

4. Effects of Different Development Types on the Environment

Problems with air quality, water quality, and biodiversity are serious enough that Congress has passed national legislation setting timetables for improvement. The best known of these timetables is the Clean Air Act, which sets deadlines for states to clean their air to levels that protect vulnerable populations.

In order to establish a framework for future actions, EPA recently developed a strategic plan that identifies the agency’s goals for implementing its mission “to protect human health and to safeguard the natural environment.” Five strategic goals with strong connections to aspects of the built environment are listed in Table 4-1, along with a description of how urban form affects the attainment of each goal.¹⁰³

Table 4-1: EPA Strategic Goals with Built Environment Linkages

| Health or Environmental Goal | Is attainment of these goals affected by current land-use trends and increased VMT? |
|---|---|
| 1. Clean Air | Yes, from tailpipe and evaporative emissions |
| 2. Clean and Safe Waters | Yes, from road and pavement runoff, and from deposition of airborne emissions |
| 3. Preventing Pollution and Reducing Risk in Communities, Homes, Workplaces, and Ecosystems | Yes, from habitat and ecosystem fragmentation and destruction |
| 4. Better Waste Management, Restoration of Contaminated Waste Sites, and Emergency Response | Yes, to the extent that communities abandon or fail to redevelop brownfields |
| 5. Reduction of Global and Cross-Border Environmental Risks | Yes, from greenhouse gas emissions from motor vehicles |

Although land use and transportation development affect EPA’s environmental goals, historically national efforts have relied principally on tailpipe or smokestack solutions. As Congress passed legislation to address environmental and human health threats, EPA responded with regulations aimed largely at controlling the most obvious risks, such as pollution from large industries. Although the logic and efficiency of managing risks in this manner are well recognized, it has become increasingly clear that there are limitations to this approach and that these strategies alone will not achieve our national goals. In particular, changes in the built environment threaten various environmental goals and may require new approaches.

Not all development affects the environment in the same ways. As communities examine how to grow, they are looking for strategies that will protect the environment while accommodating new growth. This section examines how various types of development patterns and practices affect the environment.

¹⁰³ EPA’s strategic plan was completed in September 1997 and addresses the Government Performance and Results Act’s direction for each executive department and agency to develop a strategic plan that outlines the goals that will provide the framework for planning and resource allocation. EPA’s strategic plan includes 10 goals. The other five are: 6) Safe Food; 7) Expansion of Americans’ Right to Know about their Environment; 8) Sound Science, Improved Understanding of Environment Risk, and Greater Innovation to Address Environmental Problems; 9) A Credible Deterrent to Pollution and Greater Compliance with the Law; and 10) Effective Management.

Although the evidence is ample that different types of development patterns can affect the environment in different ways, the understanding of these effects is not yet complete. The direct effects in terms of habitat consumption and disruption are well documented and widely accepted. By contrast, the effects of highway investment on vehicle travel and the effects of specific development patterns on travel and emissions are somewhat less well understood, and the exact magnitude of these effects is subject to some debate. This section of *Our Built and Natural Environments* synthesizes findings from several researchers, noting where greater or less certainty exists about linkages between causes and effects and the relative magnitude of effects. Where previous sections described broad land use and transportation trends and impacts, this section focuses on impacts of current development versus more environmentally sensitive development.

Certain characteristics of the built environment are associated with beneficial environmental results. This chapter discusses six of these features:

- 1) Compact development
- 2) Reduced impervious surfaces and improved water detention
- 3) Safeguarding of environmentally sensitive areas
- 4) Mixed land uses
- 5) Transit accessibility
- 6) Support for pedestrian and bicycle activity and other micro-scale urban design factors

These elements are not entirely separable from each other. For example, encouraging compactness through infill or brownfields redevelopment often facilitates mixed-use development and provides support for transit use, and walking and cycling. Safeguarding environmentally sensitive areas often involves developing more compact or clustered development. In similar ways, other elements listed above may work most effectively in combination with each other rather than individually.

Incorporating one beneficial element without others could have minimal effects or possibly prove detrimental to environmental goals. For example, increasing density without taking care to safeguard environmentally sensitive areas or to improve transit access could result in increased water quality impacts, traffic congestion, or air quality problems. The enhanced benefit of incorporating multiple aspects of design into communities is often referred to as “synergy.” Synergy is discussed in Section 4.7.

Because most practices work synergistically with one another isolating the effects of one from another can be difficult. In general, the studies presented in the first six sections of this chapter were chosen because they attempt to isolate the effects of particular strategies. However, studying one technique in isolation is often nearly impossible, and the utility of doing so is somewhat limited, as most practices are used in combination with others. Nonetheless, although findings may differ on the magnitude of the effects of different practices, the evidence is overwhelming that some developments yield better environmental results than others.¹⁰⁴

¹⁰⁴ For evidence of consensus on the view that some development practices yield better environmental results than others, see Burchell, Robert W. et al. *The Costs of Sprawl – Revisited*. Transit Cooperative Research Program (TCRP) Report 39. Washington, DC: National Academy Press, Transportation Research Board, 1998. Burchell *et al* provide a synthesis and critical assessment of the literature on sprawl.

4.1 COMPACT DEVELOPMENT

Compact metropolitan development generally means that the space needs of a population can be satisfied with less land area. Compact development can take various forms. From a regional perspective, metropolitan areas may limit the extent of development so that it does not extend too far into rural areas. New development can be targeted to specific areas, such as redevelopable areas within established communities.

Types of Compact Development

Communities can develop more compactly by using three techniques:

- Infill development
- Brownfields redevelopment
- Cluster development

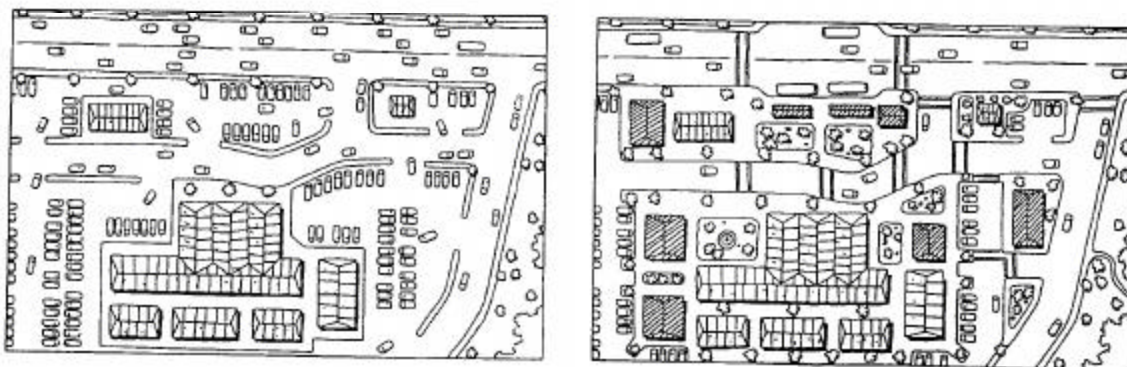
INFILL DEVELOPMENT

Infill development occurs in locations where some development has already taken place and infrastructure is already in place. In urban areas, infill development is typically executed by converting old buildings and facilities into new uses (redevelopment) or by filling undeveloped space within these areas. Figure 4-1 shows an example of infill development in an urban area, where parking lots are replaced by buildings, parks, and/or garages.

Compact Development in Practice

Some metropolitan areas have decided to preserve the scenic open space that attracted their residents in the first place, as a means of preserving the continuing desirability of their communities. A number of communities have chosen to target development and place limits on the geographic extent of regional development. In particular, Portland, Oregon, chose to implement an urban growth boundary as a means of preserving open space. Montgomery County, Maryland, established an agricultural reserve in the western half of the county. Other areas have elected to preserve greenway corridors, establish state or city parks, and purchase easements on land as ways of preserving open space. Portland plans to accommodate all market-demanded housing types within its urban growth boundary, which is periodically adjusted to ensure a 20-year supply of developable land.

Figure 4-1: Infill Development in an Urban Area



Infill development is a way to accommodate regional growth using relatively less suburban and rural greenspace. The potential for infill is considerable. In 1994, researchers at the University of California at Berkeley's Institute of Urban and Regional Development surveyed planning directors in 1,200 political jurisdictions nationally and concluded that "existing urban areas have substantial capacity for new residential development." This conclusion was reached based on a conservative estimate: The survey asked only about currently undeveloped land, not about underutilized properties that are important land resources in most older urban areas.¹⁰⁵

BROWNFIELDS REDEVELOPMENT

As a particular kind of underdeveloped land, brownfields have received significant attention as both a problem and a potential source of multiple urban benefits. Brownfields are "abandoned, idled, or underused industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental consequences."¹⁰⁶ Brownfields redevelopment has potentially strong repercussions for environmental quality and community life since undeveloped brownfield sites may be a health threat or a discouragement to further investment in established urban areas.

The General Accounting Office estimates that the nation has between 13,000 and 450,000 brownfields.¹⁰⁷ Brownfields, like infill sites, have the potential to absorb significant amounts of development. A 1982 study of three urban areas found that vacant land within developed areas could accommodate from two-thirds to 100 percent of the projected 10-year housing need.¹⁰⁸ That capacity has apparently not diminished significantly in the past 15 years. A 1996 study found that brownfields in Detroit, Chicago, Milwaukee, and Cleveland could absorb 1 to 5 years of residential development, 10 to 20 years of industrial development, or 200 to 400 years of office space.¹⁰⁹ These estimates are conservative because, due to cost constraints, only a subset of existing known brownfields was examined. Significant amounts of vacant land in each of these metropolitan areas have not been inventoried.

Brownfield sites are different from other urban infill sites because of uncertainties about environmental liability and clean-up costs. Site owners, developers, and lenders often avoid investing in brownfields because of fear of contamination and the costs associated with it. Clean-up costs of brownfields vary widely depending on site size, the intensity and type of contamination, and the nature of the remediation required. Rather than developing brownfields, firms and investors instead turn to surrounding areas and undeveloped greenfields or relatively untouched and uncontaminated land.¹¹⁰

¹⁰⁵ Pendall, Rolf. "Land Availability and Zoning: Indications from a National Survey." *On the Ground*. Fall, 1994. pp. 19-20.

¹⁰⁶ U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. *Brownfields Initiative*. (Quick Reference Fact Sheet) April, 1996.

¹⁰⁷ U.S. General Accounting Office. *Community Development: Reuse of Urban Industrial Sites*. (GAO/RCED-95-172) Washington, DC: US Government Printing Office, June 1995.

¹⁰⁸ Real Estate Research Corporation. *Infill Development Strategies*. Washington, D.C.: ULI-the Urban Land Institute and American Planning Association, 1982.

¹⁰⁹ Simons, Robert, Planning and Development, Cleveland State University. *Brownfields Supply and Demand Analysis for Selected Great Lakes Cities*. Prepared for EPA, 1996.

¹¹⁰ "What is a Brownfield?" <http://www.brownfield.org/#Brownfield>.

Local government officials frequently cite brownfields as one of their biggest environmental problems.¹¹¹ Based on a national survey of communities, the U.S. Conference of Mayors reports that “brownfields are a major problem for cities large and small and the lack of funds to clean up these sites was the most frequently identified obstacle in recycling these lands.”¹¹² Consequently, local, state, and federal agencies are targeting attention and resources to brownfields.

Redevelopment also can help assure that no stigma (of either perceived or real contamination) impedes investment in the community. As a result, clean-up and redevelopment of brownfield sites may encourage additional redevelopment in surrounding areas.

Despite the numerous barriers associated with brownfield redevelopment, productive reuse is becoming increasingly feasible and common.

CLUSTER DEVELOPMENT

In newly developed areas, clustering development into concentrated areas can protect natural habitat. Cluster developments are built at gross densities comparable to conventional developments but leave more open space by reducing lot sizes.¹¹³ Square footage of buildings and residential and commercial capacity may remain the same, but compact clusters reduce the dimensions and geometry of individual lots and shorten road lengths, as shown in Figure 4-2. In the large-lot development, private lots take up the entire area of the subdivision, while in the compact development, private lots take up only a portion of the total land area, allowing more than half the land area to remain in its natural state.

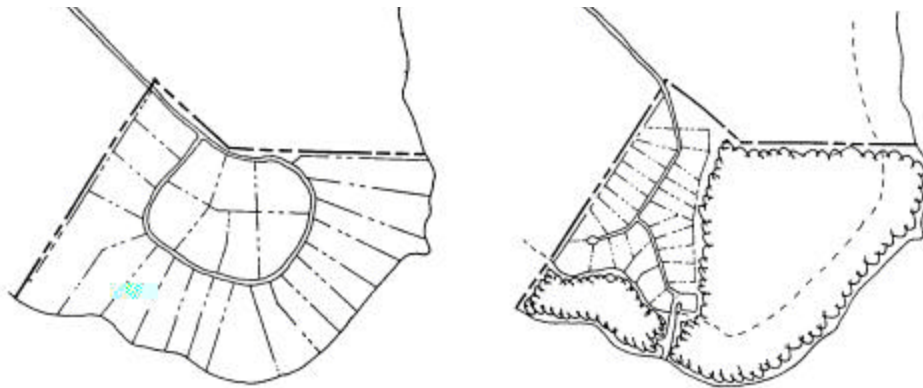
Clustering has a number of advantages in addition to the environmental benefits discussed below. One of the main advantages of cluster development as a conservation tool is that it does not take development potential away from developers, since it changes the arrangement but not the number of units permitted on a property. It also can reduce costs for developers—by requiring fewer miles of roads and, if applicable, water and sewer lines. Furthermore, cluster development does not require large public expenditures to purchase development rights.

¹¹¹ Snyder, Robin, EZ/EC EPA Programmatic Contact – Personal communication, 1997

¹¹² U.S. Conference of Mayors. “Recycling America’s Land: A National Report on Brownfields Redevelopment, Volume II.” April 1999.

¹¹³ Measures of density depend on the geographic area being examined. Perceptions of density are influenced by many factors, including the design of buildings, site layout, and mix of buildings and green space. Cluster developments are not necessarily perceived as denser than “large lot” developments, especially since they often contain larger tracts of continuous green space.

Figure 4-2: Large-Lot Development Versus Compact Development



Direct Environmental Effects of Compact Development

Compact development has some clear effects on the environment that are a direct result of reduced use of land and the nature of development or redevelopment:

- Reduced disruption and fragmentation of habitat
- Reduced impervious surfaces, resulting in improved water quality
- Clean-up of contaminated waste through brownfield redevelopment, which can reduce water pollution and community environmental risks

REDUCED DISRUPTION AND FRAGMENTATION OF HABITAT

Compact development minimizes land conversion to urban use, and maximizes retained natural habitat. Infill development of all kinds, including brownfields redevelopment, reduces development in more pristine areas since an acre built in town is often at least an acre less that is developed on a greenfield. In addition, the acre developed in an existing urban area usually requires less supporting space, especially roads and parking lots, because it can take advantage of urban transit and existing streets and parking facilities. When existing infrastructure is renovated, infill development can spare natural resources such as the wood and metal that would be needed for the construction of new facilities.

Several studies document losses of fragile lands due to development. Numerous growth management plans also have evaluated how alternative development patterns would affect fragile lands. For example, a study comparing managed growth to a continuation of past trends in Orlando, Florida, projected that managed growth would result in a loss of 20 percent fewer acres of wetlands and floodplains.¹¹⁴ Studies of alternative development patterns have found that infill and compact

¹¹⁴ Orlando, Florida. *Urban Area Growth Management Plan*. 1991.

development maximize bird species abundance and diversity compared with a lower-density development of the same number of units spread over the same area.¹¹⁵

Several analyses of development impacts on fragile lands have been conducted by Burchell *et al.* for New Jersey; Lexington, Kentucky; the Delaware Estuary; and Michigan.¹¹⁶ These studies generally find that planned versus trend development would reduce consumption of fragile environmental lands by almost one-fifth. The range of savings varied from 12 to 27 percent, depending on the starting level and location. Similar studies conducted in the San Francisco Bay area by Landis found even larger land savings under a compact growth scenario.¹¹⁷

Large-tract, low-density development is usually characterized by plantings of lawns, flowers, shrubs and trees, some of which may offer habitat for certain songbirds and other human-tolerant creatures. But the diversity of native species can be reduced significantly. Large tracts of continuous development associated with cluster development allow preservation of more natural wildlife habitats, less affected by human disturbance.

Compact development allows preservation of open space, including wetlands, farmland, and forests. Maintaining the integrity of wetlands is beneficial to water quality in many ways. (See Chapter 2.) Open space—farmlands and forests—all contribute to the economic, recreational, and ecological value of a community.

