APPENDIX B

Quality of Life Research Information

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

Urban Land Institute

Smart Growth America
Better Choices For Our Communities

Center for Clean Air Policy
Dialogue Insight Solutions

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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- Fostering collaboration within and beyond ULI's membership through mentoring, dialogue, and problem solving;
- Exploring issues of urbanization, conservation, regeneration, land use, capital formation, and sustainable development;
- Advancing land use policies and design practices that respect the uniqueness of both built and natural environments;
- Sharing knowledge through education, applied research, publishing, and electronic media; and
- Sustaining a diverse global network of local practice and advisory efforts that address current and future challenges.

Established in 1936, the Institute today has some 38,000 members in over 90 countries, representing the entire spectrum of the land use and development disciplines. ULI relies heavily on the experience of its members. It is through member involvement and information resources that ULI has been able to set standards of excellence in development practice. The Institute has long been recognized as one of the world's most respected and widely quoted sources of objective information on urban planning, growth, and development.

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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

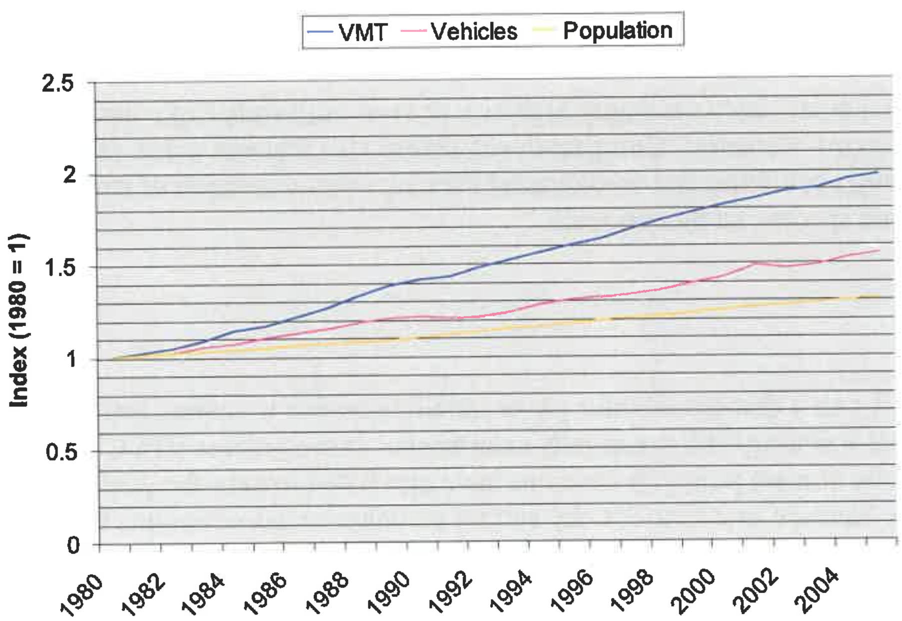
The United States is the largest emitter worldwide of the greenhouses gases that cause global warming. Transportation accounts for a full third of CO_2 emissions in the United States, and that share is growing as others shrink in comparison, rising from 31 percent in 1990 to 33 percent today It is hard 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.

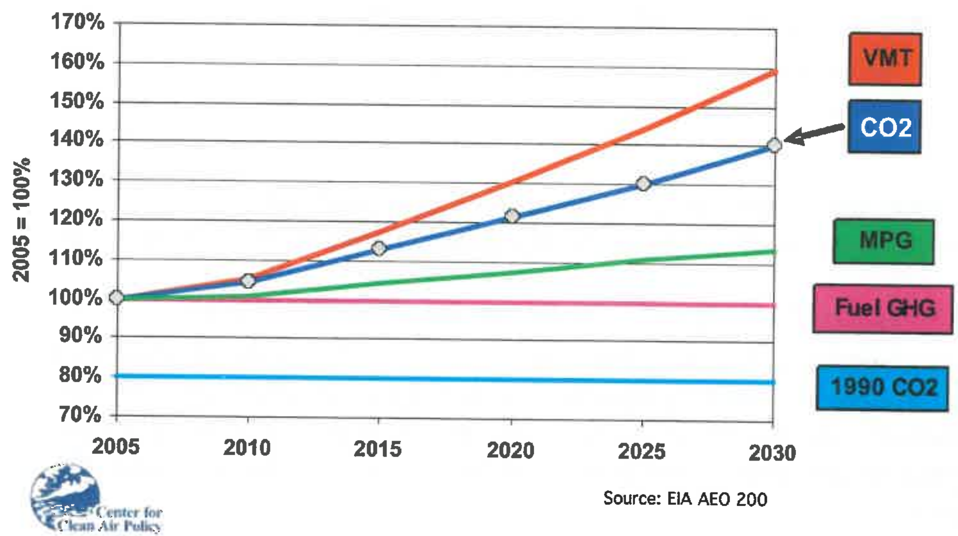
As with driving, land is being consumed for development at a rate almost three times faster than population growth. This expansive development has caused CO_2 emissions from cars to rise even as it has reduced the amount of forest land available to absorb CO_2.

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).

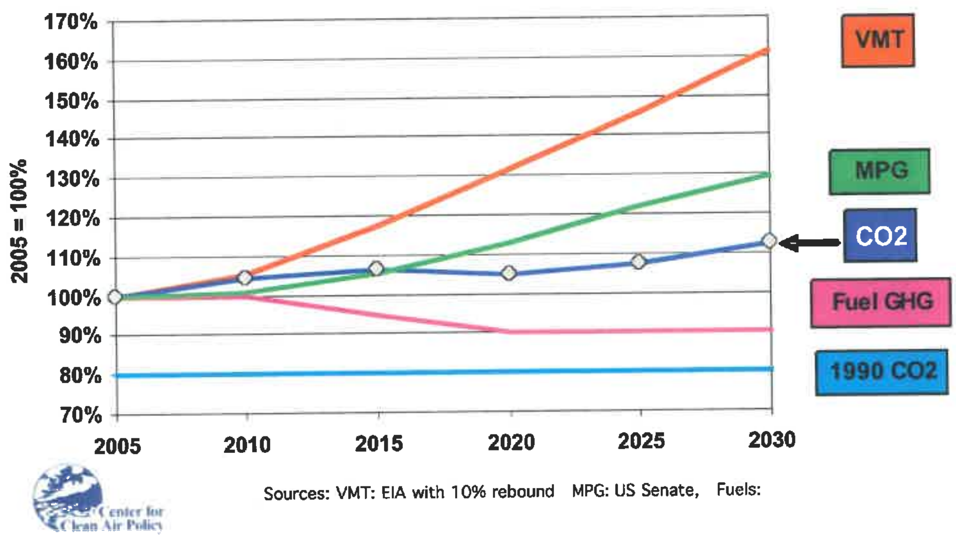
Figure 0-2 Projected Growth in CO_2 Emissions from Cars and Light Trucks
Source: EIA 2007.



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

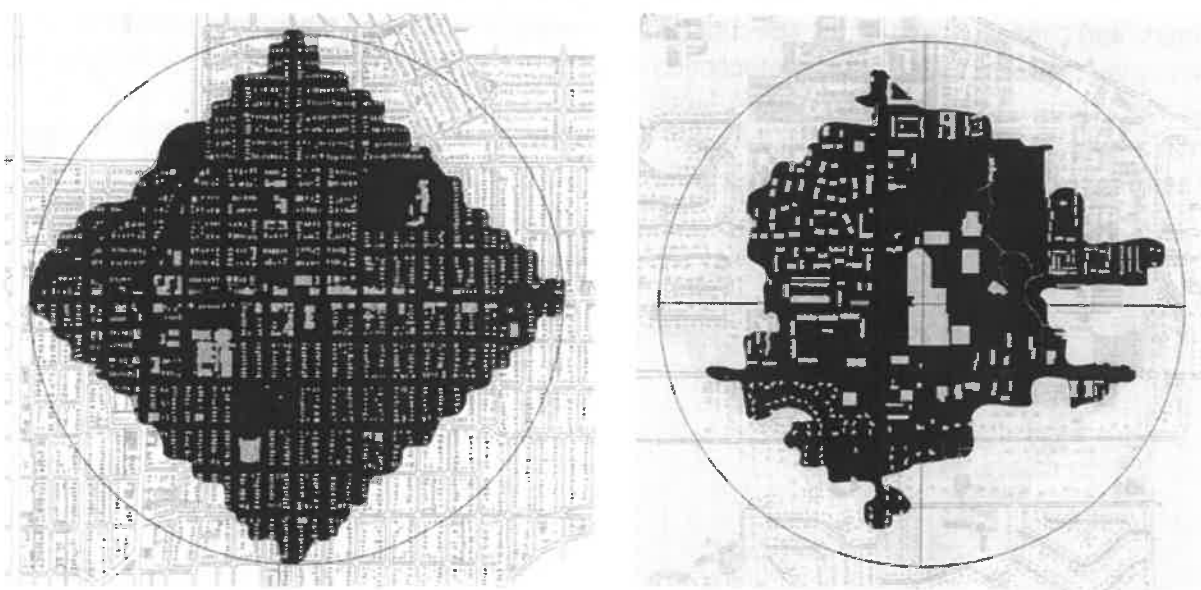
Recognizing the unsustainable growth in driving, the American Association of State Highway and Transportation Officials (AASHTO), representing state departments of transportation, is urging that the growth of vehicle miles driven be cut in half. How does a growing country—one with 300 million residents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

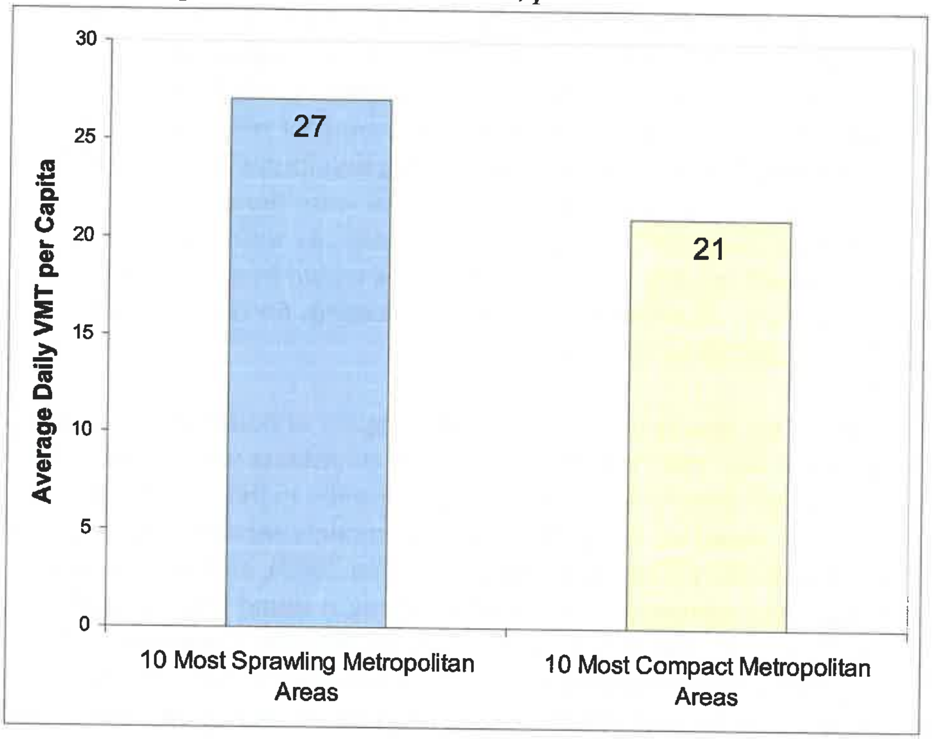
As these forms of development have become more common, planning researchers and practitioners have documented that residents of compact, mixed-use, transit-served communities do less driving. Studies have looked at the issue from varying angles, including:

- 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

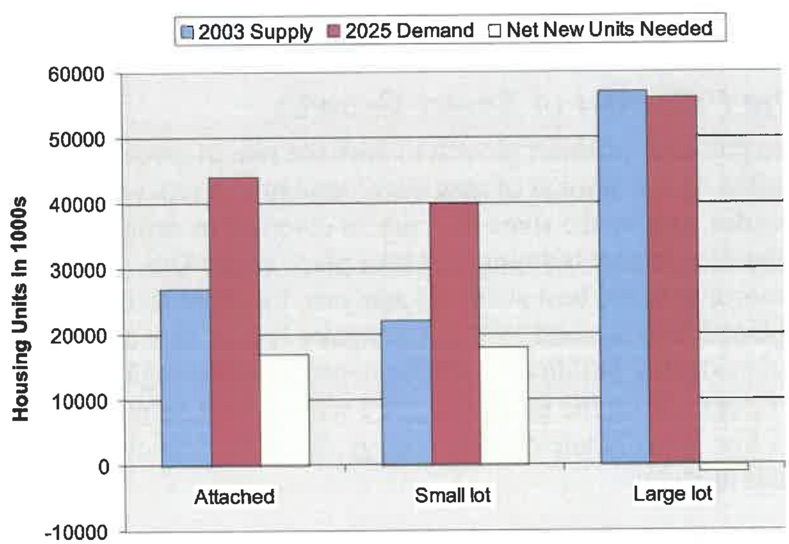
There is no doubt that moving away from a fossil fuel–based economy will require many difficult changes. Fortunately, smart growth is a change that many Americans will embrace. Evidence abounds that Americans are demanding more choices in where and how they live—and that changing demographics will accelerate 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.
© Scientific American (Socolow and Pacala 2006)

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.

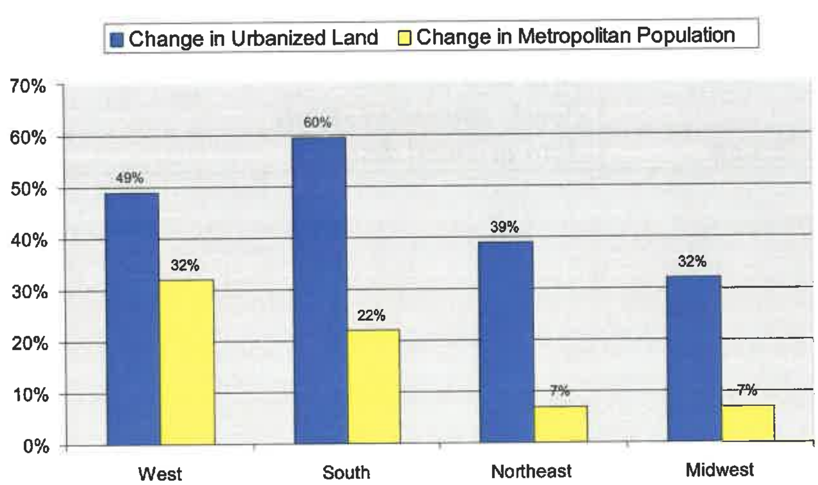
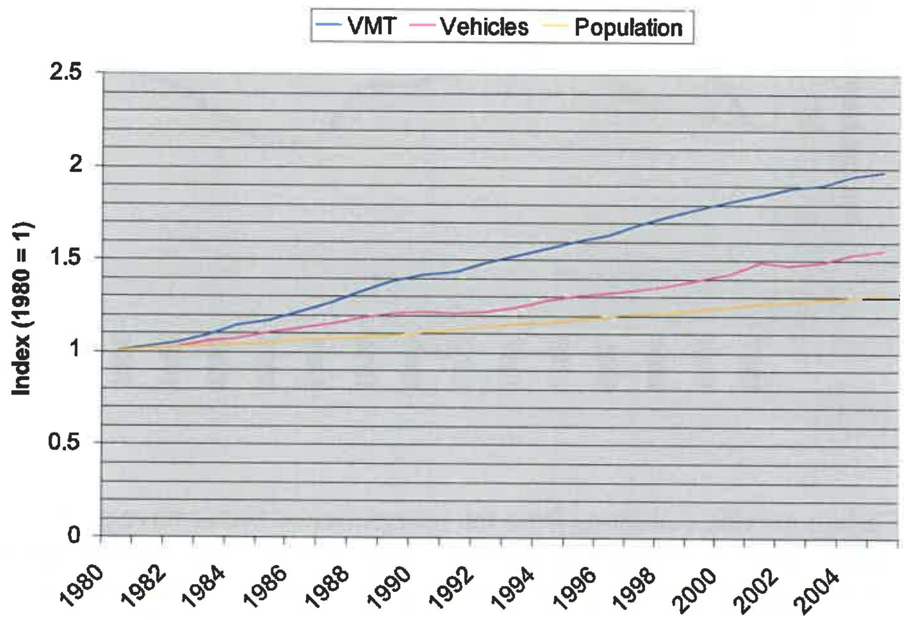


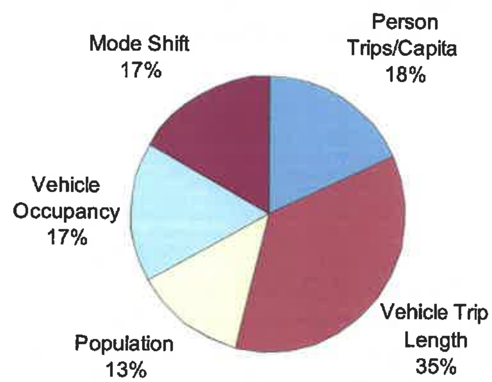
Figure 1-3 Growth of Population and Urbanized Land Area by Census Region between 1982 and 1997
Source: Fulton et al. 2001.

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.

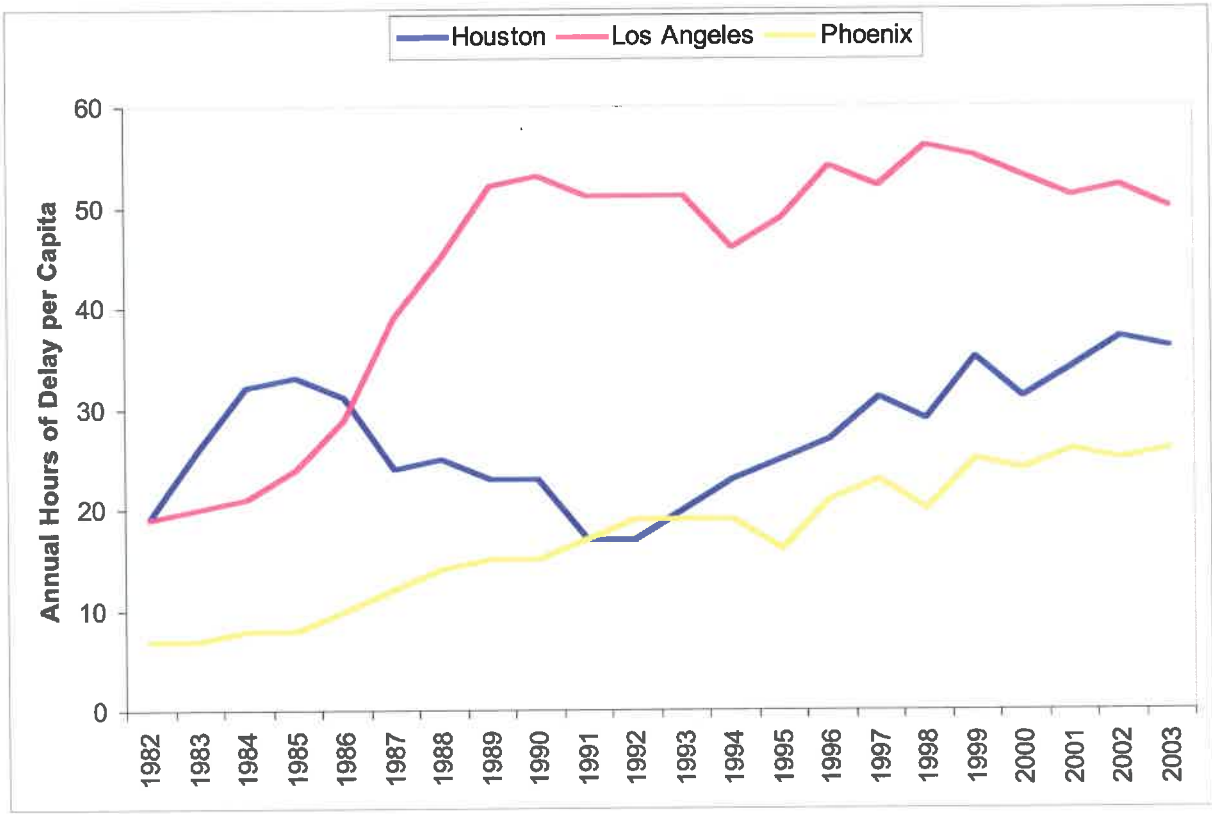


Vehicle miles traveled have grown more than twice as fast as highway capacity in urbanized areas of the United States. In all 85 urbanized areas for which statistics are available, highways became more congested between 1982 and 2003 (Schrank and Lomax 2005). This is true even in regions that struggled 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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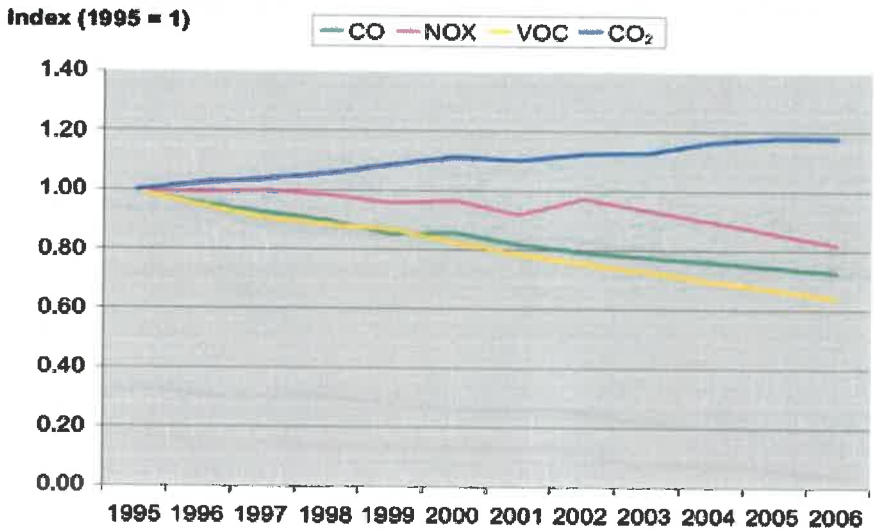
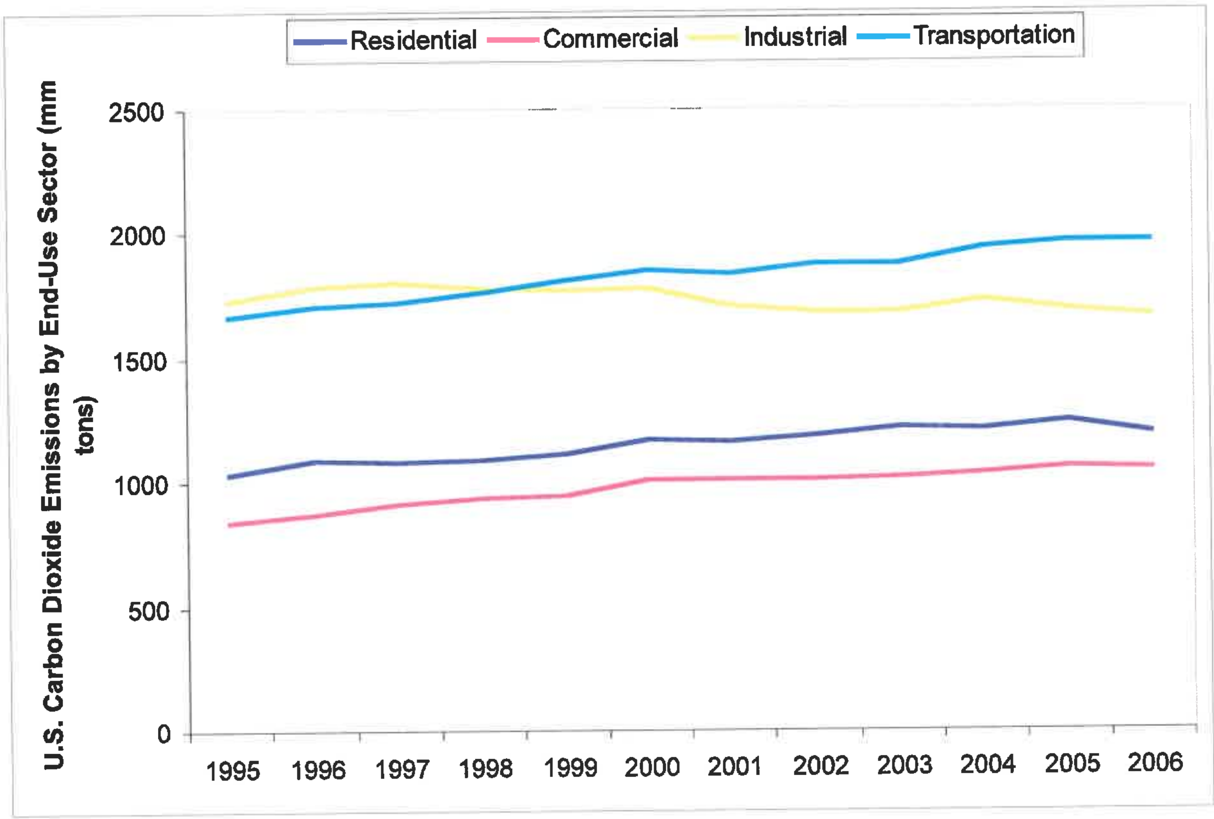
[3] The advent of "first-generation" catalytic converters in 1975 significantly reduced hydrocarbon and carbon monoxide (CO) emissions. Because lead inactivates the catalyst, 1975 also saw the widespread introduction of unleaded gasoline. The next milestone in vehicle emission control technology came 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.



