Growing Cooler: The Evidence on Urban Development and Climate Change

Reid Ewing, Keith Bartholomew, Steve Winkelman, Jerry Walters, and Don Chen

with Barbara McCann and David Goldberg

ULI Urban Land Institute

Smart Growth America
Better Choices For Our Communities

Center for Clean Air Policy
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National Center for Smart Growth Research & Education

This new book documents how key changes in land development patterns could help reduce vehicle greenhouse gas emissions. Based on a comprehensive review of dozens of studies by leading urban planning researchers, the book concludes that urban development is both a key contributor to climate change and an essential factor in combating it. The authors make the case that one of the best ways to reduce vehicle travel is compact development: building places in which people can get from one place to another without driving. This includes developments with a mix of uses and pedestrian-friendly designs. Changing demographics, shrinking households, rising gas prices, and lengthening commutes are contributing to the demand for smaller homes and lots, townhouses, and condominiums near jobs and other activities. Current government policies and regulations encourage sprawling, auto-dependent development. The book recommends changes that can be made to make green neighborhoods more available and more affordable.

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The policy recommendations presented in this book do not necessarily reflect the opinions of the Urban Land Institute.

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College Park, Maryland

Contents

Executive Summary

The phrase "you can't get there from here" has a new application. For climate stabilization, a commonly accepted target would require the United States to cut its carbon dioxide (CO_2) emissions by 60 to 80 percent as of 2050, relative to 1990 levels. Carbon dioxide levels have been increasing rapidly since 1990, and so would have to level off and decline even more rapidly to reach this target level by 2050. This publication demonstrates that the U.S. transportation sector cannot do its fair share to meet this target through vehicle and fuel technology alone. We have to find a way to sharply reduce the growth in vehicle miles driven across the nation's sprawling urban areas, reversing trends that go back decades.

This publication is based on an exhaustive review of existing research on the relationship between urban development, travel, and the CO_2 emitted by motor vehicles. It provides evidence on and insights into how much transportation-related CO_2 savings can be expected with compact development, how compact development is likely to be received by consumers, and what policy changes will make compact development possible. Several related issues are not fully examined in this publication. These include the energy savings from more efficient building types, the value of preserved forests as carbon sinks, and the effectiveness of pricing strategies—such as tolls, parking charges, and mileage-based fees—when used in conjunction with compact development and expanded transportation alternatives.

The term "compact development" does not imply high-rise or even uniformly high density, but rather higher average "blended" densities. Compact development also features a mix of land uses, development of strong population and employment centers, interconnection of streets, and the design of structures and spaces at a human scale.

The Basics

Scientific consensus now exists that greenhouse gas accumulations due to human activities are contributing to global warming with potentially catastrophic consequences (IPCC 2007). International and domestic climate policy discussions have gravitated toward the goal of limiting the temperature increase to 2°C to 3°C by cutting greenhouse gas emissions by 60 to 80 percent below 1990 levels by the year 2050. The primary greenhouse gas is carbon dioxide, and every gallon of gasoline burned produces about 20 pounds of CO_2 emissions.

Driving Up CO_2 Emissions

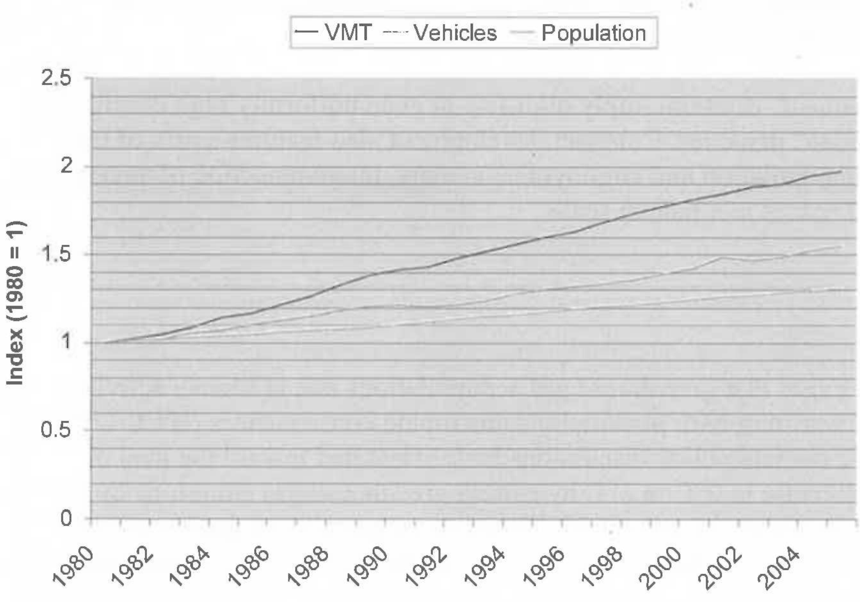
The United States is the largest emitter worldwide of the greenhouses gases that cause global warming. Transportation accounts for a full third of CO_2 emissions in the United States, and that share is growing as others shrink in comparison, rising from 31 percent in 1990 to 33 percent today It is hard to envision a "solution" to the global warming crisis that does not involve slowing the growth of transportation CO_2 emissions in the United States.

The Three-Legged Stool Needed to Reduce CO2 from Automobiles

Transportation CO2 reduction can be viewed as a three-legged stool, with one leg related to vehicle fuel efficiency, a second to the carbon content of the fuel itself, and a third to the amount of driving or vehicle miles traveled (VMT). Energy and climate policy initiatives at the federal and state levels have pinned their hopes almost exclusively on shoring up the first two legs of the stool, through the development of more efficient vehicles (such as hybrid cars) and lower-carbon fuels (such as biodiesel fuel). Yet a stool cannot stand on only two legs.

As the research compiled in this publication makes clear, technological improvement in vehicles and fuels are likely to be offset by continuing, robust growth in VMT. Since 1980, the number of miles Americans drive has grown three times faster than the U.S. population, and almost twice as fast as vehicle registrations (see Figure 0-1). Average automobile commute times in metropolitan areas have risen steadily over the decades, and many Americans now spend more time commuting than they do vacationing.

Figure 0-1 Growth of VMT, Vehicle Registrations, and Population in the United States relative to 1980 Values
Source: FHWA 2005.



This raises some questions, which this report addresses. Why do we drive so much? Why is the total distance we drive growing so rapidly? And what can be done to alter this trend in a manner that is effective, fair, and economically acceptable?

The growth in driving is due in large part to urban development, or what some refer to as the built environment. Americans drive so much because we have given ourselves little alternative. For 60 years, we have built homes ever farther from workplaces, created schools that are inaccessible except by motor vehicle, and isolated other destinations—such as shopping—from work and home. From World War II until very recently, nearly all new development has been planned and built on the assumption that people will use cars virtually every time they travel. As a larger and larger share of our built environment has become automobile dependent, car trips and distances have increased, and walking and public transit use have declined. Population growth has been responsible for only a quarter of the increase in vehicle miles driven over the last couple of decades. A larger share of the increase can be traced to the effects of a changing urban environment, namely to longer trips and people driving alone.

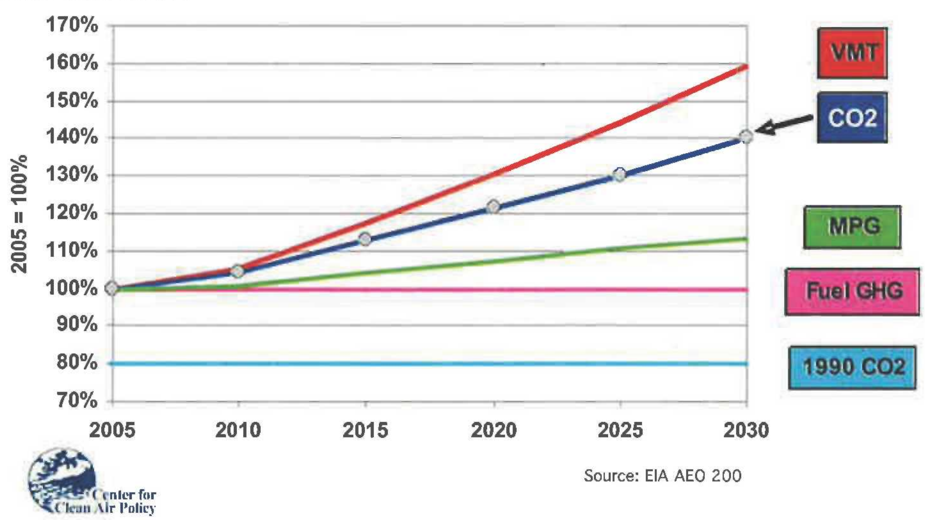
As with driving, land is being consumed for development at a rate almost three times faster than population growth. This expansive development has caused CO_2 emissions from cars to rise even as it has reduced the amount of forest land available to absorb CO_2.

How Growth in Driving Cancels Out Improved Vehicle Fuel Economy

Carbon dioxide is more difficult to control through vehicle technology than are conventional air pollutants. Conventional pollutants can be reduced in automobile exhaust with sophisticated emission control systems (catalytic converters, on-board computers, and oxygen sensors). Carbon dioxide, meanwhile, is a direct outcome of burning fossil fuels; there is no practical way to remove or capture it from moving vehicles. At this point in time, the only way to reduce CO_2 emissions from vehicles is to burn less gasoline and diesel fuel.

An analysis by Steve Winkelman of the Center for Clean Air Policy, one of the coauthors of this publication, finds that CO_2 emissions will continue to rise, despite technological advances, as the growth in driving overwhelms planned improvements in vehicle efficiency and fuel carbon content. The U.S. Department of Energy's Energy Information Administration (EIA) forecasts that driving will increase 59 percent between 2005 and 2030 (red line, Figure 0-2), outpacing the projected 23 percent increase in population. The EIA also forecasts a fleetwide fuel economy improvement of 12 percent within this time frame, primarily as a result of new federal fuel economy standards for light trucks (green line, Figure 0-2). Despite this improvement in efficiency, CO_2 emissions would grow by 41 percent (dark blue line, Figure 0-2).

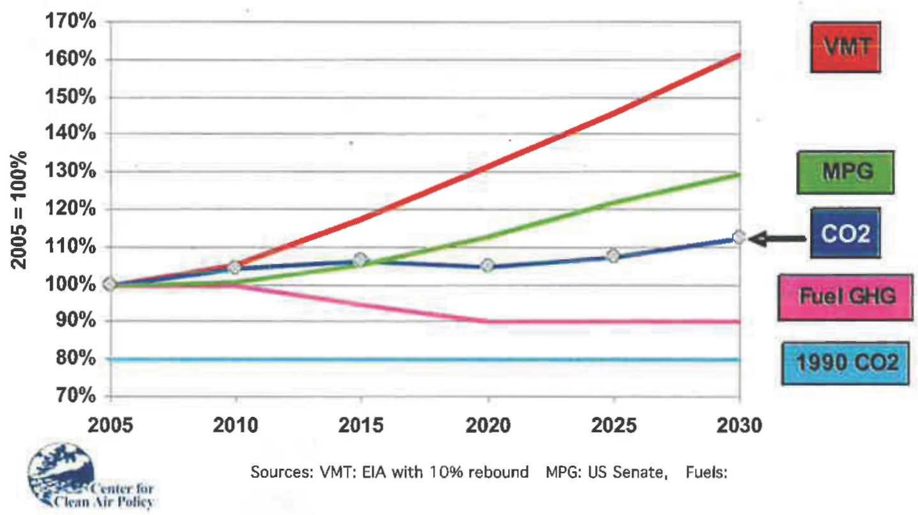
Figure 0-2 Projected Growth in CO_2 Emissions from Cars and Light Trucks
Source: EIA 2007.



U.S. fuel economy has been flat for almost 15 years, as the upward spiral of car weight and power has offset the more efficient technology. Federal and state efforts are underway to considerably boost vehicle efficiency and reduce greenhouse gas emissions. In June 2007, the U.S. Senate passed corporate average fuel economy (CAFE) standards that would increase new passenger vehicle fuel economy from the current 25 miles per gallon (mpg) to 35 mpg by 2020. (As of this writing, the House has not acted.). California plans to implement a low carbon standard for transportation fuels, specifically a 10 percent reduction in fuel carbon content by 2020.

Even if these more stringent standards for vehicles and fuels were to go into effect nationwide, transportation-related emissions would still far exceed target levels for stabilizing the global climate (see Figure 0-3). The rapid increase in driving would overwhelm both the increase in vehicle fuel economy (green line) and the lower carbon fuel content (purple line). In 2030, CO_2 emissions would be 12 percent *above* the 2005 level, and 40 percent above the 1990 level (turquoise line). For climate stabilization, the United States must bring the CO_2 level to 15 to 30 percent *below* 1990 levels by 2020 to keep in play a CO_2 reduction of 60 to 80 percent by 2050.

Figure 0-3 Projected Growth in CO_2 Emissions from Cars and Light Trucks Assuming Stringent Nationwide Vehicle and Fuel Standards*
Source: EIA 2007



As the projections show, the United States cannot achieve such large reductions in transportation-related CO_2 emissions without sharply reducing the growth in miles driven.

Changing Development Patterns to Slow Global Warming

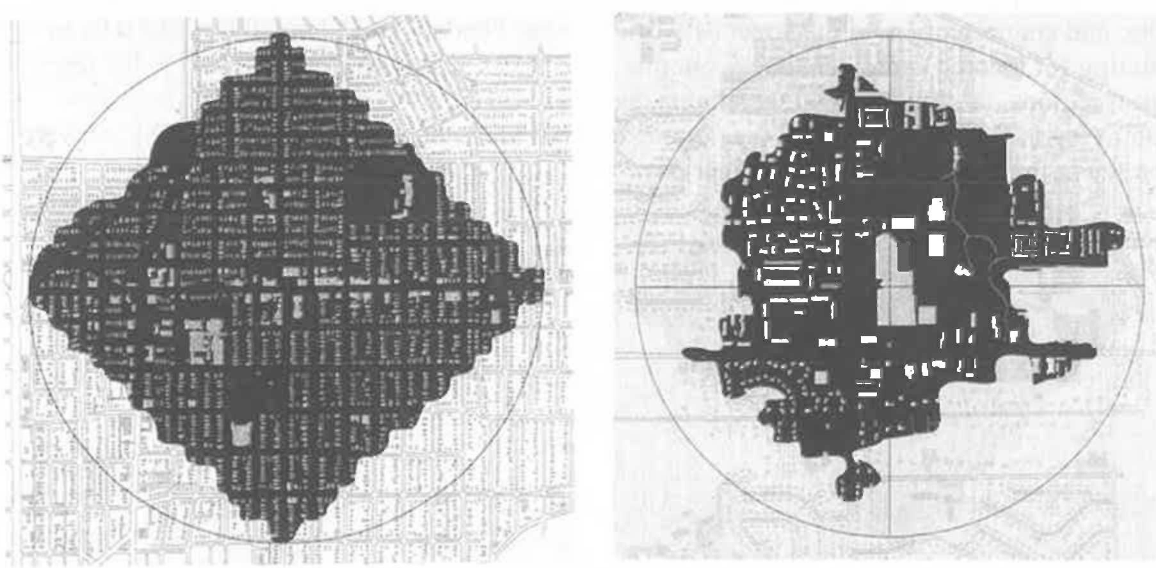
Recognizing the unsustainable growth in driving, the American Association of State Highway and Transportation Officials (AASHTO), representing state departments of transportation, is urging that the growth of vehicle miles driven be cut in half. How does a growing country—one with 300 million residents and another 100 million on the way by mid-century—slow the growth of vehicle miles driven?

