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

Todd Litman

This article provides an estimate of the amount of land that is paved for roads and parking facilities in typical urban areas, examines the full economic, social and environmental costs of this impervious surface, and discusses the amount of road and parking land area that can be considered optimal. The analysis indicates that, in a typical urban area, about three times as much land is devoted to roads and parking as to residential structures, and that per-capita road and parking facility areas vary significantly, depending on planning practices, with much higher rates in areas that have automobile-oriented transport systems and sprawled land use. It identifies current policies and planning practices that unintentionally contribute to economically excessive road and parking requirements, and provides specific recommendations for reducing the amount of land paved for transport facilities.

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A significant portion of the built environment consists of *impervious surface* (land covered by materials impenetrable to water, such as asphalt, concrete, brick, and stone), much of which consists of land paved for roads and parking facilities. Current policies and planning practices tend to increase road and parking facility land area. Public policy and planning reforms described in this report can significantly reduce the amount of land that must be paved for transportation facilities, providing significant economic, social, and environmental benefits.

This article has three primary objectives. First, it describes factors that affect urban-area impervious surface coverage. Second, it examines ways to determine the optimal supply of roads and parking, and current policies and planning practices that unintentionally result in economically excessive impervious surface area. Third, it describes various policy and planning reforms that can reduce the amount of land paved for roads and parking facilities.

Measuring the Amount of Impervious Surface in Urban Areas

To appreciate the amount of impervious surface in urban areas, consider how land in residential areas tends to be allocated. A typical residential street is 36 ft wide, or 18 ft per side. If homes average 100-ft of street frontage (taking into account empty lots and corner lots), each house requires 1,800 ft^2 of residential street area, and somewhat more to account for alleyways and intersections. Residential streets represent half of all urban street area.[1] This suggests that there are about 3,600 ft^2 of road pavement per household, or about 1,500 ft2 (about 150 m^2) per capita.

Additional land is paved for parking facilities. A typical parking space is 8–10 ft wide and 18–20 ft deep, totaling 144–200 ft^2. 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 ft^2 per space, allowing 100–150 spaces per acre (250–370/ha). Assuming there are 2–3 off-street parking spaces per capita, parking pavement area totals about 1,000 ft^2 per capita.

Various studies using a variety of analysis techniques indicate that roads and parking facilities typically cover 10%–30% of land in residential areas and 50%–70% of land in commercial areas (Akbari, Rose, and Taha, 2003; Arnold and Gibbons, 1996; Litman, 2010).

Affiliation of author: Todd Litman, Executive Director, Victoria Transport Policy Institute, Victoria, Canada.

Address correspondence to: Todd Litman, Executive Director, Victoria Transport Policy Institute, 1250 Rudlin Street, Victoria, BC, Canada V8V 3R7; (phone and fax) 250-360-1560; (e-mail) litman@vtpi.org.

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The amount of pavement per capita varies widely. Areas with denser population, narrower roadways, and less per-capita vehicle travel have less roadway supply per capita. Areas with lower vehicle ownership, fewer off-street parking spaces per capita, or more structured parking (multistory and underground parking facilities) devote less land to parking.

Table 1 and Figure 1 indicate the per capita impervious surface areas for various housing types with the same 2,000-ft^2 interior floor area. Figure 1, which illustrates the results, indicates that roads are generally the largest category of impervious surface area, followed by parking and housing. About three times as much land is devoted to transportation facilities as residential structure footprints. As a result, policies and planning practices that affect building type, development density, vehicle ownership, parking supply, and roadway design can affect per capita impervious surface area.

The Costs of Impervious Surface

Paving land for roads and parking facilities generates a variety of direct and indirect costs, which are described in more detail in the following sections (Litman, 2006a, 2009; United States [US] Environmental Protection Agency, 1999). Conventional planning practices tend to overlook some of these costs, which skews decisions to economically excessive pavement area.

Land costs. Land devoted to roads and parking facilities has opportunity costs; that is, it could be used in other productive ways, such as housing, farming, and open space (van Essen et al., 2004). 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. Road and parking facility construction and operating costs are estimated to total about $1,000–$2,000 annually per motor vehicle (Litman, 2009). Most consumers never purchase parking spaces or roadways as a separate item because these facilities are usually bundled with building space or provided by governments and businesses and so most people have little idea of what they actually cost. Figure 2 illustrates typical economic costs of various types of parking.