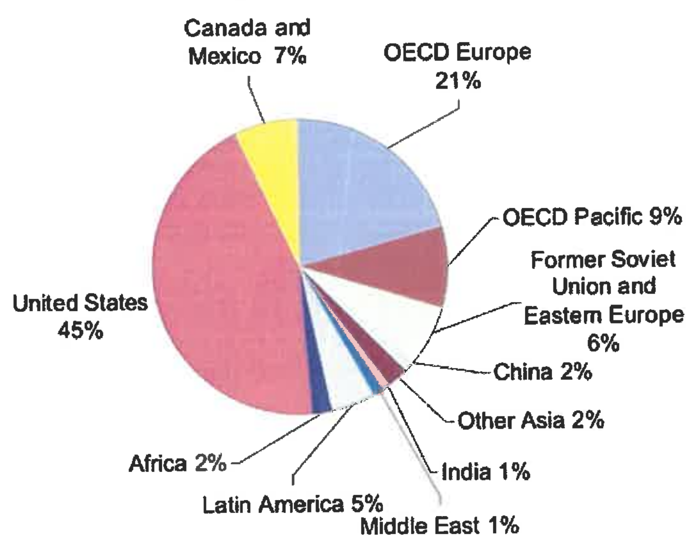
The transportation sector has become the largest source of CO_2 emissions in the United States, surpassing the industrial sector (see Figure 1-8). It now accounts for one-third of the U.S. total. Unless action is taken, the transportation sector's share of CO_2 emissions is expected to increase as VMT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

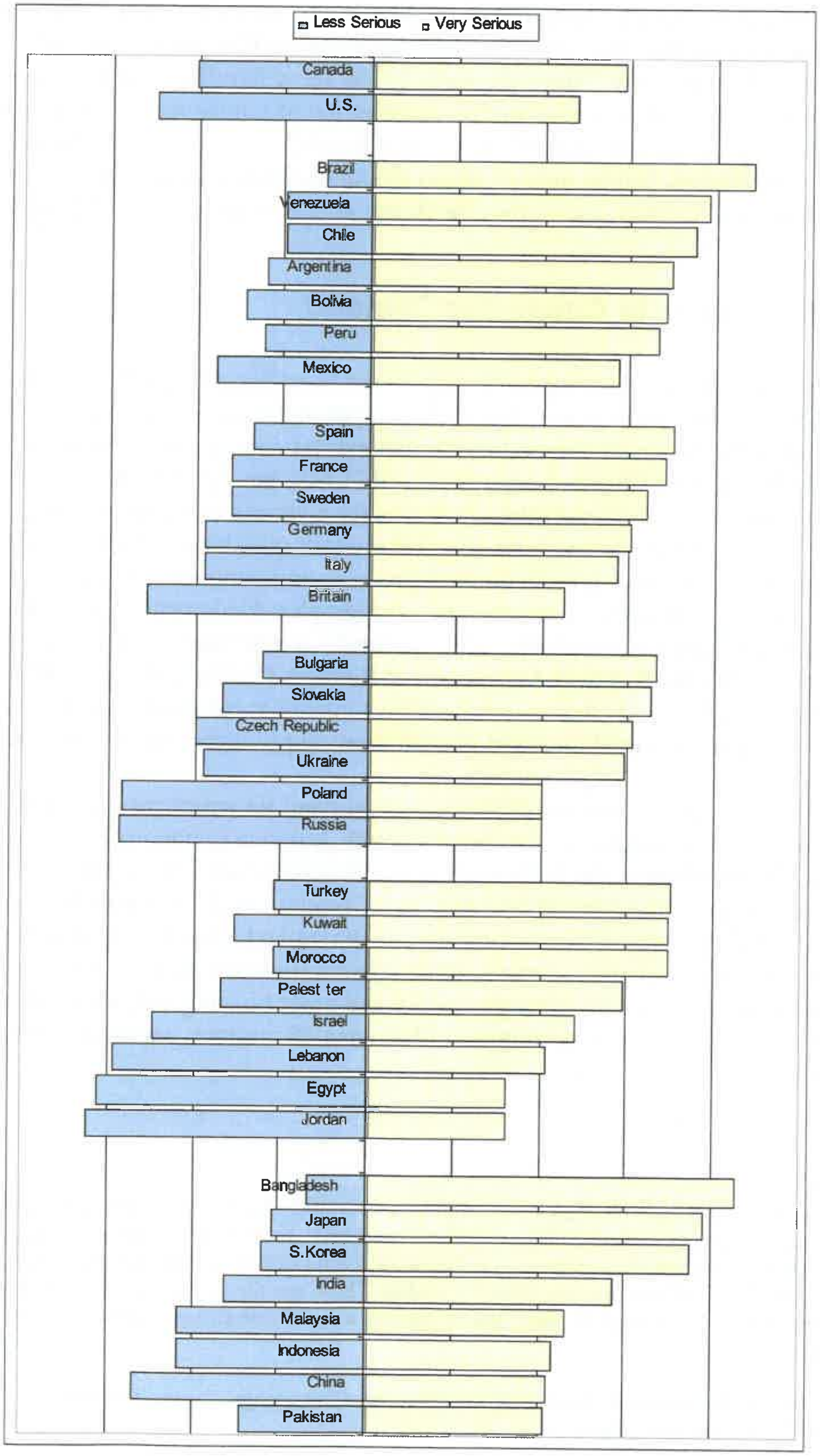
- July: Congressional lawmakers have introduced more than 125 bills, resolutions, and amendments specifically addressing global climate change and GHG emissions, compared with the 106 pieces of relevant legislation introduced during the entire two-year term of the previous Congress (Pew Center on Global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

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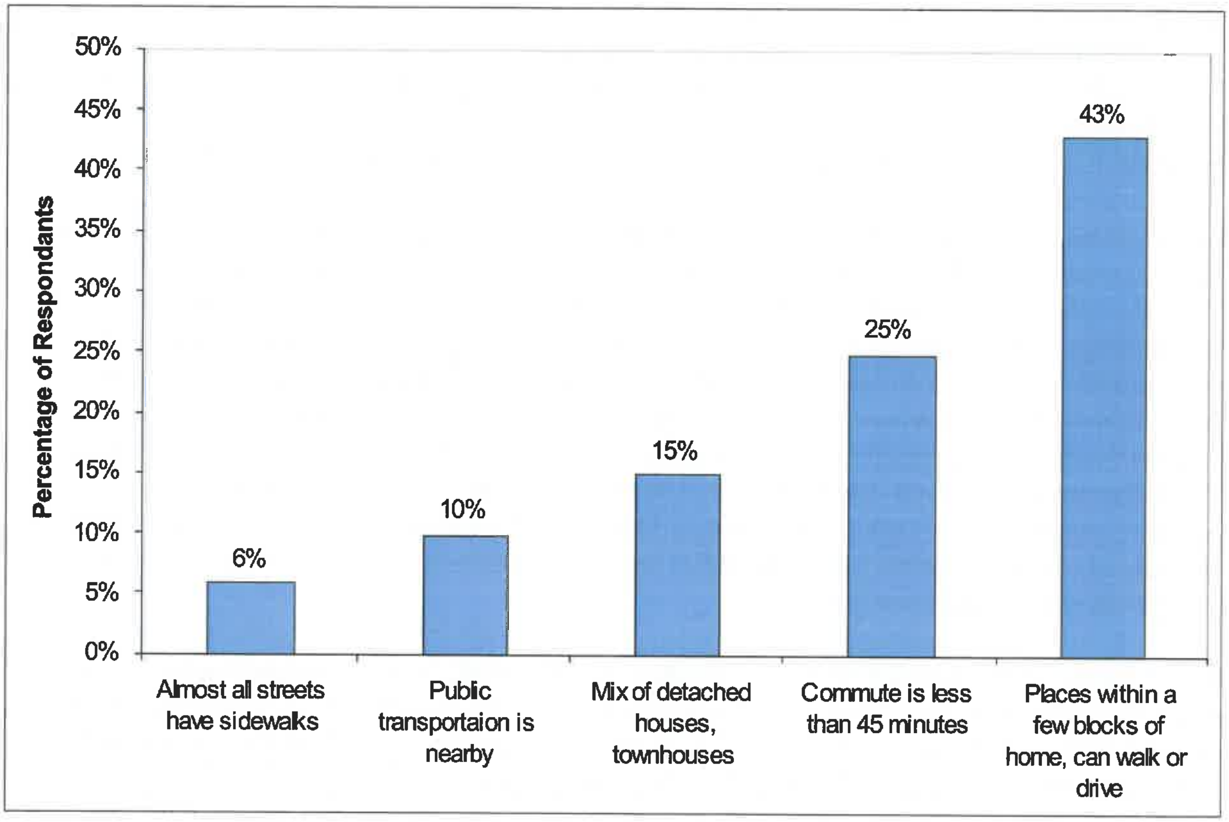
[4] The data series show significant changes in observations of physical systems (snow, ice, and frozen ground; hydrology; and coastal processes) and biological systems (terrestrial, marine, and freshwater biological systems), together with surface air temperature changes over the period 1970 to 2004. 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.

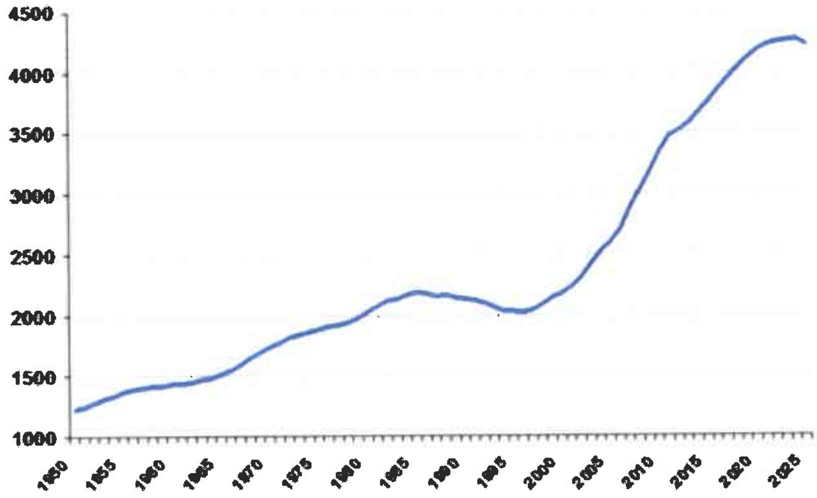
Figure 1-11 Attractions of a Smart Growth Community*
Source: Belden Russonello & Stewart 2004



* 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

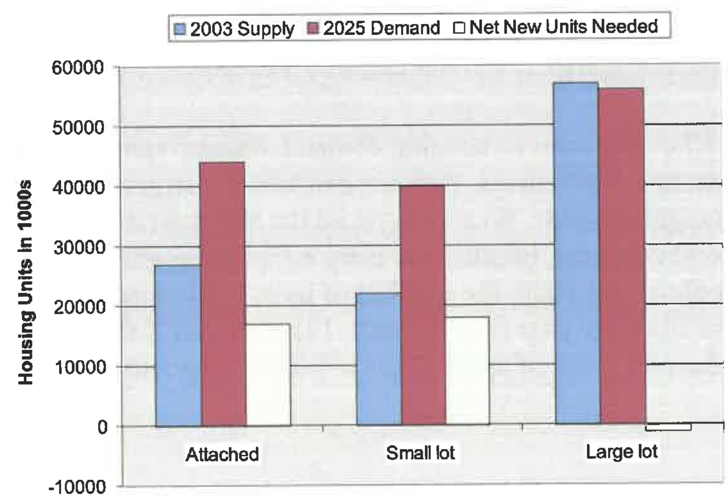


Growth in households without children (including one-person households) also will rise dramatically. From 2000 to 2025, households without children will account for 88 percent of total growth in households. (Thirty-four percent will be one-person households). By 2025, only 28 percent of households will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

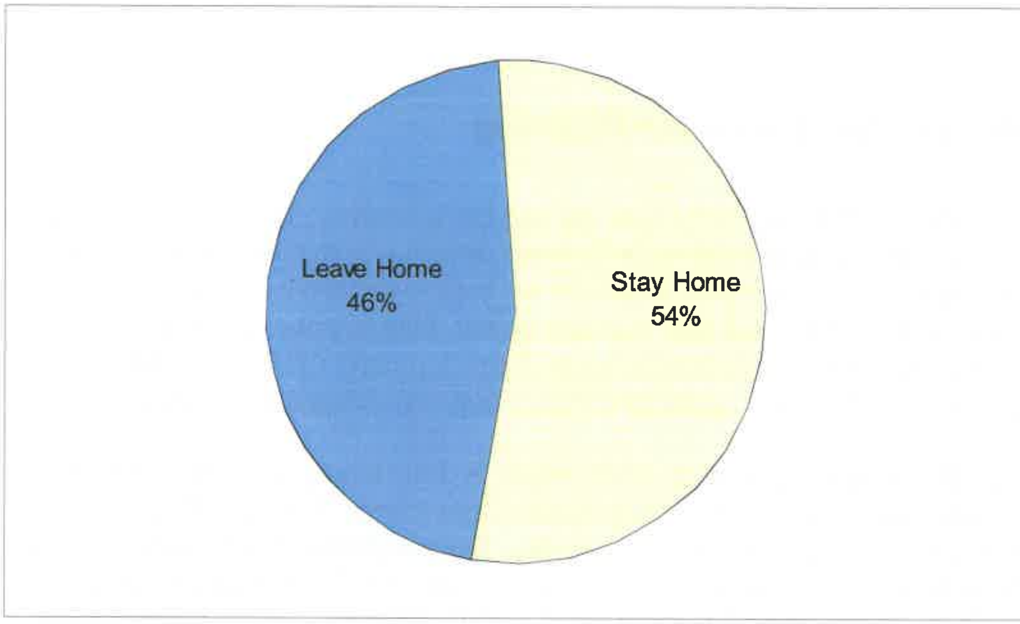
Figure 1-13 2003 Housing Supply versus 2025 Housing Demand
Source: Nelson 2006.



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.

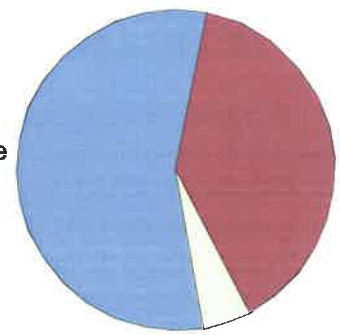


AARP surveys suggest that most people want to "age in place" (Bayer and Harper 2000; Mathew Greenwald & Associates 2003). In most areas where older Americans are aging in place, public transportation services are not available. In fact, according to a national poll, only 45 percent of Americans over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

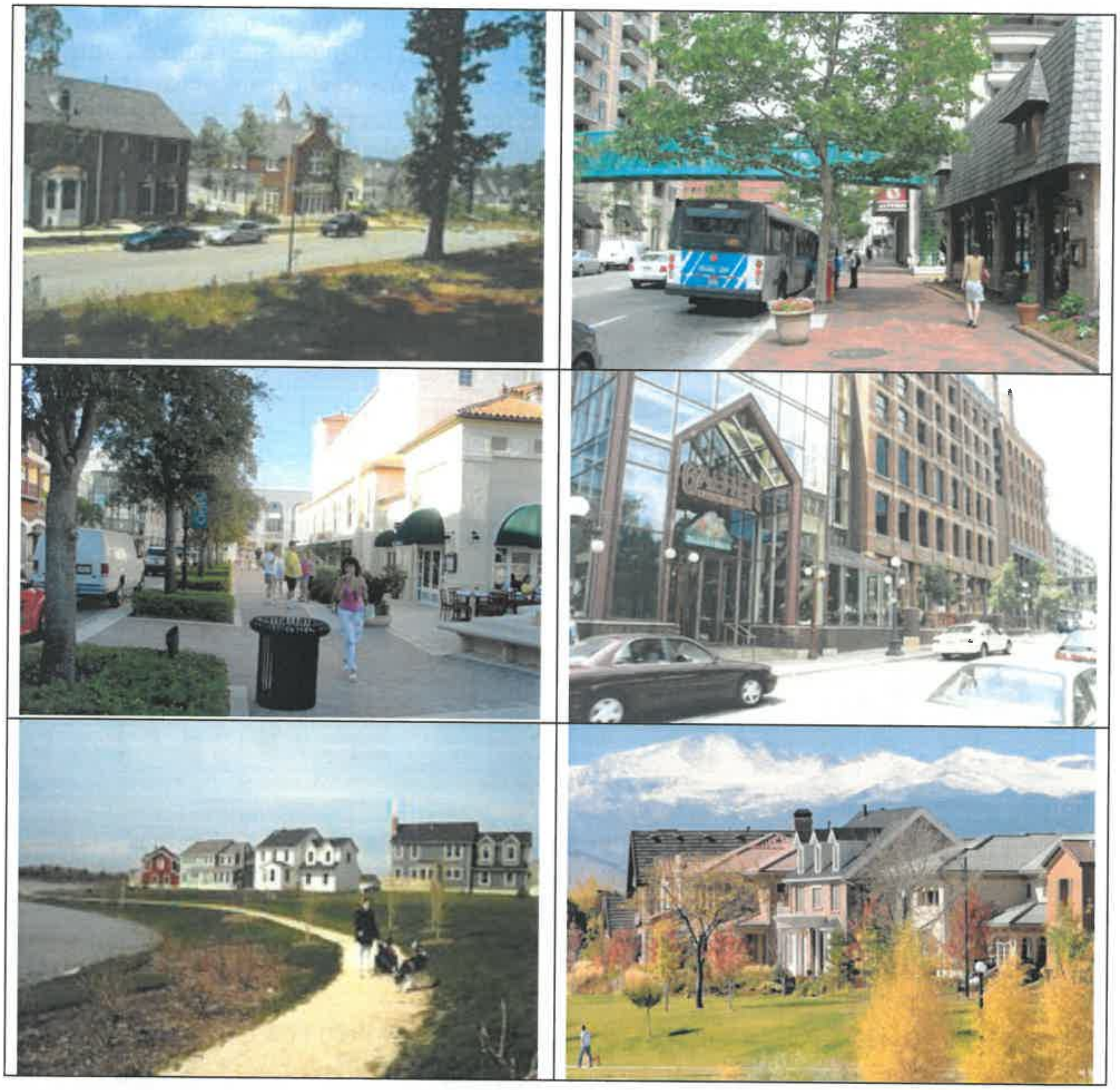
*The question was: Please tell me which of the following statements describe you more: A) If it were possible, I would like to walk more throughout the day either to get to specific places or for exercise, or B) I prefer to drive my car wherever I go?



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.

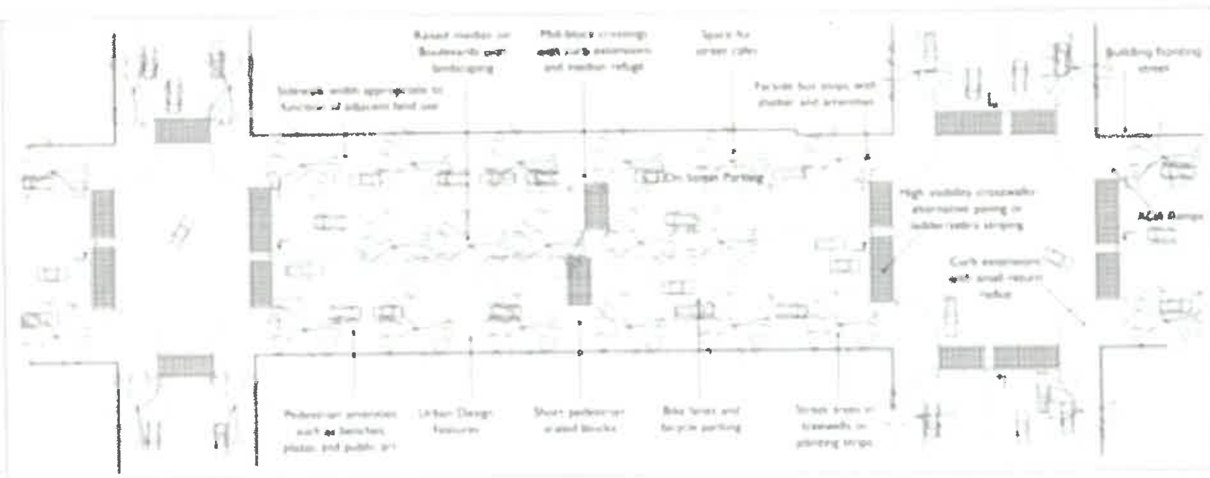
Alternative models of land development are everywhere. A 2003 listing shows 647 new urbanist developments in some state of planning or construction (New Urban News 2003), even though the new urbanist movement began only 12 years earlier. *Transit-Oriented Development in the United States: Experiences, 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



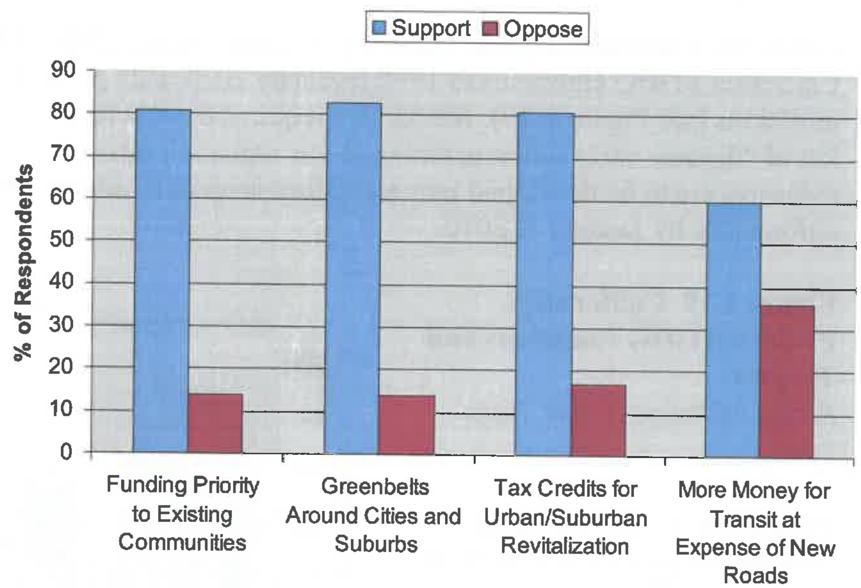
Loss of farmlands and natural areas—and the public benefits they provide—are behind a number of planning initiatives. The Maryland Smart Growth Program was motivated primarily by the rate at which the urban footprint was expanding into resource areas (see Figure 1-16). Nationally, most urbanized areas 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.

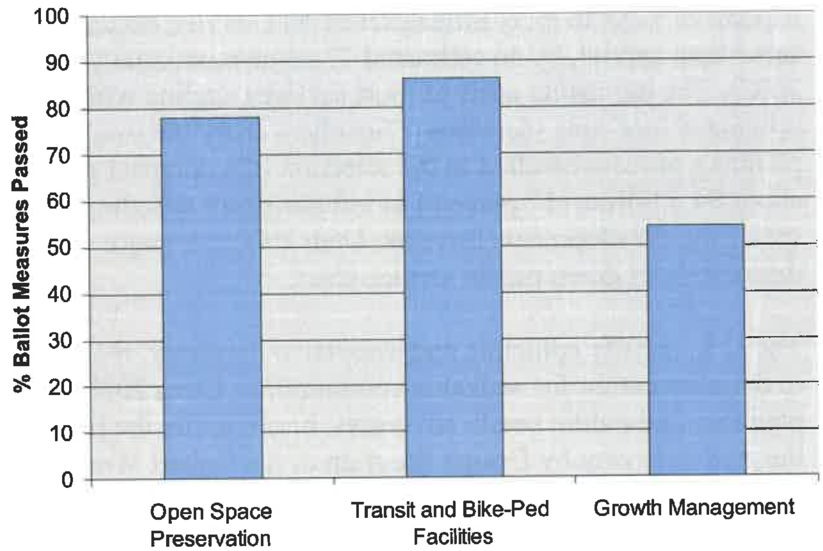
The U.S. obesity epidemic and associated mortality, morbidity, and health care costs have added to the momentum for walkable communities. Circa 2000, a new collaboration between urban planning and public health advocates, began under the banner of active living. Out of this came the Active Living by 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).

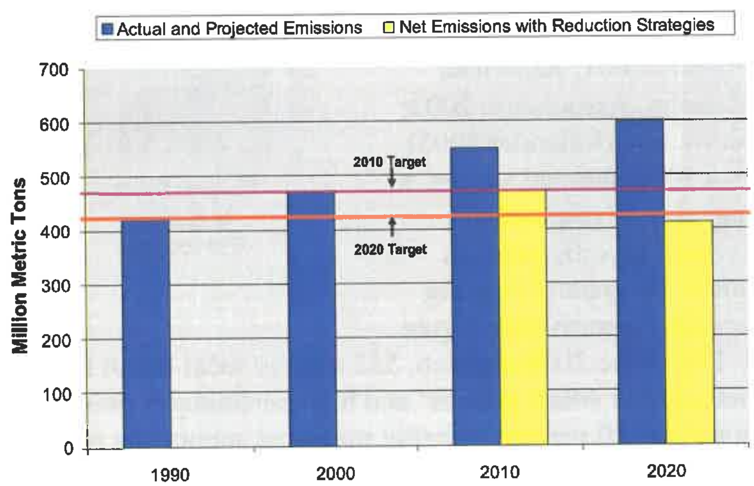
Figure 1-18 State and Local Ballot Measures Passed, 2000 Election
Source: Myers and Puentes 2001.



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.*

[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

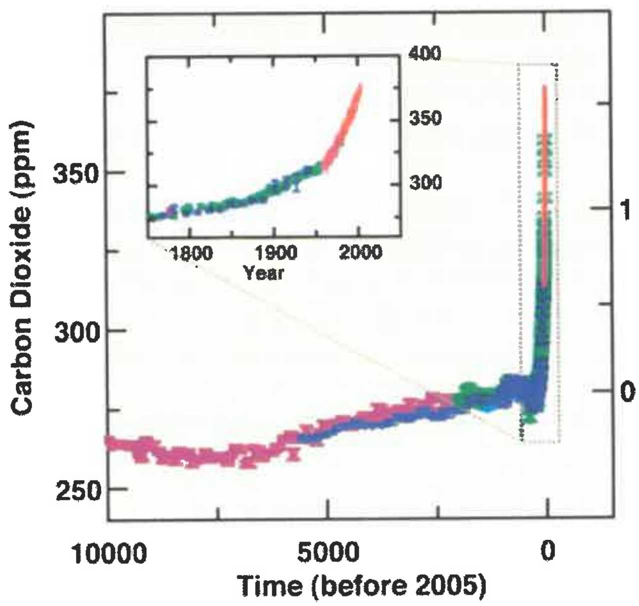
Chapter by chapter, this book addresses the impacts of the following:

- 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.

2. The VMT/CO_2/Climate Connection

There is now a scientific consensus that greenhouse gas accumulations due to human activities are contributing to global climate change (Greenough et al. 2001; Barnett and Adger 2003; Hegerl et al. 2007; IPCC 2007a). The Fourth Assessment Report of the U.N. Intergovernmental Panel on Climate Change (IPCC 2007a, p. 2) concludes that: "Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed preindustrial values determined from ice cores spanning many thousands of years." Greenhouse gas concentrations have risen from preindustrial levels of approximately 280 parts per million (ppm) CO_2 equivalent (CO_2e) to 430 ppm CO_2e (Stern 2006).[12]

Figure 2-1 Atmospheric Concentration of Carbon Dioxide (CO_2) over the Last 10,000 Years
Source: IPCC 2007a, p. 3.



The result is climate change. "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level" (IPCC 2007a, p. 5). Eleven of the last 12 years are among the 12 warmest globally since the instrumental record began in 1850 (IPCC 2007a, p. 5).[13] Long-term changes have been observed in Arctic temperatures and ice formations, ocean salinity, droughts, heavy precipitation, heat waves, and tropical cyclone intensity.

With current trends, the atmospheric concentration of CO_2e is expected to rise from 430 ppm to 630 ppm by 2050. Even if GHG emissions were held at year 2000 levels, the planet would warm by 1°C over the next 100 years. Under a variety of scenarios with differing assumptions about growth, technology, and climate feedback, the likely range of warming by 2100 is between 1.1°C and 6.4°C, with a best estimate of 1.8°C to 4.0°C (IPCC 2007a, p. 12).