REDUCED IMPERVIOUS SURFACES

Infill development accommodates new growth with significantly less impervious surfaces per unit of development than development on undeveloped land does. As shown earlier in Figure 4-1, infill development may result in minimal changes in impervious surfaces by redeveloping parking lots or sites with abandoned buildings into new buildings. The infill site has roughly the same amount of impervious surface area (since parking lots or old rooftops are now new rooftops or other structures) before and after development and little net loss of vegetative cover occurs. Since locating the buildings on undeveloped land would result in new impervious surface cover (i.e. new roads and parking facilities), development at the infill site—that uses existing infrastructure—reduces overall impervious cover. Particularly in comparison to the alternative of building on a greenfield site—undeveloped land at the urban periphery—infill development can reduce impervious surfaces by decreasing the need for new roads and parking lots. Infill also can promote mixed-use development and help support transit usage, discussed below in Sections 4.4 and 4.5.

¹¹⁵ Landis and Pendall, pp. 14-15. Also see: Johnston, Robert and Tomas de la Barra. *Comprehensive Regional Modeling for Long-Range Planning: Linking Integrated Urban Models to Geographic Information Systems*. Resubmitted to *Transportation Research: A*, 1998.

¹¹⁶ Burchell, Robert and David Listokin. *Fiscal Studies*. Report to the Governor's Commission on Growth in the Chesapeake Bay Region. Annapolis, MD: 2020 Commission, 1990; Burchell, Robert *et al.* *Impact Assessment of the New Jersey Interim State Development and Redevelopment Plan*. Trenton, NJ: New Jersey Office of State Planning. 1992.; Burchell, Robert and David Listokin. *The Economic Impacts of Trend versus Vision Growth in the Lexington (Kentucky) Metropolitan Area*. Report prepared for Bluegrass Tomorrow, Lexington, KY: January 1995; Bruchell, Robert and Harvey Moskowitz. *Impact Assessment of DELEP CCMP versus Status Quo on Twelve Municipalities in the DELEP Region*. Report prepared for the Local Governments Committee of the Delaware Estuary Program. Philadelphia, PA: August 1995; Burchell, Robert *et al.* *Fiscal Impacts of Alternative Land Development Patterns in Michigan: The Costs of Current Development Versus Compact Growth*. Southeast Michigan Regional Council of Governments. 1997.

¹¹⁷ Landis, John. "Improving Land Use Futures: Applying the California Urban Futures Model." *Journal of the American Planning Association*. 61, 4 (Autumn), 1995. pp. 438-457.

By reducing the need for impervious surfaces, compact development significantly reduces runoff and water pollution. The Center for Urban Policy Research's New Jersey Impact Assessment concluded that the state's compact development plan would produce 40 percent less water pollution than more dispersed development patterns would. The smaller impervious areas would produce 30 percent less runoff, and concentrating this development in areas served by sewers would reduce its impact on the environment by another 10 percent.¹¹⁸

In the Chesapeake Bay watershed, a study compared compact and dispersed developments on tracts of land of the same size. Compact development consumed one-third as much land as a dispersed development consumed and included about half as much impervious surface. As a result, the compact development pattern resulted in 43 percent less runoff than the more dispersed development.¹¹⁹

Studies show that the impervious surface area of a clustered development site is often 10 to 15 percent less than that of more dispersed development, depending on the size and configuration of each individual project and the original lot size and road network. The greatest reduction in impervious surface area is found when cluster development is applied on large lots. Reductions in impervious surface area are primarily due to the shorter length of road network needed to serve lots.¹²⁰ With impervious surfaces, the transportation component—roads, sidewalks, and parking lots—usually constitutes a larger share of impervious cover than rooftops do, both in residential and commercial areas.¹²¹

Although individual lots in low-density developments are generally more permeable (e.g., lawns, gardens) than higher density developments, the greater total amount of land affected by low-density development (its "footprint"), plus the greater amount of land devoted to roads and parking lots, often results in greater water quality impacts.¹²² In addition, low-density residential developments that are served by septic systems, rather than by sewers, can cause nitrogen and pathogen contamination of groundwater and surface waters if they are not properly sited, designed, installed, and maintained.¹²³

In addition, less stormwater runoff and pollutant loads are found in cluster developments, due to reductions of impervious cover. By clustering development, 30 to 80 percent of the entire site may be left undisturbed, without reducing the number of lots on a site.¹²⁴ Cluster zoning seems to be an effective method of preserving a site's existing landscape character, forested areas, aquatic and terrestrial habitat, and watershed resources, and protecting these sensitive areas from the secondary impacts typically associated with new development.

¹¹⁸ CUPR, and Landis and Pendall. The Real Estate Research Corporation in its 1974 report *The Cost of Sprawl* also found less runoff from compact communities.

¹¹⁹ Chesapeake Bay Foundation. *A Better Way to Grow*. 1996. p.7.

¹²⁰ Schueler, Tom. Environmental Land Planning Series: Site Planning for Urban Stream Protection. Center for Watershed Protection. Publication No. 95708. Washington, DC: Metropolitan Washington Council of Governments, Dec. 1995. p. 61.

¹²¹ Schueler, Tom. Environmental Land Planning Series: Site Planning for Urban Stream Protection. p. 19

¹²² Arnold, Chester L. Jr., C. James Gibbons. "Impervious Surface Coverage - The Emergence of a Key Environmental Indicator." *Journal of the American Planning Association*. Volume 62, Number 2, Spring 1996. pp. 243-258.

¹²³ U.S. Environmental Protection Agency. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*. Chapter 4, Section VII: Onsite Sewage Disposal Systems. 1991.

¹²⁴ Schueler, Tom. *Environmental Land Planning Series: Site Planning for Urban Stream Protection*. pp. 63-4.

Conventional urban fringe and suburban development—with large lot sizes, wide streets, and substantial parking—can produce storm runoff almost 50 percent greater than more compact development.¹²⁵ Watersheds containing less than 10 percent impervious surface maintain healthy streams, thus providing habitat for sensitive species. At more than 10 percent imperviousness, most watersheds show signs of impairment, and watersheds with more than 30 percent imperviousness are seriously degraded.¹²⁶

A case study of Remlick Hall Farm, a planned subdivision outside Washington, DC, illustrates the importance of development patterns for the watershed.¹²⁷ The conventional plan contains a total of 84 residential lots spread out fairly evenly over the site. Assuming a 20-foot road width, approximately 20,250 linear feet of roadway are required to serve the development pattern. Road and driveways alone, under this scenario, comprise about 10.8 acres of new impervious surface area. Including rooftops and other hard surfaces, the total impervious surface cover reaches 26.3 acres. It should be noted that this estimate is quite conservative, considering that conventional road width for suburban developments is actually approximately 32 feet, with 50 feet not uncommon in many new suburban developments.

In contrast, an alternative clustered subdivision plan clusters 52 individual residential sites to preserve farmland, shoreline areas, and forests. Roads are narrowed from 20 to 18 feet in width, while a 53 percent reduction in road length is achieved under the cluster plan. Total impervious surface cover comes to 15.37 acres. Reductions in road infrastructure lead to an estimated \$525,000 savings in development costs, as well as major savings in polluted stormwater runoff. Runoff in the conventional subdivision was estimated at 79 acre feet per year, while for the cluster development estimated runoff amounted to only 46 acre feet per year.

CLEAN-UP OF CONTAMINATION THROUGH BROWNFIELDS REDEVELOPMENT

Past industrial activity bequeathed a legacy of soil and water pollution at formerly industrialized sites. Thousands of these brownfields are located in densely populated, urban areas where residents tend to congregate and children play. Many of these sites are located near rivers and streams, which once served as valuable transportation corridors. The juxtaposition of toxic chemicals, human activity, and sensitive environmental habitats can lead to a range of problems, including compromised human and environmental health.

Even in areas where individual properties are not highly contaminated, the collective effect of a number of mildly contaminated properties in one area can be significant. The clean-up and redevelopment of these sites can lead to substantial environmental and human health benefits. The benefits of brownfields clean-up are dependent on several factors, including the type and severity of contamination; the geographic distribution of the contamination and its proximity to communities, water resources, and biologically sensitive areas; and the clean-up standard employed.

Potential public health benefits of brownfields clean-up include reduced blood lead levels, decreased risk of cancer, and minimized respiratory problems. The encapsulation (“capping”) of contamination on brownfields can reduce runoff of toxics into nearby bodies of water. This reduced runoff can lead to improvements in overall water quality and, consequently, improvements in habitat.

¹²⁵ Schueler, Tom. *Site Planning for Urban Stream Protection*. Center for Watershed Protection, Silver Spring, Maryland: 1995.

¹²⁶ Arnold, Chester L. Jr., C. James Gibbons. “Impervious Surface Coverage - The Emergence of a Key Environmental Indicator.” *Journal of the American Planning Association*. Volume 62, Number 2, Spring 1996. p. 246.

¹²⁷ Chesapeake Bay Foundation. *A Better Way to Grow*. 1996. pp. 28-31.

Brownfields redevelopment also benefits the environment; removing toxics from the site can result in cleaner soil and improved water quality. In addition, many brownfields are located in urban areas that are already served by existing sewer lines, roads, and other infrastructure. Redeveloping these properties can consequently minimize greenfield development.

Indirect Environmental Effects of Compact Development: Reduced VMT and Emissions

In addition to direct effects on habitat, water quality, and brownfields, compactness in a metropolitan area also affects travel activity. Increased compactness is viewed as a means to reduce vehicle travel because it affects travel demand in the following ways:

- *Trip lengths* – Compactness increases the number of activities accessible within a given area. By locating activities closer together, compact development can reduce travel distances.
- *Mode choice* – Locating activities closer together allows trips to be made by walking and bicycling rather than motor vehicle. In addition, density provides the “mass” needed for mass transit and carpooling. Compactness reduces the costs of providing transit services since shorter trips and trip times allow transit operators to provide the same frequency of service with fewer vehicles and fewer driver hours.¹²⁸ As a result, dense areas tend to have greater access to transit, which reduces the relative costs of using transit, and creates greater opportunities for shared rides during commuting.
- *Vehicle ownership* – Dense areas reduce the need for vehicle travel for personal mobility, so people are less likely to own as many vehicles. Dense areas also tend to be associated with limited parking availability and higher cost, as well as increased transit accessibility, all of which are associated with reduced vehicle ownership.

Efficient Use of Infrastructure

Existing public infrastructure often is inadequate for serving new low-density development. Frequently, jurisdictions or developers are forced to build new infrastructure, even while existing capacity is underutilized. For example, in metropolitan Minneapolis-St. Paul, school enrollment fell by 81,000 between 1970 and 1990 as the growth in the baby boom population ended. Approximately 130 schools were closed in the central city and immediate suburbs, yet 50 new schools were opened on the metropolitan fringe.¹²⁸ Some school closings were probably justified in terms of physical obsolescence. However, many schools were still adequate, meaning that the investment in suburban schools was inefficient.

One advantage of compact development is that it makes more efficient use of infrastructure. Development on infill sites can usually tap into existing infrastructure, including roads, water lines, sewer systems, and schools. Even when new infrastructure is necessary, compact development is still less costly because the community can be adequately served by fewer schools, fewer miles of roads, and fewer new water pipes than a low-density community might require.

EVIDENCE FROM SIMULATION MODELS

Several regional models of development patterns and transportation investments find that more compact development results in less vehicle travel and fewer emissions of air pollutants than

¹²⁸ Parsons Brinckerhoff Quade and Douglass, Inc. *Transit and Urban Form*. “Part I: Transit, Urban Form, and the Built Environment: A Summary of Knowledge.” Transit Cooperative Research Program Report 16. Washington, DC: Transportation Research Board, 1996.

dispersed development patterns do.¹²⁹ It should be noted that simulation models typically have a margin of error of 5-10 percent and that their results may not be exact in terms of the magnitude of VMT reductions. Taken together, however, these models clearly indicate that compact development does have an effect on VMT, even if consensus on the magnitude of that effect has not been reached.¹³⁰

An analysis of changing allocations of new employment and residential growth over the period 1990 to 2020 in the Puget Sound, Washington, region found that patterns of compact development reduced VMT compared with more dispersed patterns. The regional metropolitan planning organization (MPO) examined three alternative land-use patterns. In the “Major Centers” alternative, new employment growth was concentrated in a few major centers, higher density residential development within walking distance of major transit access points was encouraged, and transit investments were emphasized. The “Multiple Centers” alternative concentrated new employment and housing growth in a relatively large number of centers, with a balance of jobs and housing within each center’s area of influence, with high transit emphasis. Finally, the “Dispersed Growth” alternative dispersed employment and housing growth into newly developing areas. The modeling suggested that the Major Centers alternative would reduce VMT by 4 percent from the baseline, and the Multiple Centers alternative would reduce VMT by 1 percent from the baseline. The Dispersed alternative meanwhile was projected to increase VMT 3 percent above the baseline level.¹³¹

The estimate from the Puget Sound model may understate the benefits of planning that increases regional concentrations of development. Travel impacts were estimated using traditional four-step Urban Transportation Planning System-based models. These traditional models are not sensitive to land use characteristics when predicting vehicle ownership, mode choice, or trip frequency. In addition, these models do not account for non-motorized trips and so fail to account for trips that may be diverted to walking and bicycling in dense urban areas.

The Region 2040 process in Portland, Oregon, employed more sophisticated travel demand models that included sensitivity to land uses. Portland used the models to examine land-use scenarios. In the base case, the urban area expanded by more than half its current size. In the Growing Up alternative, urban growth was maintained inside the current urban growth boundary. The simulations suggest that

¹²⁹ Four regional simulation studies sponsored by the Federal Highway Administration are profiled in: DeCorla-Souza, Patrick. *The Impacts of Alternative Urban Development Patterns on Highway System Performance*. Presentation to ITE Conference on Transportation Engineering in a New Era. 1992. Although these models predict the future, they are based on the observed behavior of people reacting to real choices. Other simulations that demonstrate a relationship between the compactness of development and travel behavior include: Rodier, Caroline A. and Robert A. Johnston. “Travel, Emissions and Welfare Effects of Travel Demand Management Measures.” *Transportation Research*. Record 1598. 1997; Johnston, R.A., and R. Ceerla. “Land Use and Transportation Alternatives,” in D. Sperling and S. Shaheen (eds.), *Transportation and Energy*, ICEEE, 1995.

¹³⁰ Some researchers have suggested that vehicle hours traveled (VHT) have greater impact on air quality than vehicle miles traveled (VMT) do—a view implying that investments that ease congestion and increase vehicle speed may be more effective in reducing pollution than policies that aim to change land use patterns. Even if the relationship between VHT and air quality is a strong one, research on the relationship between development patterns, vehicle travel, and air quality indicates a direct relationship between VMT and air quality, suggesting that reductions in VMT will lead to improved air quality. In any case, reductions in VMT from additional capacity are likely to be short-term as induced demand returns congestion to its original levels. See Chapter 3.

¹³¹ The Multiple Centers alternative was expected to reduce delay and congestion more than any of the other alternatives, presumably because reduced VMT would more than offset potential increases in local congestion around the activity centers.

the Growing Up scenario would double the regional transit mode split to 6 percent from 3 percent in the base case and would reduce regional VMT by 16.7 percent compared with the base scenario.¹³²

REGIONAL LOCATION OF DEVELOPMENT

Recent research indicates that location of development within a metropolitan region is a significant factor in determining the vehicle travel and emissions generated by the development. One recent simulation study compared alternative locations for a proposed development located in the San Diego, CA; Montgomery County, MD; and West Palm Beach, FL, metropolitan areas.¹³³ Using four-step transportation models and a geographic information system-based analysis tool, the travel and emissions impacts of location in a central infill site in each case versus location at the regional periphery (a greenfield site) were compared.

Four-step transportation models use regional data, including data on local and regional transportation patterns, transportation behavior of residents, and roadway and transit networks, to estimate the number of trips by purpose, mode, and travel times. The first step, trip generation, estimates the total number of trips produced by households and total trips attracted by employment centers, recreational facilities, etc. In the second step, trip distribution, the model allocates trips generated in the first step to specific origin-destination movements. The third step, mode split, determines the share of trips made by mode of travel (driving, transit, walking, etc.). Traffic assignment, the final step, estimates traffic volumes by mode for each link in the transportation system.

In each of the cases modeled, the infill site generated less VMT per capita and reduced emissions of most air pollutants and greenhouse gases, as shown in Table 4-2.

Table 4-2: Travel and Emission Indicators for Infill Site versus Greenfield Site

| Case Study | Per capita daily VMT, infill as percentage of greenfield | Emissions, infill as percentage of greenfield |
|-----------------------|--|--|
| San Diego, CA | 52% | CO: 88% NO _x : 58% SO _x : 51% PM: 58% CO ₂ : 55% |
| Montgomery County, MD | 42% | CO: 52% NO _x : 69% SO _x : 110% PM: 50% CO ₂ : 54% |
| West Palm Beach, FL | 39% | CO: 75% NO _x : 72% SO _x : 94% PM: 47% CO ₂ : 50% |

Source: Allen, E, Anderson, G, and Schroeer, W, "The Impacts of Infill vs. Greenfield Development: A Comparative Case Study Analysis," U.S. Environmental Protection Agency, Office of Policy, EPA publication #231-R-99-005, September 2, 1999.

¹³² Metro. *Metro 2040 Growth Concept*. Portland, OR: December 8, 1994.