Housing affordability. Since the costs of residential parking facilities are incorporated into mortgages and rents, and local roadway costs are largely borne through property taxes, increasing parking and local road supply tends to reduce housing affordability (Jia and Wachs, 1998).

Hydrologic impacts. Impervious surfaces repel water and prevent precipitation from infiltrating soils [NEMO (Nonpoint Education for Municipal Officials) Project, www.

Table 1. Per capita impervious surface of various housing types with 2,000 sf interior space

		Single-family lot			Apartment type		
Housing type	**Units**	**Large**	**Medium**	**Small**	**Town house**	**Low rise**	**High rise**
Stories		1	2	2	3	4	10
House footprint	Square feet	2,000	1,000	1,000	667	500	200
Residential parking	Spaces	3	2	1	1	1	Underground
Residential parking land	Square feet	600	400	200	200	200	0
Vehicles		3	2	2	1	1	0.5
Nonresidential parking	Spaces	4.5	3	3	1.5	1.5	0.75
Nonresidential parking land	Square feet	900	600	600	300	300	150
Driveway length	Feet	40	30	20	15	10	5
Driveway land	Square feet	360	270	180	135	90	45
Street frontage	Feet	150	100	50	25	20	15
Roadway land	Square feet	5,400	3,600	1,800	900	720	540
Total land	Square feet	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 impervious surface area	Square feet	3,200	2,000	1,200	707	568	296

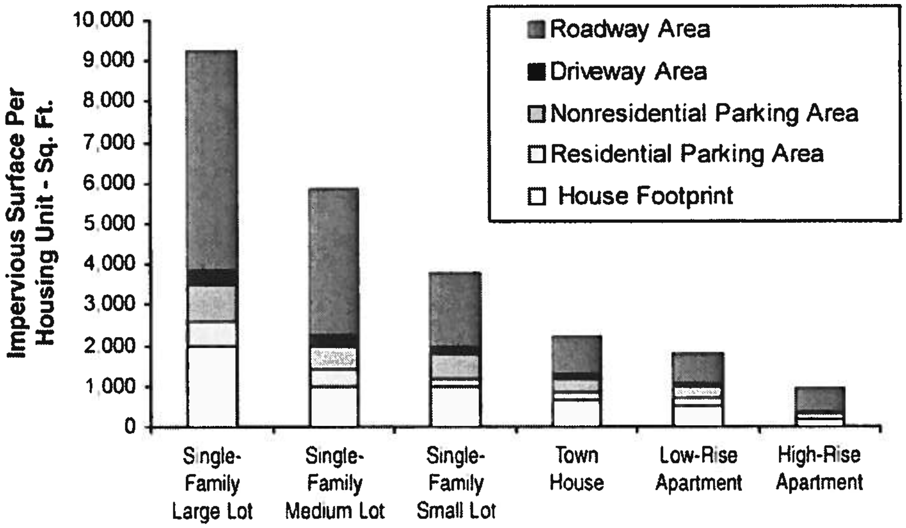

Figure 1. Impervious surface area for various types housing with 2,000 sf interior space.

nemo.uconn.edu].This increases storm-water management costs (costs of building and operating storm-water systems); reduces groundwater recharge, which has ecological impacts (e.g., reduced wetlands); and reduces groundwater available for human uses. If just 5% of a watershed is covered with impervious surfaces, surface water quality degrades significantly (Horner et al., 1997).

Water pollution. Paved surfaces collect and concentrate water pollutants such as phosphorous, nitrogen, and suspended solids (Jacob and Lopez, 2009).

Heat island effects. Pavement, particularly dark-colored asphalt, absorbs and stores solar radiation, which increases ambient temperatures. As a result, urban areas are 2°–8° F