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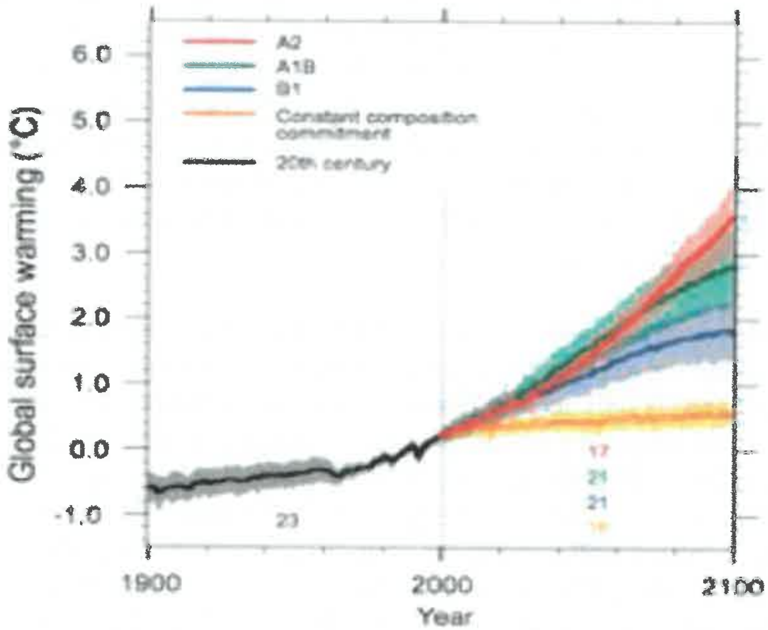
[12] Carbon dioxide equivalent (CO_2e) is an internationally accepted measure of the amount of global warming of greenhouse gases (GHGs) in terms of the amount of carbon dioxide (CO_2) that would have the same global warming potential.

[13] NASA's Goddard Institute for Space Studies identifies the five warmest years for global temperatures as (in descending order): 2005, 1998, 2002, 2003, and 2006 (Goddard 2007). Five of the last nine years have been the warmest on record in the United States (in descending order: 1998, 2006, 1999, 2001, 2005) (National Climate Data Center 2007).

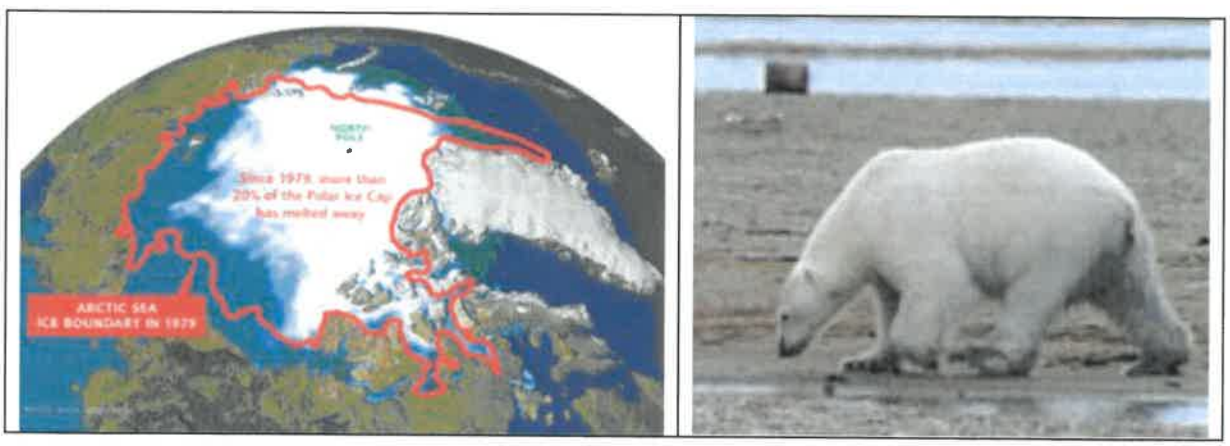
Figure 2-2 Global Average Surface Temperature Warming under Different Scenarios
Source: IPCC 2007a, p. 14.



International and domestic climate policy discussions have gravitated toward the goal of limiting the temperature increase to 2°C to 3°C (European Commission 2007). Stabilization at 450 ppm CO_2e is expected to produce a 50/50 chance of keeping warming to + 2°C above preindustrial levels, whereas 550 ppm would result in a 50/50 chance of keeping warming to +3°C (Meinshausen 2006).

With a 2°C increase in global average temperature, all coral reefs are at risk of being bleached. At 3°C, more than one-third of all species will be at risk of eventual extinction. With an increase of 2°C to 3°C, coastal flooding threatens to harm or displace 70 million to 250 million people, respectively, and hundreds of millions of people face an increased risk of hunger. In this same range of temperature increase, the Amazon rainforest and Great Lakes ecosystems are at risk of collapse (Meinshausen 2006). From 1°C to 4°C, a partial deglaciation of the Greenland Ice Sheet will occur, with the sea level destined to increase by four to six meters over centuries to millennia (IPCC 2007b, p. 17; DEFRA 2006).

A shrinking Arctic icecap threatens many species, including the polar bear.
NRDC undated



Stabilization at 450 ppm CO_2e would require global GHG emissions to peak around 2015 and be reduced 30 to 40 percent below 1990 levels by 2050 (Höhne, Phylipsen, and Moltmann 2007; Meinshausen and den Elzen 2005). The British government's review and the IPCC report show that the less we limit GHG emissions globally in the near term, the harder it will be to stabilize them at the target concentrations later (HM Treasury 2006; IPCC 2007c, p.15). For each five years that the peak in global emissions is delayed beyond 2015, the annual rate by which emissions must decline will increase by an additional 1 percent (Meinshausen and den Elzen 2005). One percent per year is a substantial level of effort, comparable to the reduction the United Kingdom achieved nationally after it switched all of its coal-fired power plants to natural gas in the 1990s (Helme and Schmidt 2007).

Determining the necessary GHG reductions in the United States to meet global targets requires assessment of and assumptions about expected GHG reductions in other countries. The emerging consensus is that industrialized countries will need to reduce their GHG emissions by 60 to 80 percent below 1990 levels by 2050 (European Commission 2007; Helme and Schmidt 2007; Höhne, Phylipsen, and Moltmann 2007; Meinshausen and den Elzen 2005; New England Governors/Eastern Canadian Premiers 2001; Schwarzenegger 2005). To meet this long-term goal, industrialized countries must reduce GHG emissions 15 to 30 percent below 1990 levels by 2020 (European Commission 2007; Höhne, Phylipsen, and Moltmann 2007; Meinshausen and den Elzen 2005). In August 2007, industrial nations agreed to GHG cuts 25 to 40 percent below 1990 levels by 2020 as a nonbinding starting point for a new round of international climate negotiations (Reuters 2007).

2.1 Prospects for the U.S. Transportation Sector

The transportation sector is responsible for 33 percent of U.S. CO_2 emissions (28 percent of U.S. GHG emissions), and its emissions are projected to grow faster than the average rate for all sectors of the economy (EIA 2007, Table A18). Passenger vehicles (cars and light trucks) are responsible for more than three-fifths of transportation sector CO_2 emissions.

The GHG reduction "required" from U.S. transportation is a function of the level of reductions that can be expected in other sectors of the economy to meet the 60 to 80 percent reduction target. While certain sectors of the economy may be able to reduce GHG emissions more than others, it is unlikely that they will be able to sufficiently overcompensate for limited progress in the transportation sector. As discussed below, current policy proposals on vehicle technology and fuels would leave passenger vehicle CO_2 emissions well above 1990 levels in 2030, significantly off course for meeting the 2050 target. Reduction in travel demand will be an important element of effective climate policy.

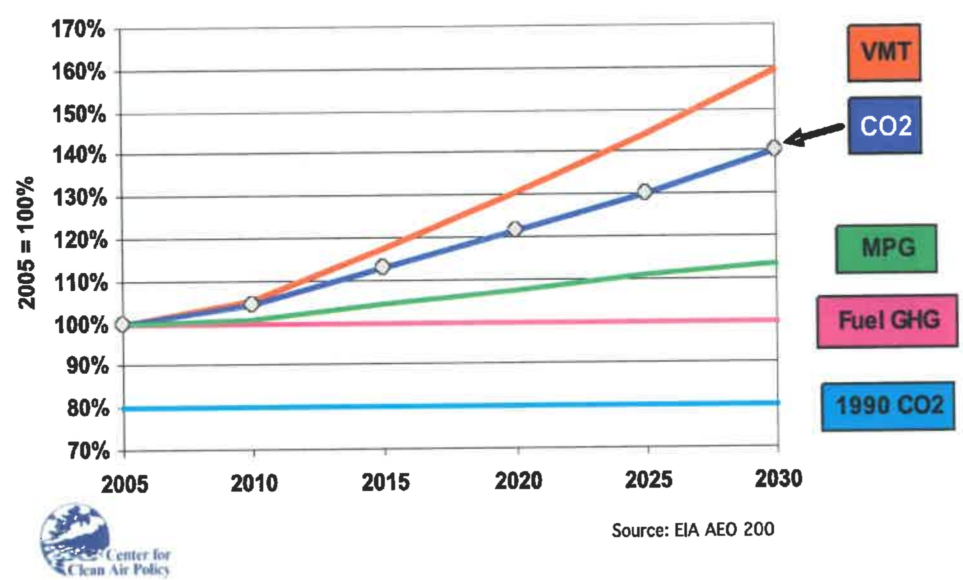
There is a popularly held expectation that electricity or hydrogen fuels will provide long-term solutions to energy security and transportation GHG concerns, essentially shifting transportation GHG emissions upstream to other sectors of the economy. Biofuels also could potentially play an important role, but their use will be limited because of land use constraints, high costs, and ecological and social concerns. A shift to electric or hydrogen cars could certainly reduce petroleum use if major technological breakthroughs and cost reductions are achieved on battery and fuel cell technologies. (Plug-in hybrid vehicles currently carry a cost premium on the order of $10,000, and the cost premium for hydrogen fuel cell vehicles is on the order of $500,000 to $1 million.)

Achieving significant GHG reductions also will require significant investments and political will. Since electricity and hydrogen are energy carriers, they result in GHG savings only if their production and transportation processes are relatively more carbon efficient than the current approach. Thus, for electricity or hydrogen to result in GHG reductions, they must be generated via low-emitting processes. Three primary energy sources could generate low-GHG electricity or hydrogen. First, renewable sources such as solar, biomass, and wind have significant but limited potential. Although these sources could potentially provide a large amount of energy, issues such as intermittent generation and local resource availability present difficulties. Second, nuclear power has great potential as a low-GHG energy source, but faces significant cost and political barriers. Third, carbon capture and sequestration (CCS)—in which CO_2 is removed from a coal (or other) power plant smokestack and injected underground into geological formations such as oil fields, gas fields, or saline formations—offers the possibility of continued use of coal resources with a much improved GHG profile. There is active research on CCS to assess costs, permanence, and storage capacity. Each of these three low-GHG energy sources holds significant promise but can offer no guarantees.

2.2 VMT and CO_2 Projections

The U.S. Department of Energy's Energy Information Administration (EIA) forecasts VMT to increase by 59 percent from 2005 to 2030 (the red line in Figure 2-3), outpacing projected population growth of 23 percent (EIA 2007, Table A7). The projected VMT increase represents a slowdown relative to historic VMT growth rates, but is within the likely range for future VMT growth (Polzin 2006). Over this time period, the EIA projects fuel economy for new passenger vehicles to increase by 16 percent (from 25 to 29 mpg) and the fuel economy of the full stock of vehicles (the green line in Figure 2-3) to increase by 13.3 percent as more efficient vehicles penetrate the fleet. CO_2 emissions would increase by 40 percent[14] over the same time frame (the dark blue line in Figure 2-3). In this case, transportation CO_2 emissions in 2030 would be 75 percent above 1990 levels (the turquoise line in Figure 2-3).

Figure 2-3 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 more efficient technology (Schipper 2007). In June 2007, the U.S. Senate passed new CAFE standards that would increase new passenger vehicle fuel economy (cars and light trucks combined) to 35 mpg by 2020 (U.S. Congress 2007). The state of California is implementing a low carbon standard for transportation fuels that calls for a 10 percent reduction in fuel carbon intensity by 2020 (Schwarzenegger 2007). If California's low carbon fuel standard were applied at the national level (the purple line in Figure 2-4), in conjunction with the Senate's CAFE standard of 35 mpg by 2020 (the green line in Figure 2-4), passenger vehicle CO_2 emissions in 2030 would be 12 percent above 2005 levels, or 40 percent above 1990 levels. In other words, projected growth of VMT would still overwhelm the CO_2 savings from vehicle and fuel regulations.[15]

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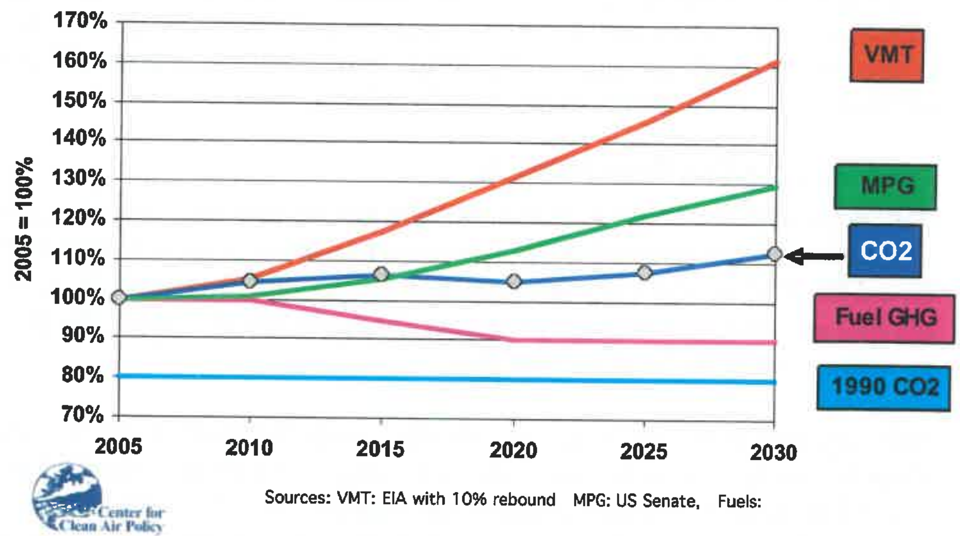
[14] 159% [vehicle miles traveled] / 1.133 [mpg] = 140% [CO_2] with constant fuel carbon content.

[15] In this scenario, VMT growth increases by 2 percentage points (61 percent growth by 2030) due to the "rebound effect" whereby driving increases as fuel economy increases (10 percent short-run elasticity).

Figure 2-4 Projected Growth in CO_2 Emissions from Cars and Light Trucks, Assuming Stringent Nationwide Vehicle and Fuel Standards*
Sources: EIA 2007; U.S. Congress 2007; Schwarzenegger 2007.

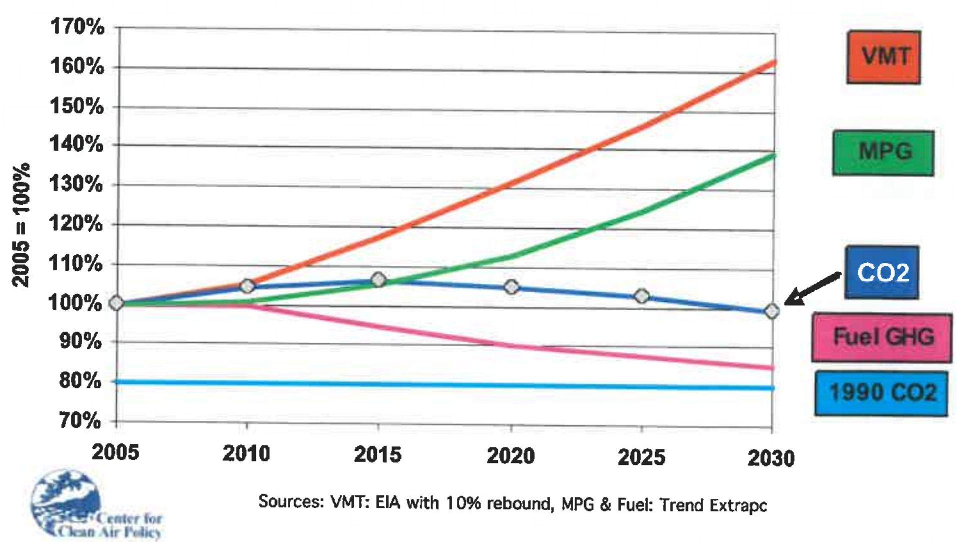
* With Senate new passenger vehicle fuel economy of 35 mpg and California low carbon fuel standard of –10 percent in 2020, applied nationally. Assumes a 10 percent rebound.



If the fuel economy and fuel carbon content trends represented in Figure 2-4 were extended through to 2030, so that new vehicle fuel economy would increase to 45 mpg and fuel carbon content would decrease to 15 percent below current levels, then 2030 CO_2 emissions would be reduced to 1 percent below 2005 levels, or 24 percent above 1990 levels (Figure 2-5).

Figure 2-5 Projected Growth in CO2 Emissions from Cars and Light Trucks, Assuming Even More Stringent Nationwide Vehicle and Fuel Standards*
Sources: EIA 2007; U.S. Congress 2007; Schwarzenegger 2007.

*Extrapolating trends from Figure 2-4 with new passenger vehicle fuel economy of 45 mpg in 2030 and low carbon fuel standard of –15 percent in 2030.



Clearly, lowering transportation CO_2 emissions to 60 to 80 percent below 1990 levels by 2050 would require even greater improvements in vehicles, fuels and, almost certainly, reductions in VMT per capita.

2.3 Other Influences on CO_2 Emissions

Carbon dioxide emissions are a function not only of VMT but also of numbers of vehicle trips (VT) and vehicle operating speeds. The number of vehicle trips is directly related to the number of vehicle starts, while average vehicle operating speed is a proxy for the entire driving cycle (starts, acceleration, cruising speed, deceleration, and stops). Both affect vehicle operating efficiency and CO_2 emissions per vehicle mile.

2.3.1 Vehicle Trip Frequencies

Starting a vehicle when it is cold uses more energy and emits more CO_2 than does starting the vehicle after it has warmed up. For an average car in California, the California Air Resources Board EMFAC model shows cold start emissions of 213 grams CO_2 after a 12-hour soak.[16] To put this in context, an average passenger car emits 386 grams of CO_2 per mile when traveling at an average speed of 30 miles per hour.[17]

Still, any cold start penalty associated with compact development is likely to be small. From the EMFAC model, CO_2 emissions from *all* vehicle starts (cold, intermediate, and hot) account for just 3.3 percent of total annual passenger vehicle CO_2 emissions in California.[18] Moreover, while there has been some speculation in the literature that compact development could increase trip frequencies, the weight of evidence suggests otherwise. Overall trip rates appear to depend largely on household socioeconomics and demographics. Controlling for these influences, vehicle trip rates are lower in compact areas because some of a household's daily trips shift from the automobile to other modes (Ewing, DeAnna, and Li 1996; Ewing and Cervero 2001).

2.3.2 Vehicle Operating Speeds

Compact development policies could have secondary effects on CO_2 emissions by lowering (or raising) average vehicle speeds. Motor vehicles with internal combustion engines are most efficient at an average speed of about 45 miles per hour, with lower efficiency and higher CO_2 emission rates for speeds above and below this "sweet spot" (see Figure 2-6). The data in Figure 2-6 come from the California Air Resources Board EMFAC model and represent average speed for vehicle trips that have been calibrated to reflect real-world driving behavior, including acceleration, starts, idling, and so forth.

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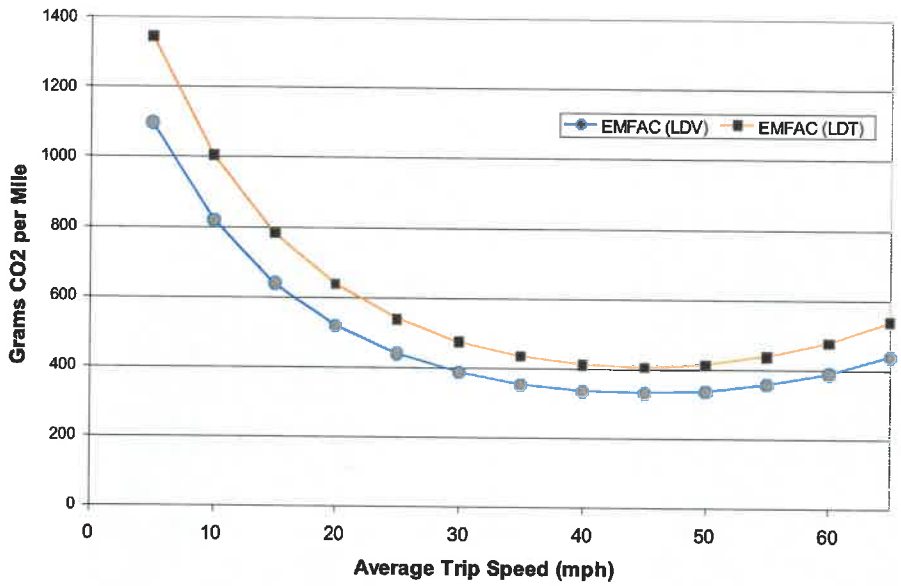
[16] Authors' calculations based on data from EMFAC 2007, V2.3 Nov. 1, 2006, provided by Jeff Long, California Air Resources Board, July 24, 2007.
[17] Authors' calculations based on data from EMFAC 2007, V2.3 Nov. 1, 2006, provided by Jeff Long, California Air Resources Board, April 25, 2007.
[18] Authors' calculations based on data from EMFAC 2007, V2.3 Nov. 1, 2006, provided by Jeff Long, California Air Resources Board, July 9, 2007.

Figure 2-6 CO_2 Emission Rate versus Average Vehicle Speed*
Source: Jeff Long, California Air Resources Board



*Data from EMFAC 2007, V2.3 Nov. 1, 2006, provided by Jeff Long, California Air Resources Board, April 2007. Data include all model years in the range 1965 to 2007. The magnitude of the curve (not the shape) is a function of temperature and humidity assumptions, in this case 80°F and relative humidity of 50 percent.

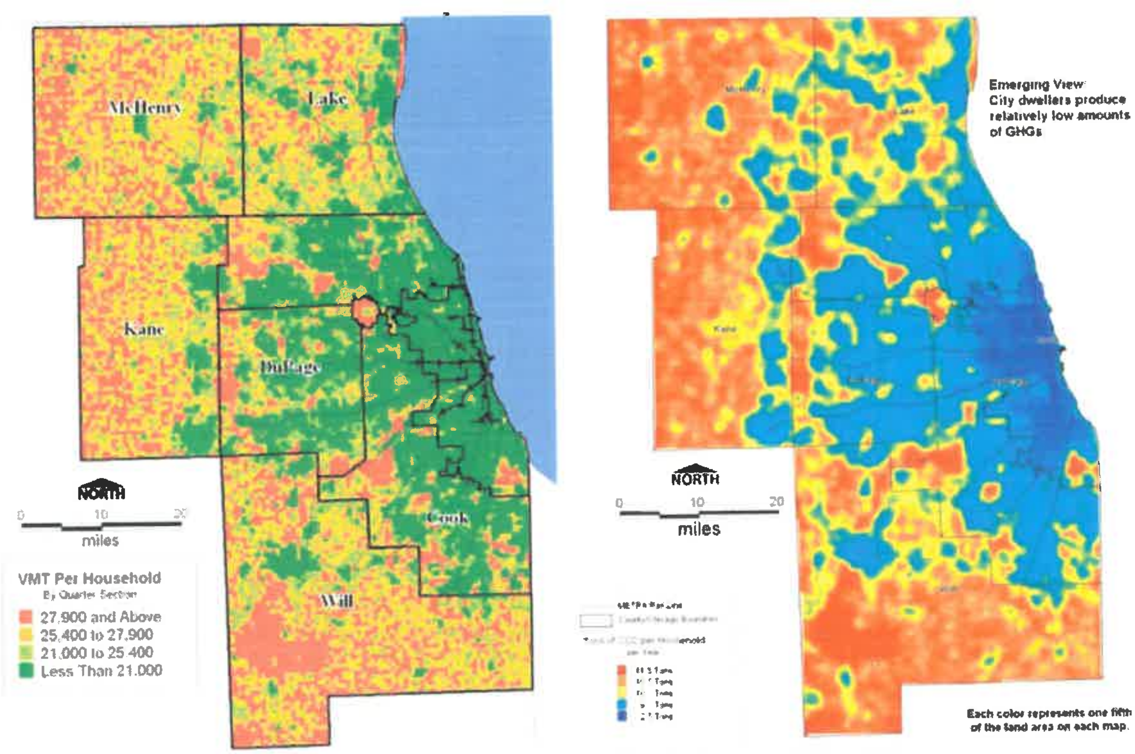
Can we therefore conclude that it would be most efficient to design cities and roadways to maximize vehicle operating efficiency? No, because the efficiency gained by designing roads for high average speeds would be negated by an increase in miles traveled. Development can and would become ever more dispersed. The phenomena of induced traffic and induced development are discussed in Chapter 5. Moreover, the most efficient speed for today's cars is probably higher than the most efficient speed for tomorrow's cars. Emission rate curves for hybrid vehicles, in particular, look different, because these vehicles experience less of a low-speed emissions penalty.

2.3.3 Synthesis

With the transition from sprawl to compact development, both VMT and VT would be expected to decline, though by different percentages. The result would be a drop in CO_2 emissions per capita. Vehicle trips will decline as travelers shift from the automobile to alternative modes, and VMT will decline as mode shifts occur and as automobile trips get shorter. Vehicle operating speeds also may decline, and would have an opposite effect on CO_2 emissions per capita. Compact development may mean lower cruising speeds and more stop-and-go driving, hence higher emissions per mile traveled (assuming conventional vehicle technology).

We can get a sense of the magnitude of these effects based on available information. All else being equal, there is a one-to-one relationship between VMT and CO_2 emissions; a 30 percent reduction in VMT will result in a 30 percent reduction in CO_2 emissions.

Figure 2-7 Close Relationship between VMT per Household and CO_2 Emissions in the Chicago Metropolitan Area
Source: Center for Neighborhood Technology undated.



Let us posit that regional density will be 50 percent higher in 2050 under compact development than with current trends, a not unreasonable assumption, given the data presented in section 1.7. Given an elasticity of peak hour speed with respect to density of –0.15 (see subsection 3.1.4), the average peak hour vehicle operating speed might decline by 0.15 times 50 percent, or 7.5 percent, with compact development. If so, average daily speed would decline by about 3 percent, since the morning and afternoon peak periods represents two-fifths of average daily traffic in metropolitan areas. Such a decline would cause a 1 to 2 percent increase in CO_2 emissions per mile at typical urban speeds (see subsection 2.3.2). Therefore, if compact development reduced VMT by 30 percent, lowered average vehicle operating speed by 3 percent, and had no effect on vehicle trips, the net impact would be a 28 percent drop in CO_2 emissions.[19]

The next chapter addresses the extent to which compact urban development can reduce VMT and associated CO_2 emissions.

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[19] 100% – (70% [VMT] x 102% [CO_2 per mile] x 96.7% [running emissions] + 3.3% [start emissions]).