¹³³ Allen, E, Anderson, G, and Schroeer, W, "The Impacts of Infill vs. Greenfield Development: A Comparative Case Study Analysis," U.S. Environmental Protection Agency, Office of Policy, EPA publication #231-R-99-005, September 2, 1999.

The sources of the projected emissions reductions differed among the sites. In West Palm Beach, the estimated travel reduction was projected to come from reductions in average trip length, with minimal changes in mode share, due to the relative auto-dependence of the region. In contrast, in Montgomery County, outside Washington, DC, more significant changes in mode share were projected to occur. In this case, the infill site was located near a major transit center, well-served by buses and heavy rail. Although projected road congestion results varied across the case studies, in general the shorter trip distances made up for slower in-town travel speeds and total vehicle trip times were lower for the infill sites.

Despite some potential increases in localized congestion, the three site comparisons suggest that infill development would reduce motor vehicle emissions compared with a greenfield site. Even when infill development cannot take advantage of regional transit, infill tends to reduce air pollution because regionally accessible, centrally located sites require shorter average trip distances than do sites along the regional periphery.

A follow-up study in Atlanta, GA, examined the transportation and emissions impacts of locating a large new development at an infill site formerly occupied by the former Atlantic Steel mill, compared to suburban alternatives.¹³⁴ Results suggest that vehicle miles of travel associated with a suburban site could run as much as 52 percent higher, while NO_x emissions could be 81 percent higher than would result from placing the same amount of development at the Atlantic Steel site.

EVIDENCE FROM EMPIRICAL STUDIES

Increasing regional compactness generally involves increasing density in specific targeted areas of the region. A large number of empirical studies (based on comparisons of actual communities) have found that population density is associated with reduced vehicle travel.¹³⁵

VMT at Infill versus Suburban Development Sites: The Atlantic Steel Case

EPA recently conducted an analysis to determine the transportation and emissions impacts of locating a new development at an infill site (formerly used by Atlantic Steel) compared with several suburban sites. EPA used Atlanta's regional travel model and EPA's MOBILE 5 emissions model to analyze the likely effects of developing each site with the same amount and mix of development. The study concluded that, depending on which suburban site is considered, development on the infill site would result in the following savings:

- VMT savings of 15-52 percent
- NO_x emissions savings of 37-81 percent
- VOC emissions savings of 293-316 percent

Transit share of work trips were projected to be significantly higher at the Atlantic Steel site: 27 percent of work trips made by transit compared with the regional average of approximately 8 percent and the 0-13 percent transit share that would result from development at the suburban alternatives.

Source: U.S. Environmental Protection Agency. November 1, 1999. "Transportation and Environmental Analysis of the Atlantic Steel Development Project." Prepared by Hagler Bailly.

¹³⁴ U.S. Environmental Protection Agency. "Transportation and Environmental Analysis of the Atlantic Steel Development Project." Prepared by Hagler Bailly, November 1, 1999.

¹³⁵ Boyce, D.E., M.C. Romanos, B.N. Janson, P. Prastacos, M. Ferris, and R.W. Eash. *Urban Transportation Energy Accounts*. September 1981.; University of Toronto/York University Joint Program in Transportation, Data Management Group. *The Transportation Tomorrow Survey: Travel Survey Summary for the Greater Toronto Area*. June 1989; Harvey, G. *Relation of Residential Density to VMT per Resident: Oakland*. Metropolitan Transportation Commission. 1990. As cited by Holtzclaw, John. "Explaining Urban Density and Transit Impacts on Auto Use." Presented to State of California Energy Resources Conservation and Development Commission, January 1991.

One well known study by Holtzclaw found that a doubling of residential densities is associated with a decrease of 20 to 30 percent in VMT per capita.¹³⁶ His analysis, which used odometer readings from 27 California communities, suggested that residential density and access to public transportation were the two urban form factors that most reliably predict household auto travel behavior. Communities with higher residential density and transit service had the lowest rates of auto ownership and vehicle mileage per capita. Holtzclaw concludes that if a region's population doubles wholly by infill, its vehicle miles of travel will likely increase by only 40 to 60 percent, rather than the 100 percent if the population grew at its present density. Doubling population at low density (as is common in many new suburbs) would likely increase average auto mileage by 150 to 186 percent.

An earlier study, based on data for 105 U.S. metropolitan areas, including the New York City region, also found a correlation between density and mode share, and reported threshold densities at which transit use increases.¹³⁷ According to the study, at densities between 1 and 7 dwellings per acre, transit use is minimal, while at densities above 60 dwellings per acre, more than half the trips tend to be made by public transportation. The authors conclude that a minimum density of 7 dwellings per acre appears to be a threshold above which transit use increases sharply.

The highest density areas (e.g., Manhattan) tend to have the most transit service and the tightest parking supply. Recent evidence suggests that the effects of density on household travel behavior are complex and may be more related to characteristics typically associated with dense development than to population density itself. High-density areas tend to be associated with higher parking costs, limited parking, increased transit service, and a mix of land uses. Dense areas also tend to be located toward the center of a metropolitan region rather than on the periphery, and as a result are more accessible. Separating these effects is difficult, so the statistical significance of density in studies that fail to account for other urban form factors may be due in part to the strength of density as a proxy for other difficult-to-observe variables that affect travel behavior.¹³⁸

Population density also tends to be correlated with income, a primary source of differences in travel behavior. A number of studies have attempted to control for income and other household characteristics to identify the independent effects of urban form on travel behavior. These studies generally find that urban form factors do have a discernible effect on travel behavior, even after accounting for household characteristics. For example, a study using data from the 1985 American Housing Survey performed a regression analysis to simultaneously test the effects of various factors on components of travel demand. The study found that vehicle ownership and vehicle mode share decline with neighborhood density. The study, which controlled for household income, household size, adequacy of public transit service, and location within a central city, found that households in an area of high-rise apartments were likely to own 0.42 fewer vehicles than households in a nearby

¹³⁶ Holtzclaw, John. "Explaining Urban Density and Transit Impacts on Auto Use." Presented to State of California Energy Resources Conservation and Development Commission, January 1991.

¹³⁷ Pushkarev, B. and J. Zupan. *Public Transportation and Land Use Policy*. Bloomington, IN: Indiana University Press, 1977.

¹³⁸ For example, a study by Kockelman, K. ("Travel Behavior as a Function of Accessibility, Land Use Mixing, and Land Use Balance: Evidence from the San Francisco Bay Area." Submission to the 76th Annual Meeting of the Transportation Research Board, January 1997), on the effect of urban form on VMT, automobile ownership, and mode choice found that under all but the vehicle ownership model, the effect of population density was minor after controlling for accessibility. Work by Cambridge Systematics et al. (*Making the Land Use Transportation Air Quality Connection: Model Modifications*. Vol. 4. Prepared for Thousand Friends of Oregon, May 1996) on the Portland regions' travel models also found that residential density was not statistically significant in explaining vehicle ownership; rather, a measure of land use mix, transit accessibility to jobs, and the pedestrian environment were statistically significant in predicting vehicle ownership levels.

neighborhood with single-family detached units. Holding transit service and number of vehicles constant, the probability of automobile commuting was greater in a neighborhood of single-family units or low-rise apartments than in a neighborhood with mid- or high-rise buildings. For example, the probability that a person in a one-car household commutes by transit was almost 30 percent if that household lived in a mid- to high-rise multifamily neighborhood in the central city but was less than 10 percent if that person lived in a mostly single-family neighborhood in the city.¹³⁹

A multivariate regression analysis of mode choice based on travel data from the Puget Sound region found that employment density at trip origins and destinations was significant in predicting the percentage of travel by each mode—more significant, in fact, than population density, after accounting for various control variables such as household type, proportion with a driver’s license, and vehicle availability. Modal shifts from single occupant vehicles (SOV) to transit and walking occurred between 20 and 75 employees per acre (causing SOV percentage to drop from about 90 percent to 60 percent), and again with more than 125 employees per acre.¹⁴⁰

4.2 DESIGN FOR REDUCED IMPERVIOUS SURFACES AND IMPROVED WATER DETENTION

As described in Chapter 2, impervious surfaces have substantial environmental impacts. Impervious surfaces increase peak discharges, pollutant loads, and volumes and velocity of runoff. In areas with large paved surfaces (such as parking lots), high volumes of storm runoff are carried out through storm drains into watercourses, starting soon after the storm begins and continuing during the duration of heavy rainfall. During periods of heavy rainfall, widespread coverage by impervious surfaces can increase the likelihood of serious flash flooding. Absorbing runoff where it originates helps reduce flooding and maintain the water table, wells, and creeks.¹⁴¹

Techniques for Reducing Impervious Surfaces and Improving Water Detention

Compact development often minimizes or reduces impervious land area, as described in Section 4.1. Compact development devotes less land area to roads and may also devote fewer acres to buildings if residential or commercial space is built up vertically rather than out horizontally. In addition to compact or cluster development, other variations in built environment designs can reduce impervious cover and improve stormwater infiltration and detention. This section describes those designs.

Techniques for reducing impervious surfaces and improving water detention include:

- Modification of street standards and parking requirements

¹³⁹ Cervero, Robert. “Mixed Land Uses and Commuting: Evidence from the American Housing Survey.” *Transportation Research*. Vol. 30, No. 5, 1996. pp. 361-377.

¹⁴⁰ Frank, L. and G. Pivo. “Impacts of Mixed Use and Density on Utilization of Three Modes of Travel: Single-Occupant Vehicle, Transit, and Walking.” *Transportation Research Record* 1466, 1994, pp. 44-52.

¹⁴¹ Thelen, Edmund, and L. Fielding Howe. *Porous Pavement*. The Franklin Institute Press. 1978.

- Use of porous surfaces rather than concrete and asphalt
- Use of open and natural drainage systems
- Landscaping that helps retain soil moisture and conserve water usage

MODIFYING STREET STANDARDS AND PARKING REQUIREMENTS

Surfaces used for transportation infrastructure account for much of the imperviousness at a development site and in urban areas. In areas with dispersed development patterns, for example, roads and parking lots account for as much as 70 percent of the total impervious surface.¹⁴² Impervious areas may be reduced in size, while retaining their utility.

Reduced street widths (to widths typical in many existing communities) have been found to handle traffic and emergency response equipment adequately while significantly reducing the impervious surface area.¹⁴³ Reducing street widths provides benefits beyond reduced imperviousness: Less clearing and grading is required, neighborhood traffic is slowed (traffic calming), and construction and maintenance savings accrue.¹⁴⁴ In fact, livability issues, pedestrian-friendliness, and traffic calming are major reasons reduced street widths have been proposed. Portland, Oregon, for example, implemented its Skinny Streets Program in 1991 to reduce street widths and calm traffic. Reducing street widths has helped to preserve livability in communities, lessen stormwater runoff, reduce construction costs of new streets, and limit the impact of grading on slopes.¹⁴⁵

Existing roads also can be retrofitted to reduce impervious surface area. For example, cul-de-sacs may be retrofitted with vegetated islands designed to retain and infiltrate stormwater, and vegetated grass swales may be used in place of concrete curbing to capture and infiltrate runoff from paved streets.¹⁴⁶ Median islands can be added with grass, flowers, or other vegetation.

Another way to reduce impervious cover is modifying or downsizing parking areas. Studies suggest that parking is greatly oversupplied in both residential and commercial areas. Zoning codes typically require between three and five spaces per 1,000 gross square feet of office building area, with four spaces per 1,000 square feet often used as a rule of thumb.¹⁴⁷ Parking utilization surveys, however, typically show peak demand levels of between two and three spaces per 1,000 square feet.¹⁴⁸ A case

¹⁴² Chesapeake Bay Foundation. *A Better Way to Grow*. 1996. p.6.

¹⁴³ Federal Highway Administration. *Flexibility in Highway Design*. 1998; Institute of Transportation Engineers. *Traffic Calming in Practice*. Landor Publishing. 1994.

¹⁴⁴ Schueler, Tom. *Environmental Land Planning Series: Site Planning for Urban Stream Protection*. p.148.

¹⁴⁵ Southworth, Michael, and Eran Ben-Josaph. *Streets and the Shaping of Towns and Cities*. McGraw Hill, 1997. p.34.

¹⁴⁶ See Institute of Transportation Engineers (ITE). *Traditional Neighborhood Development Street Design Guidelines*. (Pub. No. RP-027). 1997. for more information about street designs.

¹⁴⁷ Bergman, David. "Off-Street Parking Requirements." *APA Planning Advisory Service Report 432*. Chicago: American Planning Association. 1991; Gruen Gruen + Associates. *Employment and Parking in Suburban Business Parks: A Pilot Study*. Washington, DC: Urban Land Institute, 1986; Shoup, Donald. "Cashing Out Employer-Paid Parking." FTA-CA-11-0035-92-1. Washington, DC: U.S. Department of Transportation. 1993.

¹⁴⁸ Cervero, Robert. *America's Suburban Centers: The Land Use Transportation Link*. Winchester, MA: Unwin Hyman, 1989; Gruen Gruen + Associates. *Employment and Parking in Suburban Business Parks: A Pilot Study*. Washington, DC: Urban Land Institute, 1986.

study of suburban office buildings in southern California found that parking was oversupplied by a factor of almost two in the typical sites studied—the amount of parking supplied averaged 3.8 spaces per 1,000 square feet, while only 2.1 spaces were used during peak times.¹⁴⁹ Similarly, a recent survey of parking demand at neighborhood commercial lots in Iowa City, Iowa, during the 10-day period before Christmas found that the highest parking occupancy rate was 74 percent; over the count period and all sites, the average occupancy rate was 36 percent. The parking supply at the sites closely matched parking required in the city zoning ordinance. Based on these data, Iowa City reduced its parking requirements for neighborhood commercial lots by 33 percent.¹⁵⁰

Conventional design standards for parking areas may be revised to reduce the total parking area by several means. Parking standards can be developed for average parking needs rather than for those of a single peak day, such as holiday shopping periods. Research shows that a 10 to 15 percent reduction in total impervious cover can be achieved through either: (a) substituting parking stalls designed for compact cars for 30 percent of all spaces, (b) sharing parking arrangements (in which two businesses agree to share parking spaces, enabled by different peak times for parking demand), and (c) using the smallest allowable dimensions for regular parking stalls. If all three measures are used in combination, a 30 percent reduction in total impervious cover could be attained.¹⁵¹

USE OF POROUS SURFACES

Porous surfaces allow the soil to absorb precipitation, reducing runoff and replenishing the water table compared with impervious surfaces. Two types of paved surfaces allow soil to absorb water:

- *Surfaces that allow some precipitation to seep into the soil, such as lattice blocks, bricks set in sand, stones bonded with epoxy, perforated cast concrete slabs, steel grids, and wood slabs or logs (corduroy)* — Surfaces such as lattice blocks and bricks set in sand can be used in place of concrete and asphalt for certain purposes such as sidewalks, walkways, driveways, parking areas, and low-volume roads. They usually do not lend themselves to projects requiring large pavement areas or heavy traffic volumes.¹⁵²
- *A porous pavement, which involves a porous asphalt layer and underground stone reservoir.*¹⁵³ — Precipitation passes through the pavement and is collected and stored in stone voids beneath the top surface. The stored water then gradually infiltrates into the subsoil. To the extent that stormwater can be absorbed using porous pavement, stormwater collector systems and treatment plants can be minimized. Pervious pavement may be designed to retain rainfall completely with no runoff or to retain enough precipitation so that runoff flow is delayed and

¹⁴⁹ Willson, Richard W. "Suburban Parking Requirements: A Tacit Policy for Automobile Use and Sprawl." *Journal of the American Planning Association*. Vol. 61, No. 1 Winter 1995. pp. 29-42.

¹⁵⁰ Shaw, John. "Minimum Parking Requirements in Midwestern Zoning Ordinances." Paper presented at 76th Annual Meeting of the Transportation Research Board. January 1997.

¹⁵¹ Schueler, Tom. *Environmental Land Planning Series: Site Planning for Urban Stream Protection*. p.168.

¹⁵² Thelen, E., and L. F. Howe. *Porous Pavement*. The Franklin Institute Press, 1978.

¹⁵³ See: Schueler, Thomas, Peter Kumble, and Maureen Heraty, Anacostia Restoration Team, Metropolitan Washington Council of Governments. "A Current Assessment of Urban Best Management Practices: Techniques for Reducing Non-Point Source Pollution in the Coastal Zone." Prepared for U.S. Environmental Protection Agency. March 1992. Field, R., H. Masters, and M. Singer. "Porous Pavement: Research; Development; and Demonstration," *Transportation Engineering Journal of the American Society of Civil Engineers*. Volume 108, Number TE3, May 1982. pp. 244-258.

peak demand on storm sewers is reduced.¹⁵⁴ The use of porous pavement is highly constrained, requiring deep and permeable soils, limited traffic, and suitable adjacent land uses.