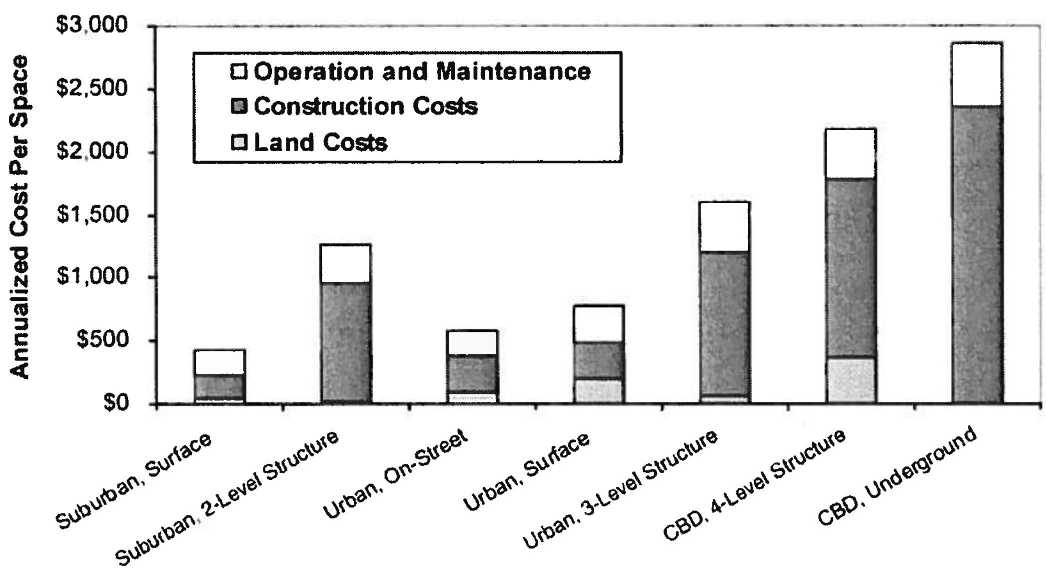

Figure 2. Typical annualized costs per parking space ("parking costs"; Litman, 2009).

hotter in summer, which increases energy demand, smog, and discomfort (Akbari et al., 1992).

Increased vehicle travel and associated costs. Increased parking and roadway supply tends to increase per-capita vehicle ownership and use, and decrease use of other travel options (Manville and Shoup, 2005). The additional vehicle travel increases various costs, including traffic congestion, consumer travel costs, crashes, energy consumption, and pollution emissions (Litman, 2009).

Sprawl costs. Expanding road and parking area encourages more dispersed development, which increases various economic benefits, including the costs of providing public services (e.g., water, sewage, garbage, emergency response, and school) and total transportation costs (Burchell et al., 2005; Litman, 2006a).

Reduced open space, loss of wildlife habitat, and aesthetic degradation. Undeveloped land, farmland, and green space provide various environmental and aesthetic benefits, including wildlife habitat, groundwater recharge, privacy, noise reduction, reduced ambient temperatures, and improved air quality (White, 2007). Larger roads and parking facilities tend to reduce adjacent property values due to noise and aesthetic degradation.

Optimal Road and Parking Supply

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

On this basis, decisions concerning road and parking supply (such as the number and width of traffic lanes, and the number and size of parking spaces) should reflect consideration of all impacts; that is, benefits and costs, and consideration of various options for addressing parking problems. In an economically optimal parking market, developers would build only the amount of parking supply that could be funded by user fees, and if there is a shortage of parking, businesses and governments would implement management solutions whenever they are more cost effective than expanding supply. For example, if an office building had insufficient parking supply, the managers would arrange to use a nearby church's parking lot during weekdays, encourage workers to use alternative commute modes, and provide financial incentives to reduce driving if those strategies are cheaper than expanding parking supply. Current planning practices, however, tend to assume it is desirable to maximize road and parking supply, and so fail to apply cost effective management strategies that can reduce the size of such facilities. With better planning and management, road and parking demand can often be satisfied with much less supply.

For example, most communities have zoning codes that require generous minimum parking and roadway supply. The process used to establish these requirements often results in significant oversupply (Knepper, 2007). These requirements are based on demand surveys that measure the number of trips generated and parking spaces occupied at various sites. 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 (Daisa and Parker, 2010; Shoup, 2005). Most demand studies were performed in automobile-dependent locations, where parking is not efficiently managed or priced. They are generally based on 85th percentile demand curves (which means that 85 of 100 sites will have unoccupied parking spaces even during peak periods) and a 10th design hour (parking facilities are sized to fill only 10 hr per year). These standards result in more supply than actually needed at most destinations.

As a result, many parking facilities are frequently underused (Kuzmyak et al., 2003; Pijanowski 2007; Shoup, 1999). Parking occupancy surveys indicate that many parking facilities have far more parking spaces than are really needed, and this oversupply will increase if efforts to encourage alternative commute modes are successful (Cervero and Arrington, 2008; Weinberger, Kaehny, and Rufo, 2009).

Similarly, current planning practices result in economically excessive roadway supply. For example, dedicated roadway funding favors highway expansion to reduce traffic congestion, even if public transit improvements, more efficient road pricing, and commute trip reduction programs are often more cost effective overall ["least cost planning"; Victoria Transport Policy Institute (VTPI), 2007]. Roadway widths are often excessive. For example, planners in Eugene, Oregon, found that local road rights-of-way could be reduced 16%–20% over standard practices without reducing performance (West and Lowe, 1997).