3. The Urban Development/VMT Connection

Four different rich empirical literatures inform the discussion of urban development and its impacts on VMT, the primary determinant of transportation-related CO_2 emissions:

- aggregate travel studies, such as sprawl index research conducted for Smart Growth America;
- disaggregate travel studies, such as Smart Growth Index elasticity estimates;
- regional simulation studies, such as Portland's LUTRAQ (Land Use, Transportation, Air Quality) study; and
- project simulation studies, such as the EPA's Atlantic Steel study.

In this chapter, we review each literature in turn and present order-of-magnitude effect sizes. For two literatures—disaggregate travel studies and regional simulation studies—the sample of studies is large enough to permit meta-analyses of study results. A meta-analysis is a special kind of literature synthesis, conducted most often in scientific fields. It is more than a literature review, as it generalizes across studies quantitatively, taking individual studies as units of analysis and combining study results to arrive at average effect sizes and confidence intervals.

The different literatures provide a consistent picture. 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 the specific form of compact development, as outlined in the following sections.

3.1 Aggregate Travel Studies

For decades, it has been known that compact areas have lower levels of automobile use per capita and greater use of alternative modes of transportation than do sprawling areas. They also tend to generate shorter trips. The combined effect is significantly less VMT per capita in compact areas (see Figure 3-1). This fact has been documented most famously by Newman and Kenworthy (1989a, 1989b, 2006, 2007), Holtzclaw (1991, 1994), and Holtzclaw et al. (2002). This same-shaped exponential decline in vehicular travel with density is found in many data series (see Figures 3-2 and 3-3 for communities in the Baltimore area and for higher-income cities worldwide).

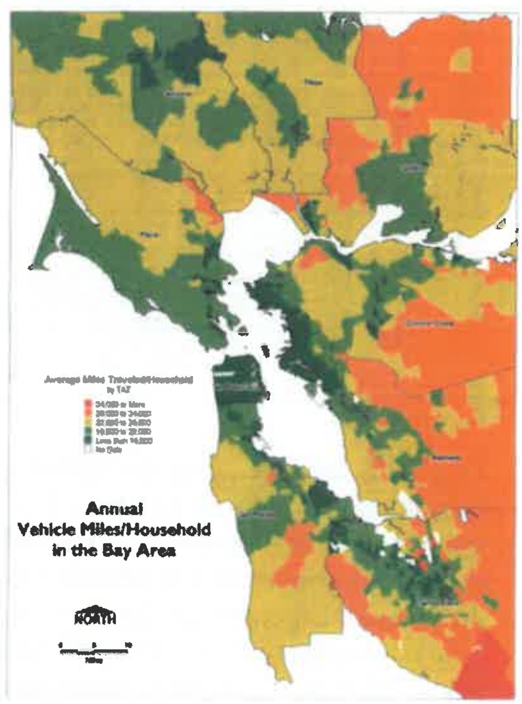


Figure 3-1 Vehicle Miles Traveled per Household for Neighborhoods in the San Francisco Metropolitan Area
Source: Holtzclaw et al. 2002.

Figure 3-2 Vehicle Miles Traveled per Capita versus Residential Density for Baltimore Neighborhoods
Source: Baltimore Metropolitan Council, 2001 Travel Survey.

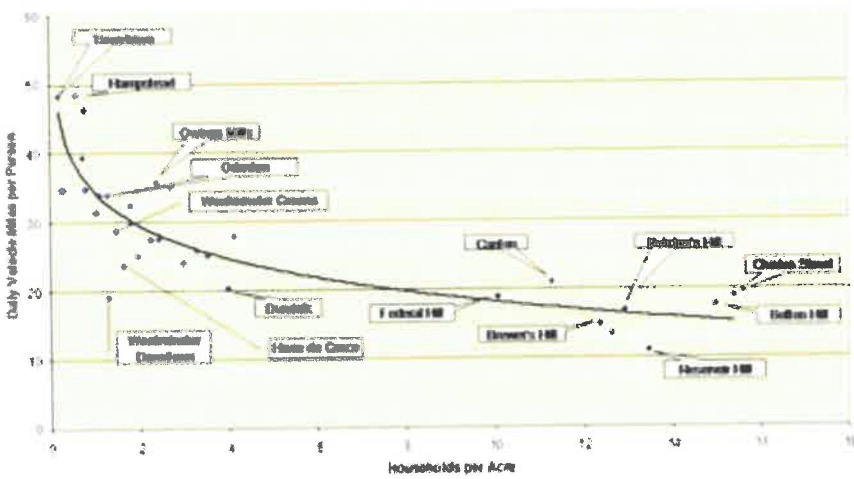
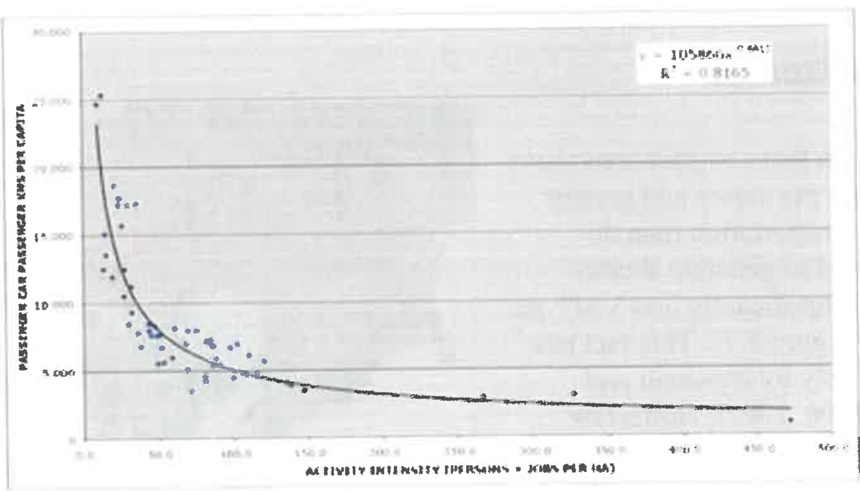


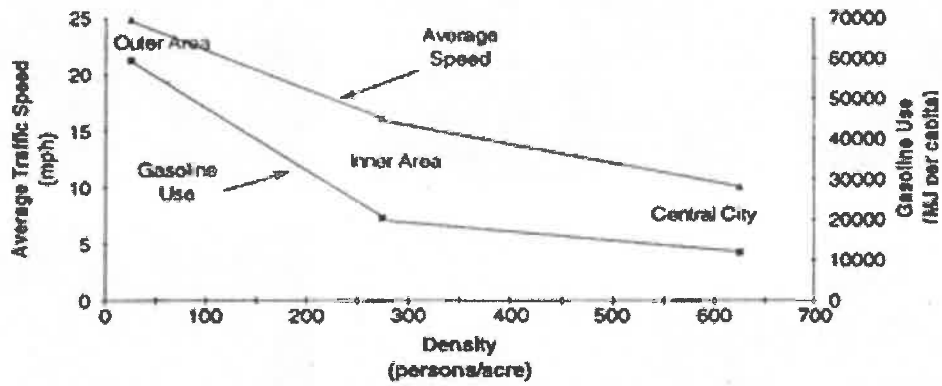
Figure 3-3 Vehicle Kilometers Traveled per Capita versus Activity Intensity for 58 Higher- *Income Cities Source: Newman and Kenworthy 2006.*



Four facts, however, preclude broad generalizations about urban development patterns and fuel consumption or CO_2 emissions. First, dense areas may experience more congestion and lower travel speeds than sprawling areas, hence lower vehicle fuel economy for whatever VMT they produce. Second, dense areas may have different population characteristics than sprawling areas, differences that could confound urban development and travel relationships. Third, density is only one aspect of urban form, albeit an important one. Urban sprawl is defined more broadly as any development pattern in which homes, workplaces, stores, schools, and other activities are widely separated from one another. Fourth, any relationships that appear in aggregate statistics for neighborhoods, cities, or metropolitan areas would not necessarily apply to individual households, the ultimate travel decision makers.[20]

In a paper entitled "The Transport Energy Trade-Off: Fuel-Efficient Traffic versus Fuel-Efficient Cities," Newman and Kenworthy (1988) addressed the first of these qualifiers. They concluded that the lower VMT in compact areas overwhelms any effect of lower vehicle fuel economy (see Figure 3-4). They subsequently substantiated this relationship for many other places (Newman 2006; Newman and Kenworthy 2006, 2007).

Figure 3-4. Per Capita Gasoline Consumption in Inner and Outer Portions of the New York Metropolitan Area
Source: Newman and Kenworthy 1988.



The second qualifier is not so easily dismissed. In Figures 3-2 through 3-4, residential density is not the only characteristic that distinguishes Taneytown from Charles Street in the Baltimore metropolitan area, or one higher-income city from another, or the inner and outer areas of the New York metropolitan area. Culture, socioeconomics, demographics, transit availability, and even gas prices could account for most or all of the differences in per capita vehicle use. Critics of these early studies argued, correctly, that until these other factors were controlled, the independent effect of urban development patterns would be unknown and unknowable (Gomez-Ibanez 1991; Gordon and Richardson 1989).

Likewise, the third qualifier also is not easily dismissed. If poor accessibility is the common denominator of sprawl, then sprawl is more than low-density development. The term also encompasses scattered or leapfrog development, commercial strip development, and single-use development such as bedroom communities. In scattered or leapfrog development, residents and service providers must pass vacant land on their way from one developed area to another. In classic strip development, consumers must pass other uses on the way from one store to the next; this is the antithesis of multipurpose travel to an activity center. In a single-use development, of course, different uses are located far apart as a result of the segregation of land uses. Poor accessibility also could be a product of fragmented street networks that separate urban activities more than need be (see the photos below of sprawling development patterns).

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[20] This is due to the so-called ecological fallacy. The ecological fallacy is a widely recognized error in the interpretation of statistical data, whereby inferences about individuals are based solely upon aggregate statistics for the group to which those individuals belong.

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.

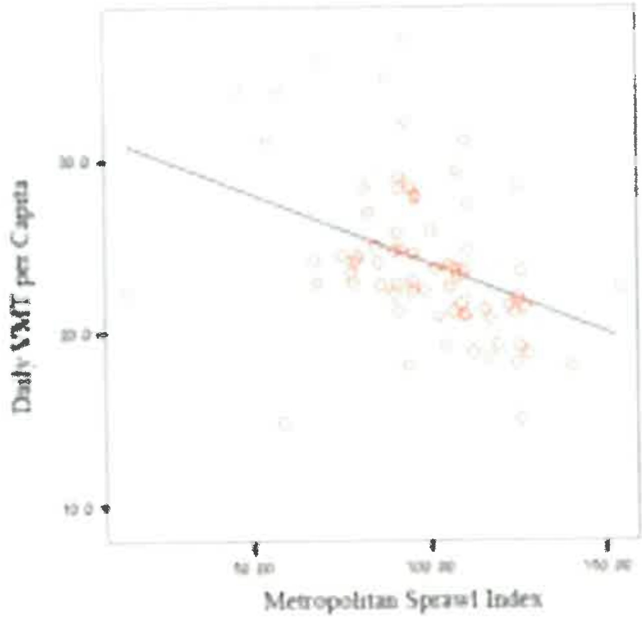
Obviously, these relationships are not independent of each other. The lower level of vehicle ownership in dense metropolitan areas contributes to higher mode shares for alternatives to the automobile. These, in turn, contribute to lower VMT, which contributes to lower traffic fatalities and ozone levels. 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.

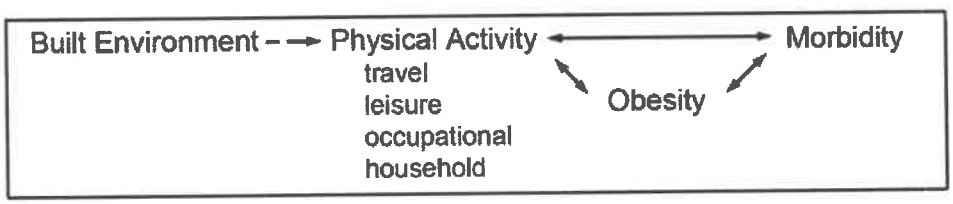
3.2 Disaggregate Travel Studies

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.

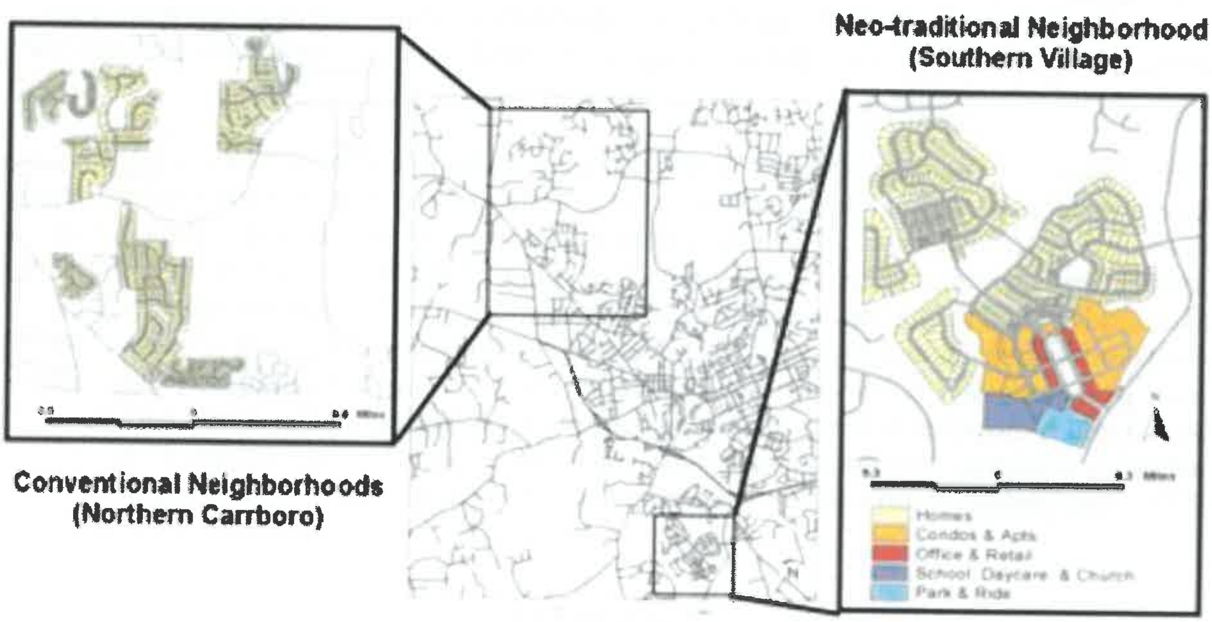
Figure 3-7 Causal Pathways Linking the Built Environment to Health
Source: Ewing et al. 2003.



3.2.1 Accessibility Again

The concept of sprawl seems particularly tailored to large areas such as metropolitan areas and their component counties. The degree to which employment is concentrated in central business districts or suburban centers, for example, is a characteristic of an entire metro area, not of an individual community or neighborhood. Yet there are analogous measures for subareas as small as neighborhoods (see Figure 3-8), and these analogous measures have been studied in depth for their relationships to trip frequency, trip distance, and mode choice.

Figure 3-8 Neighborhoods with Different Designs and Travel Characteristics in Chapel Hill, North Carolina
Source: Khattak and Rodriquez 2005.



Accessibility influences the way household needs are met through travel. Two types of accessibility have been shown to be significant. One is ease of access to activities from one's place of residence, the other ease of access to activities from other activities.

Residential accessibility affects the destination, mode and, arguably, even the frequency of home-based trips. It has been the focus of nearly all travel and physical activity research. However, the relevant environment for many trips is someplace other than home. Non–home based trips account for 25 to 30 percent of trips in most urban areas, and the percentage is growing as people's complex lives cause them to link trips into complex tours.

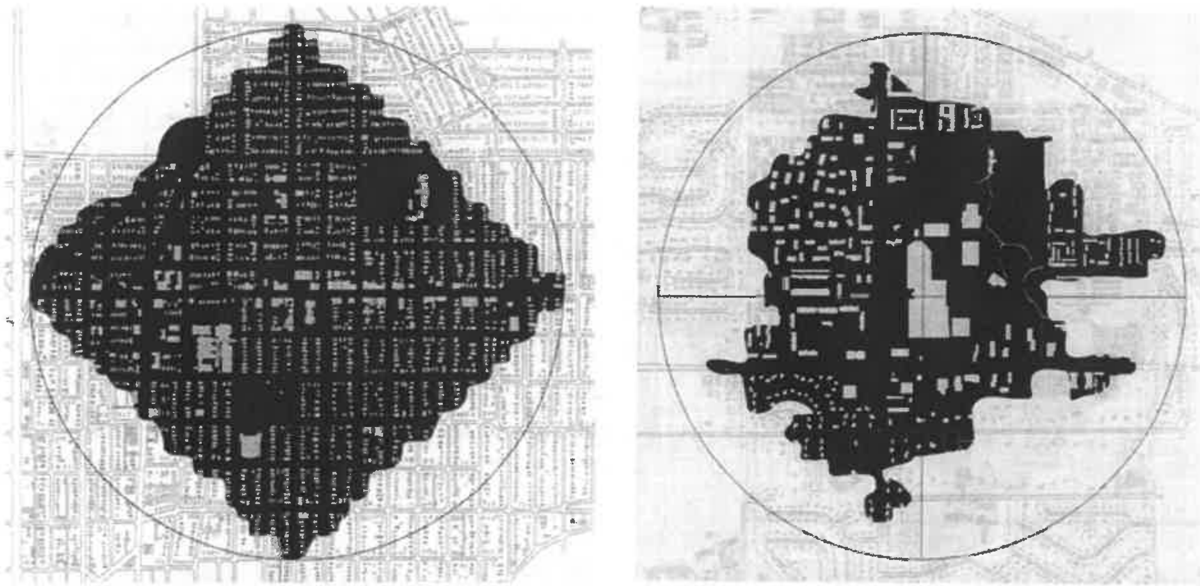
Trip chaining, or the linking of trips into tours, has been increasing over time (Levinson and Kumar 1995; McGuckin, Zmud, and Nakamoto 2005). Trips are more likely to be linked into long tours in areas of poor residential accessibility, simply because this is a way for households living in sprawl to economize on travel (Ewing, Haliyur, and Page 1994; Ewing 1995; Krizek 2003; Limanond and Niemeier 2004; Noland and Thomas 2006). The more sprawling the area, the more important it becomes to concentrate common destinations in centers, so a single auto trip can meet multiple needs. Conservatively, the ability to link trips in tours cuts overall household travel by 15 to 22 percent relative to separate trips for the same purposes (Oster 1978).

3.2.2 Measuring the Five Ds

In travel research, urban development patterns have come to be characterized by "D" variables. The original "three Ds," coined by Cervero and Kockelman (1997), are density, diversity, and design. The Ds have multiplied since then, with the addition of destination accessibility and distance to transit. If we could think of an appropriate label, parking supply and cost might be characterized as a sixth D.

Density usually is measured in terms of persons, jobs, or dwellings per unit area. Diversity refers to land use mix. It often is related to the number of different land uses in an area and the degree to which they are "balanced" in land area, floor area, or employment. Design includes street network characteristics within a neighborhood (see Figure 3-9). Street networks vary from dense urban grids of highly interconnected, straight streets to sparse suburban networks of curving streets forming "loops and lollipops." Street accessibility usually is measured in terms of average block size, proportion of four-way intersections, or number of intersections per square mile. Design also is measured in terms of sidewalk coverage, building setbacks, streets widths, pedestrian crossings, presence of street trees, and a host of other physical variables that differentiate pedestrian-oriented environments from auto-oriented ones.

Figure 3-9 Destinations within One-Quarter Mile of Center for Contrasting Street Networks in Seattle
Source: Moudon et al. 1997.



Destination accessibility is measured in terms of the number of jobs or other attractions reachable within a given travel time, which tends to be highest at central locations and lowest at peripheral ones. Distance to transit usually is measured from home or work to the nearest rail station or bus stop by the shortest street route.

3.2.3 D Variables versus VMT and VT

The D variables have a significant effect on the overall VMT and VT of individuals and households, mostly through their effect on the distance people travel and the modes of travel they choose (Ewing and Cervero 2001). Trip frequencies appear to be primarily a function of travelers' socioeconomic and demographic characteristics and secondarily a function of the built environment; trip lengths are primarily a function of the built environment and secondarily of socioeconomic and demographic characteristics; and mode choices depend on both, though probably more on socioeconomics.

Trip lengths are generally shorter at locations that are more accessible, have higher densities, or feature mixed uses. This holds true for both the home end (that is, residential neighborhoods) and nonhome end (activity centers) of trips. Alternatives to the automobile claim a larger share of all trips at higher densities and in mixed-use areas. Walk mode shares can rise to 20 percent or more in mixed-use neighborhoods even without high-quality transit service (see Figure 3-10).

These studies indicate that transit use varies primarily with local densities and secondarily with the degree of land use mixing (see Figure 3-11). Some of the density effect is, no doubt, due to shorter distances to transit service. Walking varies as much with the degree of land use mixing as with local densities (see Figure 3-12). An unresolved issue is whether the relationship of density to travel behavior is due to density itself or to other variables with which density co-varies, such as good transit service, limited parking, and so forth.

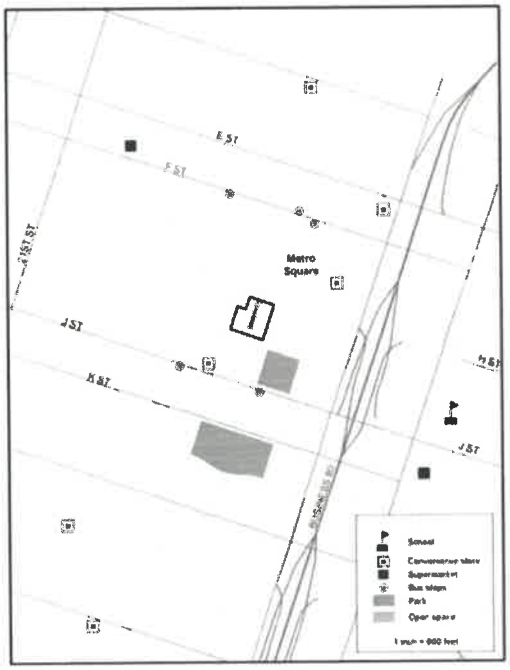


Figure 3-10 Built Environment and Mode Shares of Metro Square in Sacramento, California
Source: NRDC 2000.

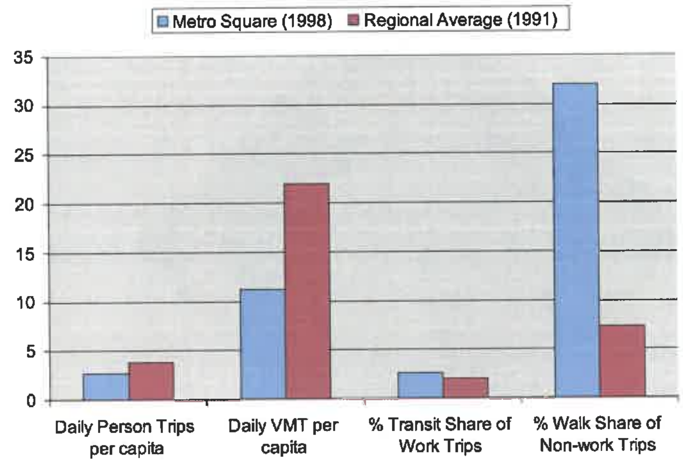
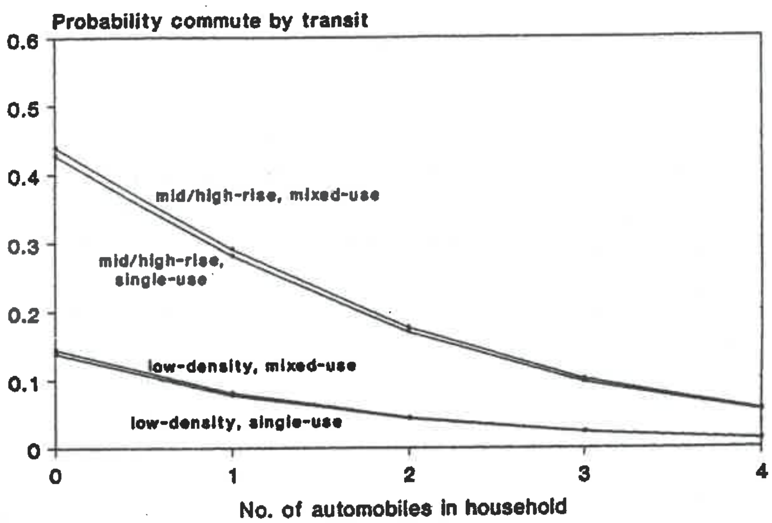


Figure 3-11 Effects of Density and Mixed Use on Choice of Transit for Commutes*
Source: Cervero 1996.



*Data for more than 45,000 U.S. households showed transit use primarily dependent on density of development. At higher densities, the addition of retail uses in neighborhoods was associated with several percentage point higher levels of transit commuting across 11 U.S. metropolitan areas.

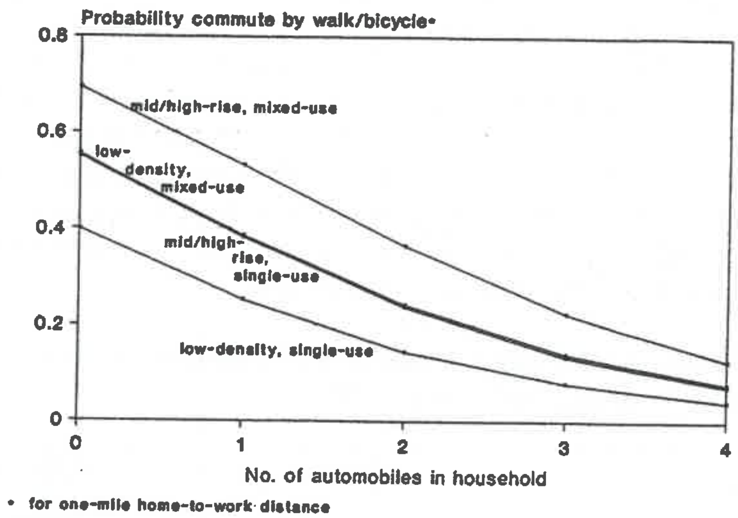


Figure 3-12 Effects of Density and Mixed Use on Choice of Walk/Bike for Commutes*
Source: Cervero 1996.

*Rates of walk and bicycle trips (for a one-mile home-to-work trip) are comparable for low-density, mixed-use neighborhoods as compared with high-density, single-use ones, controlling for vehicle ownership levels.

The third D—design—has a more ambiguous relationship to travel behavior than do the first two. Any effect is likely to be a collective one involving multiple design features. It also may be an interactive effect involving land use and transportation variables. This is the idea behind composite measures such as Portland, Oregon's "pedestrian environment factor" and Montgomery County, Maryland's "transit serviceability index" (see Figure 3-13). Portland's pedestrian environment factor is the sum of four variables related to 1) ease of street crossing, 2) sidewalk continuity, 3) street network connectivity, and 4) topography. Because of the subjective nature of these variables, the pedestrian environment factor has been replaced with an "urban design factor," which is a function of intersection density, residential density, and employment density.

