Policy Institute

1250 Rudlin Street, Victoria, BC, V8V 3R7, CANADA

www.vtpi.org info@vtpi.org

Phone & Fax 250-360-1560

"Efficiency - Equity - Clarity"

Pavement Busters Guide

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

by

Todd Litman

Victoria Transport Policy Institute

31 March 2008



Abstract

This guide identifies ways to reduce the amount of land required for roads and parking facilities. It examines ways to determine optimal road and parking supply and the full economic, social and environmental costs of increased impervious surface. It identifies current policies and planning practices that unintentionally contribute to economically excessive road and parking requirements, and specific strategies for reducing the amount of land paved for roads and parking facilities. This analysis indicates that road and parking pavement area can often be reduced significantly in ways that are cost effective and maintain adequate levels of accessibility.

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More efficient management can often reduce the amount of land paved for roads and parking facilities.

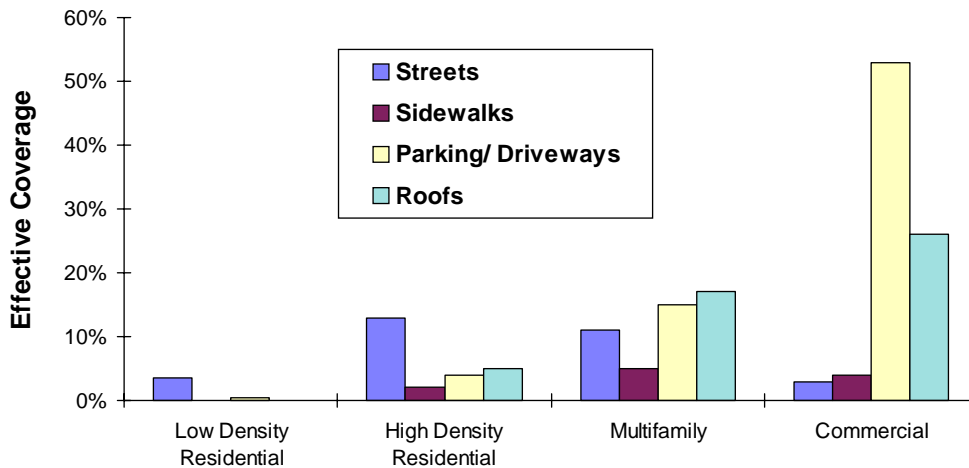
“Form no longer follows function, fashion, or even finance; instead, form follows parking requirements.” Donald Shoup

Introduction

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

A significant portion of the *built environment* (land developed for human activities) consists of *impervious surface* (land covered by materials impenetrable to water, such as asphalt, concrete, brick, and stone), a major portion of which consists of roads and parking facilities. Roads and parking facilities typically cover 10-25% of urban land, and more than 50% in major commercial centers such as downtowns and shopping malls, 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.

Current policies and planning practices favor generous road and parking supply. They are often inefficient and unfair, resulting in an economically excessive amount of land devoted to transport facilities. Alternative, cost-effective practices 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 the full 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 various strategies for reducing the amount of land paved for roads and parking facilities.

Measuring Pavement Area

A typical residential street is 36 feet (12 meters) wide. If homes have 100 foot average frontage, each house requires 1,800 square feet (sf) (or 180 square meters [sm]) of residential street area, and somewhat more to account for intersections. Residential streets represent half of all urban street area,¹ which suggests that there are about 3,600 sf (350 sm) of road pavement per household, or about 1,500 sf (150 sm) per capita.

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 300-400 sf (28-37 sm) per space, allowing 100-150 spaces per acre (250-370 per hectare), as illustrated in Figure 2. Assuming there are two to three off-street parking spaces per capita, parking pavement totals about 1,000 sf per capita.

This suggests that on average about 2,000 sf of urban land is paved for roads and parking facilities per capita, which is about three times the land devoted to homes. Per capita pavement area varies depending on many factors. For example, increased population density reduces per capita road pavement (since there are more people per length of roadway), reduced per capita vehicle ownership or off-street parking spaces per capita reduces total parking area, and reduced peak-period vehicle travel reduces the need to expand roadways.