Since porous pavements can replicate natural drainage patterns, they are useful for pavement in areas where the natural character of the land should be preserved and in areas where surfacing will be only temporary. If removed later, the land is returned to its natural state.¹⁵⁵

Over time, porous pavement sites have a high failure rate due to partial or total clogging of the facility that occurs when porous asphalt is clogged by sediment and oil.¹⁵⁶ In addition, porous surfaces should not be exposed to spillage of toxic chemicals and intermediates and so should not be used for highways and heavy-duty streets.¹⁵⁷

OPEN AND NATURAL DRAINAGE SYSTEMS

In a traditional closed drainage system, stormwater is removed as fast as possible with curbs and gutters, catch basins, underground pipers, culverts, and/or lined channels. An open drainage system, in contrast, detains stormwater for short periods in swales and filter strips, and for longer periods in ponds and wetlands.¹⁵⁸ Extended detention lowers peak discharge rates and gives physical, chemical, and biological processes time to work on pollutants.

Figure 4-3 demonstrates how the inclusion of a detention pond in a new development can spread the discharge period out over time. After development, because of impervious surfaces, the total volume and peak flow of stormwater is much greater than before urbanization. A detention pond does not reduce the amount of runoff but spreads the flow to minimize erosion and the potential for flash flooding. Stormwater is detained in the basin and released at a constant rate.

Open drainage systems can be more cost-effective than storm sewer systems. In addition, wetlands and wet ponds have amenity value that can be captured in the price of adjacent lands.¹⁵⁹

¹⁵⁴ Thelen, E. and L. F. Howe. *Porous Pavement*. The Franklin Institute Press, 1978.

¹⁵⁵ U.S. Environmental Protection Agency, Office of Research and Monitoring. *Investigation of Porous Pavements for Urban Runoff Control*. March, 1972.

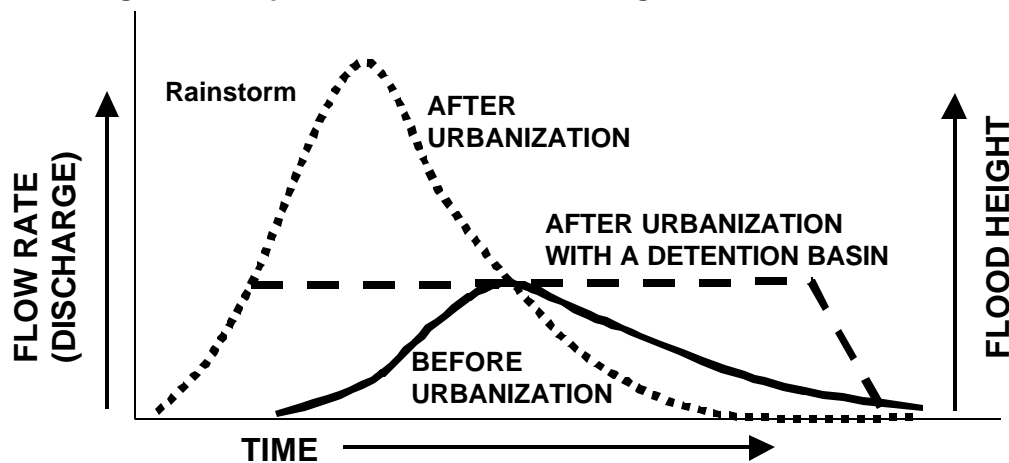
¹⁵⁶ Ways to improve longevity include routine vacuum sweeping, restriction of use to low-intensity parking areas, restrictions on access by heavy trucks, and restrictions of use of de-icing chemicals. Source: Schueler, Thomas, Peter Kumble, and Maureen Heraty, Anacostia Restoration Team, Metropolitan Washington Council of Governments. "A Current Assessment of Urban Best Management Practices: Techniques for Reducing Non-Point Source Pollution in the Coastal Zone." Prepared for U.S. Environmental Protection Agency. March 1992.

¹⁵⁷ Thelen, E. and L. F. Howe. *Porous Pavement*. The Franklin Institute Press, 1978.

¹⁵⁸ Field, R., H. Masters, and M. Singer. "Porous Pavement: Research; Development; and Demonstration." p.244-258.

¹⁵⁹ Ewing, R. *Best Development Practices*. Joint Center for Environmental and Urban Problems. Florida Atlantic University/Florida International University. May 1995. p.106.

Figure 4-3: Impact of Urbanization and Mitigation on Runoff Rates



Source: Adapted from Harbor, J. "A Practical Method for Estimating the Impact of Land Use Change on Surface Runoff, Groundwater Recharge and Wetland Hydrology." *Journal of the American Planning Association*. 60: 1, Winter 1994. pp. 95-108.

LANDSCAPING

Effective landscaping can retain soil moisture and conserve water usage in any developed area. Natural vegetation can reduce runoff, provide habitat for birds and other native wildlife, and reduce water consumption. Trees, shrubs, and other plants can help reduce runoff by absorbing precipitation. Locally adapted plants with large leaf surfaces and deep fibrous root systems absorb the most water.¹⁶⁰

Conversely, conversion of woodlands and undisturbed land affects storm runoff and groundwater discharge. An 11 to 100 percent loss of natural groundwater recharge, along with an 11- to 19-fold increase in stormwater, occurred at one site when its woodlands were converted to residential and commercial land use.¹⁶¹

Landscaping in suburban areas can reduce water usage itself. All development requires water, but low-density development tends to require more water for lawns and gardens. Adequate water supply is an important issue in some regions of the country. Development in several states—most notably six of the eight mountain states—is leading to net water supply depletion.¹⁶² A water-conserving landscaping scheme applies mulches instead of turf to retain soil moisture. Vegetation species used in xeriscaping typically require minimal irrigation and less maintenance. Less maintenance implies fewer air emissions from lawn and garden equipment.

¹⁶⁰ Ewing, R. *Best Development Practices*. p.114.

¹⁶¹ Harbor, J. M. "A Practical Method for Estimating the Impact of Land Use Change on Surface Runoff, Groundwater Recharge, and Wetland Hydrology." *Journal of the American Planning Association*. Vol. 60, 1994. p. 95-108.

¹⁶² U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation. *Natural Resources for the 21st Century: An Evaluation of the Effects of Land Use on Environmental Quality*. Washington, DC: June, 1989. p. 61.

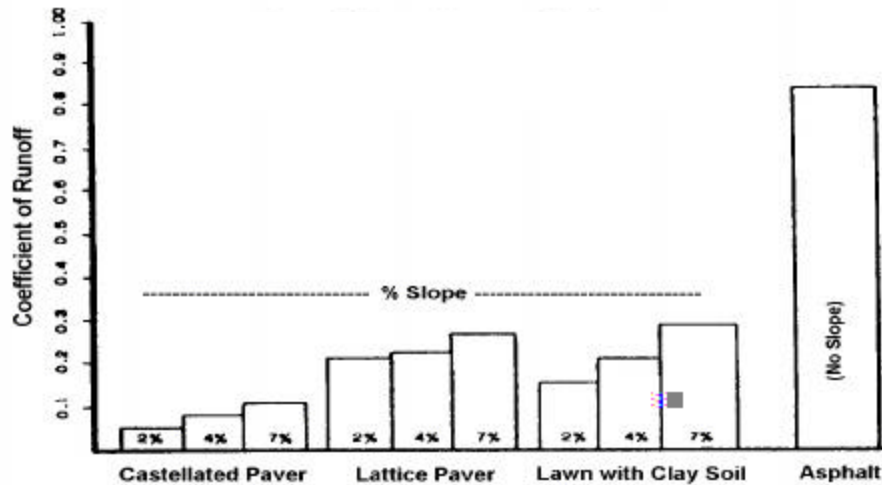
Direct Environmental Effects of Reducing Impervious Surfaces and Improving Water Detention

Reducing impervious surfaces and improving water detention can have positive effects on hydrology and water quality, plus vegetation and wildlife.

Large parking lots are major contributors to runoff. A 1-acre parking lot produces 16 times as much runoff as does a 1-acre meadow.¹⁶³ Parking lot runoff usually has a more detrimental effect on water quality than runoff from most other impervious cover because parking lots tend to be heavily polluted by leaks and drips from vehicles. Because smaller parking lots also decrease vehicle travel, decreasing the size of parking lots can reduce both runoff and associated pollutant loads.¹⁶⁴

Using porous surfaces is another strategy for reducing runoff and increasing groundwater recharge. In Figure 4-4, runoff from three types of pervious pavement are compared with an asphalt surface. All three pervious surfaces are shown to exhibit much lower coefficients of runoff than asphalt.¹⁶⁵

Figure 4-4: Comparison of Runoff from Various Surfaces



Source: Adapted from Day, G.E. "Investigation of Concrete Grid Pavements." In Downing, W.L. *Proceedings of the National Conference on Urban Erosion and Sediment Control: Institutions and Technology*. Great Lakes National Program Office, U.S. Environmental Protection Agency. Chicago. 1980, pp. 127-136. As presented in Ewing, R. *Best Development Practices: Doing the Right Thing and Making Money at the Same Time*. Prepared for the Florida Department of Community Affairs. May 1995.

¹⁶³ Chesapeake Bay Foundation. *A Better Way to Grow*. 1996. p.4.

¹⁶⁴ Higgins, Thomas, K.T. Analytics, Inc. "Parking Management and Traffic Mitigation in Six Cities: Implications for Local Policy." Paper presented to Transportation Research Board, January 1989. U.S. Department of Transportation. *Implementing Effective Travel Demand Management Measures: Inventory of Measures and Synthesis of Experience*. September 1993. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. *Transportation Control Measure Information Documents*. March 1992.

¹⁶⁵ Ewing, R. *Best Development Practices*. p.104.

Porous pavement systems also have been shown to have high removal rates for sediment, nutrients, organic matter, and trace metals. The majority of the removal occurs as the result of the exfiltration of runoff into the subsoil and subsequent absorption or straining of pollutants within the subsoil.¹⁶⁶

Open and natural drainage systems also can serve as effective pollutant removers. At one site near Orlando, Florida, an alternative stormwater treatment system of catch basins, wet ponds, and marsh areas was established. During larger storm events for 1993-94, pollutant levels were measured for stormwater flowing into, through, and out of the system. Table 4-3 shows average reductions in pollutant concentrations found with the natural drainage system.¹⁶⁷

**Table 4-3: Pollutant Removal Efficiencies,
Lake Greenwood Stormwater Treatment System, Florida**

| Pollutant | Removal Efficiency |
|-------------------|--------------------|
| Total Solids | 91% |
| Total Lead | 81% |
| Total Zinc | 59% |
| Total Phosphorous | 85% |
| Total Nitrogen | 64% |

Source: McCann, K. and L. Olson. Greenwood Urban Wetland Treatment Effectiveness. Florida Department of Environmental Protection. Tallahassee, FL, 1994, pp. 17 and 28. Cited in Ewing, Reid. *Best Development Practices: Doing the Right Thing and Making Money at the Same Time*. Prepared for the Florida Department of Community Affairs. May 1995.

The natural drainage system proved effective in significantly reducing pollutant loads in runoff, with reductions of 59 to 91 percent in pollutant levels.

When properly designed, open and natural drainage systems also can provide valuable habitat areas. The more natural the drainage system, the more valuable it will be for wildlife and water quality. Vegetated swales, stormwater ponds, marshes, and wetlands can serve as habitat for many creatures, including wetland birds and other waterfowl.¹⁶⁸

Porous pavement can be beneficial to native vegetation and wildlife as well, by allowing roadside vegetation to receive the water it needs to survive and grow. Porous pavement is particularly beneficial to water-starved street trees in urban areas.¹⁶⁹

¹⁶⁶ Schueler, Thomas, Peter Kumble, and Maureen Heraty, Anacostia Restoration Team, Metropolitan Washington Council of Governments. "A Current Assessment of Urban Best Management Practices: Techniques for Reducing Non-Point Source Pollution in the Coastal Zone." Prepared for U.S. Environmental Protection Agency. March 1992.

¹⁶⁷ Ewing, R. *Best Development Practices*. p.105.

¹⁶⁸ Franklin, T.M. "Use of Urban Stormwater Control Impoundments by Wetland Birds." *Wilson Bulletin*. Vol. 97, 1985, pp. 120-122; Adams, L.W. *et al.* "Design Considerations for Wildlife in Urban Stormwater Management." *Transactions of the 51st North American Wildlife and Natural Resources Conference*, 1986, pp. 249-259.

¹⁶⁹ U.S. Environmental Protection Agency, Office of Research and Monitoring. *Investigation of Porous Pavements for Urban Runoff Control*. March, 1972.

4.3 DESIGN FOR SAFEGUARDING SENSITIVE AREAS

Minimizing environmental impacts not only involves decisions about how much to build, but also where to build. Some locations lessen direct effects on habitat and water resources. Minimizing harmful environmental impacts may mean forestalling development in sensitive natural areas such as streams, wetlands, floodplains, steep slopes, mature forests, swamps, critical habitat areas, and shorelines.

Environmentally sensitive areas have benefits beyond scenic value. Riparian buffers along rivers and streams, for example, are often critical habitats. One study indicates that nearly 70 percent of all vertebrate species use riparian areas in some significant way during their life cycles.¹⁷⁰

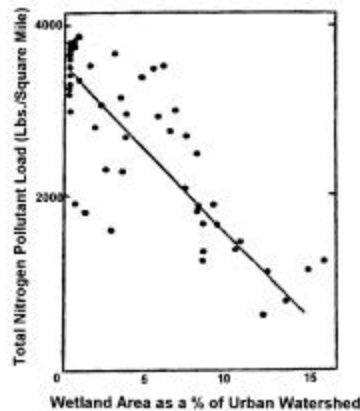
Techniques for Safeguarding Environmentally Sensitive Areas

Different communities have different types of environmental assets that they want to protect, so techniques for safeguarding environmentally sensitive areas vary across communities. Three of the most commonly used techniques are wetlands protection, establishing riparian buffers, and use of greenbelts.

WETLANDS PROTECTION

Wetlands are an especially valuable resource. Reductions in wetland area as a percentage of an urban watershed are associated with increases in water pollutant loads, as shown in Figure 4-5. Each point on the graph represents a watershed, showing the pollutant load in relation to wetland area as a percentage of the watershed. Total nitrogen pollutant loads increase as the percentage of wetlands decreases.

Figure 4-5: Increase In Pollutant Load with Loss of Wetland Area



Source: Adapted from Oberts, G.L. "Impacts of Wetlands on Watershed Water Quality." In B. Richardson (ed.), *Selected Proceedings of the Midwest Conference on Wetland Values and Management*. Freshwater Society, Navarre, MD: 1981, pp. 213-226. Cited in Ewing, R. *Best Development Practices: Doing the Right Thing and Making Money at the Same Time*. Prepared for the Florida Department of Community Affairs. May 1995, p. 96.

Although development of undisturbed areas inevitably will persist to some degree, well-designed communities and infrastructure can protect the most sensitive natural areas and minimize adverse

¹⁷⁰ Ewing, R. *Best Development Practices*. p.95.

impacts. The best means of safeguarding sensitive areas is simple avoidance. Given the same site and development program, new development can stand back from wetlands or encroach into them. When encroachment on wetlands is unavoidable, cautious planning can minimize negative impacts.

RIPARIAN BUFFERS

Protection of sensitive areas can be improved by establishing buffers. Riparian buffers between land and water along shorelines, around wetlands, and adjacent to tidal guts, creeks, and streams may be applied systematically to create a “green corridor” along the banks of rivers or streams. Three primary aquatic areas qualify for buffers: the shoreline of a lake or estuary, a delineated wetland, or a stream channel.

Buffer systems are typically inexpensive and simple to implement. Often a prescribed distance, usually between 25 and 100 feet from a water’s edge or mean high tide mark, is adopted by a local jurisdiction as the setback standard for a protected buffer area. Typically, construction, grading, dredging, and any other form of environmental disturbance are prohibited or severely restricted within the buffer area.¹⁷¹ Usually only low-intensity uses such as recreation are allowed. Natural and cultural characteristics of the river basin determine correct buffer width. Relevant natural factors include seasonal water levels, the nature and extent of adjacent wetlands and floodplains, the steepness of adjacent topography, the nature of riparian vegetation, and the wildlife values of adjacent lands. Relevant cultural factors include riverfront parcel size and depth, traditional use patterns of the river and its adjacent lands, and existing development along the river.

¹⁷¹ Mantell, M. A., S. F. Harper, and L. Propst. *Creating Successful Communities: A Guidebook to Growth Management Strategies*. The Conservation Foundation. Island Press, 1990.

Multiple Species Conservation Plan, County of San Diego, California: A Case Study

On March 18, 1998, the San Diego City Council approved a Multiple Species Conservation Plan (MSCP), a subregional development and conservation plan under California's Natural Communities Conservation Program. The MSCP covers approximately 900 square miles in San Diego County and includes goals and criteria to conserve the habitats of more than 85 species in the area. The regional plan designates those areas that may be developed and those that must be conserved. To the greatest extent possible, the plan tries to use public lands to satisfy required conservation levels.