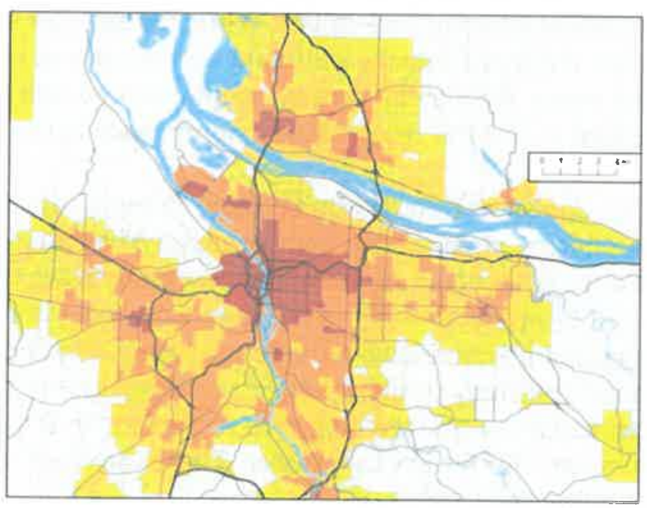


Figure 3-13 Values of the Urban Design Factor across the Portland Metropolitan Area
Source: Portland Metro.

For 14 carefully controlled travel studies, Ewing and Cervero (2001) synthesized the literature by computing elasticities of VMT and VT with respect to the first four Ds—density, diversity, design, and destination accessibility. These summary measures were incorporated into the EPA's Smart Growth Index (SGI) model, a widely used sketch planning tool for travel and air quality analysis. In the SGI model, density is measured in terms of residents plus jobs per square mile; diversity in terms of the ratio of jobs to residents relative to the regional average; and design in terms of street network density, sidewalk coverage, and route directness (two of three measures relating to street network design). These are just a few of the many ways in which the 3Ds have been operationalized at the neighborhood level (see literature review, Ewing and Cervero 2001).

Figure 3-14 presents elasticities of VT and VMT with respect to the four Ds. An elasticity is a percentage change in one variable with respect to a 1 percent change in another variable. Hence, from the elasticities presented in Figure 3-14, we would expect a doubling of neighborhood density to result in approximately a 5 percent reduction in both VT and VMT, all other things being equal. The effects of the four Ds captured in this table are cumulative. Doubling all four Ds would be expected to reduce VMT by about one-third. Note that the elasticity of VMT with respect to destination accessibility is as large as the other three combined, suggesting that areas of high accessibility—such as center cities—may produce substantially lower VMT than dense mixed-use developments in the exurbs.

Figure 3-14 Typical Elasticities of Travel with Respect to the Four Ds
Source: Ewing and Cervero 2001.

	Vehicle Trips (VT)	Vehicle Miles Traveled (VMT)
Local Density	– .05	– .05
Local Diversity (Mix)	– .03	– .05
Local Design	– .05	– .03
Regional Accessibility	– –	– .20

3.2.4 Meta-Analysis of Disaggregate Travel Studies

Since Ewing and Cervero's 2001 literature review, the published literature on the built environment and travel has mushroomed. A more recent review identified 40 published studies of the built environment and travel, and selected 17 that met minimum methodological and statistical criteria (Leck 2006). While the analysis stopped short of estimating average effect sizes, it did evaluate the statistical significance of relationships between the built environment and travel. Residential density, employment density, and land use mix were found to be inversely related to VMT at the $p < 0.001$ significance level.

The number of rigorous studies now exceeds 100, including studies examining four or five D variables at once, studies comparing travel behavior across nations, studies focusing on children, and studies accounting for residential preferences that may confound results. The EPA is funding a full-blown meta-study of this ever-expanding literature, which will summarize the most pertinent literature qualitatively and, using standard methods of meta-analysis, will combine individual study results into average elasticities or percentage point adjustments of VMT, VT, and transit use and walking with respect to the D variables. Confidence intervals will be computed for the average values. These summary measures will become available for sketch planning applications.

3.3 Regional Growth Simulations

In the "old days," metropolitan planning organizations (MPOs) developed their plans by testing different transportation alternatives against a single future land use forecast. One alternative might have more highways, another more transit or a new beltway or more arterial street improvements. But future land use patterns were always assumed to be fixed.

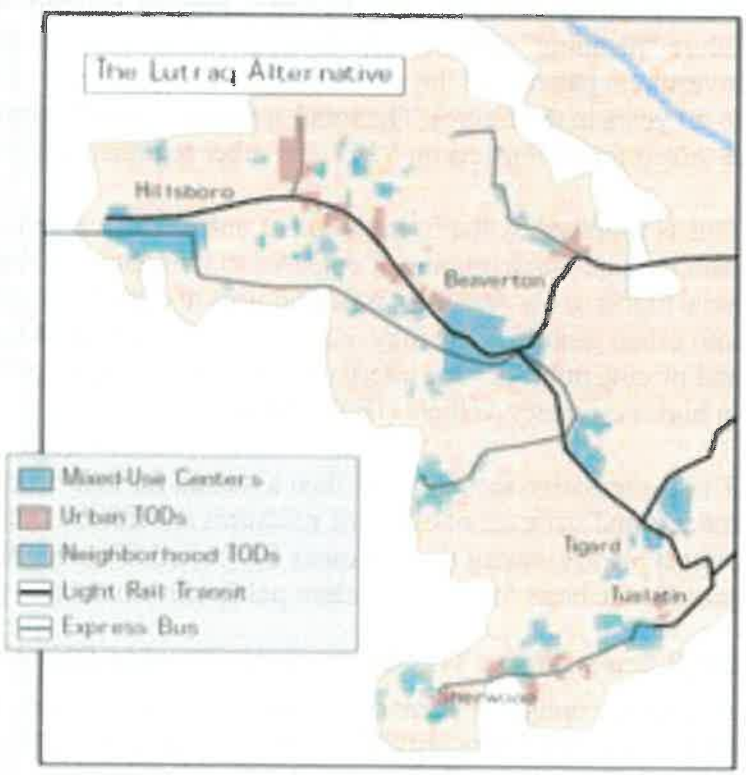
Future land use projections typically were extrapolations of recent trends, assumed to be unaffected by additions to urban infrastructure, most importantly by transportation improvements. In other words, future land use patterns were treated as fixed inputs into the analysis, not as variables or possible outcomes.

All that changed in the early 1990s with the advent of regional scenario planning, which matches alternative land use plans with alternative transportation plans. These plans are run through simulation models to project impacts on VMT, land consumption rates, air pollutant emission levels, housing affordability indexes, and other outcome measures. In theory, the most cost-effective plan is adopted.

3.3.1 The Rise of Scenario Planning

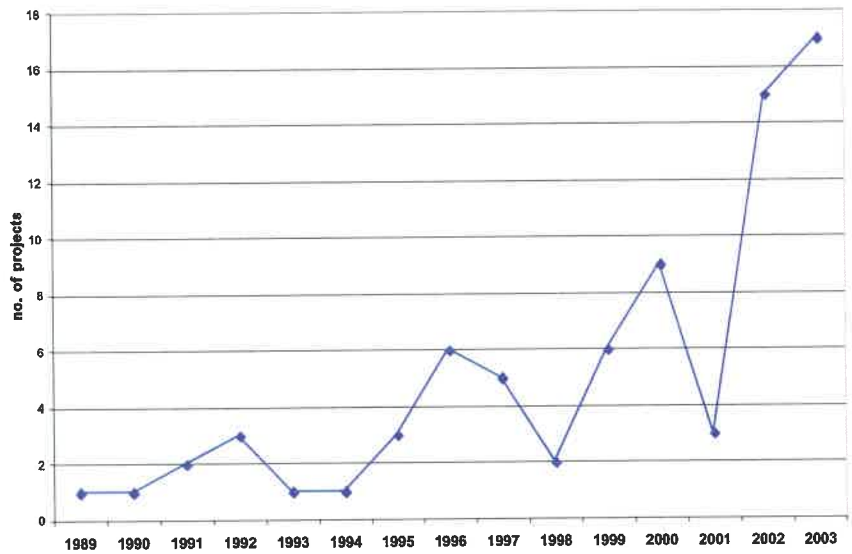
Scenario planning got a major boost from the well-publicized success of Portland, Oregon's Land Use, Transportation, Air Quality (LUTRAQ) study, which called for combining light-rail investments with transit-oriented development and travel demand management policies (1000 Friends of Oregon 1997). Portland Metro, the regional government, turned down a proposed western bypass beltway in favor of the LUTRAQ plan when regional travel forecasts showed the LUTRAQ alternative would produce significantly fewer VMT and lower levels of congestion than would trend development with the new freeway (see Figure 3-15).

Figure 3-15 The LUTRAQ Plan for the Western Portland Metro
Source: 1000 Friends of Oregon 1997.



The number of scenario planning studies undertaken in the United States has grown dramatically since LUTRAQ (see Figure 3-16). Regional scenario planning has transitioned from state-of-the-art to state-of-the-practice at MPOs (Ewing 2007). Such studies also have become common outside the United States (Johnston 2006). In fact, many advances in integrated land use/transportation modeling have come from outside the United States.

Figure 3-16 Number of Scenario Planning Projects by Completion Date
Source: Bartholomew 2007.



3.3.2 The Scenario Planning Process

The typical scenario planning process compares a "trend" scenario to one or more alternative future "planning" scenarios. In the trend scenario, urban development and transportation investment patterns of the recent past are assumed to continue through the planning horizon (20 to 50 years in the future). The trend scenario—usually some version of urban sprawl—is assessed for its impacts on VMT and other regional outcomes.

This is followed by the formulation of one or more alternative futures that vary with respect to land use and transportation. Compared to the trend scenario, the planning alternatives usually have higher gross densities, mix land uses to a greater extent, and/or channel more development into urban centers. They may incorporate a variety of transportation infrastructure investments and pricing policies. One alternative may invest more in transit lines, another might invest more in high-occupancy-vehicle (HOV) lanes.

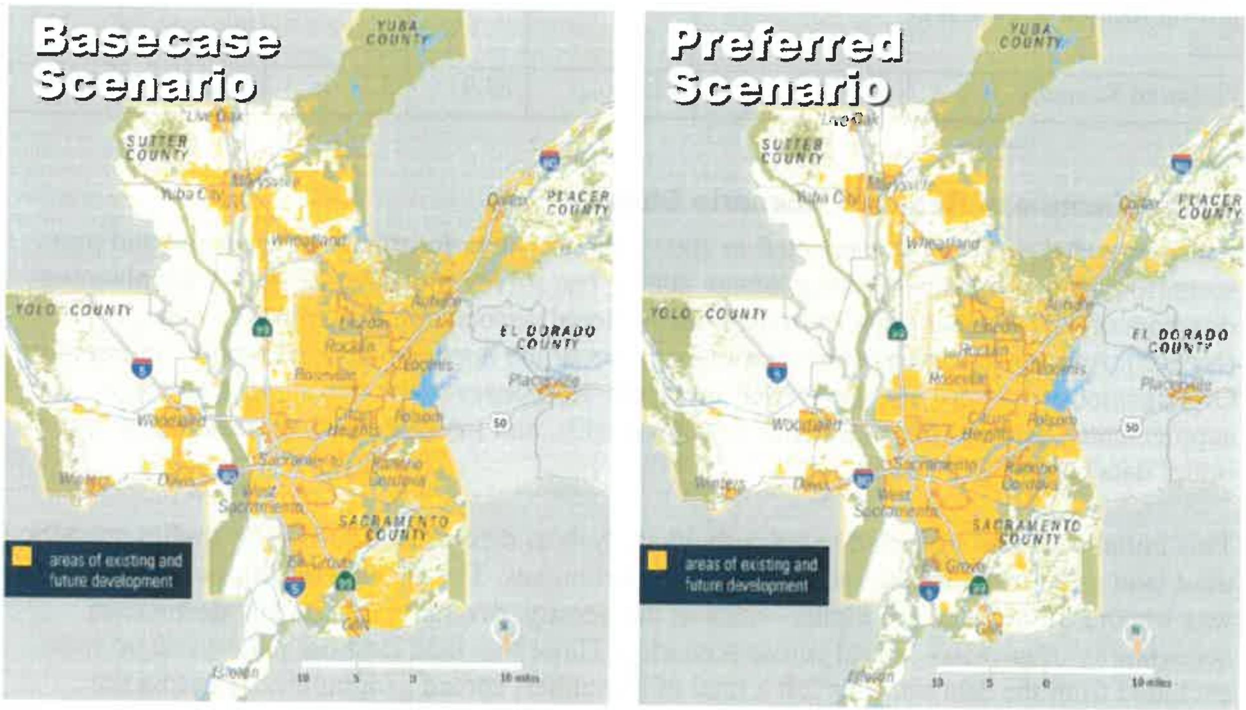
These alternative scenarios are then assessed for their impacts using the same travel forecasting models and same set of outcome measures as with the trend scenario. Vehicle miles traveled is almost always among the outcomes forecasted. The resulting comparison of scenarios can provide the basis for rational urban policy development.

3.3.3 Case Study: The Sacramento Region Blueprint Study

A leading example of scenario planning technique comes from the Sacramento region. Concerned about dispersed future growth patterns, housing, transportation, and air quality, the Sacramento Area Council of Governments initiated the Sacramento Region Blueprint Transportation–Land Use Study to craft a future growth strategy for the region (SACOG undated). Scenarios were constructed through a bottom-up process, starting at the neighborhood level. At a series of 25 neighborhood workshops, citizen participants were shown future "business as usual" development scenarios for their neighborhoods. Participants then were asked to develop a series of smart growth alternative scenarios, which were fed into a geographic information systems (GIS) modeling program that provided real-time assessments of each scenario's land use and transportation impacts.

The neighborhood scenarios provided the basis for countywide scenarios. Four scenarios were crafted for each of the region's six counties—a trend scenario plus three alternatives that combined different growth rates, land use mixes, housing types, densities, and infill/redevelopment proportions. These scenarios were analyzed for their land use and transportation impacts, creating information for several countywide workshops. The output of those workshops provided the basis for four regional-scale scenarios. Regionwide workshops then led to the creation of a fifth scenario—with a substantially smaller urban footprint than the so-called base case or trend—that ultimately was selected as the preferred option (see Figure 3-17).

Figure 3-17 Urban Footprints of Base Case and Preferred Scenarios for the Sacramento, California, Region
Source: SACOG (2005).



As illustrated in Figure 3-18, transit use and walking/bicycling increase and VMT decreases in the Sacramento region as the levels of density and infill development increase. The preferred scenario from the blueprint project is now being implemented through amendments to local government land use plans and through the region's long-range transportation plan.

Figure 3-18 Selected Data for Scenarios from the Sacramento Region Blueprint Study
Source: SACOG (2005).

Scenarios	Single-Family: Multifamily Hou	% Housing Growth throu Infill	% Auto Trips	% Transit	% Walk/Bi	Daily VM per House
A: Business as usual (trend)	75:25	27.0	91.0	1.6	7.3	51.08
B: Higher housing densities A, with growth focused at th urban fringe	67:33	39.0	83.2	4.0	12.7	37.60
C: Higher housing densities A, with growth focused on central infill sites	65:35	38.3	81.8	4.8	13.4	36.70
D: Higher housing and employment densities, with growth focused on central in sites	64:36	44.0	79.9	4.8	15.3	35.70
Preferred Scenario	65:35	41.0	83.9	3.3	12.9	34.90

3.3.4 A Sample of Regional Scenario Studies

An open-ended survey was conducted in 2003/2004 to gather information on current and past scenario planning practices (Bartholomew 2007). The survey initially was sent to the planning directors of 658 member organizations in the National Association of Regional Councils (NARC). Additional surveys were sent to members of the Association of Metropolitan Planning Organizations that were not also NARC members. Responses to the two surveys were supplemented by hundreds of e-mails, telephone calls, and Internet searches, resulting in an initial data pool of 153 studies.

This initial pool was subjected to a threshold analysis to determine whether the studies actually used land use/transportation scenario planning techniques. The primary discriminating criterion was whether future land use inputs—such as the density, diversity, design, and destination accessibility of growth—varied across scenarios. Those that held land use patterns static were excluded from the data set. This left a total of 80 studies, spread geographically across the country. Large and fast-growing regions are overrepresented in the sample.

Most studies test three or four scenarios (including a trend scenario) that vary in density, mix, and arrangement of future land uses. Half of the studies also test alternative transportation infrastructure investments. Twelve incorporate a transportation pricing element. Three-quarters of the studies evaluate scenarios for transportation impacts; more than half for impacts on open space and resource lands; 33 for impacts on criterion air pollutants; 18 for impacts on fuel use; and ten for greenhouse gas emissions (Bartholomew 2005).

A subset of 23 studies was selected for this publication, based on three criteria: simulations conducted at the regional scale, consistent population and employment totals across the scenarios, and availability of data for all scenarios on density, population growth, and VMT. Together, these studies tested a total of 85 regional development scenarios—one trend scenario per study, plus 62 planning scenarios that could be compared to trend.

3.3.5 Differences across Scenarios

The percentage difference in regional VMT for each planning scenario, relative to its respective trend scenario, is shown in Figure 3-19. Each bar represents a different planning scenario; the value shown is the percentage difference between that scenario and the study's trend scenario. Across studies, the median reduction in regional VMT is 5.7 percent, none too impressive. However, there is wide variation in values across scenarios, from + 5.2 percent to –31.7 percent, which suggests that regional growth patterns may have a substantial impact in the best case scenario.

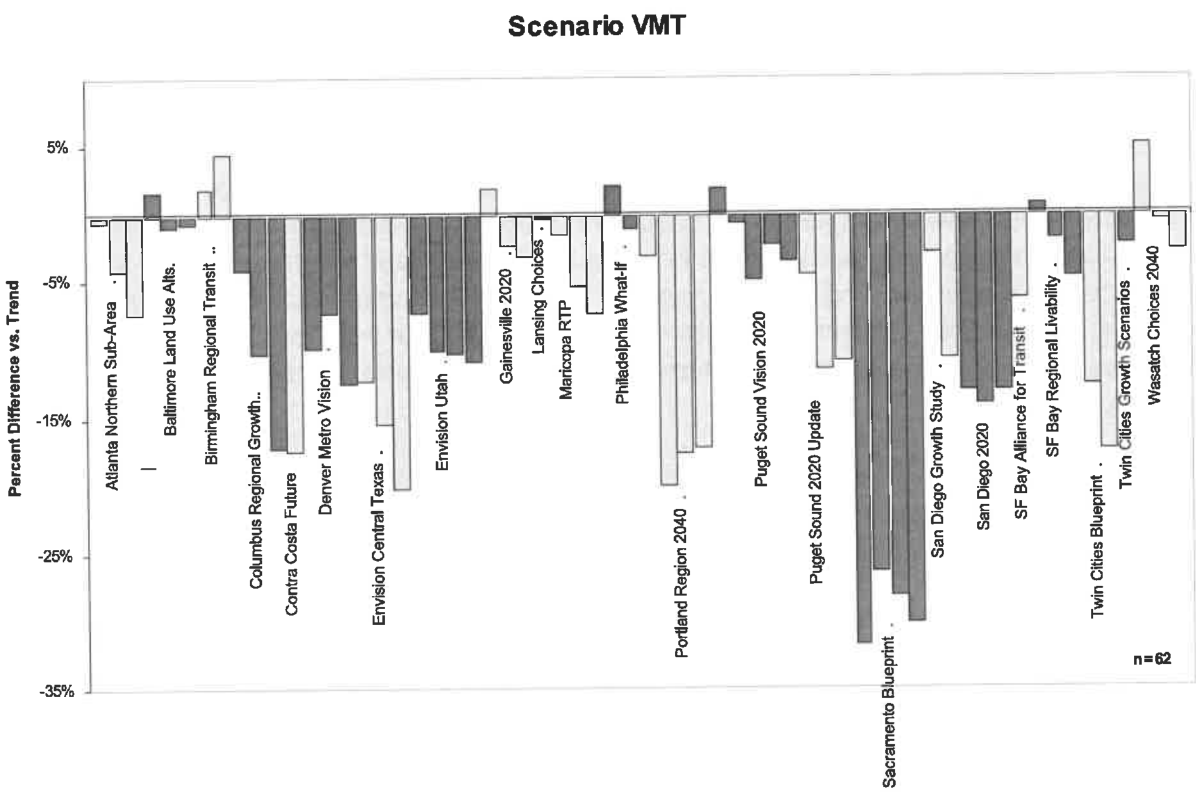
Why is there so much difference in VMT across scenarios? Bartholomew identifies many of the potential sources of variation that could be considered in a meta-analysis. These, with their presumed impact on VMT, include the following:

- nature of the scenarios (denser, more mixed, and more centered ones result in bigger VMT reductions);
- planning time horizon (longer horizons result in bigger VMT reductions);
- rate of growth (more growth that can be redirected results in bigger VMT reductions);
- reallocation of transportation dollars (higher transit investments result in bigger VMT reductions); and
- addition of travel demand management strategies (higher costs of automobile travel result in bigger VMT reductions).

While a few planning scenarios are more dispersed than trend, the great majority are more compact (see Figure 3-20). The median increase in regional density of planning scenarios over trend is 13.8 percent. Here, again, there is wide variation across scenarios, from a 14.8 percent lower density for the most dispersed scenario to a 64.3 percent higher density for the most compact scenario.

The two variables are plotted against one another in Figure 3-21. As anticipated, this simple scatter plot shows that higher scenario densities are associated with greater VMT reductions relative to the trend. The relationship appears strong and linear.

Figure 3-19 VMT Differences for 62 Scenarios Relative to the Trend Scenario*
Source: Bartholomew 2005.



*Additional information about most of these projects is available through a digital library on scenario planning maintained by the University of Utah (http://www.lib.utah.edu/digital/collections/highways/).

Figure 3-20 Scenario Densities for 62 Planning Scenarios Relative to the Trend Scenario
Source: Bartholomew 2005.

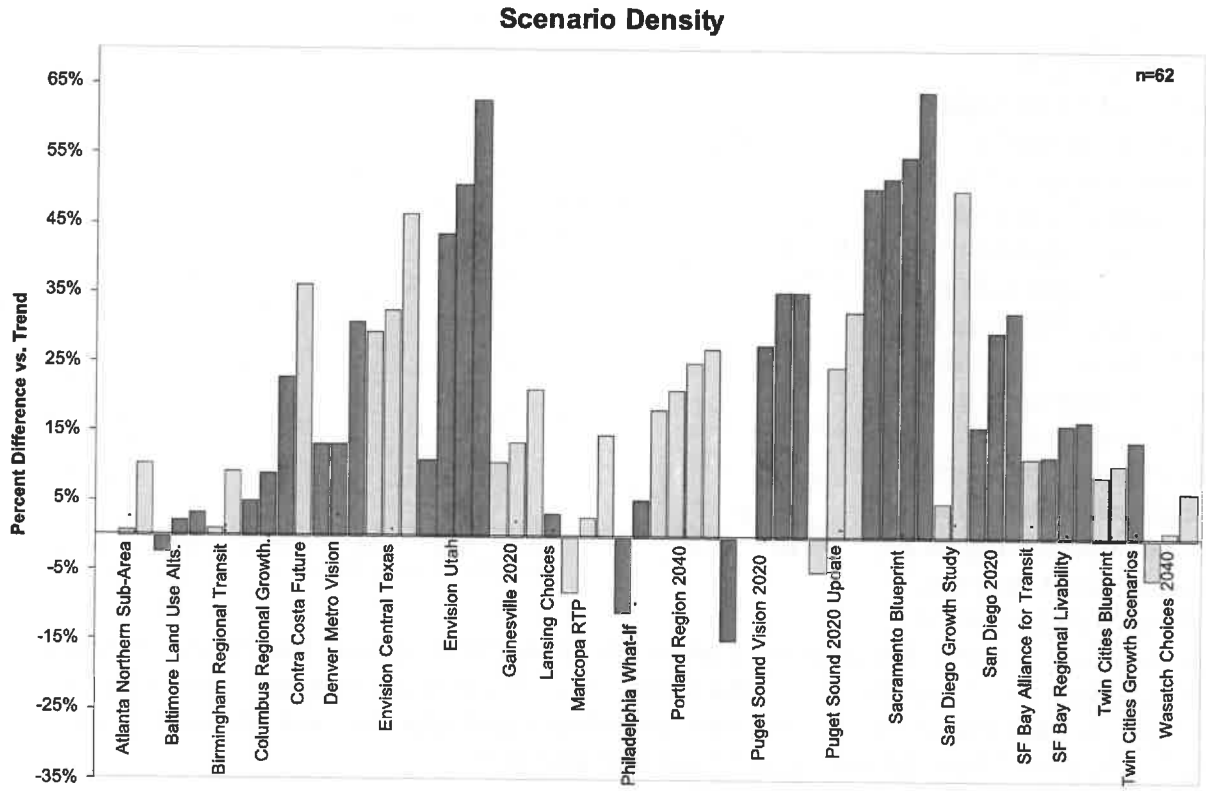
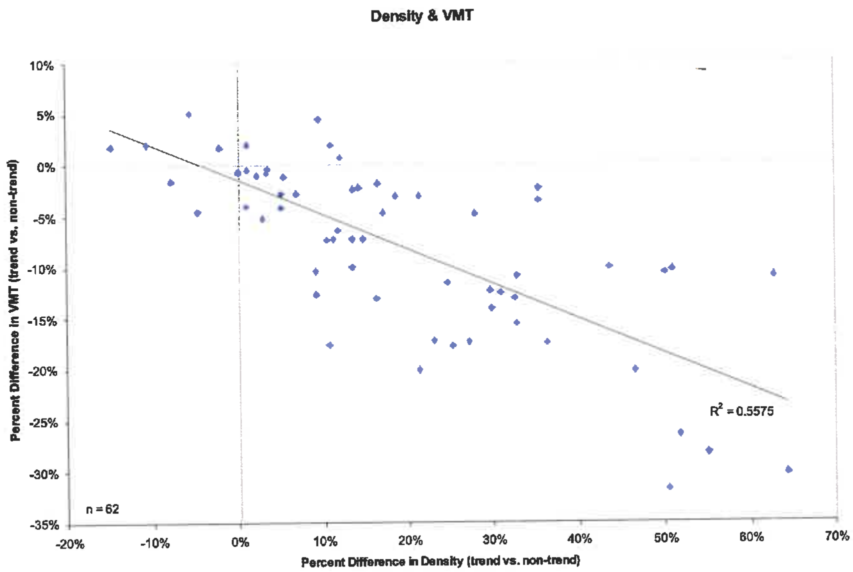
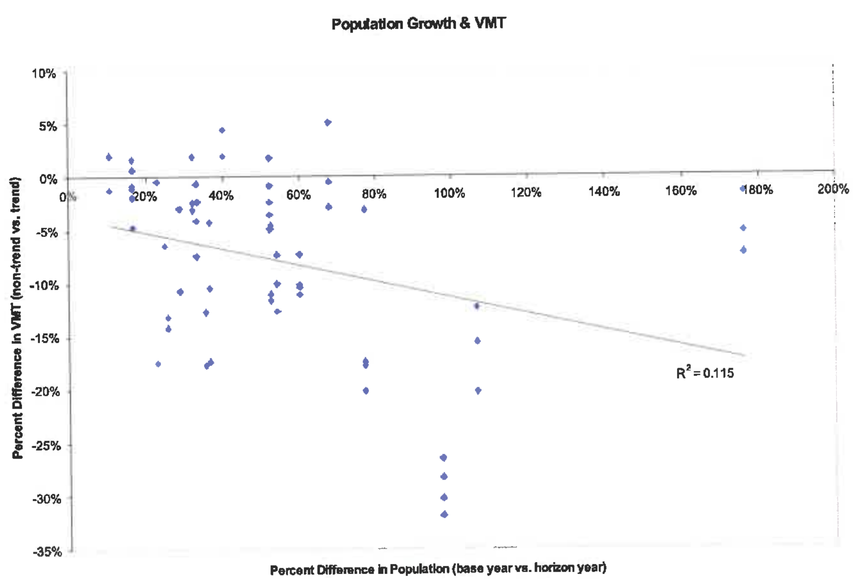


Figure 3-21 VMT versus Density for 62 Planning Scenarios Relative to the Trend
Source: Bartholomew 2005.