Table 1 Impervious Surface Of Various Housing Types (Square Feet)

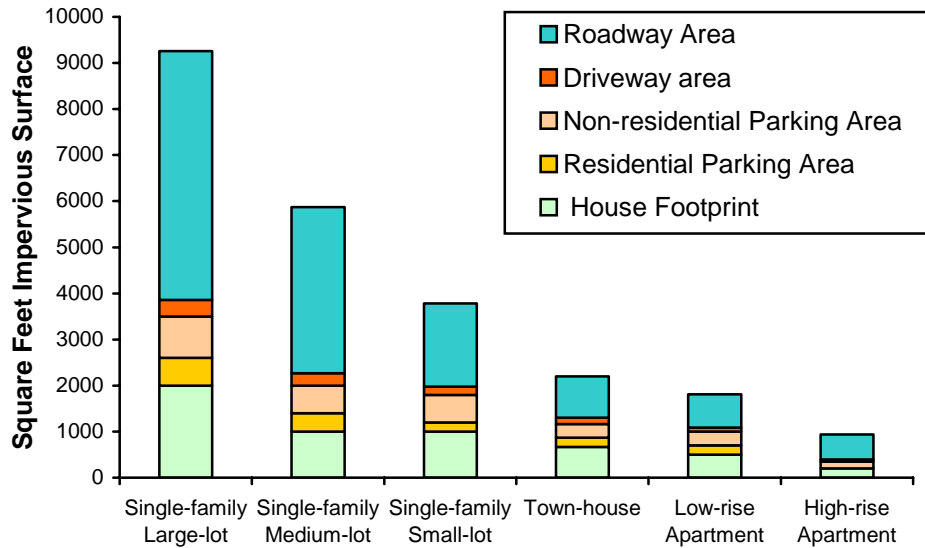
Housing Type	Units	Single-family Large-lot	Single-family Medium-lot	Single-family Small-lot	Town-house	Low-rise Apt.	High-rise Apt.
Stories		1	2	2	3	4	10
House footprint	Sq. Ft.	2,000	1,000	1,000	667	500	200
Residential parking	Spaces	3	2	1	1	1	Underground
Res. parking land	Sq. Ft.	600	400	200	200	200	0
Vehicles		3	2	2	1	1	0.5
N.R.* parking	Spaces	4.5	3	3	1.5	1.5	0.75
N.R.* parking land	Sq. Ft.	900	600	600	300	300	150
Driveway length	Feet	40	30	20	15	10	5
Driveway land	Sq. Ft.	360	270	180	135	90	45
Street frontage	Feet	150	100	50	25	20	15
Roadway land	Sq. Ft.	5,400	3,600	1,800	900	720	540
Total land	Sq. Ft.	8,000	5,000	3,000	1,767	1,420	740
Residents	Per home	2.5	2.5	2.5	2.5	2.5	2.5
Per capita	Sq. Ft.	3,200	2,000	1,200	707	568	296

This table indicates typical impervious surface area for various housing types with 2,000 square feet of interior space. (N.R. = Non-residential)*

¹ According to Table HM-20 in FHWA's *Highway Statistics 2005* (www.fhwa.dot.gov/ohim/ohimstat.htm), there are 1,022,725 total urban road miles of which 723,952 are local. Assuming that local roads average half the width of other types of roads, they represent about half the total road area.

Table 1 indicates impervious surface area for various housing types, all with the same 2,000 sf of interior floor area. Figure 2 illustrates the results. This analysis suggests that roads are the largest category of impervious surface area, followed by parking and housing, and that impervious surface area per household can vary significantly depending on factors including development density, vehicle ownership rates, parking spaces per vehicle and building type.

Figure 2 Impervious Surface Area Of Various Housing Types (Square Feet)



Land requirements per parking space vary depending on type and size. Off-street spaces require driveways and access lanes. Landscaping typically adds 10-15% to parking lot area.

Although land paved for roads and parking facilities represents a relatively small portion of total land area, roads and parking facilities tend to concentrate in areas with high populations and industrial activities, and so compete with other productive uses.² More efficient management that reduces road and parking land requirements can free up valuable land for other productive uses and provide other benefits.

² For more discussion of road and parking land area see the “Roadway Land Value” and “Parking Costs” chapters of *Transportation Cost and Benefit Analysis*, Victoria Transport Policy Institute (www.vtpi.org).