Aggressive measures certainly are available, including imposing ever stiffer fees and taxes on driving and parking or establishing no-drive zones or days. Some countries are experimenting with such measures. However, many in this country would view such steps as punitive, given the reality that most Americans do not have a viable alternative to driving. The body of research surveyed here shows that much of the rise in vehicle emissions can be curbed simply by growing in a way that will make it easier for Americans to drive less. In fact, the weight of the evidence shows that, with more compact development, people drive 20 to 40 percent less, at minimal or reduced cost, while reaping other fiscal and health benefits.

How Compact Development Helps Reduce the Need to Drive

Better community planning and more compact development help people live within walking or bicycling distance of some of the destinations they need to get to every day—work, shops, schools, and parks, as well as transit stops. If they choose to use a car, trips are short. Rather than building single-use subdivisions or office parks, communities can plan mixed-use developments that put housing within reach of these other destinations. The street network can be designed to interconnect, rather than end in culs-de-sac and funnel traffic onto overused arterial roads. Individual streets can be designed to be "complete," with safe and convenient places to walk, bicycle, and wait for the bus. Finally, by building more homes as condominiums, townhouses, or detached houses on smaller lots, and by building offices, stores and other destinations "up" rather than "out," communities can shorten distances between destinations. This makes neighborhood stores more economically viable, allows more frequent and convenient transit service, and helps shorten car trips.

Figure 0-4 Destinations within One-Quarter Mile of Center for Contrasting Street Networks in Seattle
Source: Moudon et al. 1997.



This type of development has seen a resurgence in recent years, and goes by many names, including "walkable communities," "new urbanist neighborhoods," and "transit-oriented developments" (TODs). "Infill" and "brownfield" developments put unused lots in urban areas to new uses, taking advantage of existing nearby destinations and infrastructure. Some "lifestyle centers" are now replacing single-use shopping malls with open-air shopping on connected streets with housing and office space as part of the new development. And many communities have rediscovered and revitalized their traditional town centers and downtowns, often adding more housing to the mix. These varied development types are collectively referred to in this publication as "compact development" or "smart growth."

How We Know that Compact Development Will Make a Difference: The Evidence

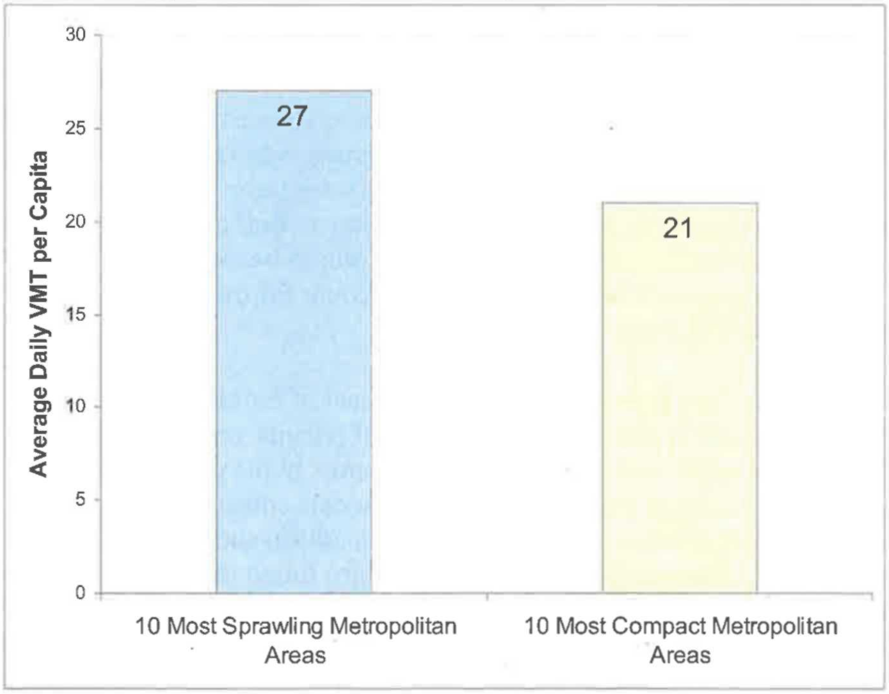
As these forms of development have become more common, planning researchers and practitioners have documented that residents of compact, mixed-use, transit-served communities do less driving. Studies have looked at the issue from varying angles, including:

- research that compares overall travel patterns among regions and neighborhoods of varying compactness and auto orientation;
- studies that follow the travel behavior of individual households in various settings; and
- models that simulate and compare the effects on travel of different future development scenarios at the regional and project levels.

Regardless of the approach, researchers have found significant potential for compact development to reduce the miles that residents drive.

A comprehensive sprawl index developed by coauthor Reid Ewing of the National Center for Smart Growth at the University of Maryland ranked 83 of the largest metropolitan areas in the United States by their degree of sprawl, measuring density, mix of land uses, strength of activity centers, and connectedness of the street network (Ewing, Pendall, and Chen 2002, 2003). Even accounting for income and other socioeconomic differences, residents drove far less in the more compact regions. In highly sprawling Atlanta, vehicles racked up 34 miles each day for every person living in the region. Toward the other end of the scale, in Portland, Oregon, vehicles were driven fewer than 24 miles per person, per day.

Figure 0-5 Average Daily Vehicle Miles Traveled
Source: Ewing, Pendall, and Chen 2002, p. 18.



This relationship holds up in studies that focus on the travel habits of individual households while measuring the environment surrounding their homes and/or workplaces. The link between urban development patterns and individual or household travel has become the most heavily researched subject in urban planning, with more than 100 rigorous empirical studies completed. These studies have been able to control for factors such as socioeconomic status, and can account for the fact that higher-income households tend to make more and longer trips than lower-income families.

One of the most comprehensive studies, conducted in King County, Washington, by Larry Frank of the University of British Columbia, found that residents of the most walkable neighborhoods drive 26 percent fewer miles per day than those living in the most sprawling areas. A meta-analysis of many of these types of studies finds that households living in developments with twice the density, diversity of uses, accessible destinations, and interconnected streets when compared to low-density sprawl drive about 33 percent less.

Many studies have been conducted by or in partnership with public health researchers interested in how the built environment can be better designed to encourage daily physical activity. These studies show that residents of communities designed to be walkable both drive fewer miles and also take more trips by foot and bicycle, which improves individual health. A recent literature review found that 17 of 20 studies, all dating from 2002 or later, have established statistically significant relationships between some aspect of the built environment and the risk of obesity.

Two other types of studies also find relationships between development patterns and driving: simulations that project the effect of various growth options for entire regions and simulations that predict the impact of individual development projects when sited and designed in different ways. In regional growth simulations, planners compare the effect of a metropolitan-wide business-as-usual scenario with more compact growth options. Coauthor Keith Bartholomew of the University of Utah analyzed 23 of these studies and found that compact scenarios averaged 8 percent fewer total miles driven than business-as-usual ones, with a maximum reduction of 31.7 percent (Bartholomew 2005, 2007). The better-performing scenarios were those with higher degrees of land use mixing, infill development, and population density, as well as a larger amount of expected growth. The travel models used in these studies would be expected to underestimate the impacts of site design, since most only crudely account for travel within neighborhoods and disregard walk and bike trips entirely.

Of the project-level studies, one of the best known evaluated the impact of building a very dense, mixed-use development at an abandoned steel mill site in the heart of Atlanta versus spreading the equivalent amount of commercial space and number of housing units in the prevailing patterns at three suburban locations. Analysis using transportation models enhanced by coauthor Jerry Walters of Fehr & Peers Associates (Walters, Ewing, and Allen 2000), and supplemented by the EPA's Smart Growth Index (to capture the effects of site design) found that the infill location would generate about 35 percent less driving and emissions than the comparison sites. The results were so compelling that the development was deemed a transportation control measure by the federal government for the purpose of helping to improve the region's air quality. The Atlantic Station project has become a highly successful reuse of central city industrial land.

Atlantic Station today. *Jacoby Development Company*

What Smart Growth Would Look Like

How would this new focus on compact development change U.S. communities? Many more developments would look like the transit-oriented developments and new urbanist neighborhoods already going up in almost every city in the country, and these developments would start filling in vacant lots or failing strip shopping centers, or would revitalize older town centers, rather than replacing forests or farmland. Most developments would no longer be single-use subdivisions or office parks, but would mix shops, schools, and offices together with homes. They might feature ground-floor stores and offices with living space above, or townhomes within walking distance of a retail center. Most developments would be built to connect seamlessly with the external street network.

The density increases required to achieve the changes proposed in this publication would be moderate. Nelson's work shows that the average density of residential development in U.S. urban areas was about 7.6 units per acre in 2003. His predictions of shifting market demand indicate that all housing growth to 2025 could be accommodated by building condominiums, apartments, townhomes, and detached houses on small lots, while maintaining the current stock of houses on large lots. Under this scenario, while new developments would average a density of 13 units per acre, the average density of metropolitan areas overall would rise modestly, to about nine units per acre. Much of the change would result from stopping the sprawling development that has resulted in falling densities in many metropolitan areas.

Several publications provide a glimpse of what this future might look like. Images of compact development are available in *This is Smart Growth* (Smart Growth Network 2006) and *Visualizing Density* (Lincoln Institute of Land Policy 2007).

The Potential of Smart Growth

The potential of smart growth to curb the rise in greenhouse gas emissions will, of course, be limited by the amount of new development and redevelopment that takes place over the next few decades, and by the share of it that is compact in nature. There seems to be little question that a great deal of new building will take place as the U.S. population grows toward 400 million. According to the best available analysis, by Chris Nelson of Virginia Tech, 89 million new or replaced homes—and 190 billion square feet of new offices, institutions, stores, and other nonresidential buildings—will be constructed through 2050. If that is so, two-thirds of the development on the ground in 2050 will be built between now and then. Pursuing smart growth is a low-cost climate change strategy, because it involves shifting investments that have to be made anyway.

Smart Growth Meets Growing Market Demand for Choice

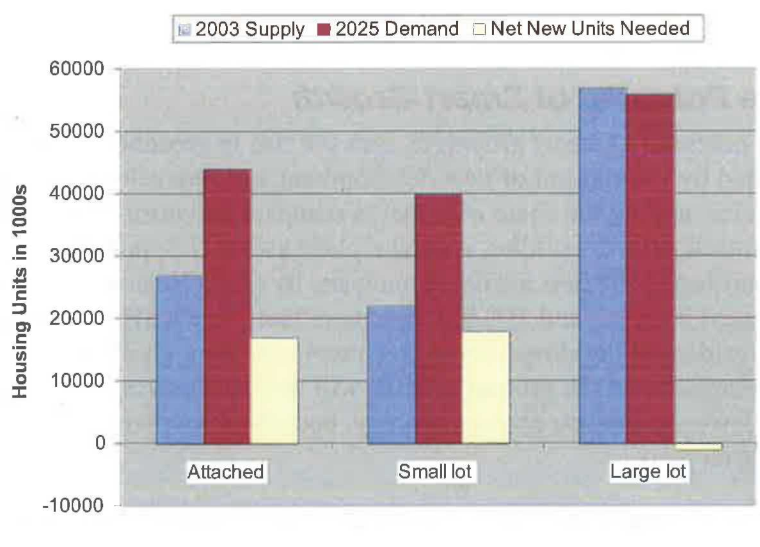
There is no doubt that moving away from a fossil fuel–based economy will require many difficult changes. Fortunately, smart growth is a change that many Americans will embrace. Evidence abounds that Americans are demanding more choices in where and how they live—and that changing demographics will accelerate that demand.

While prevailing zoning and development practices typically make sprawling development easier to build, developers who make the effort to create compact communities are encountering a responsive public. In 2003, for the first time in the country's history, the sales prices per square foot for attached housing—that is, condominiums and townhouses—was higher than that of detached housing units. The real estate analysis firm Robert Charles Lesser & Co. has conducted a dozen consumer preference surveys in suburban and urban locations[1] for a variety of builders to help them develop new projects. The surveys have found that in every location examined, about one-third of respondents prefer smart growth housing products and communities. Other studies by the National Association of Homebuilders, the National Association of Realtors, the Fannie Mae Foundation, high-production builders, and other researchers have corroborated these results—some estimating even greater demand for smart growth housing products. When smart growth also offers shorter commutes, it appeals to another one-quarter of the market, because many people are willing to trade lot or house size for shorter commutes.

Because the demand is greater than the current supply, the price-per-square foot values of houses in mixed-use neighborhoods show price premiums ranging from 40 to 100 percent, compared to houses in nearby single-use subdivisions, according to a study by Chris Leinberger of the Brookings Institution.

This market demand is only expected to grow over the next several decades, as the share of households with children shrinks and those made up of older Americans grows with the retiring of baby boomers. Households without children will account for close to 90 percent of new housing demand, and single-person households will account for a one-third. Nelson projects that the demand for attached and small-lot housing will exceed the current supply by 35 million units (71 percent), while the demand for large-lot housing will actually be less than the current supply.

Figure 0-6 2003 Housing Supply versus 2025 Housing Demand
Source: Nelson 2006.



[1] These locations include Albuquerque, Atlanta, Boise, Charlotte, Chattanooga, Denver, Orlando, Phoenix, Provo, Savannah, and Tampa.

Total Estimated VMT Reduction and Total Climate Impact

When viewed in total, the evidence on land use and driving shows that compact development will reduce the need to drive between 20 and 40 percent, as compared with development on the outer suburban edge with isolated homes, workplaces, and other destinations. It is realistic to assume a 30 percent cut in VMT with compact development.

Making reasonable assumptions about growth rates, the market share of compact development, and the relationship between CO_2 reduction and VMT reduction, smart growth could, by itself, reduce total transportation-related CO_2 emissions from current trends by 7 to 10 percent as of 2050. This reduction is achievable with land-use changes alone. It does not include additional reductions from complementary measures, such as higher fuel prices and carbon taxes, peak-period road tolls, pay-as-you drive insurance, paid parking, and other policies designed to make drivers pay more of the full social costs of auto use.

This estimate also does not include the energy saved in buildings with compact development, or the CO_2-absorbing capacity of forests preserved by compact development. Whatever the total savings, it is important to remember that land use changes provide a permanent climate benefit that would compound over time. The second 50 years of smart growth would build on the base reduction from the first 50 years, and so on into the future. More immediate strategies, such as gas tax increases, do not have this degree of permanence.

The authors calculate that shifting 60 percent of new growth to compact patterns would save 85 million metric tons of CO_2 annually by 2030. The savings over that period equate to a 28 percent increase in federal vehicle efficiency standards by 2020 (to 32 mpg), comparable to proposals now being debated in Congress. It would be as if the fleetwide efficiency for new vehicles had risen to 32 mpg by 2020. Every resident of a compact neighborhood would provide the environmental benefit expected from, say, driving one of today's efficient hybrid cars. That effect would be compounded, of course, if that person also drove such an efficient car whenever he or she chose to make a vehicle trip. Smart growth would become an important "third leg" in the transportation sector's fight against global warming, along with more efficient vehicles and lower-carbon fuels.

A Climate-Sparing Strategy with Multiple Payoffs

Addressing climate change through smart growth is an attractive strategy because, in addition to being in line with market demand, compact development provides many other benefits and will cost the economy little or nothing. Research has documented that compact development helps preserve farmland and open space, protect water quality, and improve health by providing more opportunities for physical activity.

Studies also have confirmed that compact development saves taxpayers money, particularly by reducing the costs of infrastructure such as roads and water and sewer lines. For example, the Envision Utah scenario planning process resulted in the selection of a compact growth plan that will save the region about $4.5 billion in infrastructure spending over a continuation of sprawling development.

Finally, unlike hydrogen-fueled vehicles and cellulosic ethanol, which get a lot of attention in the climate-change debate, the "technology" of compact, walkable communities exists today, as it has in one form or another for thousands of years. We can begin using this technology in the service of a cooler planet right now.