While much VMT reduction may be accounted for by higher densities, the scatter around the regression line in Figure 3.21 suggests that other factors also are at work. Figure 3-22 plots the percent difference in VMT for each planning scenario relative to trend against the percent population growth during the planning period for the metropolitan region as a whole (from base year to target year). Again, a correlation is apparent. The greater the increment of population growth that can be redirected in a planning scenario, the greater the difference in VMT. The growth increment is a function of both planning horizon (the further out, the more growth can be reallocated) and growth rate (the higher the growth rate, the more growth can be reallocated).

Figure 3-22 Percent Difference in VMT versus Percent Increase in Population for Planning Scenarios Relative to the Trend
Source: Bartholomew 2005.



Other variables may contribute to VMT changes as well. Several were represented by dummy variables in this meta-analysis. A dummy variable is a variable that assumes a value of one or zero, depending upon whether a condition is met. Dummies are regularly used to represent categorical variables in analyses such as this.

Lacking numeric data on these variables, we relied on narrative descriptions of scenarios in study documents to create dummy variables. For example, one dummy variable was used to distinguish between scenarios that mix and balance residential and commercial land uses to a high degree (assigned a value of one), and scenarios that mix and balance land uses only to the same degree as in trend development (assigned a value of zero). Some of the dummies were specific to scenarios; others were specific to regions and/or studies.

3.3.6 Meta-Analysis of Regional Simulation Studies

With so many independent variables, it becomes hard to discern relationships from simple scatter plots. This is a multivariate problem that requires a multivariate analysis to isolate the effect of each independent variable on the dependent variable, holding the other variables constant.

The analysis is further complicated by the multilevel nature of the data structure. Scenarios are "nested" within regions, with the typical region having two or three alternatives to the trend. Scenarios for the same region are not independent of each other, as they share the characteristics of their respective regions. Thus, standard (ordinary least squares) regression analysis cannot be used to analyze this multivariate data set. Rather, a hierarchical or multilevel modeling technique is required.[23]

A hierarchical linear model was estimated for the continuous outcome, percent difference in VMT relative to trend. Independent variables tested were at two levels, those specific to scenarios and those specific to studies (the latter common to all scenarios for a given region). Independent variables specific to scenarios were as follow:

- percent difference in gross density relative to trend development (–15 percent to +64 percent);
- development centralized/infill emphasized (one if yes, zero if no); and
- land uses highly mixed (one if yes, zero if no).

Independent variables common to scenarios for a given region but different across regions/studies are as follow:

- percent population growth increment relative base population (10 percent to 176 percent);
- auto use priced higher (one if yes, zero if no); and
- transportation investments coordinated with land uses (one if yes, zero if no).

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[23] For region-level characteristics, ordinary least squares (OLS) regression analysis would underestimate standard errors of regression coefficients and would produce inefficient regression coefficient estimates. Hierarchical modeling overcomes these limitations, accounting for the dependence of scenarios for the same region and producing more accurate regression coefficient and standard error estimates (Raudenbush and Byrk 2002). Within a hierarchical model, each level in the data structure is represented by its own submodel. Each submodel captures the structural relations occurring at that level and the residual variability at that level. To represent such complex data structures, this study relied on HLM 6 (Hierarchical Linear and Nonlinear Modeling) software.

The best-fit model is presented in Figure 3-23. For theoretical reasons, the model was estimated with no constant term (as a regression through the origin). If nothing changes from trend, there should be no reduction in regional VMT. There are three significant influences on VMT: the population growth increment, centralized development, and mixed land use. All three are associated with decreases in VMT relative to trend. The increase in density relative to trend has the expected sign but falls just short of significance. Coordinated transportation investment also has the expected sign but is not significant.

The elasticity of VMT with respect to the population growth is –0.068, meaning that there is a 0.068 percent decrease in VMT per capita for every 1 percent increase in population relative to the base year. This does not argue for population growth per se, but simply indicates that regions that are growing rapidly have more opportunity to evolve toward a compact urban form than regions that are growing slowly.

Centralization of regional development and mixing of land uses both are inversely related to VMT at the 0.05 probability level. From their coefficients, we would expect a 1.5 percent drop in regional VMT with centralized development, and a 4.6 percent drop in regional VMT with mixed-use development (after controlling for other variables).

While the regional density variable is not statistically significant, our best guess at the elasticity of VMT with respect to regional density is –0.075, meaning that there would be a 0.075 percent decrease in VMT for every 1 percent increase in population density. This is a little higher than the elasticity estimate from the disaggregate travel studies in section 3.2. The density variable likely is soaking up some of the effect of other D variables that are not adequately represented in the regional growth simulations.

The coordinated transportation investment variable also is not statistically significant. Again, our best estimate of the impact of coordinated transportation investments, controlling for other variables, is a 2.1 percent reduction in regional VMT.

When forced into the model, the imposition of transportation pricing policies has a positive coefficient, suggesting that it would lead to higher VMT. This counterintuitive result is discussed in section 3.3.9.

Plugging realistic numbers into the best-fit model in Figure 3-23, we can estimate the VMT reduction associated with a shift to compact development. If such a shift increases average regional density by 50 percent in 2050, emphasizes infill, mixes land uses to a high degree, and has coordinated transportation investments, it would be expected to reduce regional VMT by about 18 percent over 43 years at an average metropolitan growth rate of 1.3 percent annually.[24]

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[24] Computed as –0.074*50 – 1.50*1 – 4.64*1 – 0.068*73 – 2.12*1. The 73 in the preceding formula represents a growth increment of 73 percent, or 43 years at an average growth rate of just over 1.28 percent per year.

Figure 3-23 Best-Fit Model of Percent VMT Reduction Relative to Trend (with Robust Standard Errors)

	Coefficient	t	P
Difference in density (% above trend)	–0.074	–1.48	0.15
Development centralized	–1.50	–2.13	0.037
Land uses mixed	–4.64	–2.15	0.036
Population growth increment (% over base)	–0.068	–2.02	0.056
Transportation coordinated	–2.12	–1.01	0.33

3.3.7 The Conservative Nature of Scenario Forecasts

This forecasted reduction in regional VMT with compact development is almost surely an underestimate due to limitations of the travel demand models used in these studies. It is widely known, and oft-stated, that conventional regional travel models of the type used in most regional scenario studies are not sensitive to the effects of the first three Ds—density, diversity, and design (Walters, Ewing, and Allen 2000; Johnston 2004; Cervero 2006; DKS Associates and University of California 2007; Beimborn, Kennedy, and Schaefer undated). Conventional models can simulate land use and transportation system effects on travel at the gross scale of a region, but not at the fine scale of a neighborhood. In particular, they cannot account for the micromixing of land uses, interconnection of local streets, or human-scaled urban design. Most do not even consider walk or bike trips, adjust vehicle trip rates for car shedding at higher densities, or estimate internal trips within mixed-use developments.[25]

[25] What is missing from conventional travel demand models are five D variables. The following is true of nearly all conventional four-step models: 1) Only trips by vehicle are modeled, and trip rates are related only to characteristics of people, not characteristics of place. The possibility of households in urban settings making fewer vehicle trips—and instead using nonmotorized modes—is not considered. 2) Households, jobs, and other trip generators are assumed to be located at a single point, the zone centroid, and the entire local street network is reduced to one or more centroid connectors to the regional street network. This precludes the modeling of intrazonal travel in terms of the local built environment. 3) The choice between transit and auto modes is modeled solely in terms of characteristics of travelers and modes. The characteristics of origins and destinations—their transit-friendliness and walkability—are disregarded. 4) Trips are treated as unlinked, when a majority of trips nowadays are part of tours (trip chains) in which each trip depends on the trips preceding and following it, in a linked fashion. Destinations doubtless are chosen based not only on the attractions they contain, but also based on their accessibility to other trip attractions. 5) Trip attractions are summed for component land uses in a given zone, with each use treated as independent of the others. Yet mixed-use development is known to generate fewer vehicle trips than the component uses individually. 6) Daily travel is allocated to the peak hour based on fixed factors, disregarding the tendency for peak spreading when land uses become concentrated enough to produce serious peak-hour congestion. Peak spreading is the rescheduling of trips from the peak hour to the shoulders of the peak.

These failings and others have prompted:

- the U.S. Department of Transportation to spend millions of dollars developing a new generation of travel demand models under the Travel Model Improvement Program;
- the U.S. EPA to develop the Smart Growth Index model;
- leading MPOs such as Portland Metro (for the LUTRAQ study) to enhance their conventional "four-step" models with additional steps and feedback loops; and
- other leading MPOs to post-process model outputs or develop direct transit ridership models.

How much additional VMT reduction might be achieved with compact development, beyond that forecasted in regional growth simulations? To a first approximation, we can think of conventional travel models as accounting for one of the D variables, destination accessibility. The effects of the other D variables, outlined in section 3.2, are largely neglected. Were they factored into the analyses, one could easily reach VMT reductions of 20 percent or more.

3.3.8 Regional Growth and Vehicle Emissions

Our sample of regional growth studies is not large enough, and the studies themselves are not sophisticated enough, to support meta-analyses of impacts of smart growth on other outcomes (beyond VMT). At most, they support qualitative statements and inferences.

Vehicle emissions, including CO_2, are not merely a function of VMT, but also reflect the numbers of cold starts plus vehicle operating speeds (see section 2.3). Figure 3-24 shows that for many scenarios, an increase in density is associated with a drop in average peak hour operating speeds—an outcome that could result in increased emissions because gasoline engines function more efficiently at higher speeds.

Figure 3-24 Percent Differences in Peak Hour Average Speed versus Density for Planning Scenarios Relative to Trend

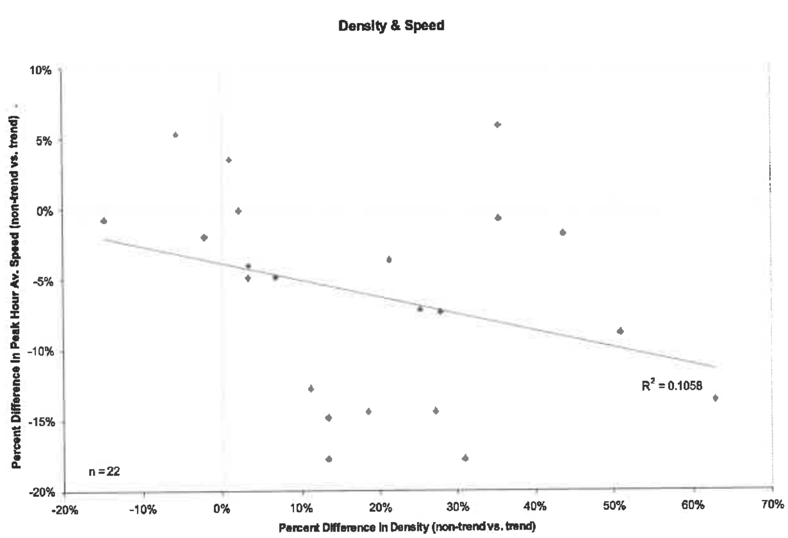


Figure 3-25. Percent Difference in NOx Emissions versus Percent Difference in Density for Planning Scenarios Relative to the Trend

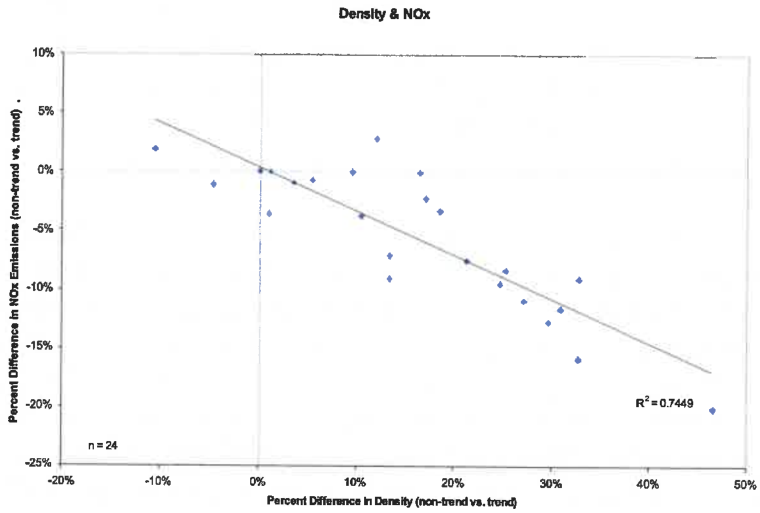
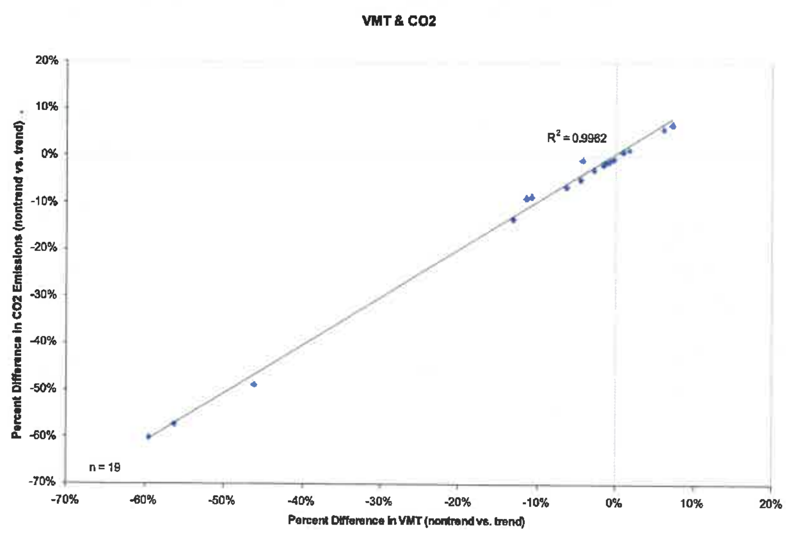


Figure 3-25 plots nitrogen oxide (NOx) emissions versus density differences for 24 planning scenarios. The scatter plot shows a strong association between the two variables. The strength of the association appears equivalent to that between VMT and density. Because most or all of these studies use vehicle emission models that account for differences in vehicle operating speeds, we can reasonably conclude from these data that any effect of density on emissions through vehicle operating speeds is overwhelmed by the effect of density on emissions through VMT. As with the observations above on energy consumption and speed (Figure 3-4), compact development is associated with lower emissions, notwithstanding possible reductions in vehicle speeds.

Data on regional CO_2 emissions are more limited. The scarcity of the forecasts indicates that the agencies undertaking scenario planning studies—primarily MPOs—have not focused on carbon emissions as a planning issue. Figure 3-26 plots VMT versus CO_2 differences for 19 planning scenarios. The near-perfect correlation and the elasticity value close to 1.0 suggest the multiplication of VMT by some constant factor to arrive at CO_2 forecasts.

Figure 3-26 Percent Difference in VMT and CO_2 Emissions for Planning Scenarios Relative to Trend



3.3.9 Regional Growth and Transportation Pricing

The meta-analysis in section 3.3.6 produced one anomalous result. When forced into the model, the imposition of transportation pricing policies has a positive coefficient, suggesting that it would lead to higher VMT. This is probably explained by confounding variables and the small sample of studies that actually test pricing policies.

In theory, the impact of pricing schemes on land development patterns could be positive or negative, depending on the pricing scheme. Increasing the price of driving (roads or parking) in only one part of a metropolitan region or along only a limited number of corridors could shift future economic and development activity away from the priced area or corridors and toward areas that are unpriced (Deakin et al. 1996). This could increase overall driving and VMT. Using an areawide pricing approach, however, could result in a concentration of future growth. This would occur as households and businesses seek to reduce or avoid the extra costs (Komanoff 1997). Some simulation-based evidence supports this conclusion (Gupta, Kalmanje, and Kockelman 2006).

If transportation pricing is ultimately adopted as a strategy to reduce VMT and CO_2, compact development could prove useful in both cushioning the blow to household budgets and enhancing the travel reduction effects (see Cambridge Systematics 1994). The LUTRAQ project, which was not included in the meta-analysis, provides data that support this conclusion. The project compared three scenarios: 1) a trend scenario that assumed the continuation of recent development practices and transportation investments, including a new highway; 2) the same scenario with an areawide parking pricing/free transit pass policy added;[26] and 3) a transit-oriented development scenario (LUTRAQ) with two additional rail lines and the same parking/transit pass component. Adding the LUTRAQ land use/transit element to the pricing/subsidy package tripled reductions in NOx and nearly quadrupled reductions in VMT and CO_2 emissions (see Figure 3-27).

Figure 3-27 Percentage Reduction in Transportation Outcomes with Transportation Pricing, and Pricing and Compact Development Combined
Source: 1000 Friends of Oregon 1996.

	Pricing/Subsidy	LUTRAQ w/ Pricing/Subsidy
Daily VMT	– 2%	– 7.9%
NOx Emissions (kg/day)	– 2.9%	– 8.7%
CO_2 Emissions (kg/day)	– 2%	– 7.9%

[26] The pricing policy assumed an areawide $3.00 per day parking charge for drive-alone work trips. The income was used to provide free transit passes to all commuters in the study area.

3.4 Project-Level Simulations

We also can assess the effects of the built environment through comparisons of VMT and vehicle emissions generated by individual land developments. These comparisons may be based on actual travel diaries or odometer readings for residents of existing developments. Or they may be based on simulations using conventional travel models calibrated and validated for the study region and, in some cases, enhanced to capture the effects of localized variations in density, diversity, and design.

Unlike regional scenario studies, project-level simulations have the advantage of focusing on the subset of the regional population for whom the built environment actually varies. Site plans can vary in density, diversity, or design, without differences in regional location or proximity to transit. Regional location can vary from transit-served brownfields to auto-only greenfields, without any difference in site plans. Or both can vary. The amount of development (housing and employment) generally is held constant in project-level simulations, but acreage may differ across site plans.

3.4.1 Case Study: Atlantic Steel Project XL

The 1999 study of the Atlantic Steel project—now known as Atlantic Station—is a prominent example of project-level simulation with both types of variation. The redevelopment project is on a 138-acre former steel mill and brownfield site in Midtown Atlanta. A developer proposed converting the vacant site into a "new town in town." Its location—close to primary regional destinations and to rapid transit—and its dense, mixed-use design made the proposed Atlantic Steel redevelopment a classic smart growth infill project, favored by everyone from the city's mayor to the vice president of the United States (at the time, Al Gore).

The dilemma was that the redevelopment project required a bridge over Interstate 75/85 to connect to a rapid transit station and a neighborhood to the east, plus ramps for access to the interstate highways. At the time, the Atlanta region was out of compliance with federal transportation conformity requirements and, as a result, could not tap into federal funds to add to its highway system. It could not even construct certain highway improvements using nonfederal funds. The proposed bridge and ramps were included in this prohibition.

Under a program called Project XL (excellence and leadership), the EPA has the power to waive environmental regulations when a superior environmental outcome may be achieved by some otherwise prohibited action. Based on an analysis showing that redevelopment of the Atlantic Steel site would produce less VMT and vehicle emissions than development of likely alternative sites in outlying areas, the EPA ultimately waived the conformity requirement for this project.

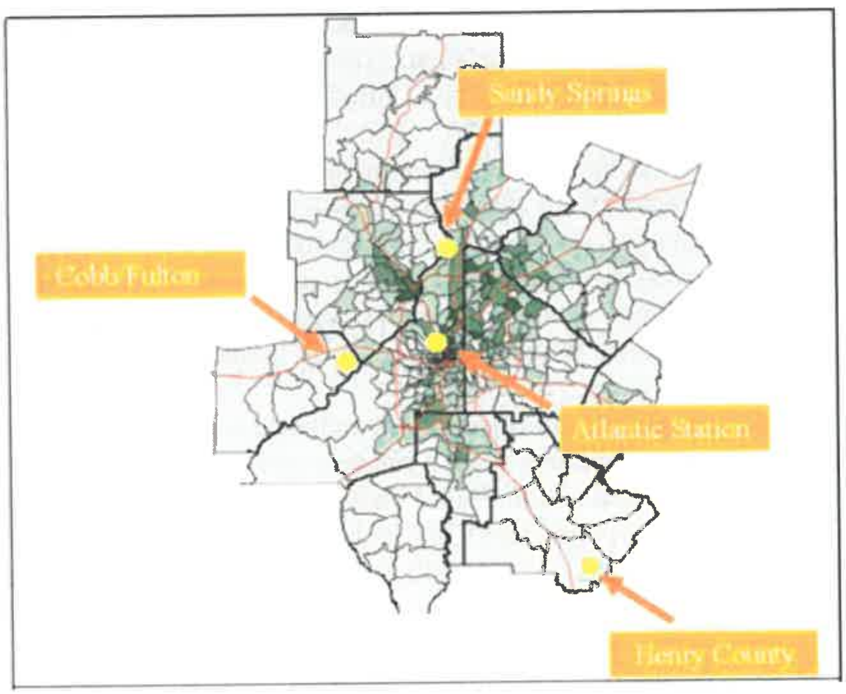
For this analysis, a team of consultants evaluated the Atlantic Steel project from two standpoints:

- *Regional location.* The Midtown site was compared to three greenfield sites large enough to accommodate the proposed development. The sites were at increasing distances from the urban core: a perimeter beltway location, a suburban location, and an exurban location, each with a development density and site plan typical of its location. The map below shows the location of the Atlantic Steel site and the three greenfield sites relative to the urban core.

- *Site plan.* Three alternative plans for the Atlantic Steel site—incorporating different intrasite densities, land use mixes, street networks, and streetscape design elements—were compared. They were the Jacoby Development Corporation's original site plan, an "improved new urbanism case" developed through a charrette process by Duany Plater-Zyberk & Company (DPZ), and a final compromise plan incorporating key DPZ concepts.

The original Jacoby design mixed land uses primarily on the site's east side, nearest the MARTA rapid transit station. On the west side, the developer proposed a single-use office park with buildings set back from the street and separated by stretches of undeveloped green area and parking. Residences were located between the office park and the retail/hotel district. The street network was an adaptation of the site's existing grid system, with some connections to neighborhood streets to the south.

Alternative regional locations evaluated.
Based on EPA (1999)



With everything riding on EPA approval, the agency had the leverage to push for a more integrated site plan. The DPZ plan, generated at a design charrette, mixed land uses within the site to a great degree, while holding the amount of office, retail, and residential development constant. Only the far west side retained the single-use character of the original site plan, in an office district. The redesign featured shorter blocks, narrower streets, improved streetscapes, and clear pedestrian paths. Auto speeds were controlled to provide a better pedestrian environment. Densities were increased near transit stops. The street grid of the surrounding neighborhood was extended into the site, and land uses were moved to permit shared parking.

Jacoby's final site plan is a compromise between the two earlier plans. The land use mix is more fine-grained than the original plan's but not as fine-grained as the DPZ redesign. The street network is more fine-meshed than the original plan's but less so than the redesign. Other concepts from the DPZ charrette, and from the literature on the built environment and travel, have been retained.

Alternative site plans evaluated
Based on EPA (1999)

Figure 2 Atlantic Steel site, Jacoby original

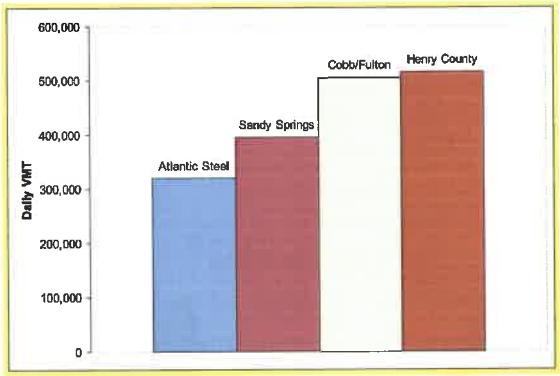
Figure 3 Atlantic Steel site, DPZ

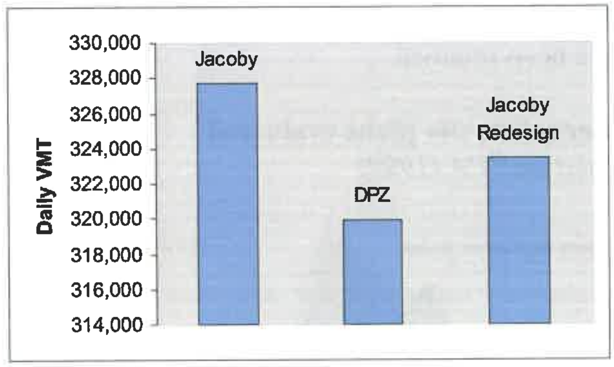
Figure 4 Jacoby site redesign

First, the EPA consultant team performed an in-depth evaluation of travel forecasting methods used in the Atlanta region. The evaluation resulted in various refinements to the Atlanta Regional Commission's conventional travel forecasting model to better account for regional location and destination accessibility, and in postprocessing of model outputs to better account for the first three Ds—density, diversity (mix), and design (Walters, Ewing, and Allen 2000). Postprocessing employed an early version of the Smart Growth Index model with elasticities derived from a review of recent research on the built environment and household travel (as described in section 3.2).

Model results demonstrated that VMT and emissions would be about 30 percent lower at the Atlantic Steel infill site than at the remote greenfield locations, and an additional 5 percent lower with the revised site plan (see Figure 3-28). As a result, for the first time, the EPA designated a land development proposal as a regional transportation control measure, allowing for approval of the project and funding of transportation Aimprovements. Atlantic Station has become a highly successful, largely built and occupied, infill community (see photographs below).

Figure 3-28 VMT Generated by Regional Location and Site Plan Alternatives
Source: EPA 1999.





Atlantic Station today.