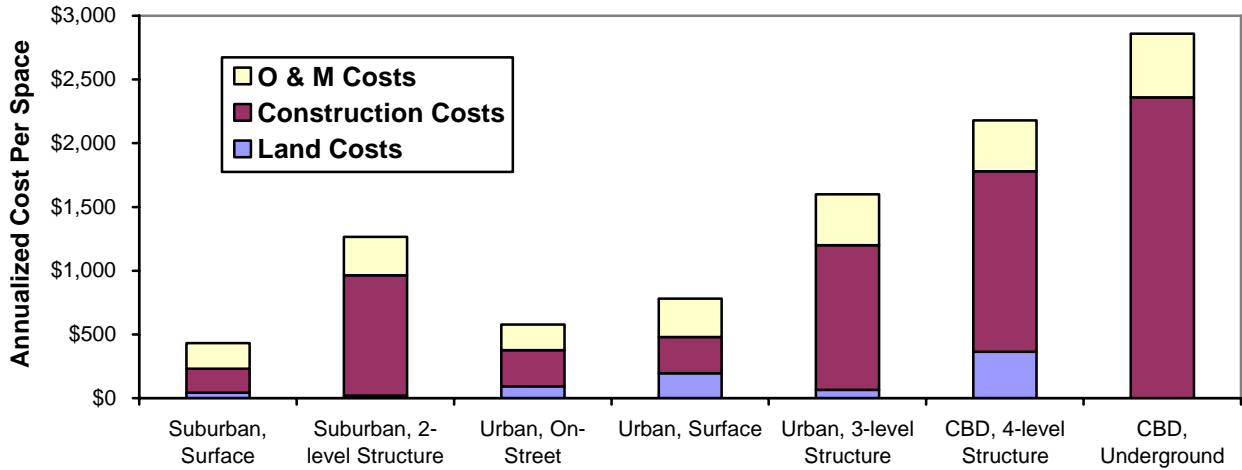
Impervious Surface Costs

Paving land for roads and parking facilities imposes various direct and indirect costs, as described below (USEPA, 1999; Litman, 2006a and 2007a). Current planning practices tend to overlook some of these costs, which skews decisions toward economically excessive pavement area. Described more positively, strategies that reduce road and parking pavement area can provide more benefits than usually recognized.

- *Land costs.* Land devoted to roads and parking facilities has opportunity costs, that is, it could be used in other productive ways, including housing, farming and openspace (van Essan, et al, 2004). The value of land devoted to roads and parking is estimated to total \$1,000 to \$2,000 annually per motor vehicle (Litman, 2003). Conventional planning generally ignores these costs except when additional land must be purchased for new facilities; the opportunity costs of existing roads and parking facilities, and land costs to businesses for parking facilities, are not generally considered in the planning process.
- *Facility costs.* Roads and parking facility construction and operating costs are also estimated to total about \$1,000 to \$2,000 annually per motor vehicle (Litman, 2007a).
- *Hydrologic impacts.* Impervious surfaces repel water, and prevent precipitation from infiltrating soils (NEMO Project). This increases stormwater management costs (costs of building and operating stormwater systems) and reduces groundwater recharge, which has ecological impacts (for example, reduced wetlands) and reduce groundwater available for human uses. If just 5% of a watershed is covered with impervious surfaces, surface water quality degrades significantly (Horner, et al, 1996).
- *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, 1992).
- *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 (Shoup, 2005). This increases various costs, including traffic congestion, consumer costs, accidents, energy consumption and pollution emissions (Litman, 2007a).
- *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, 2006a).
- *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 (Jia and Wachs, 1998).
- *Reduced openspace and wildlife habitat.* Undeveloped land, farmland and greenspace provide various environmental and aesthetic benefits, including wildlife habitat, groundwater recharge, privacy, noise reduction, reduced ambient temperatures, and improved air quality (White, 2007).
- *Aesthetic degradation.* Larger roads and parking facilities tend to reduce adjacent property values because they are unattractive and noisy (Nelessen, 1994).

Most consumers never purchase parking spaces or roadways as a separate item (these facilities are usually bundled with building space or provided by governments and businesses) and so they have little idea of their costs. Figure 3 illustrates typical annualized costs per parking space, excluding indirect and environmental costs.

Figure 3 Typical Annualized Costs per Parking Space (“Parking Costs” Litman, 2007a)



This figure illustrates typical annualized costs per parking space.

Optimal Road and Parking Supply

According to market theory, optimal road and parking supply is the amount consumers would purchase if they paid directly all costs and had various transport and parking options to choose from (“Market Principles,” VTPI, 2007; Litman, 2007b). For example, optimal road supply is the amount that could be financed through direct user fees that covered all direct and indirect roadway costs, with reasonable transport options available (walking, cycling, driving, ridesharing, transit, telework, etc). Similarly, optimal parking supply is the amount consumers would purchase if they paid fees that covered all direct and indirect costs, and they had a reasonable variety of transport and parking options to choose from.

From a planning perspective, optimal road and parking supply is the most cost effective way to provide an adequate level of service, taking into account all impacts and options (“Least Cost Planning,” VTPI, 2007). For example, optimal road supply is the amount that allows people to reach the destinations they want with minimum costs to users (delay, risk and user fees) and governments (roadway construction and operating expenses). From a narrow perspective, this assumes that roads should be sized to accommodate unlimited vehicle traffic, but planners increasingly recognized that in some situations this is infeasible, so alternative options may be acceptable. For example, optimal urban road supply may be less than needed to accommodate unlimited automobile travel if improvements to alternative modes and demand management strategies (such as road pricing), can maintain an adequate level of service.