Explanations for Excessive Road and Parking Supply

Why do policies and planning practices often favor generous road and parking supply? From some perspectives, building generous road and parking supply seems sensible and efficient.

Generous road and parking supply helps prevent congestion and ensure emergency access. Convenient vehicle access is considered important to businesses and therefore for local economic development. Parking regulations, fees, and enforcement are often frustrating to users and unpopular due to their spillover impacts (when parking regulations and pricing cause motorists to park where they are unwanted), so public officials often prefer policies that ensure generous and free parking supply. The costs of generous parking requirements are largely borne by the private sector and so may seem cheaper than providing public parking facilities. Incorporating parking into building costs appears equitable, since businesses simply pass such costs on to their customers.

In addition, it can be difficult to determine what road and parking supply is truly optimal. Since automobile ownership and use grew steadily over the last century, and roads and parking facilities are durable and can be difficult to expand, it may seem sensible to require extra road and parking capacity to accommodate possible future growth.

Transportation agencies are primarily concerned with traffic movement and administrative convenience, and so have little interest in innovative management strategies that achieve other objectives and require policy reforms. From an administrative perspective, it seems easiest and fairest to apply rigid standards rather than more flexible policies that may be challenged. Funding is often dedicated to roads and parking facilities, and so would require legal and administrative changes to be spent on other solutions, even if they are more cost effective overall. Many zoning codes and development practices are based on outdated assumptions, which may have been appropriate when land costs were relatively low and there was less concern about development affordability or environmental quality.

On grounds that they are being cautious and conservative, engineers and planners often justify policies favoring generous road and parking supply although such decisions increase facility costs, stimulate vehicle travel, and increase sprawl, which in turn increase resource consumption, consumer costs, accidents, and environmental risks, which is actually the opposite of being cautious and conservative.

Many decision makers are unaware of the full costs of excessive road and parking supply, or of cost-effective alternative strategies that can meet transportation demands in ways that require far less land for transportation facilities.

Strategies to Reduce Road and Parking Requirements

Various strategies can reduce the amount of land that must be paved for transportation facilities. Some help reduce per-capita vehicle ownership and use, and therefore demand for roads and parking facilities. Others result in more efficient use of these facilities, for example, by sharing parking facilities rather than every building meeting all of its parking demands on site (Litman, 2006b). Many of these strategies provide multiple benefits, such as reducing traffic problems or construction costs. Examples are described in the following sections.

Mobility Management

Mobility management (also called *transportation demand management*, or TDM) refers to various policies and programs that encourage people to change their travel behavior in ways that increase transport system efficiency. This includes improvements to alternative modes (walking, cycling, public transit, etc.), more efficient pricing (road tolls, parking pricing, distance-based vehicle insurance and registration fees, and higher fuel taxes), programs that encourage the use of alternative modes (for example, by employers or schools), and smart growth land-use policies that reduce the distance that people must travel to access services and activities).

Efficient Road Pricing

Charging users directly for using roads, with higher fees under peak conditions, encourages more efficient travel, which reduces the need to expand highways. Efficient road pricing typically reduces peak traffic by 10%–30%, and more if part of a comprehensive mobility management program (ICF International, 1997). Older pricing methods have high transaction costs, including inconvenience to motorists, high labor costs, and additional delay and fuel use as vehicles stop at toll booths, but newer, electronic pricing methods are more convenient, accurate, flexible, and cost effective.

Streetscaping

Streetscaping refers to roadway design intended to create safer, more multimodal and attractive roadways. It typically includes traffic calming and road diets, which reduce lane widths and the number of traffic lanes (Burden and Lagerway, 1999); bus and bike lanes where appropriate; wider sidewalks; and improved crosswalks, landscaping, and other amenities to improve pedestrian conditions.

Efficient Parking Management

In most areas there is little effort to manage parking facilities efficiently. A number of specific parking management strategies can significantly reduce the number of parking spaces needed in a particular area, which allows pavement area to be reduced. Specific parking management strategies are described in the following sections.

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

Efficient parking and pricing

Cost-recovery parking pricing (fees set to pay for parking facilities) typically reduces parking demand 10%–30% ("parking evaluation"; VTPI, 2007). *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 pay for only the amount of parking they actually need) can have similar impacts as pricing. Newer parking pricing methods are more convenient, accurate, flexible, and cost effective, and so allow efficient parking pricing to be applied in more situations.