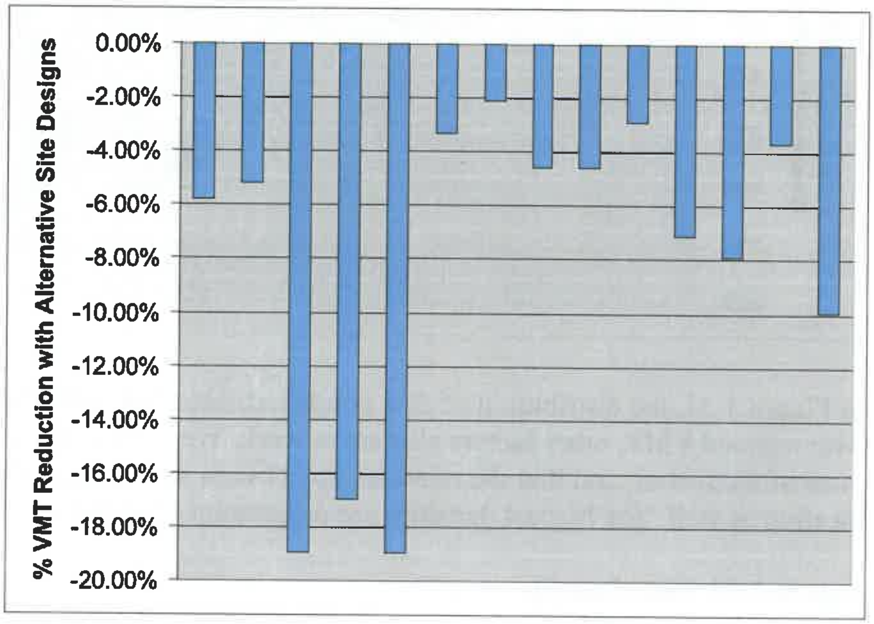


Source: Jacoby Development Company

3.4.2 Site Plan Influences on VMT

The Atlantic Steel study—and similar studies in San Diego, Wilmington, Portland, Oak Ridge, San Antonio, and Toronto—have forecasted the impacts of site design on vehicle trips, VMT, and/or CO_2 emissions (Hagler Bailly 1998; EPA 1999, 2001a, 2001b; IBI Group 2000). Figure 3-29 presents the findings of these studies. In each case, alternative development plans for the same site are compared to a baseline or trend plan.

Figure 3-29 Effect of Site Design Alone on VMT

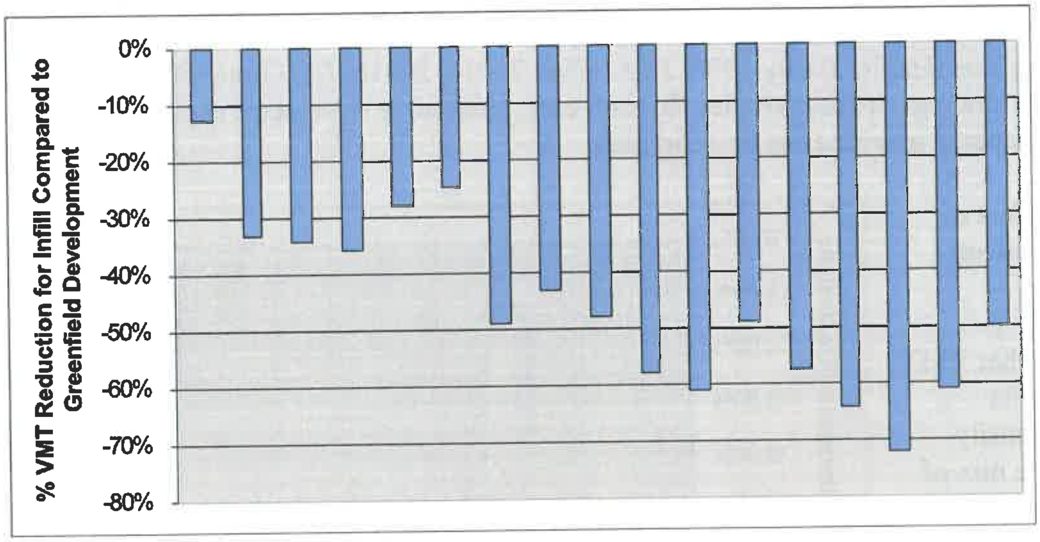


Results suggest that VMT and CO_2 per capita decline as site density increases and the mix of jobs, housing, and retail uses becomes more balanced. However, the limited number of studies, differences in assumptions and methodologies from study to study, and the variability of results make it difficult to generalize.

3.4.3 Regional Location Influences on VMT

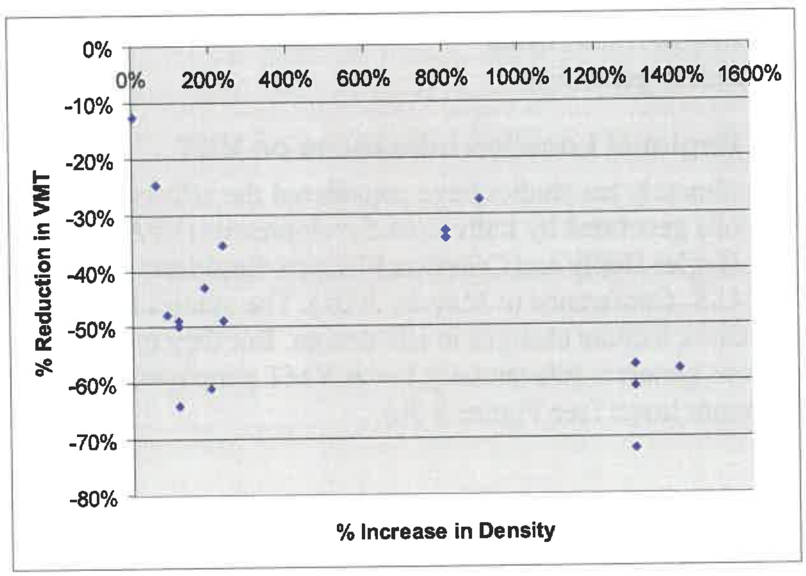
Approximately ten studies have considered the effects of regional location on travel and emissions generated by individual developments (EPA 1999, 2001a, 2001b, 2006; Hagler Bailly 1998; Hagler Bailly and Criterion Planners/Engineers 1999; IBI Group 2000; Allen and Benfield 2003; U.S. Conference of Mayors 2001). The studies differ in methodology and context, and in some cases include changes in site design. But they tend to yield the same conclusion: infill locations generate substantially lower VMT per capita than do greenfield locations, from 13 to 72 percent lower (see Figure 3-30).

Figure 3-30 Effect of Regional Location and Site Design on VMT



In Figure 3-31, the distribution of data points indicates that, while higher density is associated with reduced VMT, other factors also are at work. We suspect that regional location explains most of the scatter, and that the relationship between density and VMT is due in part to regional location as well. The highest densities are programmed for the most central locations.

Figure 3-31 Relationship between Density Increase and VMT Reduction

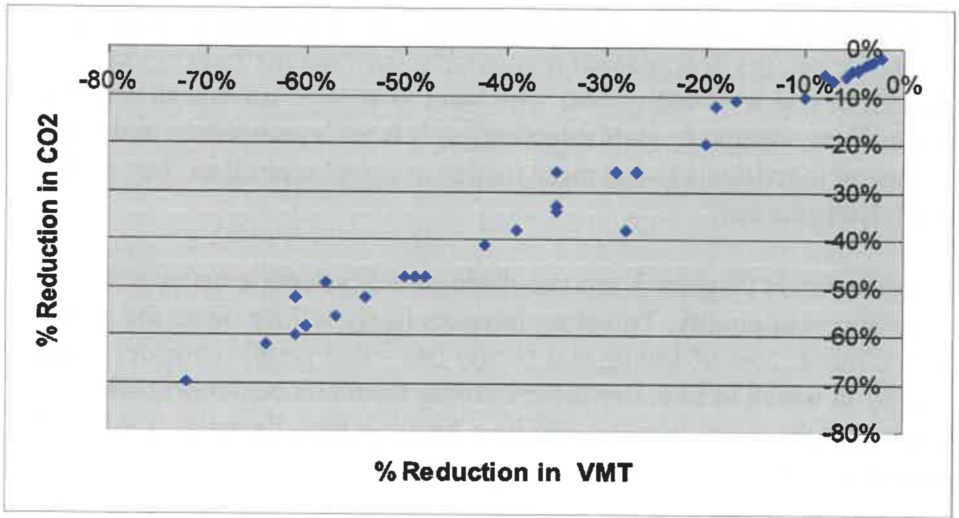


The data from project-level simulations are too limited to conduct a true meta-analysis of the variance in VMT per capita. However, the data clearly suggest that development that combines an infill location with higher density and good urban design can produce dramatic VMT reductions compared to typical greenfield development. VMT reductions cluster between about 30 and 60 percent. When compared with the results of the site design studies, which show VMT reductions of 2 to 19 percent, the effect of regional location appears much stronger than that of project density and site design alone.

3.4.4 The Relationship between VMT Reduction and CO_2 Reduction

These project-level simulations indicate that dense infill developments also are associated with reduced CO_2 emissions (see Figure 3-32). On a percentage basis, CO_2 reductions are not quite as large as VMT reductions. The regression line suggests an elasticity of CO_2 emissions with respect to VMT of 0.96. This is likely due to emission penalties associated with reduced vehicle operating speeds at infill locations.

Figure 3-32 Reduction in CO_2 Emissions versus Reduction in VMT



4. Environmental Determinism versus Self Selection

There is a long-running debate in urban planning about the degree to which the physical environment determines human behavior. The theory of environmental or architectural determinism ascribes great importance to the physical environment as a shaper of behavior. The counter view is that social and economic factors are the main or even exclusive determinants of behavior.

To outsiders, this debate may seem simplistic. Any extreme view would be. Yet, we all bring paradigms to the study of travel behavior, paradigms that affect our interpretation of the facts. Depending on one's point of view, the documented relationship between the built environment and travel might just as well be due to 1) individuals who want to walk or use transit selecting pedestrian- or transit-friendly environments (self selection) as it is to 2) pedestrian- and transit-friendly environments causing individuals to use these modes of travel more than they would otherwise (environmental determinism).

For many of the studies reviewed in Chapter 3, we can discount self selection because the unit of geographic analysis is the region or county. Travel preferences likely fall far down the list of factors—after job access, climate, cost-of-living, and family ties—that people consider when choosing a region or county in which to live. For those moving from one neighborhood to another, however, a desire to walk or use transit could be a factor in their decision, a possibility to which we now turn our attention.

4.1 The Empirical Literature on Self Selection

Does residential choice come first, and travel choice or some other outcome follow (environmental determinism)? Or do people's propensities for travel and physical activity determine their choice of residential environment (self selection)? Between environment and attitude, which drives behavior?

More than anything else recently, the possibility of self-selection bias has engendered doubt about the travel benefits of compact urban development patterns. According to a Transportation Research Board/Institute of Medicine report (2005), "If researchers do not properly account for the choice of neighborhood, their empirical results will be biased in the sense that features of the built environment may appear to influence activity more than they in fact do. (Indeed, this single potential source of statistical bias casts doubt on the majority of studies on the topic to date.)"

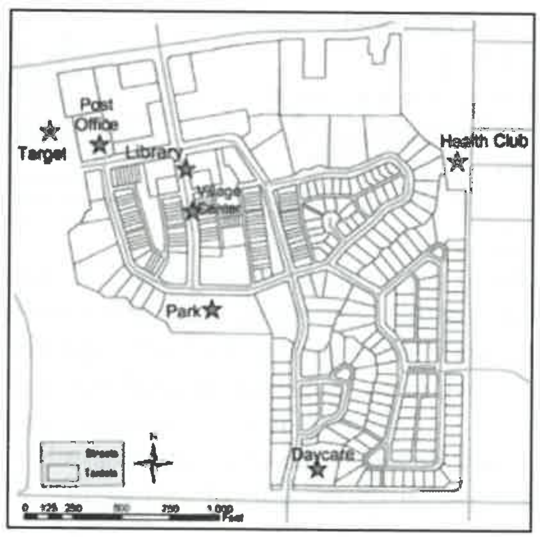
Self selection occurs if the choice of residence depends in a significant way on attitudes about, or preferences for, one mode of transportation over another. In the language of research, such attitudes will confound the relationship between residential environment and travel choices. Most of the "evidence" for or against self selection is circumstantial.

Many studies have cited associations between attitudes and travel choices as evidence of self selection. Favorable attitudes about walking correlate with walking; favorable attitudes about the environment correlate with transit use. It would be surprising, indeed, if travelers who are favorably disposed toward a given mode did not use that mode more frequently than others, regardless of where they live. But this does not mean that attitudes account for the observed relationship between the built environment and travel. For self selection to occur, attitudes must also influence residential choices.

Planning researchers frequently ask new residents whether transit accessibility, walkability, or access to specific destinations were factors in their location decisions. Access considerations usually fall well down the list of location factors, after housing price and quality, neighborhood amenities, and school quality.

Typical of such surveys is one by Dill (2004). Fairview Village is a mixed-use, new urbanist neighborhood in suburban Portland, Oregon, with interconnected streets and attractive streetscapes (see the photograph and site plan below). Residents were asked to rate the importance of location factors in choosing their new home. The highest-rated factors were neighborhood safety, neighborhood style, and house price. Among access variables, "quick access to the freeway" was ranked highest at number eight. Pedestrian access ranked lower. "Having stores within walking distance" was 12th in importance, and "having a library within walking distance" was 14th. Still, pedestrian access was rated as more important in Fairview Village than in two nearby subdivisions matched for income, home value, home size, and year built. Apparently, self selection is present but weak. Whatever the underlying cause, attitude, or environment, walk trips are much more frequent in Fairview Village, and VMT per adult is 20 percent lower than in otherwise comparable suburban subdivisions (see Figure 4-1).

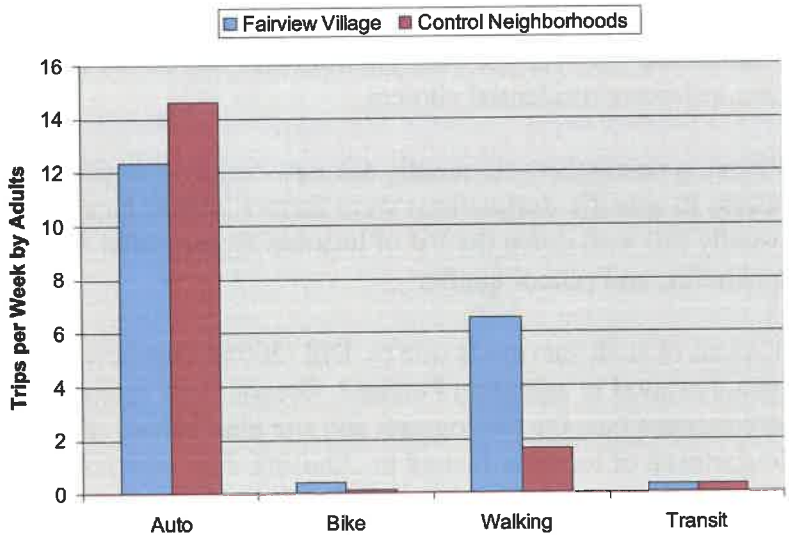
Fairview Village City Hall and nearby housing.



Fairview Village site plan.
Source: Rose 2004

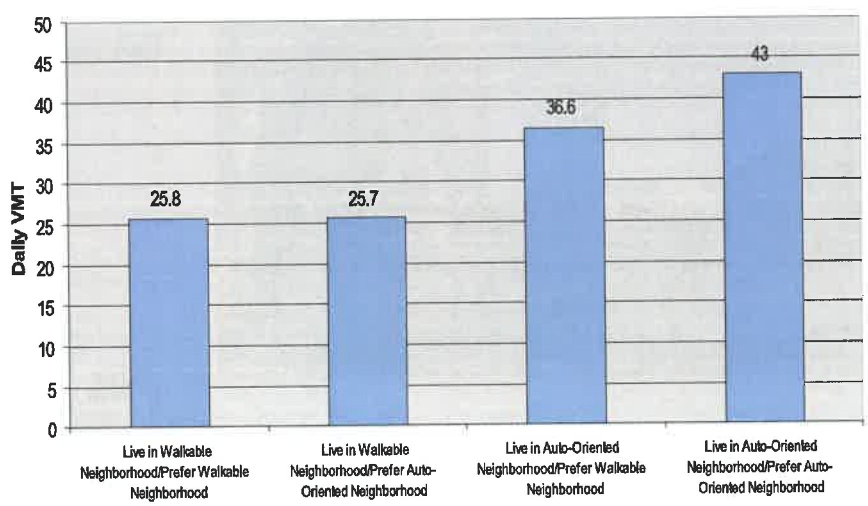
Figure 4-1 Number of Trips by Mode and by Neighborhood*
Source: Based on data in Dill 2004.

*By adults, per week.



The strongest survey-based evidence of self selection is Lund's (2006) study of people who had recently moved to transit-oriented developments (TODs) on rail lines in California. For TOD residents, transit access ranked third among location factors in San Francisco and fifth in Los Angeles and San Diego (where, amazingly, it ranked lower than highway access). One-third of all respondents mentioned transit access as one of the top three reasons for locating in a TOD. These residents were much more likely to use transit than those not citing transit access as a location factor. Yet, because the survey did not collect comparable data on prior travel mode, we cannot draw any inference regarding the strength of attitudes versus environment or on the effect of transit-oriented development on net regional transit use.

Figure 4-2 Average VMT by Neighborhood Type and Residential Preference
Source: Frank et al. forthcoming.



The strongest survey-based evidence of environmental determinism is Frank et al.'s (forthcoming) in-depth study of 8,000 households in Atlanta, which indicates that the built environment and availability of alternatives can lead anyone, regardless of preference, to drive less. Just comparing those who stated a preference for walkable environments, VMT was 40 percent lower among those who actually lived in a walkable neighborhood than among those who lived in an auto-oriented neighborhood (see Figure 4-2). Roughly one in three current residents of automobile-oriented neighborhoods would prefer to live in a walkable environment but were unable to find one, given current development patterns. This alone indicates a ready-made market for compact development.

At least 28 studies using different research designs have attempted to test and control for residential self selection (Mokhtarian and Cao forthcoming; Cao, Mokhtarian, and Handy 2006). Nearly all of them found "resounding" evidence of statistically significant associations between the built environment and travel behavior, independent of self-selection influences: "Virtually every quantitative study reviewed for this work, after controlling for self-selection through one of the various ways discussed above, found a statistically significant influence of one or more built environment measures on the travel behavior variable of interest (Cao, Mokhtarian, and Handy 2006).

Mokhtarian and colleagues find research designs used in studies to date all wanting in some respect. Still to be determined through future research are the absolute and relative magnitudes of this influence. What all of this tells us is that the built environment and self selection *both* influence travel choices; we just do not yet know enough to calculate their relative impacts.

4.2 The Built Environment May Matter in any Case

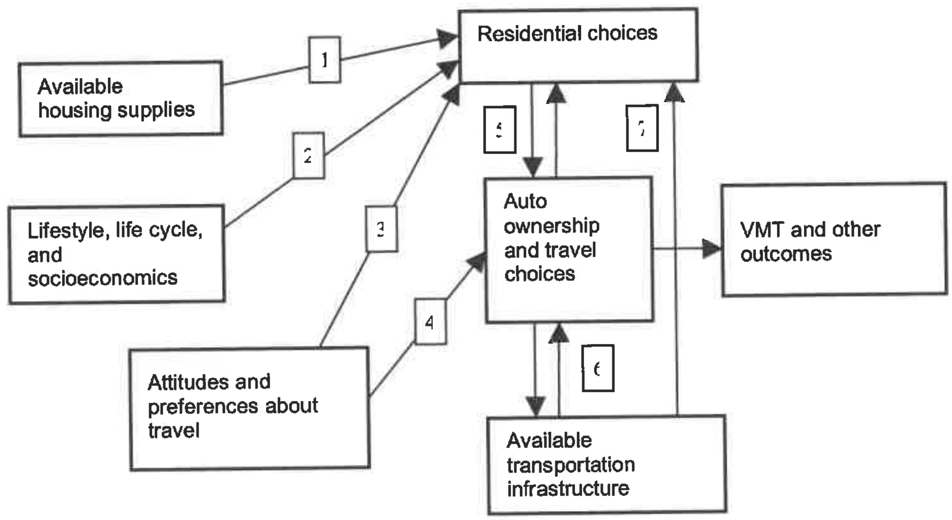
The fact that people to some extent "self select" into neighborhoods matching their attitudes is itself a demonstration of the importance of the built environment in travel behavior. If there were no such influence, people who prefer to travel by transit or nonmotorized modes might as well settle in sprawling areas, where they have no alternative to the automobile.

Whether the association between the built environment and travel is due to environmental determinism or self selection may have little practical import. Where people live ultimately depends on housing supply and demand. As Lund, Willson, and Cervero (forthcoming) note, ". . . if people are simply moving from one transit-accessible location to another (and they use transit regularly at both locations), then there is theoretically no overall increase in ridership levels. If, however, the resident was unable to take advantage of transit service at their prior residence, then moves to a TOD (transit-oriented development) and begins to use the transit service, the TOD is fulfilling a latent demand for transit accessibility and the net effect on ridership is positive)."

The conceptual model in Figure 4-3 indicates why self selection may be less important than the recent focus in the literature suggests. Attitudes about travel have direct effects on travel choices (link 4). Attitudes also may have indirect effects through the mediator, residential choice (link 3). This is the theory of self selection. If link 3 is strong relative to link 4, self selection may be the main mechanism through which the built environment affects travel and health outcomes. If link 3 is weak, residential choices may still affect travel directly through link 4. This is the theory of environmental determinism.

Note that strong self selection may actually enhance the effect of the built environment on travel, not render it insignificant, as some of the literature implies. Whether it does or not depends on housing supply (link 1) relative to demand (links 2 and 3). Housing supply may affect travel regionally if certain types of residential environments are undersupplied. We will refer to this as the theory of latent demand. As shown in Figure 4-4, the ability to self select (link 3) is moderated by housing supplies.

Figure 4-3 Mechanisms by which Attitudes and Preferences Might Affect Travel Choices and VMT



Think of travel outcomes in two dimensions (as in Figure 4-4). One dimension relates to the relative strength of self selection versus environmental determinism. The other depends on the supply of walkable or transit-served places relative to demand across a region. Of course, these dichotomies are false. Both dimensions are continuous, and reality almost certainly lies somewhere along a continuum.

But for three of the four extreme scenarios, the development of new walkable, transit-oriented places should lead to net increases in walking and transit use across the region. Even if self selection is the dominant mechanism through which the built environment influences travel, developers meeting latent demand for walkable, transit-oriented environments will be contributing to reduced VMT. Indeed, the only way that these developers will not have a positive impact is if such places already are adequately supplied.

This does not appear to be the case. There is ample evidence that the demand for walkable, transit-oriented environments far exceeds the current supply. In a study of residential preferences in Boston and Atlanta, Levine, Inam, and Tong (2005) find a huge unmet demand for pedestrian- and transit-friendly environments, particularly among Atlanta residents (see Figure 4-5). It causes these researchers to conclude:

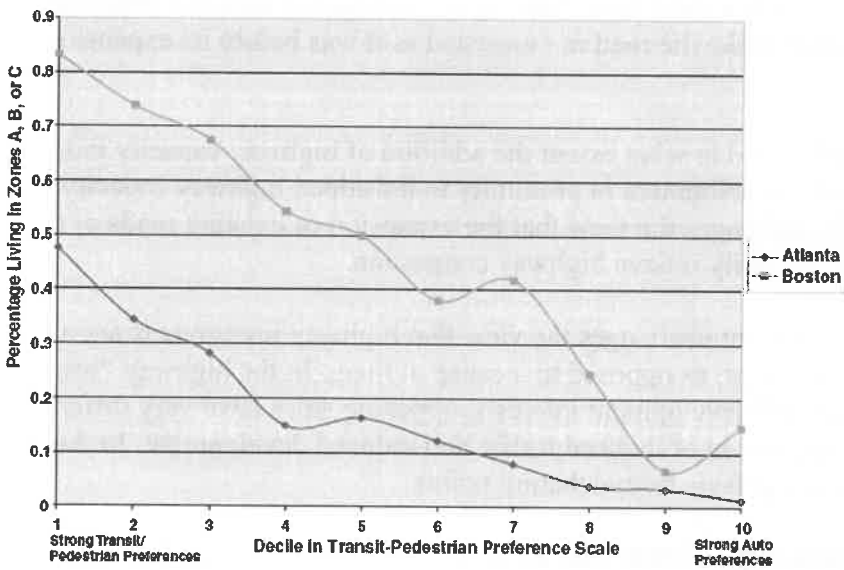
> . . . given the gap depicted in Figure [4.5], it seems unlikely that new transit-oriented housing in Atlanta would fill up with average Atlantans; rather, it would tend to be occupied by people with distinct preferences for such housing who previously lacked the ability to satisfy those preferences in the Atlanta environment. Self-selection in this case would be a real effect, but it would hardly negate the impact of urban form on travel behavior. This is because in the absence of such development, those households would be unlikely to reside in a pedestrian neighborhood and would have little choice but to adopt auto-oriented travel patterns.

For more data on the growing and unmet demand for compact development, see Belden Russonello & Stewart (2003), Myers and Gearin (2001), Center for Transit-Oriented Development (2004), Levine and Frank (2007), Logan (2007), and Nelson (2006).

Figure 4-4 Effect of New Walkable, Transit-Oriented Developments on Regional VMT

	Self Selection Dominates	Environmental Determinism Dominates
Walkable, transit-oriented places undersupplied at present	VMT decreases	VMT decreases
Walkable, transit-oriented place adequately supplied at present	VMT stays the same	VMT decreases

Figure 4-5 Relationship of Transit-Pedestrian Preference to Residence in Transit- and Pedestrian-Friendly Zones
Source: Levine, Inam, and Tong 2005



Thus, it is clear that both self selection and environmental determinism may account for VMT reductions with compact development. A recent study in the San Francisco Bay Area suggests that more than 40 percent of the ridership bonus associated with TOD is a product of residential self selection (Cervero and Duncan 2003). Whatever the source, regional transit ridership is higher than it would be otherwise, and regional VMT is lower.

5. Induced Traffic and Induced Development

Figure 4.3 illustrates two additional links with potential impacts on regional VMT. Link 6 represents a phenomenon called induced traffic, link 7 a related phenomenon called induced development.

Tony Downs of the Brookings Institution first explained the phenomenon of induced traffic in his 1962 "Law of Peak-Hour Traffic Congestion." As he explained more recently,

> … traffic flows in any region's overall transportation networks form almost automatically self-adjusting relationships among different routes, times, and modes. For example, a major commuting expressway might be so heavily congested each morning that traffic crawls for at least thirty minutes. If that expressway's capacity were doubled overnight, the next day's traffic would flow rapidly because the same number of drivers would have twice as much road space. But soon word would spread that this particular highway was no longer congested. Drivers who had once used that road before and after the peak hour to avoid congestion would shift back into the peak period. Other drivers who had been using alternative routes would shift onto this more convenient expressway. Even some commuters who had been using the subway or trains would start driving on this road during peak periods. Within a short time, this triple convergence onto the expanded road during peak hours would make the road as congested as it was before its expansion (Downs 2004).

Controversy exists over whether and to what extent the addition of highway capacity induces new traffic and promotes urban development in proximity to the added highway capacity. The notion of induced traffic challenges the view that the expansion of existing roads or the building of new roads will necessarily relieve highway congestion.