Policy Recommendations

In most metropolitan areas, compact development faces an uneven playing field. Local land development codes encourage auto-oriented development. Public spending supports development at the metropolitan fringe more than in already developed areas. Transportation policies remain focused on accommodating the automobile rather than alternatives.

The key to substantial greenhouse gas (GHG) reductions is to get all policies, funding, incentives, practices, rules, codes, and regulations pointing in the same direction to create the right conditions for smart growth. Innovative policies often are in direct conflict with the conventional paradigm that produces sprawl and automobile dependence.

Here, we outline three major policy initiatives at the federal level that would benefit states, metro regions, cities and towns in their efforts to meet the growing demand for compact development. These initiatives, as well as potential actions on the part of state and local governments, are discussed more fully in Chapter 7.

Federal Actions

Require Transportation Conformity for Greenhouse Gases. Federal climate change legislation should require regional transportation plans to pass a conformity test for CO_2 emissions, similar to those for other criteria pollutants. The Supreme Court ruling in Massachusetts v EPA established the formal authority to consider greenhouse gases under the Clean Air Act, and a transportation planning conformity requirement would be an obvious way for the EPA to exercise this authority to produce tangible results.

Enact "Green-TEA" Transportation Legislation that Reduces GHGs. The Intermodal Surface Transportation Efficiency Act of 1991 (known as ISTEA) represented a revolutionary break from past highway bills with its greater emphasis on alternatives to the automobile, community involvement, environmental goals, and coordinated planning. The next surface transportation bill could bring yet another paradigm shift; it could further address environmental performance, climate protection, and green development. We refer to this opportunity as "Green-TEA."

Provide Funding Directly to Metropolitan Planning Organizations (MPOs). Metropolitan areas contain more than 80 percent of the nation's population and 85 percent of its economic output. Investment by state departments of transportation in metropolitan areas lags far behind these percentages. The issue is not just the amount of funding; it is also the authority to decide how the money is spent. What is necessary to remedy the long history of structural and institutional causes of these inequities is a new system of allocating federal transportation funds directly to metropolitan areas. The amount of allocation should be closer to the proportion of an MPO's population and economic activity compared to other MPOs and non-MPO areas in the same state.

1. Introduction

The phrase "you can't get there from here" has a new application. The United States cannot achieve a 60 to 80 percent reduction in carbon dioxide (CO_2) emissions by 2050 relative to 1990 levels—a commonly accepted target for climate stabilization—unless the transportation sector contributes, and the transportation sector cannot do its fair share through vehicle and fuel technology alone. We have to sharply reduce the growth of vehicular travel across the nation's sprawling urban areas, reversing trends that go back decades.

With regard to urban development and travel demand management, this publication asks and answers three critical questions facing the urban planning profession, the land development community, and federal, state, and local policy makers:

- What reduction in vehicle miles traveled (VMT) is possible in the United States with compact development rather than continuing urban sprawl?
- What reduction in CO_2 emissions will accompany such a reduction in VMT?
- What policy changes will be required to shift the dominant land development pattern from sprawl to compact development?

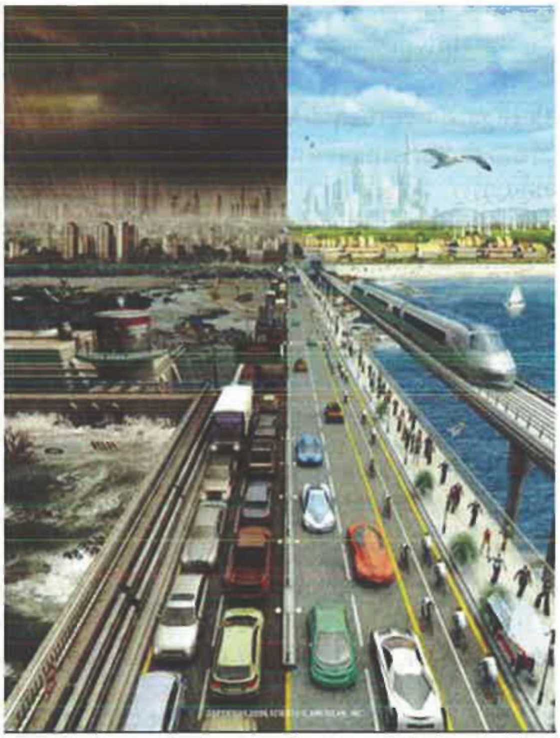
1.1 Background

The transportation sector accounts for 28 percent of total greenhouse gas (GHG) emissions in the United States and 33 percent of the nation's energy-related CO_2 emissions (EIA 2006, p. xvi; EIA 2007a, p. 15). The United States, in turn, is responsible for 22 percent of CO_2 emissions worldwide and close to a quarter of worldwide GHG emissions (EIA 2007b, p. 93). It is hard to envision a "solution" to the global warming crisis that does not involve slowing the growth of transportation CO_2 emissions in the United States

The transportation sector's CO_2 emissions are a function of vehicle fuel efficiency, fuel carbon content, and VMT, factors sometimes referred to as a "three-legged stool." Energy and climate policy initiatives at the federal and state levels have focused almost exclusively on technological advances in vehicles and fuels, the first two legs. Yet, there is a growing recognition that managing VMT has to be part of the solution, that the third leg is needed to support the stool.

In *A Call for Action*, the U.S. Climate Action Partnership (USCAP)—which is made up of major U.S. corporations and environmental groups—includes promoting "better growth planning" (USCAP 2007). The United Nations Intergovernmental Panel on Climate Change (IPCC 2007c, p. 20) lists "influenc[ing] mobility needs through land use regulations and infrastructure planning" among policies and measures shown to be effective in controlling GHG emissions." California's Climate Action Team (2007) expects "smart land use and intelligent transportation" to make the second-largest contribution toward meeting the state's ambitious GHG reduction goals.

The architects of the principal GHG stabilization framework are banking on major changes in urban development and travel patterns. "The task of holding global emissions constant would be out of reach, were it not for the fact that all the driving and flying in 2056 will be in vehicles not yet designed, most of the buildings that will be around then are not yet built, the locations of many of the communities that will contain these buildings and determine their inhabitants' commuting patterns have not yet been chosen . . ." (Socolow and Pacala 2006).



Alternative futures, circa 2056.

A recent report by the U.S. Environmental Protection Agency (EPA) finds: "By themselves, individual approaches incorporating vehicle technologies, fuels, or transportation demand management (TDM) approaches could moderately reduce, but not flatten, emissions from now until 2050. Most of the system approaches analyzed, by contrast, could . . . nearly flatten the entire U.S. transportation sector emissions, despite the passenger vehicle category representing only half of the sector's emissions" (Mui et al. 2007). In other words, all three legs of the policy stool will be required to flatten transportation CO_2 emission levels.

1.2 The Nature of Compact Development

This publication makes the case for compact development—or its alias, smart growth—rather than continued urban sprawl. It does so in the context of global climate change.

The term "compact development" does not imply high-rise or even uniformly high-density development. A discussion of alternatives to urban sprawl always seems to gravitate toward high-density development, and leads to fears that more compact development will result in the "Manhattanization" of America. That is not what this book is about.

According to data provided by Chris Nelson of Virginia Tech, the blended average density of residential development in the United States in 2003 was about 7.6 units per net acre (see Figure 1-1). This estimate includes apartments, condominiums, and townhouses, as well as detached single-family housing on both small and large lots. A net acre is an acre of developed land, not including streets, school sites, parks, and other undevelopable land.

Because of changing demographics and lifestyle preferences, Nelson projects a significant change in market demand by 2025. The mix of housing stock required to meet this demand would have a blended density of approximately nine units per net acre. Given the excess of large-lot housing already on the ground relative to 2025 demand, all net new housing built between now and then would have to be attached or small-lot detached units (not including replacement of large-lot housing). The density of new and redeveloped housing would average about 13 units per net acre, 75 percent above 2003 average blended density. That is a typical density for a townhouse development. Apartments and condos boost the average, while single-family detached housing lowers it.

Figure 1-1 Projections of Housing Demand and Density in 2025
Source: Nelson 2006.

	Density (Units per Net Acre)	2003 Units (in 1,000s)	2025 Units (in 1,000s)	Difference (in 1,000s)
Attached	20	27,000	44,000	17,000
Small-lot detached	7	22,000	40,000	18,000
Large-lot detached	2	57,000	56,000	-1,000
Average blended density (per net acre)		7.6	9.1	13.3

The role of density, however, should not be overemphasized. As important as density is, it is no more fundamental to compact development than are the mixing of land uses, the development of strong population and employment centers, the interconnection of streets, and the design of structures and spaces at a human scale (see Figure 1-2). Images of compact development are available in *This is Smart Growth* (Smart Growth Network 2006) and *Visualizing Density* (Lincoln Institute of Land Policy 2007).

Figure 1-2 Nature of Compact Development versus Sprawl
Sources: Ewing 1997; Ewing, Pendall, and Chen 2002.

Compact Development	Sprawl
Medium to high densities	*Low densities*
Mixed uses	*Single uses*
Centered development	*Strip development*
Interconnected streets	*Poorly connected streets*
Pedestrian- and transit-friendly design	*Auto-oriented design*

1.3 The High Costs of Urban Sprawl and Automobile Dependence

In 1997, the *Journal of the American Planning Association* (JAPA) carried a pair of articles on the merits of urban sprawl versus compact development (Gordon and Richardson 1997; Ewing 1997). The authors debated the characteristics, causes, and costs of sprawl, and briefly discussed cures. Gordon and Richardson's lead article—titled "Are Compact Cities a Desirable Planning Goal?"—argued that U.S. real estate markets are producing what consumers want; that the social, economic, environmental, and geopolitical impacts of that development are benign; and hence that there is no need for urban planning intervention in markets. Most relevant to concerns over global climate change, the authors contended that a "global energy glut" and vehicle emission controls rendered compact development unnecessary.

Ewing's counterpoint---"Is Los Angeles–Style Sprawl Desirable?"—defined sprawl broadly as 1) leapfrog or scattered development, 2) commercial strip development, or 3) large expanses of low-density or single-use development, as in sprawling bedroom communities, and compact development as the reverse. The article argued that U.S. real estate markets have many imperfections that cause them to "fail," that the social welfare costs of such failure are enormous, and that urban planning interventions therefore are warranted. Particularly relevant to the global climate change debate is the following:

> While the best case envisioned by [Gordon and Richardson] has the real price of gasoline holding steady, it is the worst case that worries others . . . . The fact that the most recent large-scale war fought was in the Persian Gulf is itself a testament to the risk of relying on the political stability of this region for a commodity [oil] so essential to economic activity . . . . Being unregulated, carbon dioxide emissions represent a bigger threat to national welfare than do regulated emissions. There is now a near-consensus within the scientific community that carbon dioxide build-up in the atmosphere is causing global climate change, and that the long-term effects could be catastrophic.

A decade later, there seems to be little doubt that the "worst case" scenario is upon us. The urbanized area of the United States has grown almost three times faster than metropolitan population, as urban development sprawled outwards unchecked (see Figure 1-3). This development pattern has boosted VMT and reduced the amount of forest land available to absorb CO_2.

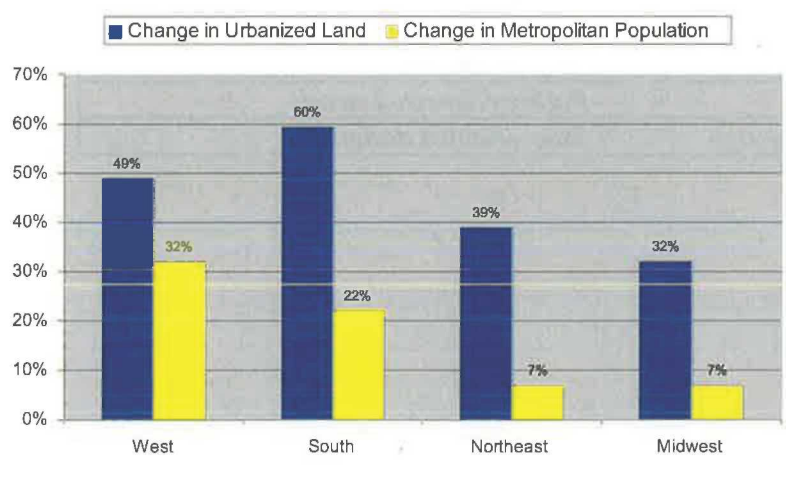
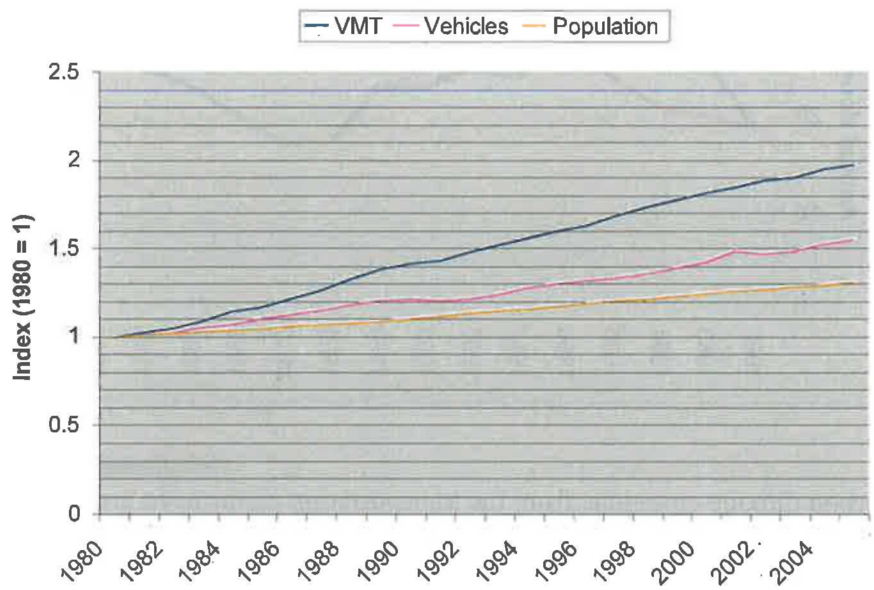


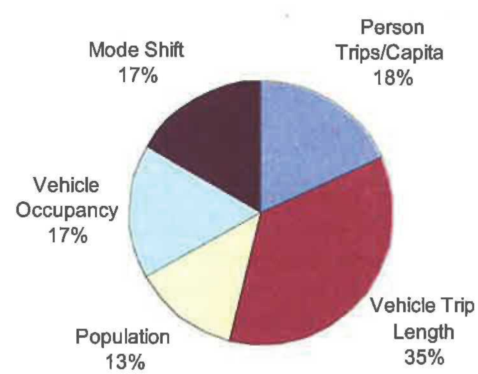
Figure 1-3 Growth of Population and Urbanized Land Area by Census Region between 1982 and 1997
Source: Fulton et al. 2001.

Vehicle miles traveled in the United States have grown three times faster than the population, and almost twice as fast as vehicle registrations (see Figure 1-4). In one analysis, 36 percent of the VMT growth was explained by increasing trip length (see Figure 1-5), which is a function of development patterns. Another 17 percent was explained by shifts to automobile trips from other modes of transportation. Again, development patterns are implicated. Yet another 17 percent was due to lower vehicle occupancy, as rates of carpooling declined. Only 13 percent of the growth in VMT was explained by population growth. Using comparable methodology, we estimate that one-third of the national growth in VMT between 1990 and 2001 was due to longer vehicle trips.[2]

Figure 1-4 Growth of VMT, Vehicle Registrations, and Population in the United States relative to 1980 Values
Source: FHWA 2005.