Before the development of the MSCP, non-federal property owners wishing to build on or alter their land in ways that might result in the incidental "take," or harm, of a listed species had to obtain an Incidental Take Permit (ITP) from the U.S. Fish and Wildlife Service. In order to obtain an ITP, the property owner had to develop a Habitat Conservation Plan (HCP) outlining ways in which the negative effects on the listed species would be offset.

Because the new MSCP functions as a Habitat Conservation Plan for the region, it allows issuance of all ITPs for covered species. Political jurisdictions develop their own plans consistent with the MSCP, then obtain ITPs for the plan area. The jurisdictional possession of ITPs for the entire sub-area eliminates the need for private citizens to develop HCPs for activities that are already taken into consideration under the MSCP and, in most cases, the Environmental Impact Report for the entire MSCP will satisfy the requirements for project-specific Environmental Impact Reports.

A regional conservation plan such as the MSCP is advantageous to all involved: Critical species and habitats are protected, and private landowners benefit from a simplified development process.

Sources: Merrick, J. (1998). The San Diego Multiple Species Conservation Plan. In *Improving Integrated Natural Resource Planning: Habitat Conservation Plans*, [Web page]. National Center for Environmental Decision-making Research. Available: <http://www.ncedr.org/casestudies/hcp/sandiego.htm> [1998, October 14]; County of San Diego, Department of Land Use and Planning. <http://www.co.san-diego.ca.us/cnty/cntydepts/landuse/planning/mscp/>; US Fish and Wildlife Service [Web page] <http://endangered.fws.gov/hcp/index.html>

GREENBELTS

Greenbelts are areas of preserved open space, or areas of significantly reduced development, designed as buffers to protect areas of land or water resources from development impacts. The preservation of patches of high-quality habitat, connected by wildlife corridors, can preserve wildlife and ecosystems even in areas with significant adjoining development. Wildlife corridors can serve as "land bridges" between "habitat islands" and as dwelling habitats in their own right.¹⁷²

Greenbelts also may be used to preserve agricultural land, recreational areas, and natural resources in close proximity to a town or city. Greenbelts are achieved through zoning, creative development planning, or land acquisition, or a combination of these approaches. Since greenbelts are usually considered amenities, they have the potential to increase property values of adjacent land.

Direct Environmental Effects of Protecting Environmentally Sensitive Areas

Buffers, greenbelts, and other preservation tools have numerous environmental benefits. They can protect watersheds, guard animal habitats, and preserve existing vegetation. For example, buffers may reduce watershed imperviousness (by preventing development on land along the streambed), provide effective flood insurance (by keeping structures away from floodplains), protect stream temperatures

¹⁷² Ewing, R. *Best Development Practices*. p. 95.

(with their canopies), stabilize streambanks, and protect against streambed erosion (since trees and vegetation are more resistant to bank erosion than grass is). Buffers can protect sensitive areas from physical encroachment and scenic degradation, and preserve wildlife habitat for terrestrial and aquatic animals.¹⁷³

Since buffers are able to intercept and absorb runoff before it reaches the water resource, they have the potential to improve water quality by reducing runoff volume. Buffers act as a sort of natural scrubber, preventing excess nutrients and pollutants from entering waterways and wetland areas.¹⁷⁴ A buffer's ability to reduce pollutant loads depends on runoff velocity and site conditions such as soil, vegetation, buffer size, and slope.¹⁷⁵

4.4 MIXED LAND USES

Standard zoning separates uses into distinct zones for residential, commercial, or industrial uses. In contrast, mixed-use development locates land uses with complementary functions close together. Complementary uses may include housing, shopping, offices, restaurants, and movie theaters—any destinations that people travel to on a regular basis.

Techniques for/ Types of Mixed Use Development

Mixed-use development can occur on a number of levels: site-specific, neighborhood, or subregional. On a site-specific basis, individual buildings or complexes can be designed to incorporate a variety of uses. For example, a single building might include apartments, offices, and retail. At the neighborhood level, mixed-use development refers to the arrangement of different uses across several blocks or acres of land so that they are not physically isolated from one another. Finally, at the subregional level, mixed-use often aims to balance jobs and housing so that people have the opportunity to live closer to their places of employment.

Direct Environmental Effects of Mixed-Use Development: Habitat and Water Quality

Mixing land uses can have direct effects on habitat loss and runoff since mixed-use developments have the potential to use surface parking lots and transportation infrastructure more efficiently, requiring less pavement. When office buildings also contain retail shops and restaurants, the infrastructure that supports the building—the roads and parking lots—is in use for more of the day. Office traffic arrives during rush hour and uses the parking lot during the day. That parking can be used in the evenings for restaurant and theater traffic. The alternative is two sets of roads and parking lots—one set serving office buildings and another that serves retail and entertainment areas.

¹⁷³ Schueler, Tom. *Environmental Land Planning Series: Site Planning for Urban Stream Protection*. Center for Watershed Protection. Publication No. 95708. Washington, DC: Metropolitan Washington Council of Governments, December 1995. p. 90.

¹⁷⁴ Center for Watershed Protection. *Blueprint to Protect Coastal Water Quality*. Land Ethics, Inc. Section 4-3.

¹⁷⁵ Jones, H., L.M. Maureen Heraty, and B. Jordan. *Environmental Land Planning Series: Riparian Buffer Strategies for Urban Watersheds*. Urban Watershed Planning Section. Washington, DC: Department of Environmental Programs. Metropolitan Washington Council of Governments. December, 1995. p.3.

Indirect Environmental Effects of Mixed-Use Development: Reductions in Vehicle Travel

At any level—building, neighborhood, or regional—the travel-related environmental effect of mixing uses is similar. By encouraging people to walk, bike, and use transit rather than drive, mixed-use development patterns reduce VMT. Reductions in VMT lead to decreases in automobile emissions, thereby improving regional air quality.

Mixing land uses can reduce VMT in several ways:

- *Trip lengths* – By locating activities closer together, a mix of land uses can minimize travel distances and improve access to employment, services, or recreational opportunities.
- *Mode choice* – Locating activities closer together allows trips to be made by walking and bicycling rather than by driving motor vehicles and increases the opportunity for non-auto trip chaining. Individuals can drive to one destination, for example, and then walk to others once they have parked their car.
- *Vehicle ownership* – Access to employment and shopping by walking and bicycling reduces the need to own a motor vehicle for personal mobility.

Land use mixing may influence travel demand in a number of ways, but its greatest impact is thought to be on mode choice.¹⁷⁶ Mixed land use areas influence mode choice by enhancing the relative convenience of non-auto modes. For example, mixing employment and residential uses may reduce commute distances, thus making walking, bicycling, and transit more competitive with auto travel in terms of time. Alternatively, mixing employment or residential centers with retail and commercial establishments may increase the attractiveness of alternatives to single occupant vehicle driving by reducing the need for a vehicle to accomplish mid-day tasks or errands typically completed on the way to or from work.

Evidence of the effects of land use mixing on travel patterns is organized around three geographic levels of mixing:

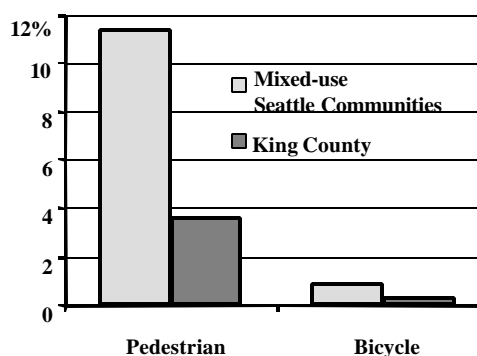
- Mix (or balance) of jobs and housing within subregions
- Mix of uses within neighborhoods or communities
- Mix of uses at employment centers.

¹⁷⁶ Cervero, R. “Mixed Land Uses and Commuting: Evidence from the American Housing Survey.” *Transportation Research*. Volume 30, Number 5. 1996. p. 363.

MIXING USES WITHIN RESIDENTIAL NEIGHBORHOODS

Several empirical studies have found that places with a mix of land uses and retail services located within walking distance of residences have higher levels of pedestrian travel and fewer vehicle trips compared with solely residential neighborhoods. For example, a comparison of travel diaries of residents in three Seattle mixed-use neighborhoods with those of residents of suburban, single-use neighborhoods in surrounding King County found that the average trip length was significantly lower in the mixed-use neighborhoods. In most cases, the average distance per trip driven by residents of mixed-use neighborhoods was half that of those living in the single-use neighborhood. For work trips, nonmotorized mode share was significantly higher in mixed-use communities—12.2 percent of trips in mixed-use Seattle neighborhoods compared with 3.9 percent of trips in the comparison communities, as Figure 4-7 shows.¹⁷⁷ The higher numbers of auto trips lead to increased emissions. In the most compact mixed-use communities, the share of weekday trips by walking was as high as 18.1 percent.

Figure 4-7: Mode Share for Work Trips in Seattle Mixed-Use Communities and King County



These findings reflect the fact that in mixed-use communities, more destinations are located near each other. In the survey, respondents of mixed-use Seattle communities reported making more than three times as many weekday trips to destinations within a mile of home as King County residents did. The results are summarized in Table 4-4.

Table 4-4: Percent of Weekday Trip Stops by Distance from Household

| Location | Distance of Stops from Household Location | | |
|-------------|---|-----------|-----------|
| | 1.0 miles | 1.5 miles | 2.0 miles |
| Mixed Use | 17.4% | 25.4% | 38.7% |
| King County | 4.5% | 11.6% | 18.2% |

An analysis of American Housing Survey data demonstrates that locating retail activities within a short walk of homes is associated with increased levels of commuting by mass transit, walking, and bicycling. Households with grocery stores and other consumer services within 300 feet—generally a one- or two-block distance—of one’s residence were less likely to commute by automobile,

¹⁷⁷ Rutherford, G.S., E. McCormack, and M. Wilkinson. “Travel Impacts of Urban Form: Implications from an Analysis of Two Seattle Area Travel Diaries.” TMIP Conference on Urban Design, Telecommuting, and Travel Behavior. October 27-30, 1996. The counter to this argument is that people self-select into areas that support their preferred behaviors. Those who prefer to avoid driving choose homes where they do not have to drive. Those who like driving choose suburbs. The implication that the latter group would drive at the rates they do now, even if for some reason they lived in dense, mixed-use, transit-served communities.

controlling for such other factors as land density, number of automobiles per household, and adequacy of public transit services.¹⁷⁸

Travel model improvements undertaken in the Portland region found that one measure of land-use mix—the number of retail jobs in a transportation analysis zone—was statistically significant in explaining residential automobile ownership and the choice between motorized and nonmotorized modes. The addition of a measure of employment density into the auto-ownership and mode choice models improved the fit of the models to actual survey data.¹⁷⁹

Locating parks and recreational facilities, small shops or grocery stores, schools, and religious institutions within residential neighborhoods also has been found to reduce VMT (and, therefore, emissions), even in places that are automobile-oriented. A comparison of work and nonwork travel among residents of six communities in Palm Beach County, Florida, found that the presence of shopping, recreation, and school facilities within communities can lower vehicle hours traveled per capita significantly even when transit is not widely available.¹⁸⁰ This study suggests that locating facilities and services *in* communities reduces vehicle travel even in locations where the automobile for all intents is the only primary mode of transportation. Increased accessibility within the region also was associated with reduced vehicle hours of travel. Given that the presence of additional uses in a neighborhood cannot directly increase speeds, the decrease in VHT must be a function of shorter trips, which would, in turn, lead to decreased emissions.¹⁸¹

MIXING USES AT EMPLOYMENT AND COMMERCIAL CENTERS

Just as improving the mix of uses in residential communities has been shown to reduce vehicle travel, mixing uses within commercial and employment areas also has been identified as a way to increase transit share and reduce vehicle use. Locating stores close to workplaces makes stores accessible by foot during the workday and allows efficient linking of trips even if the stores are distant from the employees' homes. As a result, employees may substitute mid-day pedestrian errands for after-work, vehicle-based trips. The presence of restaurants, shops, and consumer services at or near employment sites encourages transit use and ridesharing since many workers no longer need to have a car available for mid-day or after-work trips.

Pedestrian connections are an important component in mixing land uses. Many larger commercial developments contain both office space and commercial development but still require a car to get around. These developments do not function as a mixed-use area, because most of the commercial

¹⁷⁸ Cervero, R. "Mixed Land Uses and Commuting: Evidence from the American Housing Survey." *Transportation Research*. Vol. 30, No. 5, 1996. pp. 361-377. Cervero controlled for such factors as residential densities and vehicle ownership levels. His analysis also found that having retail shops beyond 300 feet yet within 1 mile of residences tended to encourage auto-commuting, perhaps because of the ability to link work and shop trips efficiently by car. In any case, the mixed-use neighborhoods were associated with shorter commuting distances.

¹⁷⁹ Cambridge Systematics *et al.* *Making the Land Use Transportation Air Quality Connection: Model Modifications*. Vol. 4. Prepared for Thousand Friends of Oregon. May 1996.

¹⁸⁰ VMT could not be easily derived from the travel survey data files. However, differences in VMT are almost certainly even more pronounced than differences in VHT are since vehicle travel speeds are highest in areas of high VHT. Ewing, R., P. Haliyur, and G. W. Page. "Getting Around a Traditional City, a Suburban Planned Unit Development, and Everything in Between." *Transportation Research Record 1466*. 1994. pp. 53-62.

¹⁸¹ Again, lower VHT is sometimes the product of higher vehicle speeds, which, if high enough, can increase emissions. But the decrease in VHT in this study must be from decreased trip lengths.

development is in large malls and shopping centers separated from office developments by wide highways lacking sidewalks.

Several studies have demonstrated that developing a mix of uses at employment and commercial centers reduces the portion of trips made by personal vehicles and increases rates of transit use. In particular, several studies of suburban activity centers have found that office developments that have a mix of uses, even those in auto-oriented locations, have lower vehicle trip rates. A study of 57 large U.S. office developments found that each 10 percent increase in floor space devoted to retail-commercial uses was associated with a 3 percent increase in the share of transit and ridesharing commutes.¹⁸² A follow-up survey of commuting to six large suburban activity centers, including Perimeter Center north of Atlanta and Tyson's Corner in the Washington, DC, area, found the existence of a retail component within a suburban office building was associated with an 8 percent reduction in vehicle-trip rates per employee. Buildings with mixed uses averaged 3 percent more commutes by transit than buildings containing only offices.¹⁸³ Enabling workers to switch from automobile to transit commutes decreases VMT and associated emissions.

A study of suburban centers in southern California suggested that at sites with travel demand management (TDM) incentives, areas with a substantially mixed land use had more than double the transit mode share of other site—6.4 percent share in centers with a substantial mix compared with 2.9 percent in those with a limited mix.¹⁸⁴ In locations without demand management, the presence of mixed land uses increased commute trips by transit from 3.6 to 5.5 percent. People also bicycled and walked more in areas with a substantial mix of uses.¹⁸⁵

The same study also found that having convenience-oriented services, such as restaurants, banks, child care centers, dry cleaners, drugstores, and post offices, located near work sites significantly increased the portion of commuters using transit. Among sites using financial incentives, locations with convenience services had more than double the transit share of sites with limited services nearby—7.1 percent in sites with convenience services compared with 3.4 percent in areas without convenience services. Employment sites with a substantial level of nearby convenience services also had higher rates of bicycling and walking than other sites did.

In a study of mixed-use sites in Colorado, the Colorado/Wyoming Section Technical Committee of the Institute of Transportation Engineers (ITE) found that average trip rates for individual shops in retail plazas and other mixed commercial settings were below the mean rates for freestanding stores published in ITE's Trip Generation (1991) manual.¹⁸⁶ The committee recommended adjusting trip rates downward by 2.5 percent to reflect the higher likelihood of linked walk trips, instead of separate vehicle trips

¹⁸² Cervero, R. "Land Use Mixing and Suburban Mobility." *Transportation Quarterly*. Volume 42, 1988. p. 429-446.

¹⁸³ Cervero, R. "Land Uses and Travel at Suburban Activity Centers." *Transportation Quarterly*. Volume 45, 1988. p. 479-491.

¹⁸⁴ U.S. Department of Transportation, Travel Model Improvement Program. "The Effects of Land Use and Travel Demand Management Strategies on Commuting Behavior." Prepared by Cambridge Systematics, November, 1994.

¹⁸⁵ The study also found that in locations with a substantial mix of uses, transit use increases with the introduction of financial incentives for transportation demand management. On the other hand, in areas with a limited land use mix, transportation demand management incentives appeared to shift trips from transit to rideshare, resulting in a lower transit mode share than if no incentives were offered.

¹⁸⁶ Colorado/Wyoming Section Technical Committee, Institute of Transportation Engineers. "Trip Generation for Mixed Use Developments." *ITE Journal*, Volume 57, 1987. p. 27-29.

between establishments in mixed-use settings. Replacing short car trips with walk trips would decrease the total number of auto trips, and thus the emissions levels, generated at these settings.

SUBREGIONAL BALANCE OF JOBS AND HOUSING

On a larger scale, promoting a “balance” of employment and housing at the subregional level has been identified as a way to reduce commute distances. The idea is that if people could live closer to their employment sites, they would do so to reduce commute time and costs. Balanced communities offer affordable, high-quality housing that is close enough to employment sites that residents can avoid commuting long distances on congested highways to get to work.