Shared parking

There are often opportunities to share parking among various destinations, for example, if a parking lot is used by an office building during the day, and by a restaurant or theater during evenings and weekends. This requires agreements between building managers to allow such sharing, as well as improved walking conditions, and appropriate user information to direct motorists to the parking spaces available for their use. On-street parking tends to be particularly efficient at serving multiple destinations, so efficient management of such spaces, with appropriate regulations and pricing, can reduce the total number of spaces required in an area.

Overflow parking 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 reduces land required per space compared with surface parking. A four-story parking structure uses only about a quarter as much land per space as does a surface parking lot, and underground parking requires almost no additional land. Although more costly to build (typically $10,000–$30,000 more per space), this saves land costs and 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.

Some communities maximize the number of on-street parking spaces by using a curb lane for parking rather than for traffic during off-peak periods. Still others reduce parking space size. Commuter and residential parking spaces can be somewhat smaller than shorter-term uses that 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.

Another technique is to 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. Similarly, car stackers and mechan-

Figure 3. Carstackers in a dense urban environment.

ical garages, as illustrated in Figure 3, can increase parking density.

Parking tax reform

Parking tax reform includes various tax policies that encourage property owners to reduce parking supply, and can help finance transportation and parking management programs (Litman, 2006c; Project Clean Water, 2002). Per-space levies are special taxes imposed on parking facilities, such as a $30 annual tax on each nonresidential parking space. If applied specifically to employee parking, it is called a *workplace parking levy*. A *storm-water management fee* is a utility fee based on impervious surface area to fund storm-water management services, such as a $15 annual fee per 1,000 ft^2 of pavement or a $5 annual fee per parking space (Minneapolis, 2005).

Encourage Shared Right-of-Way

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 plans that 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 (Childs, 1999; Mukhija and Shoup, 2006; Toronto City Planning, 2007). Among the most notable techniques are on-site storm-water storage and percolation, with natural wetlands for filtering. Designs can also maximize green space, particularly shade trees along roadways and in parking lots. Similarly, designs can emphasize covering parking lots with awnings, which are perfect for solar panels. To reduce solar gain, lighter materials, such as concrete rather than asphalt, can be used for parking facilities, and permeable pavement and pervious cement can be used to reduce surface runoff (Booth and Leavitt, 1999). *Hollywood driveways*, which are two strips of pavement instead of a full lane, can reduced paved area by about half.

Smart Growth

Smart growth (also called *new urbanism* and *location-efficient development*) is a general term for policies and planning practices that create more compact, mixed-use, multimodal communities, resulting in more efficient land-use development (Center for Neighborhood Technology, 2006). Smart growth is an alternative to urban sprawl.

Smart growth can substantially reduce impervious surface area per capita (although it may increase impervious surface per acre) by reducing building footprints and by reducing vehicle ownership and use and therefore road and parking requirements (Litman, 2005). Smart-growth policy reforms can provide many benefits, including infrastructure cost savings, improved housing affordability, reduced transportation problems, increased livability, and economic development (Smart Growth Network, 2002, 2004).

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. A variety of public policies and programs can help encourage this, including targeted cleanup, favorable tax policies, and public support of redevelopment projects in blighted areas.

Conclusions

Many current polices and planning practices, such as dedicated roadway funding, generous minimum parking requirements, and unpriced facilities, result in economically excessive road and parking supply; that is, more land devoted to roads and parking facilities than consumers would choose if they had better options and efficient pricing. This increases various economic, social, and environmental costs.

More efficient transport and parking management can reduce the amount of land that must be paved for roads and parking, providing a variety of benefits.

These strategies are most effective when implemented as an integrated program. Per-capita impervious surface can often be reduced 20%–40% by applying cost-effective transport and parking management strategies, such as sharing parking facilities, efficient road and parking pricing, and improvements to alternative modes. Even larger reductions can often be achieved with smart growth land-use policies that result in more compact development.

These strategies are often cost effective when all benefits are considered, including reductions in traffic congestion, consumer costs, accidents, and pollution emissions. Despite their overall value to society, they can be difficult to implement because they require changing established practices and organizational structures. It is important to build institutional support for such reforms. Proponents should highlight the total economic, social, and environmental benefits that can result from more diverse transport systems, more compact communities, and more efficient use of valuable resources such as clean energy, clean water, and clean land.

Note

1. According to the Federal Highway Administration (2005, Table HM-20), 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.

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