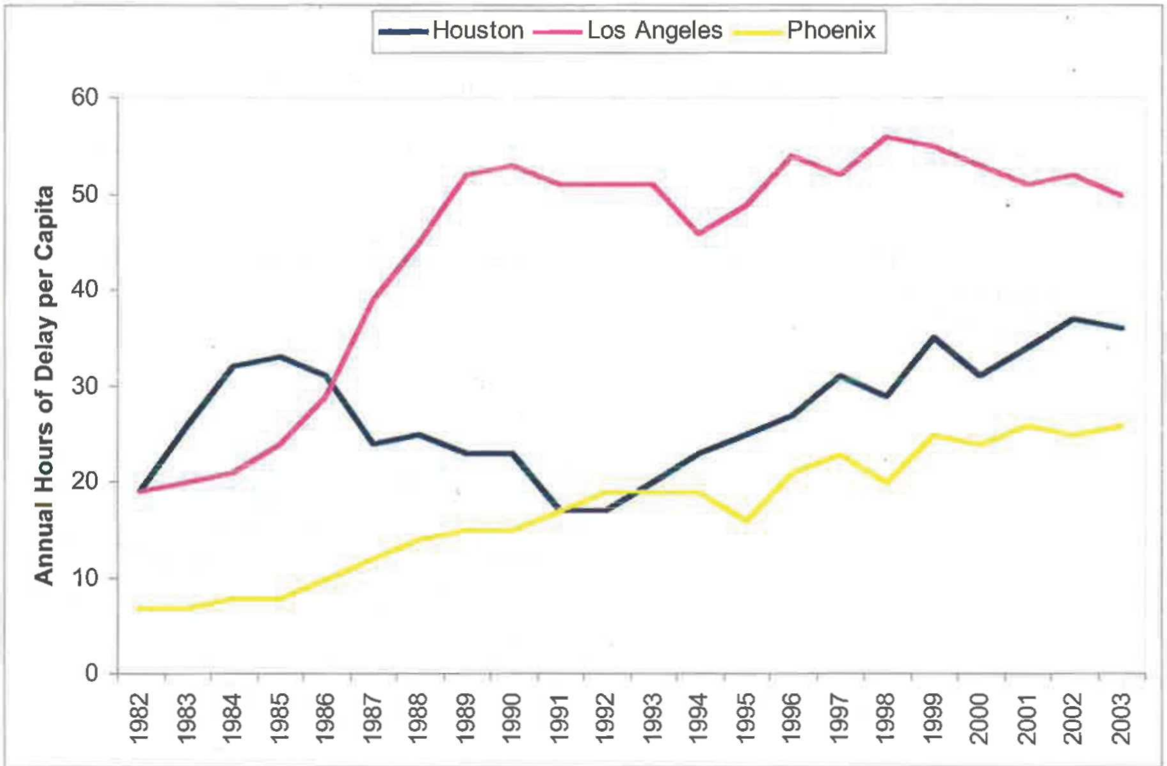


Vehicle miles traveled have grown more than twice as fast as highway capacity in urbanized areas of the United States. In all 85 urbanized areas for which statistics are available, highways became more congested between 1982 and 2003 (Schrank and Lomax 2005). This is true even in regions that struggled to pave their way out of congestion and appeared to be succeeding for a time (see Figure 1-6). Highway building itself induces more traffic and urban sprawl, in a never-ending spiral. (This will be discussed in greater detail in Chapter 5, Induced Traffic and Induced Development.)



[2] Between 1995 and 2001, total VMT in the United States increased by 34 percent, while average vehicle trip length increased by 11.5 percent (Hu and Reuscher 2004).

Figure 1-6 Growth of Annual Hours of Delay per Capita
Source: Schrank and Lomax 2005.



Carbon dioxide emissions from the transportation sector have grown while regulated pollutant emissions actually declined, thanks to improved fuel and engine technology (see Figure 1-7).[3] Carbon dioxide emissions are proportional to gasoline consumption and, during this period, improvements in vehicle fuel efficiency were overwhelmed by the growth in VMT. Under business-as-usual policies, VMT growth will continue to surpass technology gains. (See Chapter 2, The VMT/CO_2/Climate Connection, for more details.)

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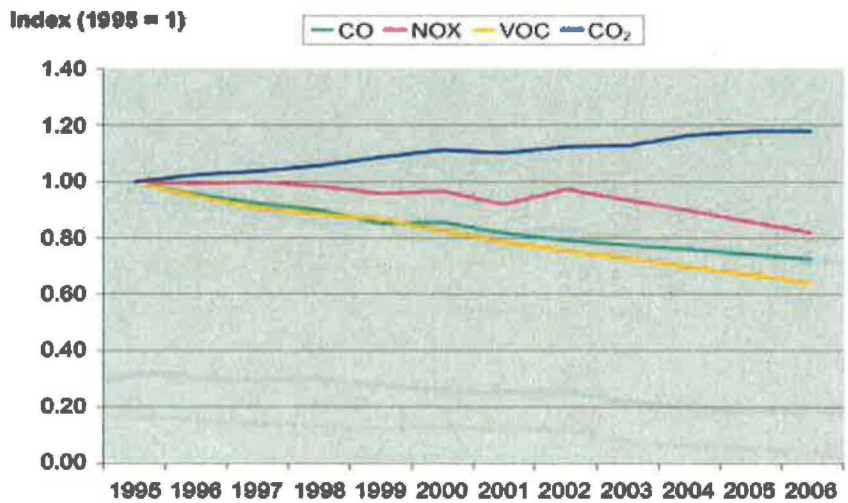
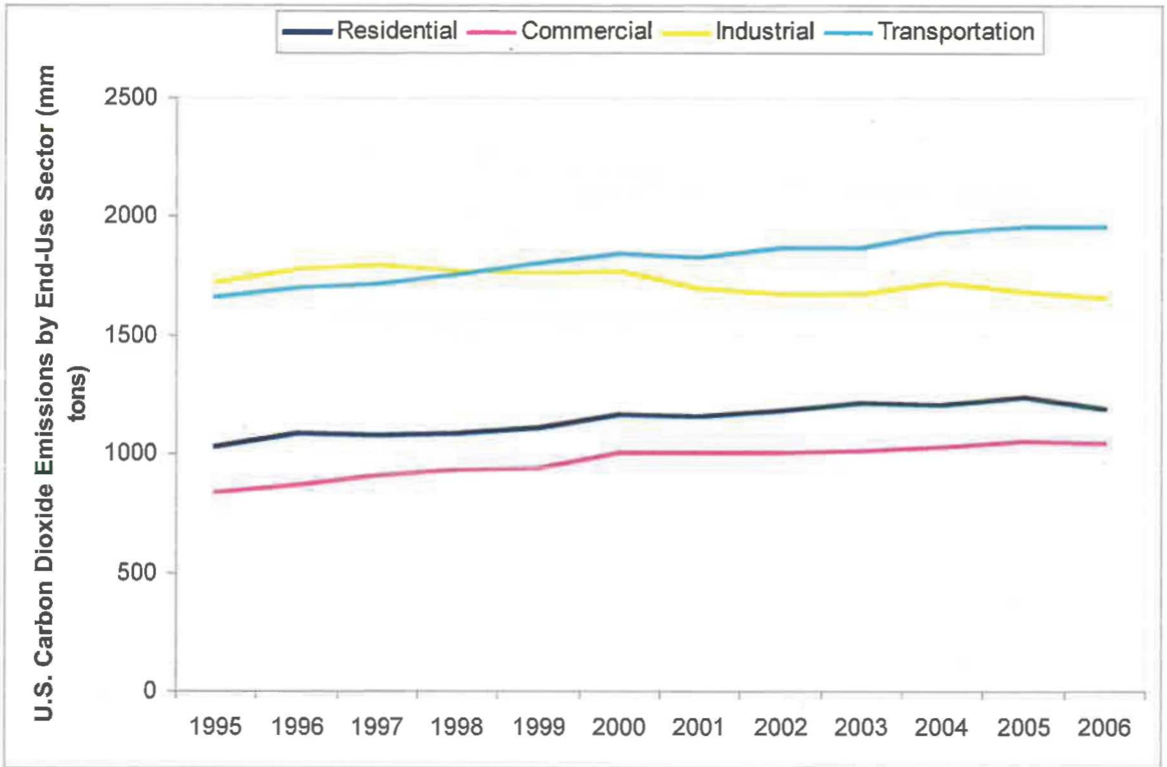
[3] The advent of "first-generation" catalytic converters in 1975 significantly reduced hydrocarbon and carbon monoxide (CO) emissions. Because lead inactivates the catalyst, 1975 also saw the widespread introduction of unleaded gasoline. The next milestone in vehicle emission control technology came in 1980 and 1981. Manufacturers equipped new cars with more sophisticated emission control systems that generally include a "three-way" catalyst (which converts CO and hydrocarbons to CO_2 and water, and also helps reduce nitrogen oxides to elemental nitrogen and oxygen). On-board computers and oxygen sensors help optimize the efficiency of the catalytic converters. Vehicle emissions are being further reduced under 1990 Clean Air Act amendments, which include even tighter tailpipe standards, improved control of evaporative emissions, and computerized diagnostic systems that identify malfunctioning emission controls.

Figure 1-7 Change in Transportation Emissions in the United States Relative to 1995 Values
Source: EPA undated.



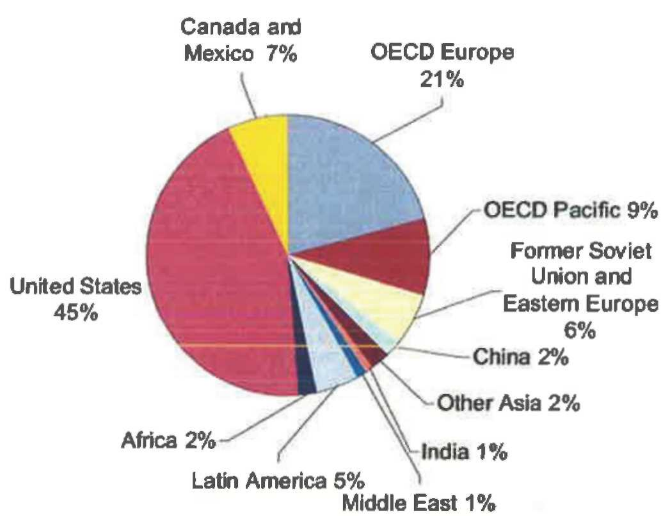
The transportation sector has become the largest source of CO_2 emissions in the United States, surpassing the industrial sector (see Figure 1-8). It now accounts for one-third of the U.S. total. Unless action is taken, the transportation sector's share of CO_2 emissions is expected to increase as VMT outpaces population growth (see Chapter 2).

Figure 1-8 U.S. Carbon Dioxide Emissions by End-Use Sector
Source: EIA 2007a.



The United States is home to only 5 percent of the world's population, but U.S. residents own almost a third of the world's cars, which account for 45 percent of the CO_2 emissions generated by cars worldwide (see Figure 1-9). U.S. cars play a disproportionate role in global warming because they are less fuel efficient than cars elsewhere in the world, and also because they are driven farther.

Figure 1-9 Light-Duty Vehicle Emissions by World Region, 2003
Source: DiCicco and Fung 2006.



1.4 A Perfect Storm in Climate Policy

Author Sebastian Junger coined the expression "a perfect storm" to describe the confluence of different weather conditions that created a powerful 1991 storm in the Atlantic Ocean. The phrase has come to describe the simultaneous occurrence of events which, taken individually, would be far less momentous than the result of their confluence. It seems an appropriate metaphor for what currently is happening in two areas of public policy and in private real estate markets. It also is a good metaphor for what will occur in U.S. urban development generally as these three forces collide.

U.S. climate policy is one area in which a perfect storm is brewing. The issue of climate change has risen to prominence worldwide, and become compelling in the United States, in only 15 years, as the following actions indicate.

- June 1992: The United Nations Framework Convention on Climate Change (UNFCCC), opened for signatures at the "Earth Summit" in Rio de Janeiro, calls for stabilizing GHG concentrations in the atmosphere. The United States is a signatory.

- December 1997: The Kyoto Protocol to the UNFCCC establishes a set of quantified GHG emission targets for developed countries. The United States does not ratify the protocol.

- June 2002: The U.S. government acknowledges for the first time that human activity is contributing to global warming, in a report issued by the U.S. Environmental Protection Agency (EPA) that is challenged by the White House.

- June 2006: A committee convened by the National Academies of Science concludes that human activities are largely responsible for recent global warming.

- September 2006: California becomes the first state to adopt legislation—the Global Warming Solutions Act of 2006 (AB 32)—requiring regulations and market actions to reduce the state's GHG emissions to 1990 levels by 2020. Eighteen other states later adopt similar targets or mandates.

The pace has accelerated in 2007:

- January 2007: Major U.S. corporations and environmental groups, banding together as the U.S. Climate Action Partnership, call for a 10 to 30 percent reduction in CO_2 emissions within 30 years (USCAP 2007).

- April: The U.S. Supreme Court rules that the EPA has the authority to regulate GHG emissions, and has the duty to do so unless it can provide a scientific basis for not acting.

- May: Tulsa, Oklahoma, becomes the 500th city to sign the U.S. Mayors Climate Protection Agreement to reduce greenhouse gas emissions (U.S. Conference of Mayors 2007).

- June: In the largest international public opinion survey ever taken, most of the world identifies environmental degradation as the greatest danger—above nuclear weapons, AIDS, and ethnic hatred (Pew Research Center 2007). Global warming, in particular, is viewed as a "very serious" problem (see Figure 1-11).

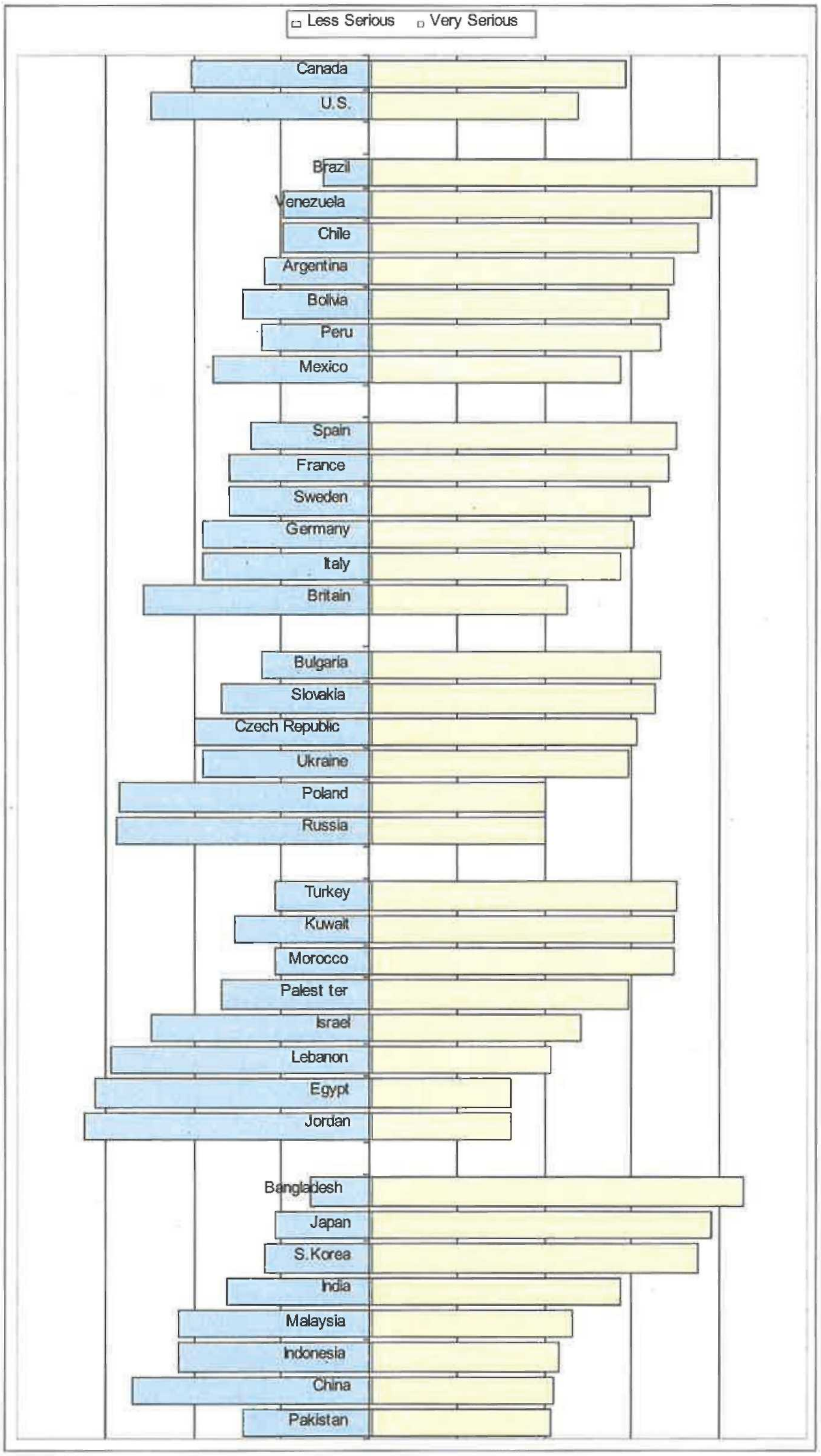
- July: Congressional lawmakers have introduced more than 125 bills, resolutions, and amendments specifically addressing global climate change and GHG emissions, compared with the 106 pieces of relevant legislation introduced during the entire two-year term of the previous Congress (Pew Center on Global Climate Change 2007).