Measuring the jobs-housing balance is somewhat difficult since there is no nonarbitrary geographic scale at which to assess the match or mismatch. Regions as a whole are by definition “balanced,” while individual blocks or neighborhoods almost never are. Considerable debate continues over the effectiveness of the jobs and housing balance as a measure for reducing congestion or improving air quality. On the one hand, increasing the availability of housing near employment centers provides individuals with the option to live closer to work. On the other hand, some researchers have found little evidence suggesting that the balance or mismatch of jobs and housing alone has had a significant effect on commuting patterns.¹⁸⁷

Those promoting a jobs-housing balance suggest that increasing the housing opportunities near major employment centers allows workers to locate closer to their jobs and may reduce traffic. A number of studies suggest that this effect may occur. For example, an analysis in Toronto suggested that the effect of substantial new office construction between 1975 and 1988 on peak-hour work trips was offset by increased housing occupied by people working in the central city.¹⁸⁸ Another study based on 1980-1990 U.S. journey-to-work data showed that “balanced” cities averaged 12 to 15 percent less work-trip VMT per employed residents than did “job-surplus” cities.¹⁸⁹

A simulation of regional development patterns in the Washington, DC area found that an alternative that promoted a closer balance between employment and housing growth within the region resulted in greater transit use and shorter average trip lengths due to greater proximity of housing to jobs. Vehicle trips per household were reduced by 5.0 percent. When combined with a 4.5 percent reduction in average trip length, the balanced alternative resulted in 9.2 percent less VMT per household.¹⁹⁰ Reducing vehicle trips and VMT can lead to similar reductions in vehicle emissions.

A number of studies have found that accessibility to jobs is one of a number of determinants of vehicle ownership. An analysis of travel in the San Francisco region found that controlling for other

¹⁸⁷ From the analysis of the location of jobs and housing in a number of regions, Giuliano, G. and K. Small (“Is the Journey to Work Explained by Urban Structure?” University of California Transportation Center. Working Paper, No. 107, June 1992) and Genevieve Giuliano and Kenneth Small (“Subcenters in the Los Angeles Region.” *Journal of Regional Science and Urban Economics*. Vol. 21, pp. 163-182) concluded that a jobs-housing balance has a statistically significant but not very large influence on actual commuting times and therefore that policies attempting to alter the jobs-housing balance alone are likely to have little impact on commute patterns.

¹⁸⁸ Nowlan and Stewart. “Downtown Population Growth and Commuting Trips.” *Journal of the American Planning Association*. Vol. 57(2), 1991. pp. 165-182.

¹⁸⁹ Cervero, Robert. “Jobs-Housing Revisited.” *Journal of American Planning Association*. 1996.

¹⁹⁰ Metropolitan Washington Council of Governments. “Transportation Demand Impacts of Alternative Land Use Scenarios.” May 31, 1991.

land use and household factors, a doubling in accessibility results in a 7.5 percent decrease in the number of vehicles owned.¹⁹¹ Efforts to incorporate land use factors into the vehicle ownership model of Portland, Oregon, also suggest that the number of retail jobs in a transportation analysis zone is statistically significant in helping to explain residential automobile ownership.¹⁹² As the number of retail jobs in a zone increases, vehicle ownership per household decreases, holding other factors like household income and size constant. The possibility of using transit to get to work is also found to reduce vehicle ownership rates, while residential density does not prove to be important on its own.

By definition, “accessible” areas require shorter travel distances than “nonaccessible” areas. However, a strategy for improving the balance of housing and jobs reduces commute trip distances only if jobs-housing imbalances are a major source of long commute lengths and if people make location decisions at least in part on the basis of commute distances. Some researchers argue that a jobs-housing imbalance has little to do with long commutes.¹⁹³ There are many reasons why the journey to work might play only a limited role in residential location decisions. Rapid job turnover and high moving costs may cause households to seek accessibility to an array of future jobs, two-worker households may be unable to find jobs close together, and the importance of nonwork trips may reduce the importance of travel time to work. In addition, other neighborhood characteristics, such as crime, school quality, and taxes, might overshadow time and travel costs.

The degree to which different factors affect location decisions is widely debated and may vary in different circumstances. An analysis of travel and housing location in the Minneapolis region found that if one is considering communities representing commute differences of only 5 minutes, local service attributes and housing characteristics dominate residential choice. However, within an entire 60-minute commute shed, commute time was found to be overwhelmingly the best explanatory variable of household location choice.¹⁹⁴ The analysis suggested that jobs-housing balances and imbalances were particularly significant influences on residential location decisions for low- to moderate-income single worker households. A recent poll of San Francisco Bay area residents found that given a choice between houses that cost the same, 60 percent would opt for a smaller home closer to where they work rather than a larger one farther away.¹⁹⁵

Although various factors might prevent households from locating close to their places of work, a jobs-housing balance provides more opportunities for living closer to work than a land-use pattern in which employment and residential areas are widely separated. As a result, communities that provide that balance are likely to require shorter commutes, which generate fewer VMT and associated emissions.

¹⁹¹ Kockelman, K. “Travel Behavior as a Function of Accessibility, Land Use Mixing, and Land Use Balance: Evidence from the San Francisco Bay Area.” Submission to the 76th Annual Meeting of the Transportation Research Board. January 1997.

¹⁹² Cambridge Systematics *et al.* *Making the Land Use Transportation Air Quality Connection: Model Modifications*. Vol. 4. Prepared for Thousand Friends of Oregon. May 1996.

¹⁹³ See Giuliano, G. “Is Jobs-Housing Balancing a Transportation Issue?” *Transportation Research Record* 1305, 1991, pp. 305-312; Giuliano, G. and K. Small. “Is the Journey to Work Explained by Urban Spatial Structure?” *Urban Studies* 30:9, 1993. p. 1485-1500.

¹⁹⁴ Levine, J. (University of Michigan) “Land Use Solutions to Transportation Problems? Rethinking Accessibility and Jobs-Housing Balancing.” Paper submitted to the 75th Annual Meeting of the Transportation Research Board. 1996.

¹⁹⁵ *San Francisco Chronicle*. “Long Haul to American Dream.” March 18, 1997. p. A-1.

4.5 TRANSIT ACCESS

Transit systems that are well designed and operated can reduce vehicle travel, resulting in reduced criteria pollutant and greenhouse gas emissions. A transit bus carrying 40 passengers requires only about one-sixth the energy consumption it takes to transport each person in a private vehicle.¹⁹⁶ Transit also helps to reduce traffic congestion. One full 40-foot bus is equivalent to a line of moving automobiles stretching six city blocks, and one full six-car heavy rail train is equivalent to a line of moving automobiles stretching 95 city blocks (assuming traffic operates at 25 mph).¹⁹⁷ Transit provides mobility to individuals of all ages, income levels, and abilities. With an aging population and increased attention being paid to linking low-income families to jobs, improved accessibility and mobility are particularly important.

Techniques for Improving Transit Access

Shifting location of employment and housing centers within a region can render once-useful transit service obsolete. These changes have encouraged many cities across the country to rethink and improve transit access. Two general ways in which transit access can be improved are by expanding transit supply through construction or service improvements, and focusing development around existing transit (transit-oriented development).

EXPANDING TRANSIT SUPPLY THROUGH CONSTRUCTION OR SERVICE IMPROVEMENTS

Cities can expand transit supply through the construction of new transit systems or the expansion of existing facilities. Constructing new systems or expanding existing ones are capital projects with a significant price tag. Cities across the country, however, are determining that an increase in transit access is worth the investment.

Salt Lake City, for example, is currently constructing new light rail and commuter rail systems. Other cities have chosen to expand or alter the mix of transit options provided to residents. The Chicago metropolitan area has proposed extending commuter rail lines to serve the suburbs on the far northern, southern, and western edges of the city. This expansion of service would remove cars and the associated emissions from the roadways and reduce congestion on the area's roads.

Cities can improve transit access by making existing transit services more responsive to the needs of the population they serve. Extending service hours, for example, could capture ridership from individuals who need to travel later or earlier than the existing service allows. Regions have found that reducing wait times at stations (by adding trains or buses to existing lines) and improving transit-related signage (by making bus stops more obvious and posting schedules and route maps at each stop) can encourage transit use.

¹⁹⁶ Average U.S. energy consumption per vehicle mile for an automobile = 5,748 Btu; for a transit bus = 39,081 Btu. US Department of Energy. *Transportation Energy Data Book*. 15th Edition, Table 2.15, p. 2-25.

¹⁹⁷ A full 40-foot bus holds about 70 people including standees. At an estimated national average of 1.2 persons per automobile, one bus is equivalent to 58 automobiles. A full heavy rail car accommodates about 180 people; a train of six cars carries 1,080 people, replacing 900 automobiles. Ten city blocks per mile, an average auto length of 16 feet, and a one-car-length-per-each-10-mile-per-hour following length is assumed. (American Public Transit Association. *1994-1995 Transit Fact Book*.)

FOCUSING DEVELOPMENT AROUND EXISTING TRANSIT STATIONS (TRANSIT-ORIENTED DEVELOPMENT)

For some areas, the most cost-effective way to improve transit access may be to increase development around existing stations, rather than extend transit service. This type of development is typically referred to as transit-oriented development (TOD). The premise of transit-oriented development is that locating residential development and employment near transit stations increases the market for transit services and yields greater ridership than is achieved at stations (or bus stops) surrounded by low-density development.

Figure 4-8 shows three different development patterns with varying levels of transit access for 640 households in a 1 square mile zone. The first development alternative features a perfectly uniform density of households to 1-acre parcels. The second alternative increases the density of households to four per acre and locates them on the east and west sides of the zone, as if oriented to north-south arterial streets. The last alternative also has density of four households per acre, but the households are oriented to the side of the zone where transit service is available. Although the three alternatives have equal overall density, they feature very different levels of transit accessibility.¹⁹⁸

Figure 4-8: Transit Access Distance and Local Land Use Organization

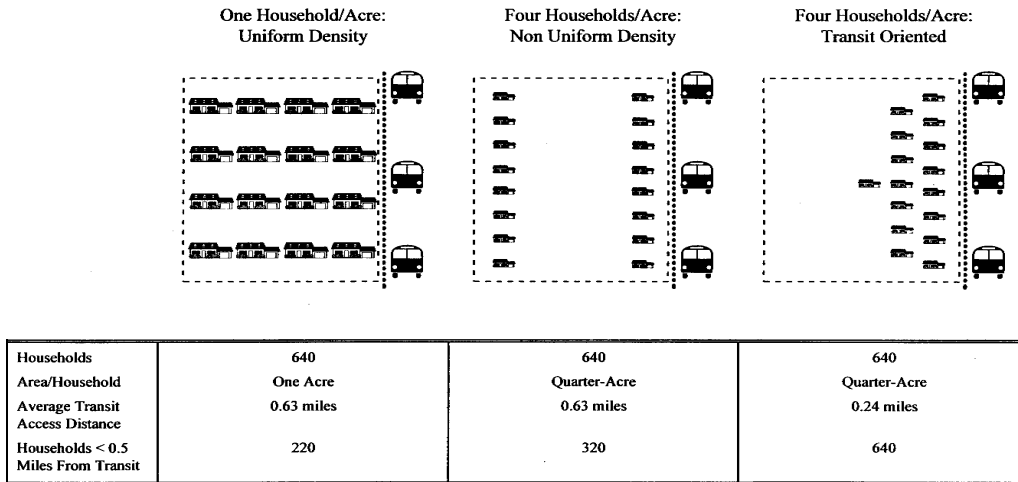


Diagram excerpted from: Eash, R. "Incorporating Urban Design Variables in Metropolitan Planning Organizations' Travel Demand Models." Prepared for Conference on Urban Design, Telecommuting, and Travel Behavior, Travel Model Improvement Program. October 1996.

As discussed below, results from a number of empirical studies and regional simulations indicate that increasing transit accessibility through transit-oriented development has the potential to increase the share of trips made by transit.

¹⁹⁸ Locating higher density development near transit does not necessarily mean increasing an area's average density. Rather, it could simply rearrange land uses and densities so that more people are close to the transit lines.

Indirect Environmental Impacts from Improving Transit Access

Effective transit systems require supportive land use patterns. Locating high-density commercial and residential development around transit stations is expected to reduce vehicle travel for two reasons:

- *Mode Choice* – Providing increased transit access increases the likelihood that the average trip will be made by transit, irrespective of vehicle ownership rates.
- *Vehicle Ownership* – Transit provides a potential substitute for vehicle travel and is expected to reduce the need to own personal vehicles for mobility.

EVIDENCE FROM REGIONAL SIMULATIONS

A number of metropolitan areas including Orange County (CA), Los Angeles, San Francisco, Boston, Seattle, Baltimore, Washington (DC), Dallas, and Denver have conducted simulations using regional travel demand forecasting models to identify the types of urban form that best support transit use and reduce dependence on vehicle travel. These analyses generally find that compact regions with a limited number of subregional centers linked by transit can support transit ridership and reduce VMT compared with other regional development patterns.¹⁹⁹

An analysis of alternative land-use/transportation plans in the Chicago region, using a sketch-planning network of the northeastern Illinois region, indicated that compact patterns of residential and employment development would reduce vehicle travel. In particular, focusing development on regional corridors was projected to yield an increase in transit use and a decrease in average trip length due to an improvement in the jobs-housing balance. Dense regional centers were projected to produce less VMT due to increased transit use, and produce even less VMT when transit service improvements are added. In addition, this development pattern was projected to reduce auto trip lengths due to the more compact nature of the region.²⁰⁰

Montgomery County, Maryland, performed a similar analysis, using computerized transportation models to examine alternative long-range development scenarios and their impact on VMT and traffic congestion. The study found that by clustering most new development near an expanded rail and busway system, making improvements to pedestrian and bicycle conditions, and equalizing commuter subsidies, the county could accommodate a doubling of households and employment over 30 years with acceptable levels of traffic congestion. The strategy could result in countywide VMT and traffic congestion levels comparable to those of the existing 2010 forecast, while accommodating 62 percent more houses and 29 percent more jobs in the county than the current forecast does.²⁰¹

¹⁹⁹ Parsons Brinckerhoff Quade and Douglass, Inc. "Part I: Transit, Urban Form, and the Built Environment: A Summary of Knowledge." Transit Cooperative Research Program Report 16. *Transit and Urban Form*. Washington, DC: Transportation Research Board, 1996. p.5.

²⁰⁰ The sketch/aggregated planning approach did not include a trip-generation step, so auto ownership and auto occupancy were fixed parameters. These aspects suggest that the magnitude of effects may have been underestimated (Lupa, Mary, et. al., "Transportation Sketch Planning with Land Use Inputs." *Transportation Research Record 1499*. 1995. p. 83-94.)

²⁰¹ Replogle, Michael. "Land Use/Transportation Scenario Testing: A Tool for the 1990s." Silver Spring, MD: Montgomery County Planning Department. 1993. (Prepared for Presentation at Transportation Research Board 1993 Annual Meeting.)

EVIDENCE FROM EMPIRICAL STUDIES

A number of empirical studies also show a relationship between transit accessibility and factors that affect air quality, such as mode choice or car ownership. Several studies, including some international case studies, describe how regional transit systems have promoted development around stations, helping to improve accessibility and reduce regional congestion.²⁰² Locating high-density commercial and residential development around transit stations improves accessibility to transit since more households are within walking distance of transit facilities.

Several studies show that increased density around transit stations is associated with increased transit use.²⁰³ Light rail stations in higher density residential settings have higher ridership than those in lower density settings, holding constant other factors that influence ridership such as the distance between stations, the availability of feeder bus service, and the distance of the station from the Central Business District.²⁰⁴ Increasing densities depend on adequate transit service to provide access without excessive congestion. San Francisco's higher density and better transit service shorten trip lengths sufficiently to allow 1 mile on transit to replace 8 miles of driving compared with trips in suburban Danville-San Ramon.²⁰⁵ Compared with households in Danville-San Ramon, the average household in Nob Hill spent nearly \$14,000 less on autos, the average resident burnt 339 gallons less gasoline, and emitted 14 kg less hydrocarbons, 12 kg less nitrogen oxides, and 98 kg less CO per year.

Increasing accessibility of housing to transit increases transit mode shares. For the Washington, DC Metrorail (heavy rail) system, for example, a 1987 survey of residential buildings within one-third mile of a suburban station found rail transit capture rates for work trips in the range of 18 to 63 percent, which is significantly higher than the regional work-trip average. Ridership was highest for projects closest to Metrorail stations and among station-area residents headed to central Washington, DC.²⁰⁶

A more recent study of travel to regional shopping centers in California found that travel mode shares were best explained by the amount and regional coverage of public transit services and the density and proximity of the surrounding land uses. One shopping center in a suburban, low-density area with limited transit service had a 95 percent auto share, while the shopping center in an urban, high-density

²⁰² Parsons Brinckerhoff Quade and Douglass, Inc. "Part IV: Public Policy and Transit-Oriented Development: Six International Case Studies." Transit Cooperative Research Program Report 16. *Transit and Urban Form*. Washington, DC: Transportation Research Board, 1996. pp. 37-70.