How Current Practices Oversupply Road Space and Parking

Decisions concerning road and parking to supply (such as the number and width of traffic lanes, and the number and size of parking spaces) should reflect consideration of all impacts (benefits and costs) and options (including management solutions instead of expanding supply), including strategic planning objectives such as a community's desire to support smart growth land use development and alternative travel modes. Current planning practices tend to assume it is desirable to maximize road and parking supply and minimize user charges. They consider management strategies measures of last resort, to be applied only when road and parking expansion is infeasible.

For example, conventional planning practices use recommended road and parking standards published by professional organizations to determine road and parking supply in a particular situation. These standards tend to be economically excessive and can usually be adjusted significantly downward using various adjustment factors and cost effective management strategies. To appreciate why it is helpful to know a little about how these standards are developed. They are based on demand surveys, which measure the number of trips generated and parking spaces occupied at various sites (Knepper, 2007). However, the standards are often based on fewer than a dozen surveys, the results of which are often highly variable, and the analysis usually fails to account for geographic, demographic and economic factors that can affect parking demand, such as whether a site is urban or suburban, and whether parking is free or priced (Shoup, 1999a).

These standards favor oversupply in many ways. Most demand studies were performed in automobile-dependent locations, where parking is not managed or priced for efficiency. They are generally based on 85th percentile demand curves (which means that 85 out of 100 sites will have unoccupied parking spaces even during peak periods), an 85th occupancy rate (a parking facility is considered full if 85% of spaces are occupied) and a 10th design hour (parking facilities are sized to fill only ten hours per year). These standards results in more supply than actually needed at most destinations, particularly where land use is mixed, there are good travel options, or where transport and parking management programs are implemented. Table 2 summarizes various factors that result in economically excessive parking standards, supply and demand. More accurate and efficient planning practices can significantly reduce road and parking requirements.

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 parking facilities are frequently underutilized (Shoup, 1999a; Kuzmyak, et al, 2003). For example, a parking demand study at suburban office sites in southern California found that conventional standards are nearly twice as high as needed, and this oversupply will increase if efforts to encourage alternative commute modes are successful (Willson, 1995). A University of Iowa study found that parking supply exceeded peak-period demand by 16-63% at various commercial centers (Shaw, 1997). Parking surveys in 26 Seattle neighborhoods found that most had only 40-70% peak-period occupancy (Seattle, 2000).

Table 2 Planning and Market Distortions and Corrections (Litman, 2007b)

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 10 th or 20 th 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.

Similarly, current planning practices result in economically-excessive roadway supply, because roadway expansion is favored over cost-effective management strategies (Lee, 1999; "Least Cost Planning," VTPI, 2007). Alternative standards can significantly reduce roadway requirements (Homberger, 1996). 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 generous 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 much higher (COMSIS, 1994).
- Transportation agencies are primarily concerned with traffic movement, parking spillover problems, regulatory simplicity, and fiscal impacts (Willson, 1999). They are less concerned with other impacts and objectives, particularly indirect costs, and planning objectives outside their responsibility.
- A certain amount of road and parking supply can be justified for basic access (“Basic Access,” VTPI, 2007). 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, 2007a).
- Generous road and parking supply help 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.
- Generous minimum parking requirements impose no direct cost on government budgets. Increasing parking requirements is cheaper than providing public parking facilities. Incorporating parking into building costs appears equitable, since businesses simply pass such costs onto their 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, 2007b):

- 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; SPUR (1998); Litman (2006b); VTPI (2007).

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.

More Accurate and Flexible Standards

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 3.

Table 3 Adjustment Factors (Litman, 2006b; Cuddy, 2007)

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 Management	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.	Improved design sometimes allows roadway dimensions to be reduced (Cohen, 1997).
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.

Mobility Management

Mobility management (also called *Transportation Demand Management* or *TDM*) includes various policies and programs that encourage more efficient travel, as listed in Table 4. If broadly implemented such strategies can significantly reduce vehicle traffic.

Table 4 Mobility Management Strategies (VTPI, 2007)

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

Mobility management includes numerous strategies that affect vehicle travel behavior.

Parking Management

Parking management includes various strategies to encourage more efficient use of parking facilities, as listed in Table 5 (some of which are also mobility management strategies).