- August: California's attorney general settles his sprawl and carbon emissions case with San Bernardino County. The county agrees to amend its general plan and create a new GHG reduction plan within 30 months to outline opportunities and strategies—especially land use decisions—to reduce GHG emissions.

- August: Russian minisubmarines plant a national flag under the North Pole, claiming the Artic seabed as Russian territory for future oil exploration and thus precipitating an Artic land grab. Arctic oil exploration will become feasible only because global warming is melting and thus shrinking the Artic icecap—and, ironically, the oil and gas extracted will only accelerate the problem as they are burned.

- September: President George W. Bush hosts a climate change summit for top officials from the world's major economies to come to agreement on a framework for lowering global GHG emissions in the post-Kyoto era.

Figure 1-10 World Views on Global Warming: How Serious a Problem?
Source: Pew Research Center 2007



A paradigm shift can occur very rapidly in the physical sciences, as the dominant scientific view changes in response to overwhelming evidence. The 29,000 data series drawn upon by the 2,500 top climate scientists on the U.N. Intergovernmental Panel on Climate Change (IPCC 2007b) constitute that evidentiary base.[4] Since the early 1990s, the scientific community has come to agree on the reality of climate change, on the contribution of human activity to climate change, and on the catastrophic consequences if current trends continue. Social revolutions are slower than scientific revolutions. Public opinion about global warming is changing more slowly than scientific opinion, and political action may be slower still. But they, too, are changing, irrevocably.

1.5 A Perfect Storm in Consumer Demand

There are many reasons why smart growth may be the "low-hanging fruit" for reducing CO_2 emissions in the transportation sector. The most compelling factor is the large and rising consumer demand for homes in neighborhoods that exhibit compact characteristics. The real estate analysis firm Robert Charles Lesser & Co. (RCLCO) has conducted a dozen consumer preference surveys in suburban and urban locations for a variety of builders to help them develop new projects.[5] The RCLCO surveys have found that about one-third of the respondents in every location are interested in smart growth housing products and communities (Logan 2007). Preference varies by geography, economic and demographic fundamentals, and buyer profiles; life stage and income are key variables. Other studies by the National Association of Homebuilders (NAH), the National Association of Realtors (NAR), the Fannie Mae Foundation, high-production builders, and other researchers have corroborated these results, with some estimating even greater demand for smart growth housing products (Myers and Gearin 2001).

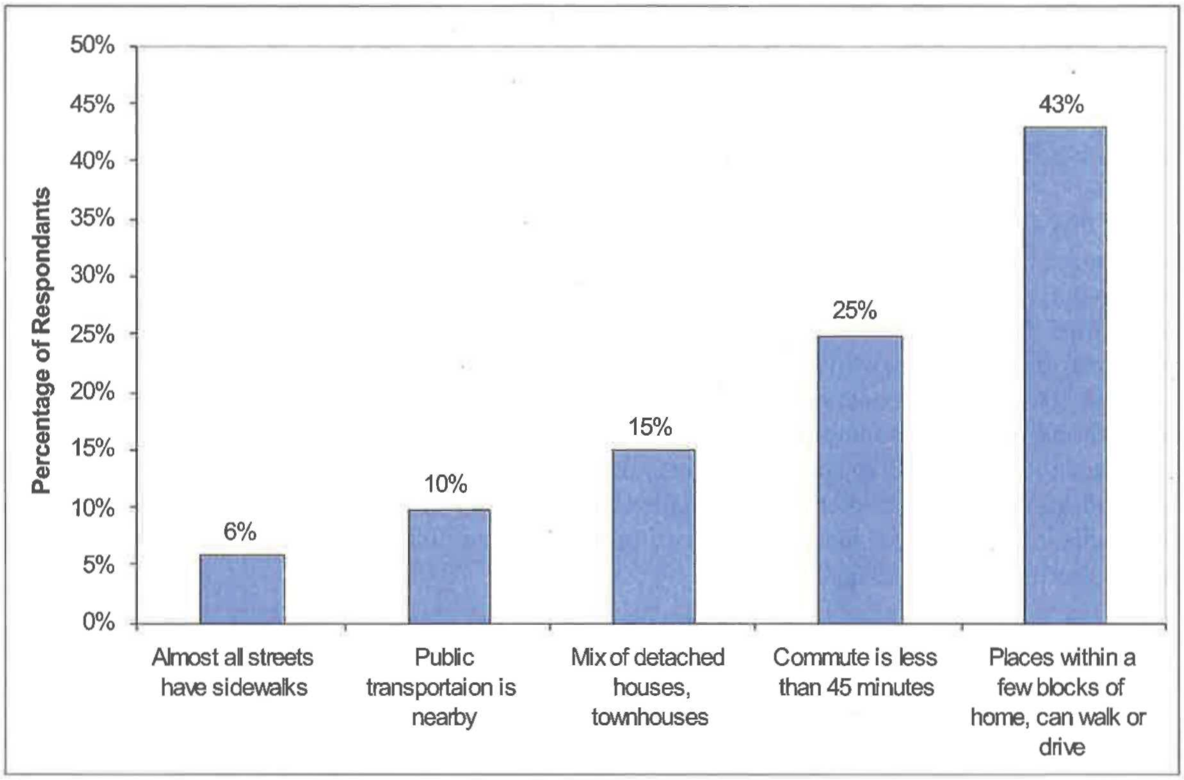
Perhaps the best national assessment of the current demand for smart growth is the National Survey on Communities, conducted for Smart Growth America (a nonprofit advocacy group) and the NAR (Belden Russonello & Stewart 2004). In this survey, respondents were given a choice between communities labeled "A" and "B." Community A was described as having single-family homes on large lots, no sidewalks, shopping and schools located a few miles away, commutes to work of 45 minutes or more, and no public transportation. In contrast, community B was described as having a mix of single-family and other housing, sidewalks, shopping and schools within walking distance, commutes of less than 45 minutes, and nearby public transportation.

[4] The data series show significant changes in observations of physical systems (snow, ice, and frozen ground; hydrology; and coastal processes) and biological systems (terrestrial, marine, and freshwater biological systems), together with surface air temperature changes over the period 1970 to 2004. A subset of about 29,000 data series was selected from about 80,000 data series from 577 studies. These met the following criteria: 1) ending in 1990 or later; 2) spanning a period of at least 20 years; and 3) showing a significant change in either direction, as assessed in individual studies.

[5] These places include Albuquerque, Atlanta, Boise, Charlotte, Chattanooga, Denver, Orlando, Phoenix, Provo, Savannah, and Tampa.

Overall, 55 percent of Americans indicated a preference for community B, the smart growth community. Of those who said they think they will buy a house within the next three years, 61 percent are more likely to look for a home in a smart growth community than a conventional community. Commute time was a major factor in how respondents chose between A and B. It appears that about a third of the market would choose the smart growth community over the conventional community if commutes were comparable, and more than another quarter would choose the smart growth community if it were located closer to employment than the conventional alternative, thereby reducing commute time.

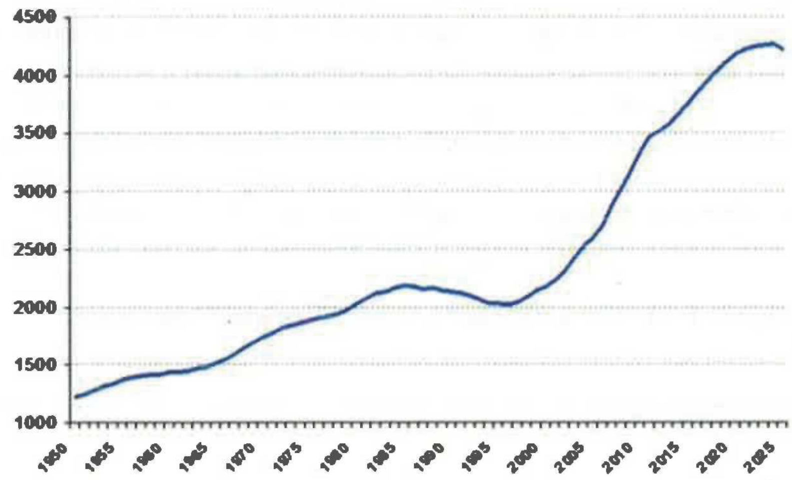
Figure 1-11 Attractions of a Smart Growth Community*
Source: Belden Russonello & Stewart 2004



* For those choosing the smart growth community. The question was "Look at the community you selected and choose the ONE most appealing characteristic of that community for you."

When it comes to housing demand, demographics are destiny. As baby boomers become empty nesters and retirees, they are exhibiting a strong preference for compact, walkable neighborhoods. So are single adults and married couples without children. These trends likely will continue, because the baby boom generation represents America's largest generational cohort. By 2020, the number of individuals turning 65 years of age will skyrocket to more than 4 million per year (see Figure 1-12) Between 2007 and 2050, the share of the U.S. population older than 65 years of age will grow from 11 percent to 15.9 percent (U.S. Census Bureau 2004).

Figure 1-12 Americans Turning 65 Years Old Annually, 1950 to 2025
Source: He et al. 2006

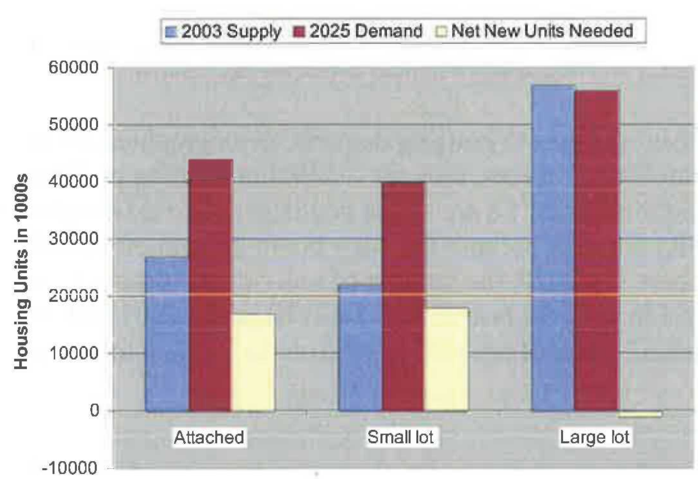


Growth in households without children (including one-person households) also will rise dramatically. From 2000 to 2025, households without children will account for 88 percent of total growth in households. (Thirty-four percent will be one-person households). By 2025, only 28 percent of households will have children (Nelson, 2006).

Some of this change in preferences also appears to be cultural, particularly among Generation Xers who are now fully engaged in the home buying market. According to research by Yankelovich, a leading marketing services consultancy, Gen Xers value traditional face-to-face relationships with neighbors and neighborhood characteristics such as sidewalks and nearby recreational facilities. Yankelovich president J. Walker Smith discussed these findings at the June 2004 NAHB conference, noting that "planned communities that foster togetherness and neighborhood life will resonate with this generation" (NAHB 2004). Another industry analyst, Brent Harrington of DMB Associates, reports that Gen Xers are looking for more diverse and compact communities characterized by smaller but better-designed homes as well as shopping and schools in more central locations, reflecting an "extreme disillusionment with the bland, vanilla suburbs" (Anderson 2004).

This means that the demand for homes located in downtown, in-town, close-in suburban, and other relatively compact locations will continue to rise. The demand for attached and small-lot housing will exceed the current supply by 35 million units (71 percent), while the demand for large-lot housing actually will be less than the current supply (see Figure 1-13).

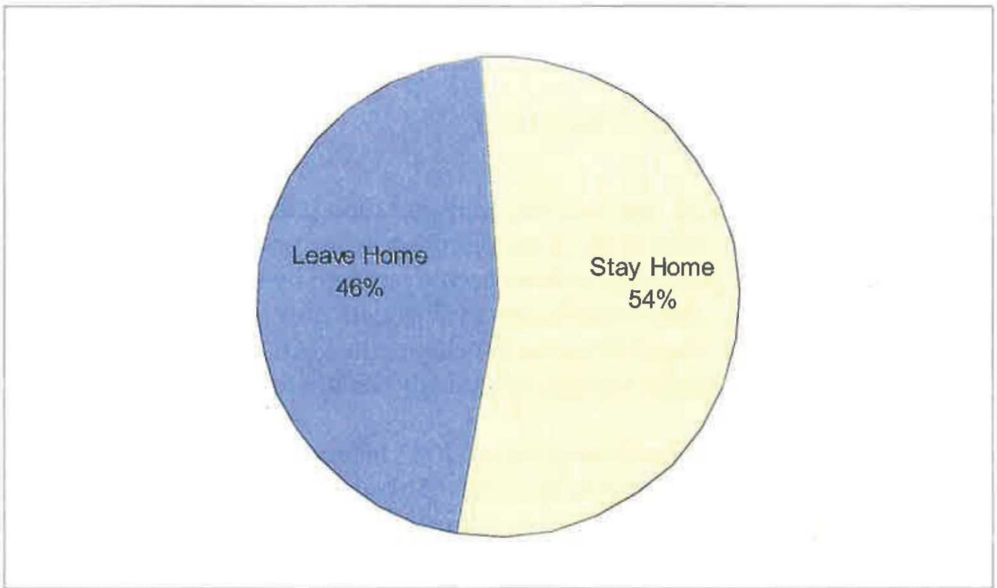
Figure 1-13 2003 Housing Supply versus 2025 Housing Demand
Source: Nelson 2006.



These trends are visible now: Downtown and in-town housing tops the list of hot markets each year in the Urban Land Institute's *Emerging Trends in Real Estate* (ULI 2005, 2006, 2007). In addition, new urban and smart growth communities are in such high demand that they not only command a price premium at the point of purchase, but also hold their premium values over time (Eppli and Tu 1999, 2007; Leinberger 2007).

In addition to changing housing and neighborhood preferences, many stakeholders are carefully watching changes in travel behavior and needs, especially among older Americans. For example, the nonprofit association AARP has made transportation and quality-of-life matters one of its top policy issues to tackle in the next decade. The AARP is concerned because roughly one in five people over 65 years of age do not drive at all, and more than half drive only occasionally; that is, they do not drive on most days (STPP 2004). Older adults who lose their ability to drive tend to lose their independence unless they have other ways of accessing shopping, recreation, medical care, and other basic needs (see Figure 1-14).