²⁰³ High densities around transit stations may reflect high land values associated with desirable, accessible locations.

²⁰⁴ For example, a study of 19 light-rail lines in 11 regions found that a 10 percent increase in residential density yields on average 5.9 percent more riders per station. Further, a 10 percent increase in CBD employment density increases light rail boardings at stations outside the CBD by about 4 percent holding other factors constant (Parsons Brinckerhoff Quade & Douglas, Inc. "Transit and Urban Form." Transit Cooperative Research Program. Washington, DC: National Academy Press, 1996). The most useful studies for examining environmental implications focus on *mode shares*, since transit ridership does not provide information on vehicle travel reduction. It is possible that dense areas yield increased transit ridership but also yield increased driving because more trips are made than in low-density areas.

²⁰⁵ The savings result from the increased convenience of higher density mixed-use areas. Holtzclaw, J. "Explaining Urban Density and Transit Impacts on Auto Use." Presented to State of California Energy Resources Conservation and Development Commission. January 15, 1991.

²⁰⁶ Station location also was found to play a role in transit ridership. Downtown offices averaged transit work trip modal shares of about 50 percent, compared with less than 20 percent for suburban office projects near rail stations. These differences may reflect differences in parking availability and price, pedestrian friendliness, or transit time compared to driving time. JHK and Associates. *Development-Related Ridership Survey I*. Washington, DC: Washington Metropolitan Area Transit Authority, 1987.

area with high transit service had the highest use of transit and walking—roughly 60 percent for the two modes combined. Modal share trends were consistent within demographic categories (e.g., age, income, household size), suggesting that site characteristics were an important factor in mode share.²⁰⁷

A study of transit-oriented development in California found that developments near transit have significantly higher shares of trips made by transit than the regional average.²⁰⁸ For the 27 surveyed residential developments near transit, rail was used for 19 percent of work trips. For developments near Bay Area Rapid Transit (BART), rail was used for 33 percent of work trips, significantly higher than the 5 percent 1990 average for the three BART-served counties. In each Bay Area city served by BART, residents living near rail stations are about five times as likely to commute by rail as is the average resident-worker in the same city. Rail's mode share falls linearly with distance from the station for the surveyed housing projects—on average, by about 0.85 of a percentage point for every 100-foot increase in walking distance.

In the same study, surveys of 18 office sites near rail found that the average rail modal split for work trips was nearly 9 percent. For worksites near BART, rail share was 17 percent, well above the Bay Area's rail work trip share of 5 percent. For offices, the ridership gradient follows an exponential decay function. For non-BART sites, only offices within 500 feet of a station have as much as 15 percent of their workers commuting by rail; beyond 500 feet, no more than 10 percent of workers take rail to work.

Proximity to transit is one of the most important factors in encouraging transit mode share. An analysis of transit-oriented developments in California concluded that barring serious problems like urban blight or high crime rates, the characteristics of the immediate surroundings (e.g., mix of land uses and pedestrian quality) were of minor importance once people were near stations. As long as development was geographically close and oriented toward a rail station, reasonable percentages of residents and workers traveled by rail. When both trip ends were clustered around a transit station, the odds of traveling by rail transit increased dramatically.²⁰⁹

Other analyses have found that distance to transit is the most significant factor in the decision whether to reach transit by foot. An analysis of pedestrian access to transit using a 1992 survey of BART riders found that distance to the transit station was the most significant factor in deciding whether to walk to the station, drive, or take a bus.²¹⁰ Generally, individuals will walk up to about a half mile.²¹¹

²⁰⁷ The suburban low-density, low-transit service sites consistently had higher shares of personal vehicle use than the urban high-density, high-transit service sites for shoppers within all income categories. JHK & Associates and K.T. Analytics. *Analysis of Indirect Source Trip Activity: Regional Shopping Centers*. Prepared for California Environmental Protection Agency, Air Resources Board. November 1993.

²⁰⁸ Cervero, R. "Ridership Impacts of Transit-Focused Development in California." University of California Transportation Center, Working Paper No. 176. 1993.

²⁰⁹ Cervero, R. "Ridership Impacts of Transit-Focused Development in California."

²¹⁰ This study found that walk trips accounted for the highest proportion of home-based access trips at stations located in dense, mixed-use areas of San Francisco—74.2 percent of trips at the 16th and Mission station and 67.2 percent of trips at the 24th and Mission station. At the opposite end of the spectrum, the Fremont station had a 3.9 percent pedestrian share and the Orinda station had a 2.8 percent pedestrian share. These stations are surrounded by large parking lots and low-density development. When individual characteristics, such as gender, age, and income, were taken into account, population density provided to be insignificant in the decision of whether to walk or take another mode to the transit station. Rather, the distance to the transit station was the most significant factor in mode choice (Loutzenheiser, David. "Pedestrian Access to Transit: A Model of Walk Trips and their Design and Urban Form Determinants Around BART Stations." Presentation to 76th Annual Meeting of Transportation Research Board, 1997.)

Transit-oriented communities often include mixed-use clusters of housing, office, and retail. By bringing these activities closer together, these developments also reduce the need to own a private vehicle. In the Portland, Oregon region, Metro incorporated a measure of transit accessibility—the number of employees within 30 minutes travel time by transit—into its vehicle ownership model. Based on statistical analysis in which the utility of owning zero, one, two, or three cars depends on a variety of factors, vehicle ownership drops as transit accessibility increases, independent of income and other household demographic factors.

4.6 SUPPORT FOR PEDESTRIAN AND BICYCLING ACTIVITY/ MICROSCALE URBAN DESIGN FACTORS

Currently we don't build either land use or transportation systems for pedestrians and bikes, creating barriers that are dangerous, inconvenient, and aesthetically displeasing.

Aspects of the built environment such as building orientation, street connectivity and design, and building design all contribute to the relative friendliness of that area to pedestrians and bicyclists, and to the general aesthetic appeal of an area. Together, these are often referred to as “microscale” urban design factors—small-scale elements that affect the safety, convenience, and desirability of living and working in areas of higher density and of using transit and nonmotorized modes of transportation.

These design factors affect travel mode choice. In areas that do not include adequate bicycle and pedestrian facilities (sidewalks, bike lanes, and crosswalks), people are more hesitant to travel by foot or bike. More than 6,000 pedestrians die in collisions with cars each year, and 110,000 are injured. , According to federal statistics, pedestrians and bicyclists account for 15 percent of all “highway” fatalities.²¹² The risks fall disproportionately on senior citizens, who make up 13 percent of the population but account for 23 percent of pedestrian fatalities. “Long crosswalk distances and traffic signals timed for young adults present added difficulties, even life-threatening hazards, for older persons at intersections,” according to the American Association of Retired Persons.²¹³

Children face similar challenges; only 13% of trips to school are made by walking,²¹⁴ a figure down from what some experts believe was more than 50% in the 1960s.²¹⁵

²¹¹ Data from the National Personal Transportation Study suggest that 70 percent of Americans walk 500 feet (one-tenth of a mile) for normal daily trips, 40 percent walk 1,000 feet (one-fifth of a mile) and 10 percent walk up to a half mile (Unterman, D. “Accommodating the Pedestrian: Adapting Towns and Neighborhoods for Walking and Bicycling.” *Personal Travel in the U.S., Vol. II, A Report of the Findings from 1983-1984 NPTS, Source Control Programs*. U.S. Department of Transportation. 1990). A study in Montgomery County, MD, found that residents will walk one-quarter of a mile median distance to a bus and one-half of a mile to a rail stop (Replogle, M. *Bicycles and Public Transportation*. 1984. Cited by Holtzclaw, J. “Using Residential Patterns and Transit to Decrease Auto Dependence and Costs.” Natural Resources Defense Council. June 1994).

²¹² In 1996, of 41,907 traffic fatalities, 5,412 were pedestrians and 761 were bicyclists. Source: U.S. Department of Transportation, Bureau of Transportation Statistics. *National Transportation Statistics 1998*. Table 3-19.

²¹³ Quote is from Jo Reed, of the American Association of Retired Persons. Figures were taken from: Witham, Drake and Bill Salisbury. “The Walking Wounded.” *St. Paul Pioneer Press*. April 14, 1997, B2.

²¹⁴ Calculations from 1995 National Personal Transportation Survey.

²¹⁵ Ulman, Marian, “A Healthy Start: Aiming to Revive the Walk to School.” *Philadelphia Inquirer*, March 28, 2000.

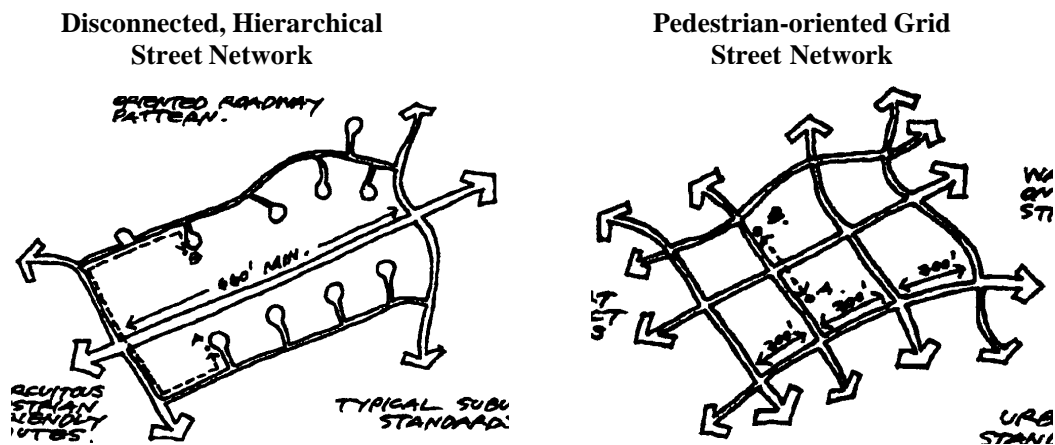
By increasing the relative desirability of walking compared with driving, urban design factors can encourage more walking or bicycling trips. Reductions in vehicle travel and emissions can occur if walking and bicycling trips replace vehicle trips.

Techniques for Enhancing Micro-Design Features

A community's micro-design may be improved through pedestrian and bicycle facilities and street connectivity, as well as design and architecture.

Pedestrian and Bicycle Facilities and Street Connectivity: Typical modern communities often contain a hierarchy of dead-end or cul-de-sac local streets that lead to collector streets and then to major arterials that connect communities to others via freeways. (See Figure 4-9.)

Figure 4-9: Street Network Design



Many communities are bounded by walls, lakes, or other physical barriers, and often do not have sidewalks. This pattern makes pedestrian and bicycle travel difficult since circuitous routes and limited access increase the length of trips. Collector and arterial streets tend to be wide to allow vehicles to move faster and to handle the large traffic volumes that are channeled onto a few high-traffic routes. Wide streets are difficult and often dangerous for pedestrians and bicyclists to cross or to share with vehicles, especially if they lack facilities such as sidewalks and crosswalks. Such poor pedestrian environments encourage people to drive, even for short trips.

Aside from well-connected street networks, features that improve the pedestrian environment include sidewalks, clearly marked crosswalks and walk signals, lighting, and other amenities, such as shade trees, benches, and streetscapes designed with the pedestrian in mind. Features that improve the bicycling environment include bicycle paths and lanes on streets, bicycle parking, clear signs, and facility design that improves accessibility.

Design and Architecture: Just as street connectivity and bike and pedestrian facilities are important, the design and placement of buildings and the aesthetics of streetscapes also shape people's attitudes toward travel. In residential areas, design for pedestrians includes making the street environment more attractive by placing porches and home entrances in the foreground, and garages and driveways more in the background. In commercial areas, pedestrian design means orienting stores to the street with

window displays and pedestrian entrances, rather than entrances through parking lots and garages. Narrow streets, shade trees, well-maintained sidewalks and traffic slowed through traffic calming measures (such as speed bumps, raised crosswalks, traffic circles, and median barriers) also improve the pedestrian environment. In less pedestrian friendly environments, structures are located without reference to neighboring buildings or properties. Some office parks lack provision for foot traffic, so that a walk from an off-site bus stop to an office might involve walking through large parking lots.

Indirect Environmental Effects of Microscale Urban Design and Pedestrian and Bicycle Support: Travel Mode Choice

The most significant benefit of good urban design is that it reduces auto travel by enabling other travel choices.

EFFECT OF DESIGN FOR PEDESTRIANS AND BICYCLISTS

Several studies have found that higher levels of pedestrian and bicycling activity occur in areas with street connectivity and pedestrian amenities than in those without those features. For example, a recent study compared two Puget Sound area neighborhoods that are similar in terms of gross residential density and intensity of commercial development: Wallingford in Seattle and Crossroads in Bellevue. The analysis found that Wallingford—the neighborhood with a high level of pedestrian network connectivity—had almost three times as much pedestrian activity as did Crossroads, which had a low level of pedestrian connectivity.²¹⁶

An analysis conducted in Portland, Oregon (using data from a home interview survey, results from regional travel forecasting models, and land use information) found that the pedestrian environment is a significant factor in mode choice decisions and vehicle miles traveled. In particular, the analysis found that improving the quality of the pedestrian environment to a level comparable to that of Portland's most pedestrian-oriented zones would result in a 10 percent reduction in VMT.²¹⁷ A similar analysis by the Maryland National Capital Parks and Planning Commission, using its regional travel models, found that pedestrian and bicycle friendliness is quantifiable and is a significant predictor of work trip mode choice.²¹⁸

Neither the Portland nor the Maryland studies explicitly included safety in their analyses. Not surprisingly however, pedestrian safety is a factor that people typically consider when deciding whether to walk in an area. An analysis of employment sites in southern California, for example,

²¹⁶ This study, however, did not address effects on vehicle travel. Moudon, *et al.* "Effects of Site Design on Pedestrian Travel in Mixed Use, Medium Density Environments." Submission to 76th Annual Meeting of the Transportation Research Board, 1997.

²¹⁷ A pedestrian environment factor (PEF), measured on a scale of 4 to 16, was developed based on street connectivity, sidewalk connectivity, ease of street crossing, and topography. A value was assessed for each zone in the travel demand forecasting model. The model found household vehicle trips and vehicle miles of travel declined with increases in the PEF. Multiple regression analysis suggested that each unit increase in the zonal PEF would reduce daily VMT per household by 2.5 percent, or 0.7 miles. Cambridge Systematics *et al.* *Making the Land Use Transportation Air Quality Connection: Analysis of Alternatives. Model Modifications.* Vol. 4. Prepared for Thousand Friends of Oregon. May 1996.

²¹⁸ Repogle, M. *Integrating Pedestrian and Bicycle Factors into Regional Transportation Planning Models: Summary of State-of-the-Art and Suggested Steps Forward.* Environmental Defense Fund. July 20, 1995.

found that areas characterized as “safe” had higher levels of transit use and bicycling and walking than those that were characterized as “unsafe.”²¹⁹

A number of studies contrasting bicycling in European cities with biking in U.S. communities note that bicycling is thriving in those metropolitan areas that have adopted policies to make bike travel faster, safer, and more convenient. In Munich, Germany, for example, bicycle use has almost tripled since 1976, with modal split rising from 6 percent to 15 percent. The increase is due in part to the fact that the length of the bikeway network was more than doubled during that period, all residential neighborhoods in the city have been traffic calmed, and bicycle parking facilities have been expanded.²²⁰

The pedestrian environment also has been found to influence decisions about vehicle ownership. In the Portland, Oregon regional travel models, data on the pedestrian environment were found to improve the predictive ability to estimate the number of vehicles owned per household.²²¹ Similarly, in a logit model for vehicle ownership developed by the Chicago Area Transportation Study, the pedestrian environment and auto work trip mode share were found to be statistically significant in predicting vehicle ownership rates. Less than 40 percent of these households in urban areas have two or more vehicles, while more than 90 percent in suburban areas have two or more vehicles.²²² As these studies indicate, a pedestrian-friendly environment allows walking trips to substitute for vehicle trips and, as a result, reduces the need to own as many vehicles.

A number of studies suggest that grid street patterns can reduce vehicle trip lengths. For example, a simulation study found that traditional grid circulation patterns reduce VMT by 57 percent compared with VMT in more conventional networks.²²³ A modeling analysis of two simple, hypothetical street patterns estimated that total morning peak hour vehicle travel would fall more than 10 percent when a conventional suburban street pattern is replaced by a grid network.²²⁴ The full VMT implications are unclear, however, since the simulations assume that trip frequencies are unaffected by the street patterns. Some researchers argue that increased accessibility associated with grid street patterns can

²¹⁹ In this study, sites were considered to have a higher level of safety if they were characterized by sidewalks, street lighting, pedestrian activity, and the absence of vacant lots. In locations that offered TDM incentives, the share of transit was 5.4 percent in safe areas compared with 3.6 percent in less safe areas. The share of bicycling and walking was 3.2 percent in safe areas compared with 1.7 percent in less safe areas. U.S. Department of Transportation, Travel Model Improvement Program. “The Effects of Land Use and Travel Demand Management Strategies on Commuting Behavior.” Prepared by Cambridge Systematics. November 1994. p. 3-18.