Mobility management and parking management should be implemented instead of road and parking facility expansion whenever it is overall cost effective, taking into account all impacts (“Least Cost Planning,” VTPI, 2007). For example, governments should implement mobility management when 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 (which are reduced in exchange for management programs).

Table 5 Parking Management Strategies (Litman, 2006b)

Strategy	Description	Typical Reduction
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, brochures and electronic communication.	5-15%
Improve Enforcement	Insure that parking regulation enforcement is efficient, considerate 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.

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. Queens, New York, is limiting the amount of residential front lawns that may be paved for parking. 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 (ICF, 1997). Cost-recovery parking pricing (fees set to pay for parking facilities) typically reduces parking demand 10-30% (“Parking Evaluation,” VTPI, 2007), with similar impacts from parking *cash-out* (travelers can choose to receive the cash equivalent of parking subsidies when they use alternative modes) and *unbundling* (parking is rented separately from building space, so occupants only pay for the amount of parking they actually need). This allows 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

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 6. *New Urbanism* (also called *Neotraditional Development*) 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 6 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 (single-use, 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 (streetscapes, pedestrian environment, public parks, public facilities).	Emphasis on the private realm (yards, shopping malls, gated communities, private clubs).

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, 2006c). 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.

Structured And Underground Parking

Structured and underground parking require less land per space than 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 reduces land costs, allow 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.

Use Parking Facilities More Efficiently

A variety of methods can be used to increase the number of vehicles that can be parked in a parking facility:

- 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 spaces for shorter-term uses which have more entering and exiting activity. A portion of spaces can be sized for compact vehicles, and special, small spaces can be provided for smaller 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 4.
- 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 4 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 (PCW, 2002; Litman, 2006c):

- *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).
- *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.

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 (Burden and Lagerway, 1999).

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.

Improve Facility Design

Various design features can reduce road and parking facility environmental impacts (Smith, 1988; Childs, 1998; Mukhija and Shoup, 2006; Toronto, 2007):

- 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 5) and *pervious cement* (cement, rock and fiber without fine particles). Such materials reduce surface runoff (Booth and Leavitt, 1999).
- Use “Hollywood” driveways, which are two strips of pavement instead of a full lane (Figure 6). This reduces paved area by about half.

Figure 5 Permeable Pavement Blocks



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

Figure 6 Hollywood Driveway



“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.

Country Lanes (www.cityfarmer.org/lanes.html)

VANCOUVER - The City of Vancouver will officially open its first Country Lane, an environmentally sustainable design that makes lanes "greener" and more attractive. Mayor Philip Owen will be on hand to unveil the demonstration pilot project. The Country Lane is designed to provide a rural aesthetic while reducing environmental impacts and discharges to the City's storm sewer system.



The lane features two narrow strips of concrete that provide a smooth driving surface. The area between and beside these bands is made up of a structural component that can support vehicles, but is top-soiled and planted with grass. The road base is a mixture of aggregate, which provides structural stability, and a sand/soil mixture that allows for drainage and provides the necessary organic material for grass growth. This engineered soil was developed by the City of Vancouver's staff.

This design will allow rain water to percolate over vegetation and through the ground. The natural absorption allowed by this combined lane surface reduces discharges into the storm sewer system and provides natural drainage. The increased vegetation will filter storm water and improve air quality.

The lane at East 27th is the first of three Country Lanes planned as demonstration pilot projects. The proposed locations were chosen because of strong community support, and a commitment by area residents to help maintain, and promote this innovative alternative to asphalt lane paving. If successful, Country Lane designs will be available for local improvements throughout the city.

Summary

Table 7 summarizes potential pavement reduction strategies identified in this guide.

Table 7 Pavement Reduction Strategies

Management Strategy	Description
Educate decision-makers	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.
More accurate and flexible standards	Adjust road and parking standards to more accurately reflect demand in a particular situation taking into account various geographic, demographic and management factors.
Mobility management	Implement mobility management programs that reduce vehicle ownership and use.
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 which indicate how parking and traffic will be managed during occasional peaks and special events.
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.
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.
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 and operations	Improved parking facility design and operations to help solve problems and achieve parking management objectives.

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. Reform proponents should highlight the benefits of change, for example, pointing out that many pavement reduction strategies also help reduce traffic congestion, accidents and pollution emissions.

Most transportation agencies were 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 an approach to resource planning that gives demand management solutions equal consideration and chooses the most cost effective option, taking into account all impacts (costs and benefits). Least cost planning 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 costs and heat island effects, create more livable communities, increase land use accessibility, and encourage more efficient travel behavior.

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 of costs of increased pavement and benefits of management solutions. 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.

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