Figure 1-14 Average Daily Travel Patterns for Non-drivers over Age 65
Source: STPP 2004.

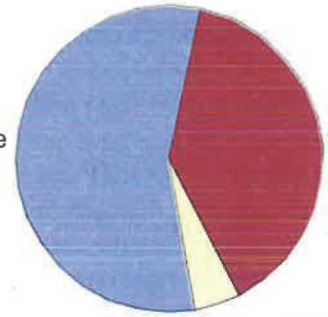


AARP surveys suggest that most people want to "age in place" (Bayer and Harper 2000; Mathew Greenwald & Associates 2003). In most areas where older Americans are aging in place, public transportation services are not available. In fact, according to a national poll, only 45 percent of Americans over 65 live within close proximity to public transportation (Mathew Greenwald & Associates 2003).

Fifty-five percent of respondents to another poll said that they would prefer to walk more throughout the day rather than drive everywhere (see Figure 1-15). The elderly are particularly inclined to walk when conditions are right (Mathew Greenwald & Associates 2003). These results, plus the high cost of special transportation services, are reasons for making sure older people can easily access transit and live in safe, walkable communities. Future community design, development, and transportation decisions will strongly influence their mobility choices.

Figure 1-15 Americans Want to Walk More*
Source: Belden Russonello & Stewart 2003.

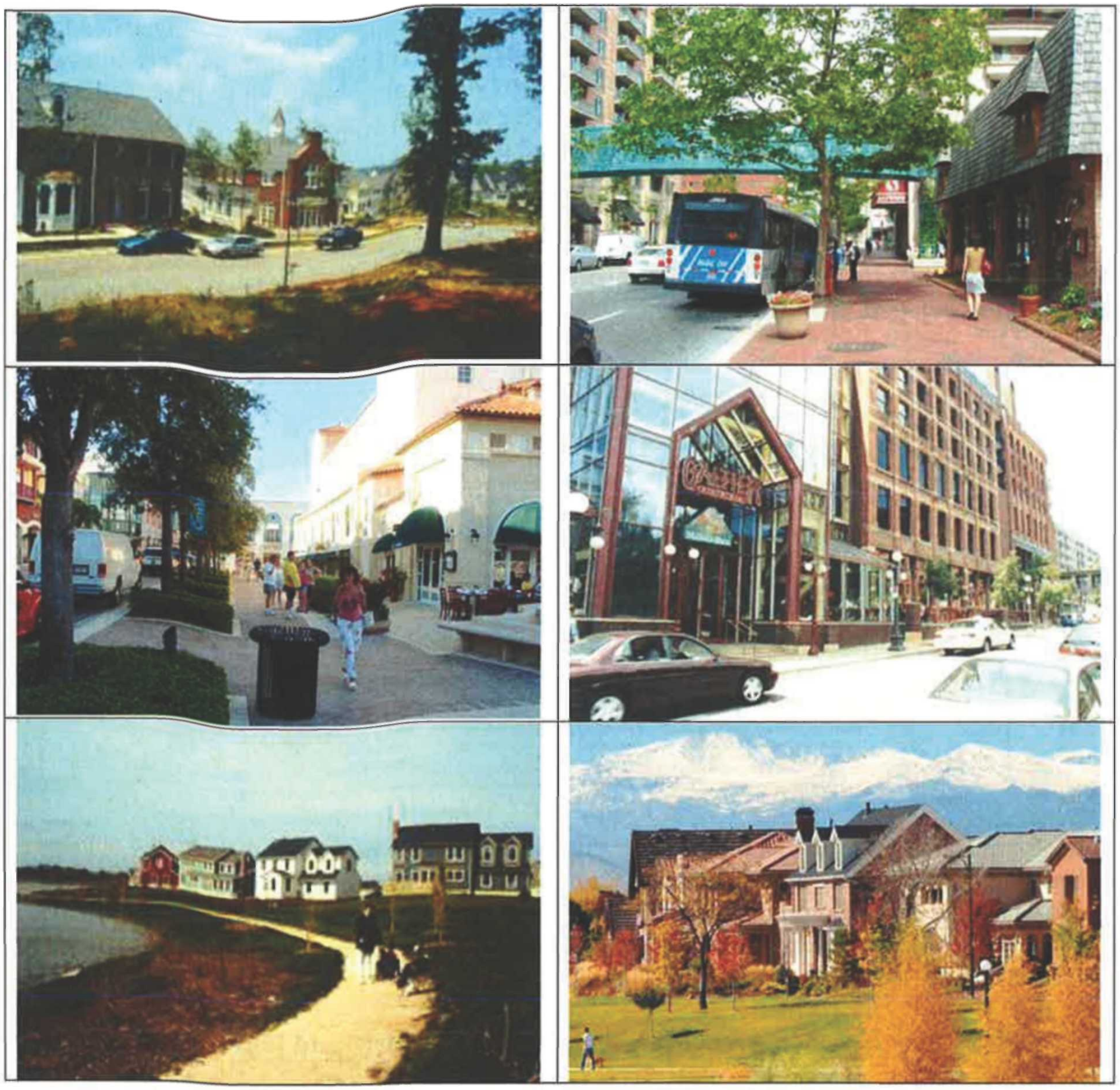
*The question was: Please tell me which of the following statements describe you more: A) If it were possible, I would like to walk more throughout the day either to get to specific places or for exercise, or B) I prefer to drive my car wherever I go?



1.6 And a Perfect Storm in Urban Planning

Yet another perfect storm is brewing in the land use and transportation planning fields. Although it is much less intense, this storm is swirling in the same direction as the ones in climate policy and consumer preferences. The urban planning field has been overtaken by movements promoting alternatives to conventional auto-oriented sprawl. Planners now advocate urban villages, neotraditional neighborhoods, transit-oriented developments (TODs), mixed-use activity centers, jobs/housing balance, context-sensitive highway designs, and traffic calming.

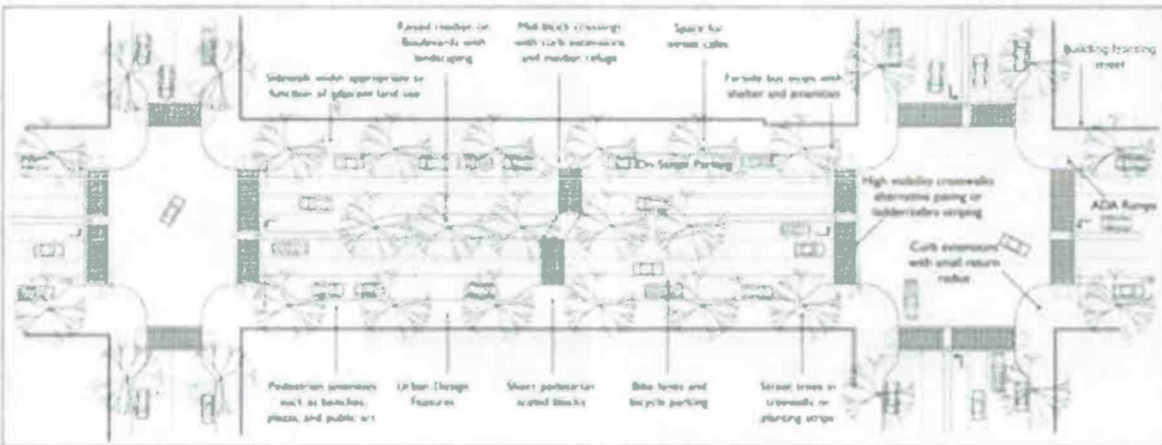
Alternative models of land development are everywhere. A 2003 listing shows 647 new urbanist developments in some state of planning or construction (New Urban News 2003), even though the new urbanist movement began only 12 years earlier. *Transit-Oriented Development in the United States: Experiences, Challenges, and Prospects* identifies 117 TODs on the ground or substantially developed as of late 2002 (Cervero et al. 2004). The first TOD guidelines were issued about a decade earlier. In 2004, there were more than 100 lifestyle centers (open-air shopping centers fashioned after main streets) in the United States, a 35 percent increase from 2000 (Robaton 2005). The U.S. Green Building Council's new rating and certification system for green development, LEED (Leadership in Energy and Environmental Design) for Neighborhood Development, generated 370 applications from land developers, many more than expected by the program sponsors.



This series of photographs illustrates alternative models of land development. Top left: Southern Village, a new urbanist village in North Carolina; top right: transit-oriented development in Bethesda, Maryland; middle left: CityPlace, a lifestyle center in West Palm Beach, Florida; middle right: infill/redevelopment (so-called "refill") in St. Paul, Minnesota; bottom left: green development in Prairie Crossing, Illinois; bottom right: Stapleton, a "new town in town" in Denver, Colorado.

Recognizing the unsustainable growth in driving, the American Association of State Highway and Transportation Officials, representing state departments of transportation, recently called for VMT growth to be cut by half during the next 50 years (AASHTO 2007). Such unlikely allies as the Institute of Transportation Engineers and the Congress for the New Urbanism have teamed up to develop new context-sensitive street standards for walkable communities (see the illustration below). At the local level, several hundred traffic-calming programs have been created in the past decade; the term traffic calming was not even used in the United States until the mid-1990s (Ewing, Brown, and Hoyt 2005).

Elements of a context-sensitive urban highway.
Kimley-Horn and Associates et al. 2006



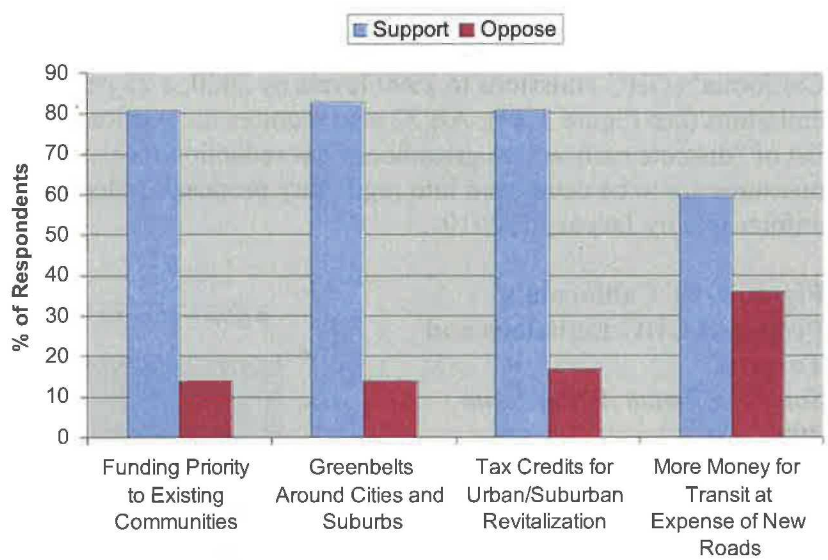
Loss of farmlands and natural areas—and the public benefits they provide—are behind a number of planning initiatives. The Maryland Smart Growth Program was motivated primarily by the rate at which the urban footprint was expanding into resource areas (see Figure 1-16). Nationally, most urbanized areas have seen their land area expand several times faster than their population (Fulton et al. 2001).

Figure 1-16 Parcel Development in Maryland, 1900 to 1960 (left) and 1961 to 1997 (right)

Fiscal constraints at the state and local levels are prompting governments to look for less expensive ways to meet infrastructure and service needs. Compact growth is less expensive to serve than sprawl, by an estimated 11 percent nationally for basic infrastructure (Burchell et al. 2002). The per capita costs of most services decline with density and rise as the spatial extent of urbanized land area increases (Carruthers and Ulfarsson 2003). The Envision Utah scenario planning process resulted in the selection of a compact growth plan that will save the region about $4.5 billion (17 percent) in infrastructure spending compared with a continuation of sprawling development (Envision Utah 2000). A major impetus for growth management is the desire to hold down public service costs.

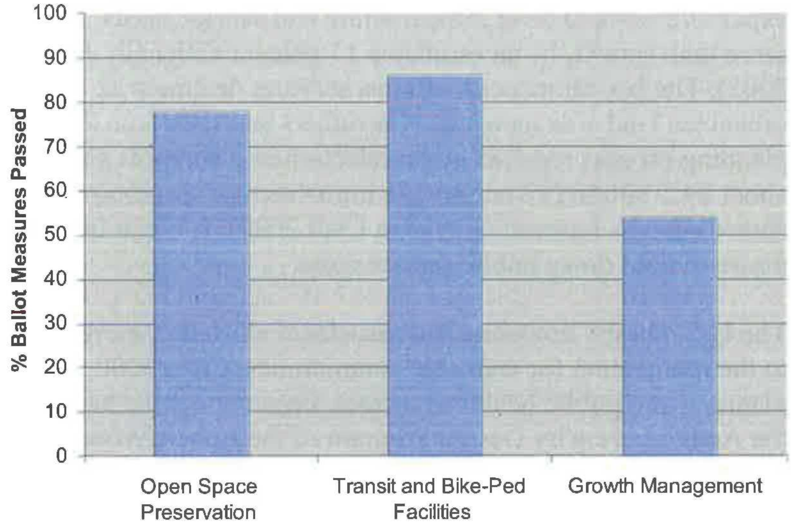
The U.S. obesity epidemic and associated mortality, morbidity, and health care costs have added to the momentum for walkable communities. Circa 2000, a new collaboration between urban planning and public health advocates, began under the banner of active living. Out of this came the Active Living by Design Program of the Robert Wood Johnson Foundation, the Active Community Environments initiative of the Centers for Disease Control and Prevention (CDC), numerous Safe Routes to School programs, and dozens of Mayors' Healthy City initiatives. A recent literature review found that 17 of 20 studies, all dating from 2002 or later, had established statistically significant relationships between some aspect of the built environment and the risk of obesity (Papas et al. 2007).

Figure 1-17 National Opinion Poll Results
Source: Belden Russonello & Stewart 2000.



Public support for smart growth policies appears to be strong and growing (Myers 1999; Myers and Puentes 2001; American Planning Association 2002; Kirby and Hollander 2005). In a 2000 national survey, a majority of respondents favored specific policies under the general heading of smart growth (see Figure 1-17). In the 2000 election, 553 state or local ballot initiatives in 38 states focused on "issues of planning or smart growth" and high percentages passed (see Figure 1-18). In 2004, voters approved 70 percent of ballot measures supporting public transit and rejected three out of four ballot initiatives on "regulatory takings" that could have significantly crimped planning efforts (Goldberg 2007).

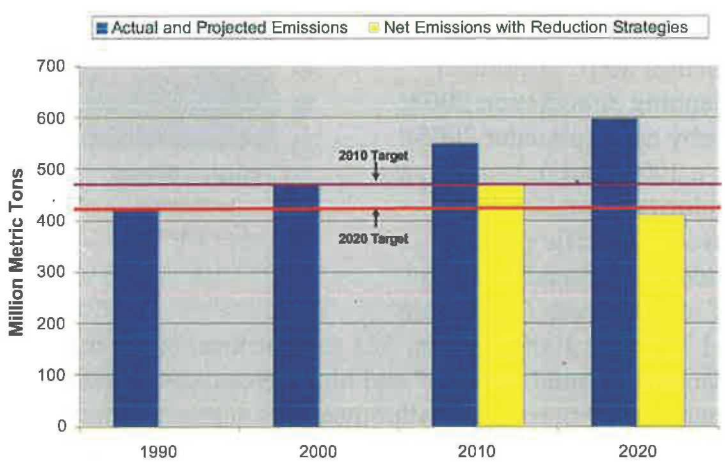
Figure 1-18 State and Local Ballot Measures Passed, 2000 Election
Source: Myers and Puentes 2001.