²²⁰ Pucher, John. “Bicycling Boom in Germany: A Revival Engineered by Public Policy.” *Transportation Quarterly*, Vol. 51, No. 4, Fall, 1997. P. 41.

²²¹ Cambridge Systematics *et al.* *Making the Land Use Transportation Air Quality Connection: Analysis of Alternatives. Model Modifications*. Vol. 4. Prepared for Thousand Friends of Oregon. May 1996.

²²² Eash, R. “Incorporating Urban Design Variables in Metropolitan Planning Organizations’ Travel Demand Models.” Conference on Urban Design, Telecommuting, and Travel Behavior. Williamsburg, VA, October 1996.

²²³ Kulash, Anglin, and Marks “Traditional Neighborhood Development: Will the Traffic Work?” *Development*, Vol. 21, July/August 1990, pp. 21-24.

²²⁴ McNally and Ryan. “A Comparative Assessment of Travel Characteristics for Neotraditional Developments.” University of California Transportation Center. University of California at Berkeley. Working Paper No. 142. August 1992.

induce additional travel. The degree to which this travel occurs by walking or driving is unclear and may differ depending on specific circumstances.²²⁵

EFFECT OF BUILDING DESIGN AND ARCHITECTURE

A preponderance of research finds that urban design can affect mode choices. However, identifying discernible travel effects from individual design features has proven difficult. For example, a study of 12 census tracts in the San Francisco Bay area found that most individual neighborhood urban design features alone were not useful for explaining mode choice. However, when considered as a bundle of attributes, the influence of urban design was apparent. Pedestrian design was found to increase the probability that a nonmotorized mode would be used for nonwork trips by about 10 percent.²²⁶ A separate analysis of four neighborhoods in the San Francisco area also found no evidence that individual residential design elements has an effect on travel. However, the research suggested that neighborhood design as a whole is an important determinant of whether residents perceive walking as an option and affects pedestrian activity in a community.²²⁷ Although certain specific design treatments, such as building orientation, might appear trivial, their collective influences may be important.²²⁸

4.7 SYNERGIES: COMBINING TECHNIQUES

Many of the above patterns and practices—compact development, mixing of land uses, higher density development oriented around transit, and pedestrian and bicycle facilities—have demonstrated positive environmental implications—reducing infrastructure requirements, reducing vehicle travel, reducing land and habitat consumption, and reducing water consumption and pollution.

The efficacy of these practices depends on how well they are implemented, and how they are combined with other programs. Some of the benefits of mixed-use development, for example, require

²²⁵ Crane, R. "Cars and Drivers in the New Suburbs." *Journal of the American Planning Association* 62: 1, Winter 1996. pp. 51-65. A 1992 study of travel in four San Francisco neighborhoods found that residents of older, compact neighborhoods made 2.75 to 5.5 times as many shopping trips by walking as residents of more auto-oriented neighborhoods, but that residents of both types of neighborhoods made about the same number of auto trips to regional shopping centers. Handy, S. *Regional Versus Local Accessibility: Implications for Non-Work Travel*. Doctoral Dissertation, University of California, Davis. Institute of Transportation Studies. 1992.

²²⁶ Transit Cooperative Research Program (TCRP). *Influence of Land Use Mix and Neighborhood Design on Transit Demand*. TCRP Project H-1. March 1996.

²²⁷ Handy, Susan. "Understanding the Link between Urban Form and Travel Behavior." Paper presented at the 74th Annual Meeting of the Transportation Research Board, January 1995. In different areas, different types of design elements may be appropriate or fit into the neighborhood environment differently. A specific element such as the absence or availability of trees and shrubs at sidewalks may not be effective in the absence of other important pedestrian enhancements. This analysis suggests the importance of comprehensive design rather than identifying a specific design element that works in all places. The overall pedestrian environment is the prime concern.

²²⁸ Cervero, Robert. *Suburban Gridlock*. New Brunswick, NJ: Rutgers University Press, 1986. p. 61. A study conducted by Susan Handy in Austin, Texas, confirms this finding. In the study, Handy surveyed residents from six Austin neighborhoods that are similar in socio-economic profile but different in design characteristics. Handy found that respondents from Clarksville—the neighborhood in which the quality of the pedestrian environment is high and many households are within walking distance of commercial areas—walked to a store about six times per month, as compared with residents of the other neighborhoods, who walked to a store between 0.72 and 2.06 times per month. Handy, Susan. "Urban Form and Pedestrian Choices: Study of Austin Neighborhoods." *Transportation Research Record* 1552. p. 142.

pedestrian amenities. The reverse is also true. Adding pedestrian facilities, such as sidewalks and crosswalks, may be most effective in reducing vehicle travel when a variety of shops and services are within a short walk. Provided together, land use characteristics produce synergy—enhanced benefits due to incorporating multiple beneficial aspects of design into communities.²²⁹

Measuring the Effects of Combined Policies

The previous sections examined the impacts of individual actions. It is nonetheless difficult to isolate the effects of specific aspects of urban form on travel. Certain land use attributes, such as high density, a mix of land uses, and a pedestrian-friendly environment tend to occur together.²³⁰ This section therefore reviews studies that look at the combined effects of density, transit, etc.

In practice, isolating the effects of individual land use characteristics on travel behavior may not be extremely important. The evidence indicates that the location of development in a region is important in affecting trip distances and that a *combination* of urban design factors is important in influencing mode choice. There appear to be synergies that come from combining beneficial aspects of land use and thresholds in the travel effects of individual land use factors. Thresholds occur when the travel effects of changing one land use factor are limited unless other land factors also are altered.

Several studies have found that changes in individual microscale aspects of urban form, such as adding sidewalks and street benches, may not be sufficient to achieve changes in vehicle ownership or mode choice if the region as a whole is oriented toward vehicle travel. For example, an analysis of travel in Palm Beach County, Florida, found that transit mode share was minimal in all communities examined despite differences in design, presumably because the entire region is relatively auto-dependent, with limited transit service. Similarly, other studies have found that in a low-density area characterized by a wide separation of distinct land uses, sidewalks and attractive landscaping are unlikely to prompt residents to walk to shops and stores.²³¹ Some newly built neotraditional communities may not significantly reduce vehicle travel if they are not regionally accessible or transit-accessible.²³²

²²⁹ A community that contains a mix of land uses but that does not provide a pedestrian-friendly environment would be unlikely to achieve the full benefits associated with a mix of uses, such as reduced vehicle trip-making. People may drive even short distances between employment, retail, and restaurants if the pedestrian environment is poor. Locating higher density development near transit and employment provides the mass necessary for local stores that rely on foot traffic to locate there. Although not all compact urban environments have a mix of uses or transit-supportive urban design, few low-density environments have meaningful land use mix or transit-oriented amenities (Parsons Brinckerhoff Quade & Douglas. "Transit, Urban Form, and the Built Environment: A Summary of Knowledge." Transit Cooperative Research Program. Washington, DC: 1996. p. 25.)

²³⁰ A number of researchers have found correlations between these variables. See: Dunphy, R. and K. Fisher. *Transportation, Congestion and Density: New Insights*. Urban Land Institute, August 1993. Holtzclaw, John. "Using Residential Patterns and Transit to Decrease Auto Dependence and Costs." Natural Resources Defense Council. June 1994. Loutzenheiser, David. "Pedestrian Access to Transit: A Model of Walk Trips and their Design and Urban Form Determinants around BART Stations." Submission to the 76th Annual Meeting of the Transportation Research Board. January 1997. Cambridge Systematics, Inc.; Parsons, Brinckerhoff, Quade & Douglas; S.H. Putman Associates, Inc. *Making the Land Use Transportation Air Quality Connection: Model Modifications*. Vol. 4. Prepared for Thousand Friends of Oregon. May 1996.

²³¹ Cervero, R. and K. Kockelman. "Travel Demand and the Three Ds: Density, Diversity, and Design." Institute of Urban and Regional Development, University of California at Berkeley. July 1996.

²³² The Kentlands community in suburban Washington, DC, is a well-known example of a new neotraditional development. Although Kentlands has been cited for its character and quality of life, the community is not located in an inner suburb or along the region's transit rail system. As a result, one would not expect significant differences in transit share or vehicle travel between Kentlands and other nearby suburban communities.

When travel options are available, however, urban form and design characteristics can affect travel behavior to a greater degree, particularly in terms of mode choices. Increases in the mix of land uses, improved transit access to employment, and enhancements to the pedestrian environment together can alter the relative utilities of different choices, under the right conditions. Density is generally viewed as important because without compactness, urban design and mix are often not sufficient to ensure a built environment in which transit, bicycle, and pedestrian travel can play an important role. More compact neighborhoods support a diversity of land uses since they require commercial activities, which may be located close enough to a large population to facilitate nonmotorized trips. Researchers have concluded that higher *densities*, *diverse* land uses, and pedestrian-friendly *designs* (the three Ds) must co-exist to a certain degree if meaningful transportation benefits are to accrue.²³³

Evidence from Comparisons of Communities

Household characteristics like income, household size, and employment characteristics affect travel behavior. Several studies that control for these factors suggest that urban design and land use patterns have an important effect on travel behavior regardless of demographics. In the San Francisco area, a comparison of two neighborhoods with similar socio-economic characteristics found that residents of the compact neighborhood were more likely to walk or bicycle than residents of the auto-oriented community. When income and auto-ownership were taken into account, households with one or more cars in the “traditional” Rockridge neighborhood were about twice as likely to use a nonautomotive mode for nonwork trips as households in the “suburban” Lafayette neighborhood. A member of a two-car household in Rockridge had a 19 percent probability of walking, bicycling, or riding transit for a nonwork trip compared with a 9 percent probability for a similar resident of Lafayette.²³⁴

The San Francisco Bay area has been the subject of considerable study due to its wide variation in land use types and neighborhoods. An analysis of trip data from a 1980 regional travel survey of San Francisco Bay area households found that those in newer suburban communities have substantially higher vehicle trip generation rates, a higher proportion of drive-alone trips, and a lower percentage of public transportation trips than households in communities that have high-density, mixed land use, and interconnected street networks.²³⁵ For all trips, the rate of travel by transit in compact communities was more than double the rate in suburban communities (7 percent compared with 3 percent) and the share of trips made by walking was 50 percent greater (12 percent compared with 8

²³³ Cervero, R. and K. Kockelman. “Travel Demand and the Three Ds: Density, Diversity, and Design.” Institute of Urban and Regional Development, University of California at Berkeley. July 1996; Cervero, R. “Mixed Land Uses and Commuting: Evidence from the American Housing Survey.” *Transportation Research*. Vol. 30, No. 5: 361-377. 1996.

²³⁴ Transit Cooperative Research Program (TCRP). *An Evaluation of the Relationship between Transit and Urban Form*. Research Results Digest, No. 7. June 1995.

²³⁵ This analysis was based on data from a 1980 regional travel survey of San Francisco Bay area households. Communities were defined as suburban if they were developed since the early 1950s with segregated land uses, have a well-defined hierarchy of roads, concentrate site access at a few key points via arterial roadways, and have relatively little transit service. Survey zones were labeled traditional if they were mostly developed before World War II, have a mixed-use downtown with significant on-street parking, and have an interconnecting street grid and mixed land uses. (Friedman, Bruce, Stephen Gordon, and John Peers. “Effect of Neotraditional Neighborhood Design on Travel Characteristics.” *Transportation Research Record 1466*. p. 63-70.)

percent). Auto use per household was about 32 percent higher in the suburban areas (7.1 trips per day) than in the compact areas (5.3 trips per day).²³⁶

Another study in the San Francisco Bay area found results similar to those cited above for nonwork trips: residents of older, compact neighborhoods make more trips by nonmotorized modes than residents of suburban neighborhoods do.²³⁷ Neighborhood design may provide the most potential for reducing nonwork VMT, since shopping and recreational activities are accessible by walking and bicycling. Residents of older, compact neighborhoods made 2.75 to 5.5 times as many shopping trips by walking as residents of more auto-oriented neighborhoods do. A set of neighborhood case studies suggests that urban form is an important determinant of whether residents perceive walking as an option. Short distances, commercial areas designed for pedestrian access, and certain types of destinations (such as restaurants) are particularly conducive to pedestrians.²³⁸

On the East Coast, trip data compiled for two older, compact neighborhoods in Portsmouth, New Hampshire, showed that trip rates in these neighborhoods, which have moderate residential densities, gridded street patterns, and local shops and services, were about 50 percent lower than those predicted by the ITE Trip Generation manual.²³⁹

Finally, a study recently conducted for a proposed suburban “village center-style” development in the San Joaquin Valley, California, estimated that the project would produce about one-third less vehicle travel per household on average than a typical single-use, low-density suburban housing tract would. The study also projected that such suburban villages could reduce the number of automobile trips by about 13 percent per household when compared with the typical suburban development pattern.²⁴⁰

An Evaluation of Synergistic Policies

Like the strategies, individual policies may be effective but they are most valuable when pursued comprehensively.

Portland, Oregon, recently adopted a regional Vision 2040 and now evaluates transportation and development projects according to how well they move the region toward that vision. The region expects to grow 60 percent by 2040, and its citizens are deciding how to meet today’s needs while not

²³⁶ The analysis suggests that community design and urban form have a significant relationship to travel behavior. The researchers eliminated from analysis those in the lowest and highest income categories; however, differences in income, demographics, and other factors may explain some of the travel differences.

²³⁷ Handy, Susan. “How Land Use Patterns Affect Travel Patterns: A Bibliography.” *Built Environment*. Winter/Spring 1992.

²³⁸ The researchers noted that given an opportunity to walk, it is likely that more residents will choose to walk. However, not all of these trips will be in place of driving; many of them will be in addition to driving trips. This increased accessibility enhances quality of life even when it does not reduce vehicle travel. The travel impact depends on what other choices are available and thus will be different in various contexts. (Handy, Susan. “Understanding the Link between Urban Form and Travel Behavior.” Paper presented at the 74th Annual Meeting of the Transportation Research Board. January 1995.)

²³⁹ White Mountain Survey Company. “City of Portsmouth Traffic/Trip Generation Study.” Ossipee, New Hampshire: White Mountain Survey Company, 1991 (unpublished), cited by Robert Cervero (“Mixed Land Uses and Commuting: Evidence from the American Housing Survey.” 1996. p. 362).

²⁴⁰ Fehr and Peers. “Effect of Stockton’s Proposed Suburban Village Center Development.” January 1992. As cited by Parker, Terry. California Air Resources Board. *The Land Use-Air Quality Linkage: How Land Use and Transportation Affect Air Quality*. 1994. p. 10.

damaging the city's ability to meet the needs of citizens in 2040. The region has decided to accommodate growth on its West Side by targeting development in transit-oriented developments. The proposed Land Use, Transportation, Air Quality Connection (LUTRAQ) alternative includes transit-oriented development, mixed-use centers, transit system improvements, and market strategies (a daily parking charge for commuters who drive alone and free transit passes, at least partially funded by parking revenues).

State-of-the-art analysis showed that the LUTRAQ alternative is superior to the more auto-oriented alternative on many fronts not just on many of the criteria discussed above related to sustainability, but also on those often used to judge standard highway projects:²⁴¹

- 22.5 percent fewer work trips made in single-occupant vehicles, saving congestion, fuel, emissions, and money
- 27 percent more trips made on transit and by walking and biking
- 18 percent less highway congestion with 10.7 percent fewer hours of vehicle travel during the afternoon rush hour
- 21 percent greater access to jobs in the region, as measured by the percentage of the area within 30 minutes travel of 500,000 jobs
- Reduced air pollution: hydrocarbons, -6 percent; NO_x, -8.7 percent; and CO, -6 percent.
- Reduced emissions of the greenhouse gas CO₂: -7.9 percent, and 7.9 percent less fuel used.

The projected benefits stem from the combination of land use measures and market-based mechanisms. These benefits are for the entire West Side. Benefits will be even larger for homes and businesses in the new transit-oriented developments. The new developments avoid wetlands and other sensitive areas, maximizing biodiversity and recreational opportunities. The plan also reduces paved areas and interferes with the hydrologic cycle as little as possible.

4. 8 SUMMARY

Research has shown that development decisions have both direct and indirect effects on the environment and that growth can be accommodated in ways that minimize negative impacts on human and natural environments and in some cases even improve environmental quality. Strategies that minimize negative environmental impacts include compact development, reduced impervious surfaces and improved water detention, safeguarding of environmentally sensitive areas, mixed land uses, transit accessibility, and support for pedestrian and bicycle activity.

Used in combination, these practices can significantly reduce impacts to habitat, ecosystems and watersheds, and can reduce vehicle travel, which in turn reduces emissions of local, regional, and global concern.

²⁴¹1000 Friends of Oregon, "Making the Connections: A Summary of the LUTRAQ Project." February 1997.