1.7 The Impact of Compact Development on VMT and CO_2 Emissions

California's landmark Global Warming Solutions Act of 2006 (AB 32) calls for restoring California's GHG emissions to 1990 levels by 2020, a 25 percent reduction relative to current emissions (see Figure 1-19). AB 32 also requires the Air Resources Board (ARB) to identify a list of "discrete early action greenhouse gas reduction measures." Once on the list, these measures are to be developed into regulatory proposals, adopted by the ARB, and made enforceable by January 1, 2010.

Figure 1-19 California's Projected GHG Emissions and Targets
Source: Climate Action Team 2007.



Pursuant to the act, the ARB released *Proposed Early Actions to Mitigate Climate Change in California* (ARB 2007). At the same time, the California Environmental Protection Agency's Climate Action Team recommended 21 additional actions for which GHG emission reductions have been quantified (Climate Action Team 2007). Of all the actions on the original list, those expected to achieve the second-largest reduction (originally 18 million metric tons per year CO_2 equivalent by 2020, since lowered to 10 million metric tons) fell under the heading of "smart land use and intelligent transportation." No details

were provided as to what this category of actions might entail, or how the targeted reduction might be achieved.
How much could a transition from sprawl to compact development reasonably reduce U.S. transport CO_2 levels relative to current trends? The answer is the product of the following six factors:

- market share of compact development;
- reduction in VMT per capita with compact development;
- increment of new development or redevelopment relative to the base;
- proportion of weighted VMT within urban areas;
- ratio of CO_2 to VMT reduction for urban travel; and
- proportion of transport CO_2 due to motor vehicle travel.

Each factor is discussed below and quantified in turn.

1.7.1 Market Share of Compact Development

The first factor that will determine CO_2 reduction with compact development is market penetration during the forecast period, 2007 to 2050. The market share of compact development in the United States is growing but probably still small (Sobel 2006). No comprehensive inventory exists.

Two factors, however, suggest that whatever the market share is today, it will increase dramatically during the forecast period. One factor is the current undersupply of compact development relative to demand (see section 1.5). "A review of existing studies on consumer demand for smart growth products as well as consumer surveys . . . consistently find that at least one third of the consumer real estate market prefers smart growth development" (Logan 2007). The other factor is changing demographics (also discussed in section 1.5). "The aging of the baby boomers is an inexorable force likely to increase the number of households desiring denser residential environments" (Myers and Gearin 2001). The question is, how fast will the supply of compact development respond to this demand?

Over the long run, it is reasonable to assume that what is supplied by the development industry will roughly equal what is demanded by the market, with a time lag. This will be true, provided government policies allow and encourage it. If a third of the market currently wants the density, diversity, and design of smart growth, and almost another third wants the destination accessibility of smart growth (see section 1.5), the market will be inclined to provide these product types.

Changing demographics and lifestyles will increase these proportions. The policy recommendations presented in Chapter 7 will facilitate market changes as well as make a contribution of their own to growing market shares. We will assume that between now and 2050, the *lower bound on the proportion of compact development is six-tenths and the upper bound is nine-tenths*, consistent with demographic trends and the current undersupply. As discussed in subsection 1.7.3, this still leaves more than 40 percent of development as it is today, largely sprawling and auto oriented.

1.7.2 Reduction in VMT per Capita with Compact Development

Based on the urban planning literature reviewed in this publication, it appears that compact development has the potential to reduce VMT per capita by anywhere from 20 to 40 percent relative to sprawl. The actual reduction in VMT per capita will depend on two factors: how bad trend development patterns are in terms of the so-called "five Ds" (density, diversity, design, destination accessibility, and distance to transit); and how good alternative growth patterns are in terms of these same five Ds. The five Ds, which are described in Chapter 3, are qualities of the urban environment that urban planners and developers can affect, which in turn affect travel choices.

Considering all the evidence presented in Chapter 3, it is reasonable to assume an *average reduction in VMT per capita with compact development relative to sprawl of three tenths*. This fraction applies to each increment of development or redevelopment but does not affect base development.

1.7.3 Increment of New Development or Redevelopment Relative to the Base

The cumulative effect of compact development also depends on how much new development or redevelopment occurs relative to a region's existing development pattern. The amount of new development and redevelopment depends, in turn, on the time horizon and the area's growth rate. The longer the time horizon and the faster the rate of development or redevelopment, the greater will be the regionwide percentage change in VMT per capita.

A recent article in the *Journal of the American Planning Association* began with the following words: "More than half of the built environment of the United States we will see in 2025 did not exist in 2000, giving planners an unprecedented opportunity to reshape the landscape" (Nelson 2006). Between 2005 and 2050, the number of residential units of all types may grow from 124 million to 176 million, or a total of 52 million.[6] In addition, each decade, roughly 6 percent of the housing stock of the previous decade is replaced,[7] with about two-thirds being rebuilt on site and another third consisting of new units built elsewhere because of land use conversions (such as a strip mall replacing houses, with the displaced homes rebuilt elsewhere).[8] Counting compounding effects, perhaps 37 million homes will need to be replaced entirely through conversion processes between 2005 and 2050. The number of new plus replaced residential units

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[6] The American Housing Survey reports about 124 million residential units in 2005 while the Census reports a population of about 296 million for the same year, for a ratio of 0.42 units per capita. As household size is not projected to change substantially over the next generation, the Census projected population for 2050 is multiplied by the ratio of residential units to population in 2005 to estimate future residential demand (see http://www.census.gov/hhes/www/housing/ahs/ahs.html).

[7] The 1990 Census reports 102 million residential units while the 2000 Census reports that 96 million survived to 2000, indicating a loss rate of about 6 percent per decade (see www.census.gov).

[8] There is no consensus on the actual rate of loss of residential units through demolition and conversion to another land use. The one-third figure is conservative based on Delphi consensus of experts (see Nelson 2006).

may reach 89 million units between 2005 and 2050, or more than 70 percent of the stock that existed in 2005.

Even more dramatic is the construction of nonresidential space, largely because, on average, about 20 percent of such space turns over each decade.[9] Nonresidential space includes retail, office, industrial, government, and other structures. From 2005 to 2050, nonresidential space will expand from about 100 billion square feet[10] to about 160 billion square feet, or by 60 billion square feet.[11] However, about 130 billion square feet will be rebuilt; some structures will be rebuilt two or more times because their useful life is less than 20 years. Perhaps a total of 190 billion square feet of nonresidential space will be constructed between 2005 and 2050, or nearly twice the volume of space that existed in 2005.

The magnitude of development ahead suggests there may be unprecedented opportunities to recast the built environment in ways that reduce a variety of emissions, especially CO_2. Furthermore, as noted in section 1.5, a very large share of this new development will be driven by emerging market forces that desire compact development, not because it reduces CO_2 emissions but rather because it is responsive to changing tastes and preferences.

Much of the built environment existing in 2005 will remain, of course, including most existing residential stock, institutional buildings, and high-rise structures. Nonetheless, we may assume that easily *two-thirds of development on the ground in 2050* will be developed or redeveloped between now and then.

1.7.4 Proportion of Weighted VMT within Urban Areas

A shift to compact development will affect *urban* VMT, not *rural* VMT. Put another way, compact development policies will affect travel within cities, not travel between cities. Two-thirds of the total VMT in the United States currently is urban. Heavy vehicles produce about four times more CO_2 emissions per mile than light vehicles, and heavy vehicles represent a higher proportion of rural VMT. Weighting VMT accordingly, 62 percent of the nation's VMT is presently urban. This estimate includes cars, trucks, and buses.

The proportion of urban VMT is growing as the United States becomes ever more urbanized. Projecting current trends out to 2050, about *four-fifths of the weighted VMT in 2050 will be urban.*

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[9] The U.S. Department of Energy's Energy Information Administration conducts the Commercial Buildings Energy Consumption Survey (CBECS) about every five years. The 1992 survey reported 68 billion square feet of nonresidential space excluding industrial space. The 1999 survey (the most compatible in format) reported 58 billion nonresident square feet existing in 1992 surviving to 1999, or an imputed loss rate of slightly more than 20 percent per decade (see http://www.eia.doe.gov/emeu/cbecs/).

[10] This figure includes industrial space (see Nelson 2006).

[11] This figure assumes about 580 square feet of space per full- and part-time worker. It is the quotient of total nonresidential space (see Nelson 2006) and workers. The U.S. Department of Commerce's Bureau of Economic Analysis reported there were 173 million total full- and part-time workers in 2005 (see www.bea.gov.) In contrast, the CBECS for 2003 estimates 1,000 square feet per full time worker. The more conservative figure is used.

1.7.5 Ratio of CO_2 to VMT Reduction

Compact development may not reduce CO_2 emissions by exactly the same proportion as VMT. The reasons, discussed in Chapter 2, are the CO_2 penalties associated with cold starts and lower operating speeds in compact areas. For the project-level simulations presented in section 3.4, the ratio of CO_2 to VMT reduction for compact development projects is around 0.95.

The material presented in section 2.3.3 indicates that a reduction in VMT of 30 percent would be expected to produce a reduction in CO_2 of about 28 percent. This figure factors in CO_2 penalties associated with cold starts and reduced vehicle operating speeds. Thus the ratio of CO_2 to VMT reduction would be around 0.93.

Given these three pieces of evidence, and weighting the second most heavily, we will conservatively assume a *CO_2 reduction equal to nine-tenths of the VMT reduction.*

1.7.6 Proportion of Transportation CO_2 from Motor Vehicles

Motor vehicles (automobiles, light- and heavy-duty trucks, and buses) contributed 79 percent of transportation CO_2 emissions in 2005 (EPA 2007, Table 3-7). This percentage is increasing over time, largely because of the growth of heavy-vehicle traffic. We will assume that *motor vehicles contribute four-fifths of transportation CO_2 emissions*, with the balance coming from aircraft, ships, and trains.

1.7.7 Net CO_2 Reduction in Comparison to Other Actions

Projecting out to 2050, the net CO_2 reduction is estimated to be as follows:

6/10 to 9/10 (market share of compact development)

x

3/10 (reduction in VMT per capita with compact development)

x

2/3 (increment of new development or redevelopment relative to base)

x

4/5 (proportion of weighted VMT within urban areas)

x

9/10 (ratio of CO_2 to VMT reduction)

x

4/5 *(proportion of transportation CO_2 from motor vehicles).*

Doing the math, compact development has the potential to reduce U.S. transportation CO_2 emissions by 7 to 10 percent, when compared to continuing urban sprawl.

A 7 to 10 percent reduction in CO_2 emissions should be put into perspective. The long-term elasticity of VMT with respect to fuel price is around –0.3 (see review by Victoria Transport Policy Institute 2007). The price of gasoline would have to double to produce an equivalent (30 percent) reduction in VMT. If one-quarter of the projected gasoline use were replaced with petroleum diesel, biodiesel, or electricity (a replacement rate viewed as "reasonable" within a 25-year time frame), transportation CO_2 emissions would decline by an estimated 8 to 11 percent (Pickrell 2003). This does not include an adjustment for CO_2 from sources other than motor vehicles. The CO_2 savings through 2030 would be at least as large as a 31-mile-per-gallon (mpg) corporate average fuel economy (CAFE) standard (2020 combined mpg for cars and light trucks), or one-third of the savings expected from the Senate's 35-mpg CAFE standard.

The 7 to 10 percent reduction is an end-year estimate. During the 43-year period, the cumulative drop in CO_2 emissions would be about half this amount. Yet, the very phenomenon that limits the short- and medium-term impacts of compact development—the long-lived nature of buildings and infrastructure—makes the reduction essentially permanent and compoundable. The next 50 years of compact development would build on the base reduction from the first 50 years, and so on into the future. More immediate strategies, such as gas tax increases, do not have the same degree of permanence.

The 7 to 10 percent reduction only relates to the transportation sector. Compact development, however, would reduce CO_2 emissions for other sectors as well. An order-of-magnitude estimate for the residential sector is provided in Chapter 6. Controlling for socioeconomic and climatic variables, an equivalent household uses 20 percent less primary energy for space heating and cooling in a compact area than in a sprawling one. This savings is primarily due to less exterior wall area in attached and multifamily housing, and less floor area consumed at higher densities.

The 7 to 10 percent reduction does not consider the impact of intelligent transportation systems, congestion pricing, pay-as-you-drive insurance, or other complementary strategies. These might be used to better manage existing roads and public transportation, supporting smart growth or, alternatively, could be used to accelerate highway capacity expansion, undermining the smart growth impacts documented in this publication.

1.8 The Organization of this Book

Chapter by chapter, this book addresses the impacts of the following:

- vehicular travel on greenhouse gas emissions;
- urban development on vehicular travel;
- residential preferences on urban development and travel;
- highway building on urban development and travel;
- urban development on residential energy use; and, finally,
- policy options for encouraging compact development and reducing vehicular travel.

Sprawling development patterns include low-density and single-use development (top left), uncentered strip development (top right), scattered and leapfrog development (bottom left), and sparse street networks (bottom right).

The fourth qualifier has led to a host of studies using disaggregate travel data; that is, data for individuals or households. Such studies are summarized in section 3.2. For now, the focus is on aggregate relationships, where the unit of analysis is the place.

3.1.1 Measuring Urban Sprawl

Around 2000, researchers began to measure the extent of urban sprawl. Their initial attempts were crude. For example, *USA Today*—on the basis of an index presented in its February 22, 2001, issue—declared: "Los Angeles, whose legendary traffic congestion and spread-out development have epitomized suburban sprawl for decades, isn't so sprawling after all. In fact, Portland, OR, the metropolitan area that enacted the nation's toughest antigrowth laws, sprawls more." Indeed, according to *USA Today*'s index, even the New York metropolitan area sprawls more than Los Angeles (Nasser and Overberg 2001).

The most notable feature of these early studies was their failure to define sprawl in all its complexity. Population density is relatively easy to measure, and hence served as the sole indicator of sprawl in several studies. Judged in terms of average population density, Los Angeles looks compact; it is the endless, uniform character of the city's density that makes it seem so sprawling. Another notable feature of these studies was the wildly different sprawl ratings given to different metropolitan areas by different analysts. With the exception of Atlanta, which always seems to rank among the worst, the different variables used to measure sprawl led to very different results. In one study, Portland was ranked as most compact and Los Angeles was way down the list. In another, their rankings were essentially reversed.

Meanwhile, others were developing more complete measures of urban sprawl. Galster et al. (2001) characterized sprawl in eight dimensions: density, continuity, concentration, clustering, centrality, nuclearity, mixed use, and proximity. The condition—sprawl—was defined as a pattern of land use that has low levels in one or more of these dimensions. Each dimension was operationally defined, and six of the eight were quantified for 13 urbanized areas. New York and Philadelphia ranked as the least sprawling of the 13, and Atlanta and Miami as the most sprawling.

Since then, Galster and his colleagues have extended their sprawl measures to 50 metropolitan areas, and are closing in on 100. Their recent work confirms the multidimensional nature of sprawl. In one study, metropolitan areas were ranked in 14 dimensions, some related to population, others to employment, and still others to both (Cutsinger et al. 2005). The 14 dimensions were reduced to seven factors through principal components analysis. Metropolitan areas ranking near the top on one factor were likely to rank near the bottom on another. Los Angeles, for example, ranked second on both "mixed use" and "housing centrality," but 48th on "proximity" and 49th on "nuclearity." With so many variables and esoteric names, this type of analysis can get very confusing.

Building on this work, Cutsinger and Galster (2006) identified four distinct sprawllike patterns among the 50 metropolitan areas: 1) deconcentrated, dense areas; 2) leapfrog areas; 3) compact, core-dominant areas with only moderate density; and 4) dispersed areas. Since none of the 50 metropolitan areas exhibited uniform sprawllike patterns in all dimensions, the authors judged it incorrect to treat sprawl as a single phenomenon.

Multidimensional sprawl indices also were developed for the U.S. EPA and Smart Growth America. They defined sprawl as any environment with 1) a population widely dispersed in low-density residential development; 2) a rigid separation of homes, shops, and workplaces; 3) a lack of major employment and population concentrations downtown and in suburban town centers and other activity centers; and 4) a network of roads marked by very large block size and poor access from one place to another. These indices were used to measure sprawl for 83 of the nation's largest metropolitan areas (Ewing, Pendall, and Chen 2002, 2003).

Principal components analysis was used to reduce 22 land use and street network variables to four factors representing these four dimensions of sprawl, each factor being a linear combination of the underlying operational variables.[21] The four factors represent a balanced scorecard of sprawl indicators. "Density" and "mix," while correlated, are very different constructs, as are "centeredness" and "street accessibility." The four factors were combined into an overall metropolitan sprawl index.

A simpler county sprawl index also was developed to measure the built environment at a finer geographic scale, the individual county. This index is a linear combination of six variables from the larger set, these six being available for counties, whereas many of the larger set were available only for metropolitan areas.[22] Initially calculated for 448 metropolitan counties (McCann and Ewing 2003), the index is now available for 954 metropolitan counties or county equivalents representing 82 percent of the nation's population (Ewing, Brownson, and Berrigan 2006).

All sprawl indices were standardized, with mean values of 100 and standard deviations of 25. The way the indices were constructed, the bigger the value of the index, the more compact the metropolitan area or county; the smaller the value, the more sprawling the metropolitan area or county. Thus, in the year 2000, the New York metropolitan statistical area had an index value of 178, while Atlanta had a value of 58. Manhattan had an index value of 352, while Geauga County (outside Cleveland) had a value of 63 (see photographs below).

[21] "Residential density" was defined in terms of gross and net densities and proportions of the population living at different densities; seven variables made up the metropolitan density factor. "Land use mix" was defined in terms of the degree to which land uses are mixed and balanced within subareas of the region; six variables made up this factor. "Degree of centering" was defined as the extent to which development is focused on the region's core and regional subcenters; six variables made up this factor. "Street accessibility" was defined in terms of the length and size of blocks; three variables made up this factor.

[22] The six variables are as follows: 1) gross population density (persons per square mile); 2) percentage of the county population living at low suburban densities, specifically, densities between 101 and 1,499 persons per square mile, corresponding to less than one housing unit per acre; 3) percentage of the county population living at moderate to high urban densities, specifically, more than 12,500 persons per square mile, corresponding to about eight housing units per acre, the lower limit of density needed to support mass transit; 4) the net density in urban areas, which was derived from the estimated urban land area for each county; 5) average block size; and 6) percentage of blocks with areas less than 1/100 of a square mile, the size of a typical traditional urban block bounded by sides just over 500 feet in length.

Satellite photographs show the nation's most compact county—New York County, also known as Manhattan—at left and its most sprawling county—Geauga County, Ohio—at right. Both photographs are presented at the same scale.
Source: www.maps.google.com

3.1.2 Relating Urban Sprawl to Travel Outcomes

The study for the EPA and Smart Growth America analyzed relationships between sprawl and various travel outcomes. The overall sprawl index showed strong and statistically significant relationships to six outcome variables. All relationships were in the expected directions. As the index increases (that is, as sprawl decreases), average vehicle ownership, daily VMT per capita, the annual traffic fatality rate, and the maximum ozone level decrease to a significant degree. At the same time, shares of work trips by transit and walk modes increase to a significant degree.

The significance of these relationships rivaled or, in some cases, actually exceeded that of the sociodemographic control variables. The index was the only variable that rose to the level of statistical significance for walk share of work trips and maximum ozone level, and had the strongest association to daily VMT per capita and the annual traffic fatality rate. It had secondary, but still highly significant, associations with average vehicle ownership and transit share of work trips.

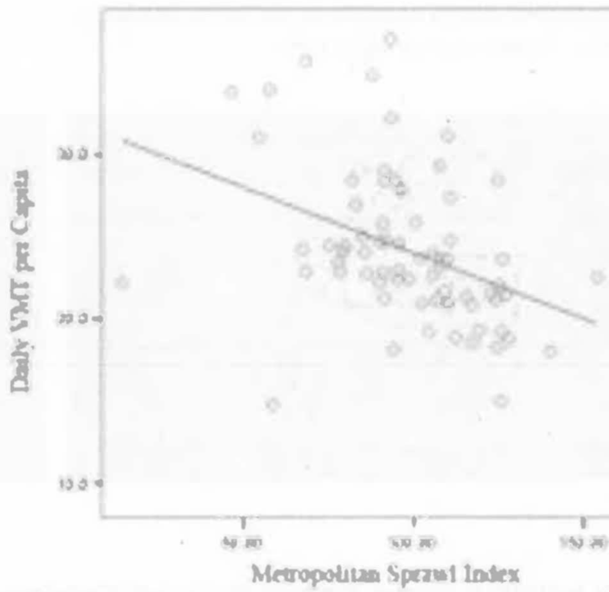
Obviously, these relationships are not independent of each other. The lower level of vehicle ownership in dense metropolitan areas contributes to higher mode shares for alternatives to the automobile. These, in turn, contribute to lower VMT, which contributes to lower traffic fatalities and ozone levels. Because of the different data sources, units of analysis, and sample sizes, it would be treacherous to model the causal paths among these outcome variables. But, intuitively, they should be related as indicated.

3.1.3 Sprawl versus VMT

The relationship between the overall metropolitan sprawl index and VMT per capita is plotted in Figure 3-5. The simple correlation is significant. The more compact an area (the larger the index value), the lower the VMT per capita.

Figure 3-5 Simple Correlation between Daily VMT per Capita and Metropolitan Sprawl Index*
Source: Ewing, Pendall, and Chen 2002.

*Larger index values = less sprawl.



Recall that the overall sprawl index is composed of four factors: density, mix, centeredness, and street accessibility (as discussed in section 3.1.1). The density factor has the strongest and most significant relationship to travel and transportation outcomes (see Figure 3-6). It has a significant inverse relationship to average vehicle ownership, VMT per capita, traffic fatality rate, and maximum ozone level, and a significant direct relationship to public transportation and walk shares of commute trips. With the exception of the traffic fatality rate, all relationships are significant at the 0.01 probability level or beyond.

To illustrate the strength of density relationships, a 50-unit increase in the density factor (from one standard deviation below average to one standard deviation above average) is associated with a drop of 10.75 daily VMT per capita (50 x –0.215). That is, controlling for metropolitan population, per capita income, and other factors, the difference between low- and high-density metropolitan areas is more than 10 VMT per capita per day, or 40 percent. Fifty units is roughly the difference in density between San Francisco (denser) and Washington, D.C. (less dense), or between Chicago (denser) and St. Louis (less dense).

The centeredness factor has the next most significant environmental influence on travel and transportation outcomes. It is inversely related to annual delay per capita and traffic fatality rate, and is directly related to public transportation and walk shares of commute trips. These associations are in addition to—and independent of—those of density, which is controlled in the same equations.

The relationship between degree of centering and VMT per capita is just short of significant at the 0.05 level. A 50-unit increase in the centeredness factor (from one standard deviation below the average to one standard deviation above) is associated with a 2.3 daily VMT per capita (50 x –0.0462), about one-quarter the change associated with the density factor. The two effects are additive. Fifty units is roughly the difference in degree of centering between New York (more centered) and Philadelphia (less centered), or between Portland (more centered) and Los Angeles (less centered).

Figure 3-6 Transportation Outcomes versus Sprawl Factors*
Source: Ewing, Pendall, and Chen 2002

	Transportation Outcomes							
	Vehicles per Household	***Transit Share of WorkTrips***	***Walk Share of WorkTrips***	***Mean Travel Time to Work***	***Annual Delay per Capita***	***VMT per Capita***	***Fatalities per 10,0000 Population***	***Peak Ozone Level***
Density factor	– –	++	++			– –	–	– –
Mix factor				–			–	+
Centers factor	– –	++	++	–	–	–	–	–
Streets factor				++	++			
Metro population		+		++	+			++
Average household size	+			++	++			
Percentage of working age	++				++	+		
Per capita income		++		++			–	
Adjusted R^2	0.56	0.67	0.36	0.61	0.63	0.28	0.44	0.40

*+ indicates a positive relationship significant at the 0.05 probability level; ++ a positive relationship significant at the 0.01 probability level; – a negative relationship significant at the 0.05 probability level; and – – a negative relationship significant at the 0.01 probability level.

The mix factor is significant for only three transportation outcomes: as a mitigating influence on travel time to work and fatal accidents and an aggravating influence on the maximum ozone level. The big surprise is that land use mix does not significantly affect other outcomes, including VMT per capita. It may be that land use mix has not been successfully operationalized because of problems with the underlying data sets (Ewing, Pendall, and Chen 2002).

The streets factor is significant for two transportation outcomes, albeit just barely and with unexpected signs. Average travel time for commute trips and annual traffic delay per capita are directly related to the streets factor. Perhaps the reason for this counterintuitive result is that the additional intersections in metro areas with dense street grids translate into more total delay, since most delays occur at intersections rather than on the stretches between them. This is the conventional wisdom among traffic engineers. In any case, street patterns appear to be much less important than land use patterns as correlates of travel and transportation outcomes.

3.1.4 Sprawl versus Congestion

It has been argued that the dispersal of jobs and housing allows residents to live closer to their workplaces than they could if jobs were concentrated in downtown and other centers. It also has been argued that the dispersal of jobs and housing eases traffic congestion by dispersing origins and destinations. These effects, if dominant, would lead to shorter trips and less congestion in sprawling metro areas. But the dispersal of jobs and housing also may result in jobs/housing imbalances across the region, cross commuting, and significantly more VMT per capita than with more compact urban development. The average commute has been getting steadily longer in miles and minutes (Hu and Reuscher 2004). The net effect of sprawl on traffic congestion is unclear a priori.

Evidence from aggregate travel studies suggests that density aggravates congestion, but not much. One study found that congestion rises with population density for counties in California (Boarnet, Kim, and Parkany 1998). Urbanized counties as a group are more congested than rural counties. However, this same study found "surprisingly congested counties that are either rural or on the fringe of urban areas." These fringe counties generate a lot of VMT. We reanalyzed congestion data from that study and, excluding one outlier, computed an elasticity of congestion with respect to density of 0.14.

Another study found little relationship between density and commute time in the largest urban areas (Gordon, Kumar, and Richardson 1989). "Travel times may be long in high- or low-density cities (e.g., New York or Houston) or short (e.g., Los Angeles or Dallas)." Basically, shorter trips and mode shifts in dense areas largely offset any effect of lower speeds.

The Texas Transportation Institute's Urban Mobility database for 85 urbanized areas also shows a weak relationship between density and congestion (Schrank and Lomax 2005). TTI measures congestion in terms of a travel time index; that is, the ratio of travel time in the peak period to travel time at free-flow conditions. A value of 1.35 indicates that a 20-minute free-flow trip takes, on average, 27 minutes in the peak period. In a cross-sectional analysis for 2003, the last year in the series, the elasticity of travel time with respect to population density is 0.085. This elasticity estimate controls for population size because bigger cities have more congestion regardless of their urban form. In a longitudinal analysis for the same 85 urbanized areas using the full TTI data series (1982 to 2003), the elasticity of change in travel time with respect to change in density is 0.107. This elasticity estimate controls for population growth because fast-growing areas have more congestion regardless of how they grow.

Such studies have been criticized for focusing on only one dimension of sprawl: "Other land use dimensions are less well studied in a comparative framework . . . while it is believed that land use patterns may play an important role in mitigating or slowing the growth of congestion in urban areas, few studies have explored the relationship between land use and congestion across more than a small number of urban areas or examined multiple measures of land use beyond population density" (Sarzynski et al. 2006).

In the Smart Growth America study, sprawl factors pulled in opposite directions (Ewing, Pendall, and Chen 2002, 2003). The overall sprawl index was not significantly related to either average commute time or annual traffic delay per capita. Both outcomes were a function primarily of metropolitan area population, and secondarily of other sociodemographic variables. Big metro areas generate longer trips to work and higher levels of traffic congestion. After controlling for population size and other sociodemographic variables, sprawl (overall) did not appear to have an effect on average commute time or annual traffic delay per capita.

Using the same overall metropolitan sprawl index as Ewing, Pendall, and Chen (2002), Kahn (2006) divided metropolitan areas into four categories and found that, relative to workers in compact metro areas, workers in sprawling ones commute an extra 1.8 miles each way. But their commute is still 4.3 minutes shorter; the extra commute distance is more than offset by higher travel speeds. Indeed, commute speed is estimated to be 9.5 mile per hour higher in the sprawling metro areas.

Why is there a difference in the sprawl/commute time relationship between two studies that test the same overall sprawl index? The first study uses U.S. Census commute data, the second American Housing Survey commute data. The first study treats sprawl as a continuous variable, the second as a categorical variable. Whatever their differences, both studies suggest higher VMT in sprawling metro areas than in compact ones.

Another recent study, by Galster and colleagues, related seven dimensions of sprawl to traffic congestion for 50 large metropolitan areas in 2000 (Sarzynski et al. 2006). Controlling for 1990 levels of congestion and changes in an urban area's transportation network and relevant demographics, the study found that density and housing centrality were positively related to year 2000 delay per capita and that housing/job proximity was negatively related to year 2000 commute time.

Differences between this and earlier studies may be due to the use of a lagged model structure, different land use measures, or a different sample of metropolitan areas. Since Sarzynski et al. were unable to study the effect of land use changes between 1990 and 2000 (for lack of sprawl indices for 2000), it is hard to interpret the coefficients of a lagged model. Relationships to delay could be bogus in all of these studies, since the delay measure used by everyone comes from the Texas Transportation Institute and is imputed rather than actually measured in the field. Considering all the evidence from aggregate travel studies, it is reasonable to assume some drop in average travel speeds with rising density. From this literature, we cannot draw any conclusions about travel speeds versus land use mix or other dimensions of sprawl.

3.2 Disaggregate Travel Studies

Land use/travel studies date from the early 1960s, when urban density was first shown to affect auto ownership, trip rates, and travel mode shares. Around 1990, researchers began to use disaggregate travel data for individuals or households; made some effort to control for other influences on travel behavior, particularly the socioeconomic status of travelers; and tested a wider variety of local land use variables than had earlier studies.

The relationship between urban development patterns and individual or household travel has become the most heavily researched subject in urban planning. There are now close to 100 empirical studies conducted with a degree of rigor—that is, with decent sample sizes, sociodemographic controls, and statistical tests to determine the significance of the various effects (see literature reviews by Badoe and Miller (2000); Crane (2000); Ewing and Cervero (2001); Saelens, Sallis, and Frank (2003); and Heath et al. (2006)). The vast majority of these studies show significant relationships between development patterns and travel behavior. Today, only the direction of causality and strength of effects seems to be seriously debated.

When funding from public health sources became available after 2000, planning researchers morphed into physical activity researchers, and the literature grew even further (see reviews by Frank (2000), Frank and Engelke (2001, 2005), Lee and Moudon (2004), Owen et al. (2004), Badland and Schofield (2005), and Handy (2006)). Both types of physical activity—for transportation and for exercise—were studied together for the first time, and the physical environment was measured comprehensively in terms of development patterns and physical activity settings (see Figure 3-7). Again, nearly all studies show significant relationships. And, again, the debate is mainly over the direction of causality and effect sizes. A special Winter 2006 issue of the *Journal of the American Planning Association* was devoted to this new research.

Figure 3-7 Causal Pathways Linking the Built Environment to Health
Source: Ewing et al. 2003.