The concept of induced development challenges the view that highway investments are a response to growth and development, as opposed to a cause of them. In the highway "wars" that ensue between environmental and development interests, opposing sides have very different positions on the nature and magnitude of induced traffic and induced development. In this brief review, we will attempt to sort out facts from debating points.

5.1 Case Study: Widening Interstate 270

Interstate 270, which angles to the northwest from the Washington, D.C., beltway in Montgomery County, Maryland, was widened in the late 1980s and early 1990s. In 1999, the *Washington Post* ran a story comparing actual traffic volumes on I-270 to pre-construction projections (*Washington Post* 1999). The article declared the widening a failure based on the amount of induced traffic, which effectively used up the added capacity. By the year 2000, traffic volume for certain sections of I-270 already exceeded forecasts for 2010.

This was a time of growing interest in the phenomena of induced traffic and induced development. The Maryland-National Capital Park and Planning Commission and the Metropolitan Washington Council of Governments responded with a study that suggested that highway-induced development was mainly responsible for the high and premature levels of congestion on I-270 (NCRTPB/MWCOG 2001). Also blamed was the failure to build all transportation facilities in the adopted regional transportation plan. Some projects had been delayed and others dropped.

On the subject of induced development, the study concluded that "higher observed traffic volumes relative to the 1984 forecast appear to be due in large part to shifts in population, employment, and travel to the I-270 corridor from other areas in the region, rather than to entirely new travel." For the region as a whole, population growth was 5 percent lower than had been forecasted in 1984, while employment growth was 9 percent higher. The two together suggested small (if any) net impacts of I-270 on regional growth.

However, population and employment had clearly shifted to the I-270 corridor, at the expense of other areas. Specifically, population and employment in the I-270 corridor were, respectively, 23 and 45 percent higher than forecasted in 1984. For all of Montgomery County, they were 7 and 21 percent higher than forecasted. Meanwhile, population and employment were 9 and 23 percent lower than forecasted in Prince George's County, and 29 and 3 percent lower than forecasted in the District of Columbia. These shifts in development are illustrated in Figures 5-1 and 5-2.

Figure 5-1 Difference between Actual and Forecasted Households by Subarea (2000)
Source: NCRTPB/MWCOG 2001.

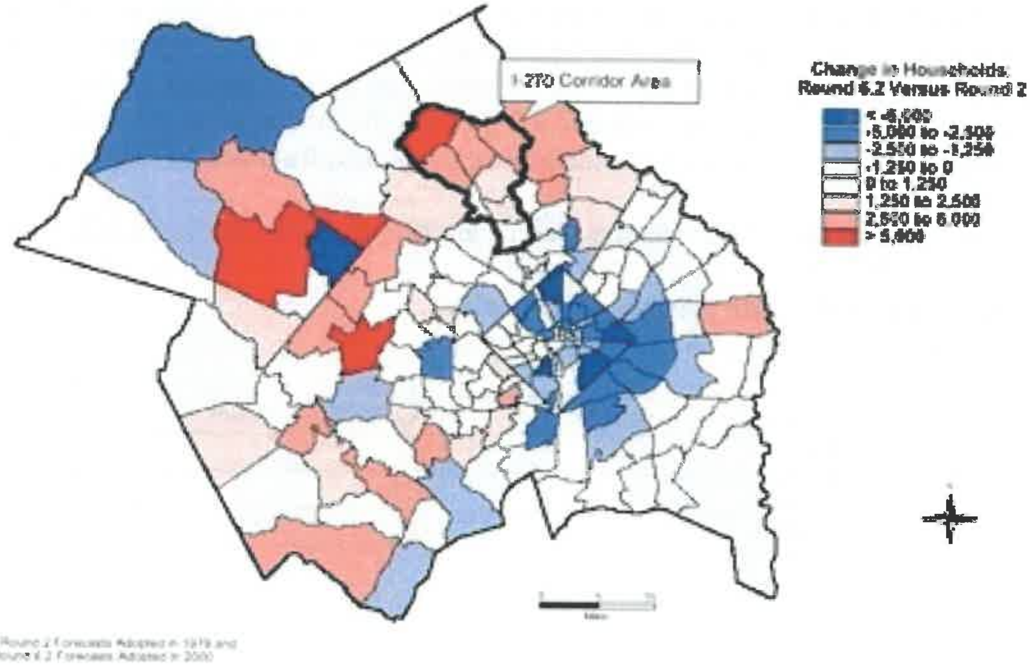
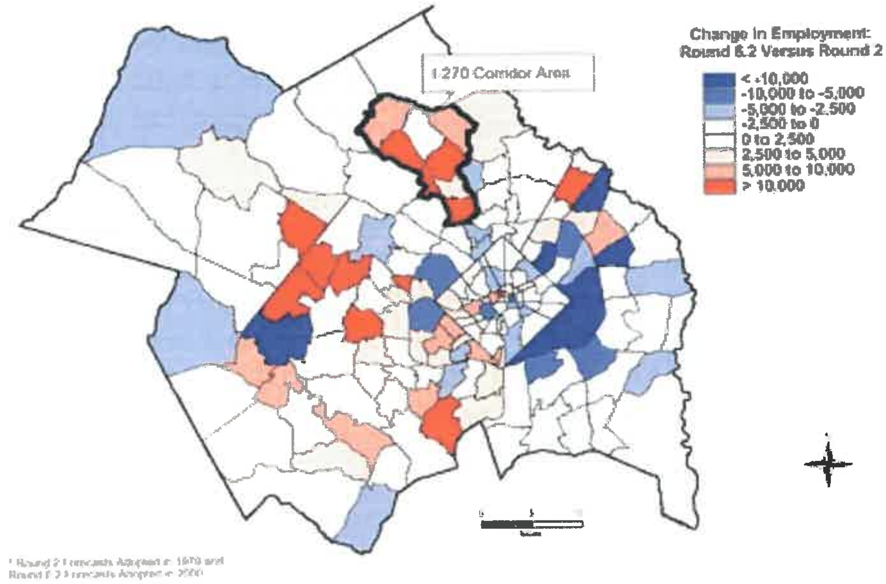


Figure 5-2 Difference between Actual and Forecasted Employment by Subarea (2000)
Source: NCRTPB/MWCOG 2001.



The experience with the I-270 widening mirrors the literature on highway-induced traffic and highway-induced development.

5.2 The Magnitude of Induced Traffic

Cervero (2002) compares elasticity values across studies in a meta-analysis. Again, an elasticity is the percentage change in one variable that accompanies a 1 percent change in another variable. An elasticity of VMT with respect to lane miles of 0.5 implies that every 1 percent increase in lane miles is accompanied by a 0.5 percent increase in VMT. At the facility level, a 100 percent increase in lane miles is what we would get if a facility were widened from two to four lanes.

In his meta-analysis, Cervero (2002) extracts the average elasticities shown in Figure 5-3.

Figure 5-3 Elasticities of VMT with Respect to Capacity
Source: Cervero 2002.

	Facility-Specific Studies	Areawide Studies
Short-term	0	0.4
Medium-term	0.265	NA
Long-term	0.63	0.73

Based on the meta-analysis, Cervero (2002) concludes that "... the preponderance of research suggests that induced-demand effects are significant, with an appreciable share of added capacity being absorbed by increases in traffic, with a few notable exceptions." The average long-term elasticity of 0.73 suggests that for every 1 percent increase in areawide highway capacity, VMT increases by 0.73. The actual increase in a given corridor or metropolitan area depends on the level of congestion. Adding capacity in an area with no congestion has no effect; adding capacity in an area with severe congestion has huge effects. This is apparent from Figure 5-4, which shows the VMT increase per lane-mile of capacity added in California metropolitan areas. The induced traffic effect is greatest in the congested San Francisco, Los Angeles, and San Diego metro areas (see Figure 5-4).

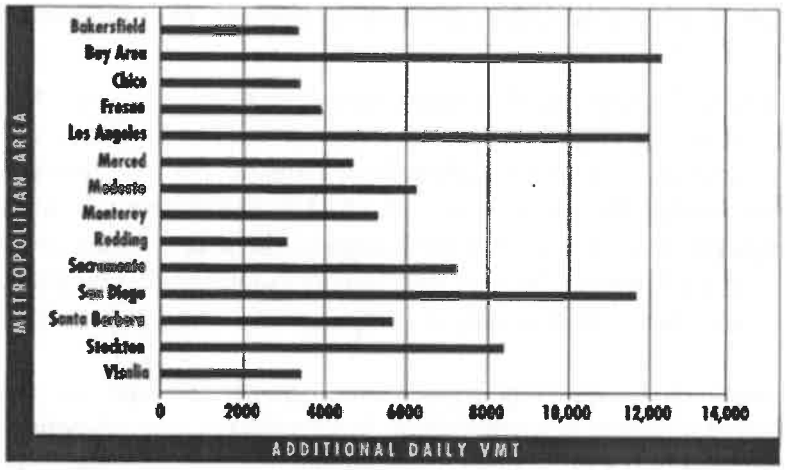


Figure 5-4 Estimated Additional VMT from an Additional Lane-Mile, California *Metropolitan Areas Source: Hansen and Huang 1997.*

5.3 The Role of Induced Development

Induced traffic and induced development are related. One can think of induced development as a cause of induced traffic, not immediately but over the longer term. To better understand induced traffic and its connection to induced development, it is necessary to explore the behavioral consequences of additions to roadway infrastructure capacity.

In the short term, a variety of behavioral changes can contribute to increased traffic without any induced development. These include route switches, mode switches, and changes in destination. In addition, new trips may be taken that would not have occurred without the addition in infrastructure capacity.

In the longer run, increases in highway capacity may lower travel times so that residents and businesses are drawn to locate in the area surrounding the expanded highway capacity. The question is always whether the new development that occurs in proximity to the highway was induced to locate there as a consequence of the expansion or whether it would have occurred anyway, regardless of the highway. Indeed, the highway investment may be a response to new or anticipated development, rather than vice versa. If the development itself would not have occurred otherwise, the development and the traffic it generates can be considered induced.

Definitionally, a gray area exists if the development that occurs near a highway would have occurred somewhere else in the region in the absence of the investment. Some would call this induced development, others redistributed development. We use the term induced development liberally, to mean any development that would not have occurred at a given location without a highway investment.

5.4 Historical Changes in Induced Development

Clearly, the impacts of highway investments are less today than they once were. Construction of the Interstate Highway System, in particular, has tied virtually every place in the country to everywhere else. Most studies finding sizable highway impacts (for example, Mohring 1961 and Czamanski 1966) date back to the first round of interstate highway construction, which created huge positive externalities for areas gaining access to the network. By the early 1970s, the Interstate Highway System was largely complete. Incremental additions or improvements to the network have since produced comparatively small improvements in interregional accessibility.

How great are highway impacts on economic and land development in the post-interstate era? This is a subject of great debate. In a well-known point-counterpoint, Giuliano (1995) minimized the importance of highway investments for three reasons: "The transportation system in most U.S. metropolitan areas is highly developed, and therefore the relative impact of even major investments will be minor. The built environment has a very long life. . . . Even in rapidly growing metropolitan areas, the vast proportion of buildings that will exist 10 to 20 years from now are already built. . . . Transport costs make up a relatively small proportion of household expenditures."

Cervero and Landis (1995) countered that "although new transportation investments no longer shape urban form by themselves, they still play an important role in channeling growth and determining the spatial extent of metropolitan regions by acting in combination with policies such as supportive zoning and government-assisted land assembly." They then challenged Giuliano's empirical evidence, and presented evidence of their own.

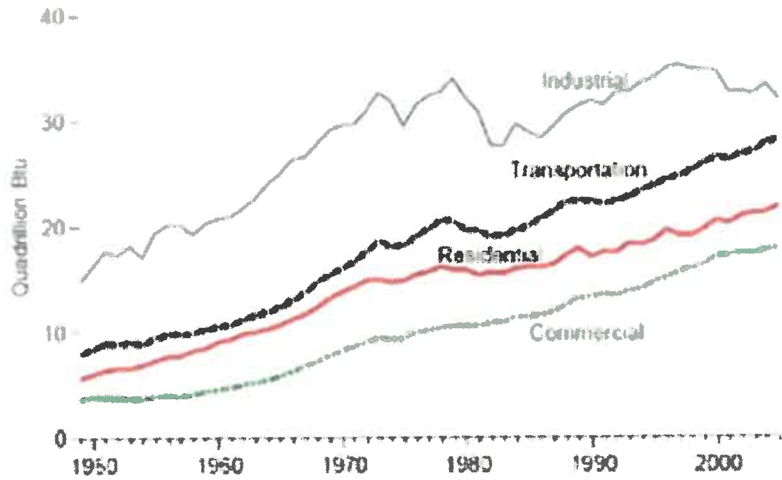
5.5 What Is Known about Induced Development

Who is right? Giuliano probably is right about aggregate impacts, while Cervero and Landis probably are right about localized impacts. The induced development literature has been reviewed by Huang (1994), Boarnet (1997), Boarnet and Haughwout (2000), Ryan (1999), and Bhatta and Drennan (2003). A recent review by Ewing (2007) concludes:

- Major highway investments have small net effects on economic growth and development within metropolitan areas. Instead, they mostly move development around the region to take advantage of improved accessibility. Induced development is very close to a zero-sum game.
- Highway investment patterns tend to favor suburbs over central cities, and thereby contribute to decentralization and low-density development.
- Major highway investments may actually hurt regional productivity, if they induce inefficient (read "low-density") development patterns.
- Corridors receiving major highway investments experience land appreciation, and therefore are likely to be developed at higher densities than developable lands outside the corridors.
- Highways may be necessary to induce development, but they are not sufficient to do so. To the extent that current planning and zoning caps hold, impacts within a corridor will be moderated.
- Counties receiving major highway investments attract population and employment growth to a greater degree than they would otherwise.
- Nearby counties may experience more or less growth than they would otherwise, depending on the strength of spillover effects.
- Nonresidential development is more strongly attracted to major highways than is residential development, particularly in the immediate vicinity of facilities.
- The induced development impacts of interstate-quality highways are wider and deeper than those of lesser highways and streets.
- It takes many years after construction for development to adjust to a new land use/transportation equilibrium.
- The induced development impacts of major highways extend out at least one mile, and probably farther.
- The relationship between highway capacity and growth is a two-way relationship, in that growth induces highway expansion as well as the reverse.

6. The Residential Sector

Figure 6-1 Total U.S. Energy Use by End-Use Sector, 1949 to 2005



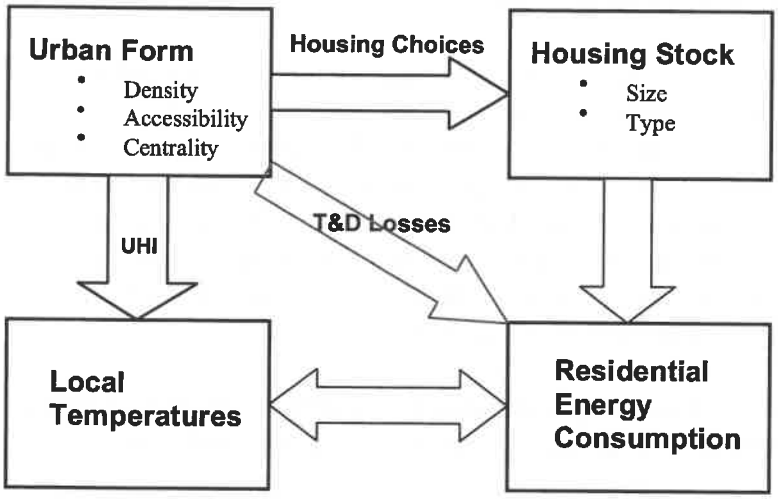
With regard to development impacts on energy use and emissions, the transportation sector has gotten most of the attention (Ewing 1994; Kessler and Schroeer 1995; Burchell et al. 1998; Bento et al. 2003; EPA 2003; Frank and Engelke 2005; Frank et al. 2006). This is understandable. The transportation sector is the second-biggest energy user in the United States, and is catching up with the industrial sector (see Figure 6-1). It is the sector that is most reliant on oil as an energy source. However, as a long-term threat to the planet, energy use by the residential sector also is significant. In 2004, the U.S. residential sector produced more than one- fifth of total energy-related CO_2 emissions (EIA 2004).

As with the transportation sector, the United States has relied almost exclusively on technological advances to address the problem of limited energy supplies and constantly increasing energy demands of the residential sector (Siderius 2004). Evidence exists that per capita energy use and associated emissions will continue to rise, and that advances in technology alone will be insufficient to achieve sustainable growth in energy use (Kunkle et al. 2004; Lebot et al. 2004; Siderius 2004). Therefore, demand-side measures will be required to keep supply and demand in reasonable balance.

Also like the transportation sector, residential energy use and related emissions have a relationship to urban development patterns. Impacts are felt through changes in housing stock, urban heat islands (UHIs), and transmission and distribution losses (see Figure 6-2). The first two effects have been quantified (see Rong and Ewing 2007). After controlling for household characteristics, residential energy use varies with house type and size, which in turn vary with the degree of urban sprawl. These relationships, taken together, allow us to estimate the effects of urban sprawl on residential energy use, indirectly, through the mediators of house type and size. The average household living in a compact county, one standard deviation above the mean sprawl index, would be expected to consume 17,900 fewer BTUs of primary energy annually[27] than the same household living in a sprawling county, one standard deviation below the mean index.

[27] Primary energy is energy contained in raw fuels, which is transformed in energy conversion processes to more convenient forms of energy, such as electrical energy and cleaner fuels. In energy statistics, these more convenient forms are called secondary energy.

Figure 6-2 Causal Paths between Urban Development Patterns and Residential Energy Consumption
Source: Rong and Ewing 2007.



UHI effects are strongest in compact areas, leading to an increase in cooling degree-days and a reduction in heating degree-days. Degree-days, in turn, directly affect space heating and cooling energy use. These relationships, taken together, allow us to estimate the effects of urban sprawl on residential energy use indirectly, through the mediating effect of UHIs. Nationwide, as a result of UHIs, an average household in a compact county, one standard deviation above the mean sprawl index, would be expected to consume 1,400 fewer BTUs of primary energy annually than an average household in a sprawling county, one standard deviation below the mean index.

Throughout most of the nation, the two effects, housing and UHI, are in the same direction, though.the housing effect is much stronger than the UHI effect. The total average savings of 19,300 BTUs amounts to 20 percent of the average primary energy use per household in the United States

[NOTE: THE FOLLOWING CHAPTER IS STILL IN PRELIMINARY FORM AND IS SUBJECT TO CHANGE]

7. Policy and Program Recommendations

Climate stabilization will require the U.S. to reduce GHG emissions by 60 to 80 percent below 1990 levels by 2050. To stay on that path, our GHG emissions will need to be well below 1990 levels by 2030, and leading analysts believe we have less than 10 and possibly less than 5 years to get on track.[28] In the transportation sector, progress will be required on all three legs of the stool: vehicle efficiency, fuel content, and vehicle miles traveled (VMT).[29] The national policy discussion on vehicles and fuels is mature and active, and a variety of proposals would have the automobile and oil industries take responsibility for their contributions to GHG. But no one has been put in charge of reducing the GHG impacts of VMT growth.

In this chapter, we aim to identify the roles and responsibilities for various levels of government to meet our climate challenge. Civic leaders, consumers, businesses, and other stakeholders can also make substantial contributions.

The key to substantial 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 are often in direct conflict with the conventional paradigm that produces sprawl and automobile-dependence. One example is the link between federal transportation funding and VMT levels, thereby rewarding states for VMT growth.[30] Another example is the low-density zoning that keeps localities car-dependent, undermining local expenditures on transit, walking, and cycling.

Fortunately, many communities and states have demonstrated that comprehensive reforms can both reduce the need for driving, and improve overall quality-of-life. They have responded to public demands and market forces pushing for compact development, and CO_2 emissions reductions have been a bonus.

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[28] Rosina Bierbaum, Dean of the School of Natural Resources at U. of Michigan, presentation to Presidential Climate Action Program analyzing trends in IPCC analyses, June 2006 at Wingspread Conference Center, Racine, WI

[29] Vehicle-hours of travel (VHT) is another useful indicator.

[30] Specifically, the formulas by which the total payout of dollars from the Federal Highway Trust Fund is sub-allocated or "apportioned" to each State rewards such factors as VMT fuel use and lane-miles of travel. An overview of the apportionment process is provided by the GAO 2006 report available at http://www.gao.gov/new.items/d06572t.pdf

7.1. Federal Policy Recommendations

Although land use planning and growth management are primarily local and state responsibilities, the federal government plays a powerful role in shaping growth patterns and travel choices through regulations, funding, tax credits, performance measures, technical assistance, and other policies. To accomplish the emissions reductions we have discussed in this book, we recommend the implementation of the following major federal policies. We have chosen these options because they are likely to deliver better performance results (e.g., greater return on investment for every public dollar invested) than the *status quo* while also fostering development with a smaller carbon footprint.

7.1.1. Require Transportation Conformity for Greenhouse Gases

Federal climate change legislation should require regional transportation plans to pass a conformity[31] test for carbon dioxide emissions, similar to 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 EPA to exercise this authority to produce tangible results.

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[31] Transportation conformity for conventional air pollutants (requiring regular assessments and course corrections to prevent transportation programs from undermining timely achievement of clean air standards) was created by the 1977 Clean Air Act Amendments and strengthened when that Act was amended in 1990. In 1991's Intermodal Surface Transportation Efficiency Act (ISTEA), Congress further codified conformity and created the Congestion Mitigation and Air Quality Improvement Program (CMAQ) as a complementary program to help regions achieve conformity (a "carrot" to conformity's "stick").

What is Conformity?[1]

Under Section 110 of the Clean Air Act,[1] states develop and implement air pollution control plans called State Implementation Plans (SIPs) to demonstrate attainment with National Ambient Air Quality Standards (NAAQS) set by EPA at levels deemed necessary to protect public health and welfare. The 1990 Clean Act Amendments, along with subsequent transportation legislation, required air quality and transportation officials to work together through a process known as conformity. A metropolitan region that has exceeded the emission standards for one or more of the pollutants must show that the region's transportation plan will conform to applicable SIPs and contribute to timely attainment of the NAAQS. According to the regulations, a proposed project or program must not produce new air quality violations, worsen existing violations, or delay timely attainment of the NAAQS.[1] The metropolitan planning organizations (MPOs) must demonstrate this conformity through their long range transportation plans and transportation improvement programs (TIPs) – which identify major highway and transit projects the area will undertake over a 20-25 year period. Projects that do not conform cannot be approved, funded or advanced through the planning process, nor can they be implemented unless the emissions budget in the SIP is revised.

If a region's TIP has expired without adopting a new TIP projected to stay within the motor vehicle emissions budget in the SIP, the area faces what is known as a conformity lapse. During this period, the MPO cannot approve funding for new transportation projects or new phases of previously funded transportation projects except for those projects that are adopted as Transportation Control Measures in the SIP or are otherwise exempt from conformity as air quality neutral activities. If an area fails to submit a required SIP by a deadline, it may face a "conformity freeze", in which it cannot approve any new projects until this deficiency is remedied, and if this failure is prolonged, can face the ultimate sanction of losing federal transportation funding. For some metropolitan areas, this potential loss of transportation funds can be more than $100 million per year.[1] While there have been 63 areas in the US that have suffered a conformity lapse, no state or region has ever lost federal transportation funds as a result of a conformity lapse, freeze, or sanctions.

State and local governments would be required to adopt mobile source CO_2 emission reduction budgets (like the emissions budgets for other pollutants) that demonstrate reasonable progress in limiting emissions.[32] Currently, regions that fail to develop transportation plans consistent with "Reasonable Further Progress" goals risk curbs on federal transportation funds. This could be reinforced by incentives that reward places that effectively reduce per capita VMT. Conversely, a portion of transportation funds could be withheld from places that fail to make progress toward reducing VMT *per capita* (see discussion below in State Policy section).

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[32] The California Energy Commission offered a similar proposal to require regional transportation planning and air quality agencies to adopt regional growth plans that reduce GHG emissions to state-determined climate change targets. California Energy Commission, "The Role of Land Use in Meeting California's Energy and Climate Change Goals." http://www.energy.ca.gov/2007_energypolicy/documents/

Though we acknowledge that to date, land use and transportation demand management (TDM) policies have generally not played a large role in meeting regional conformity requirements,[33] we believe that comprehensive strategies would be more successful. Responsibility should be "nested" so that the federal government is responsible for the GHG impacts of federal transportation spending (see Green-TEA discussion below) and state and local governments bear responsibility for the GHG impacts of their transportation spending.

7.1.2 Use Cap-and-Trade (or Carbon Tax) Revenues to Promote Infill Development

Many climate proposals[34] focus on the creation of a market-based cap-and-trade system similar to policies adopted in Europe[35] and ones that are likely to be formed in California[36] and other states. By placing a price on greenhouse gas emissions, a cap-and-trade system can send the right signal for reducing the emissions associated with vehicle travel.[37] Moreover, regulated parties (such as oil companies) will have incentives to support policies that slow VMT growth, because actions that increase VMT will make carbon emission allowances more costly. Therefore, federal policies that subsidize growth patterns that increase *per capita* VMT would generate higher overall compliance costs.

A related issue that is being discussed within the federal cap-and-trade debate is how to best use the revenues generated by such a system. If cap-and-trade is adopted, the value of carbon allowances will be worth an estimated $50 to $300 billion per year by 2020 based on recent Congressional proposals. A portion of these revenues could be used to fund infrastructure for infill development, technical assistance to help communities seeking to rewrite codes and regulations that inhibit infill development, and transportation choices that support compact infill development.

In order to ensure adequate emission reductions, to accelerate the introduction of new technology into the marketplace and to moderate the price of allowances, some are proposing policies which complement a cap-and-trade system. Specifically, two of three legs of the transportation sector stool would be covered by new product performance standards. In the case of the auto industry, the longstanding tool is the Corporate Average Fuel Economy (CAFE) program. California is developing a low-carbon fuel standard (LCFS) that leads the nation. With the successful launch of the new Leadership in Energy and Environmental Design—Neighborhood Development

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[33] For example, in its 2002 SIP, the State of Maryland included smart growth policies that it expects to yield modest air quality benefits. Sacramento anticipates significant emissions savings from land use measures in its Blueprint transportation plan. In Atlanta, a modeling exercise on the emissions benefits of infill development rescued the region from its conformity lapse and associated restrictions on funding new transportation projects (1998-2000), but the region lacked the political support or transit funding to implement the modeled smart growth scenario. See CCAP (2004), "Two for the Price of One: Clean Air and Smart Growth (Workshop Primer)." http://www.ccap.org/transportation/smart_two.htm and "Atlanta's Experience with Smart Growth and Air Quality." http://www.ccap.org/transportation/smart_two.htm

[34] For example, see, Pew (2007), "Senate Greenhouse Gas Cap-And-Trade Proposals," http://www.pewclimate.org/docUploads/Economy-wide%20bills%20110th%20Senate%20-%20August%202.pdf

[35] See European Union Greenhouse Gas Emission Trading Scheme, http://ec.europa.eu/environment/climat/emission.htm

[36] For example, see California Market Advisory Committee, http://www.climatechange.ca.gov/policies/market_advisory.html

[37] For example, see Winkelman et. al (2000), "Transportation and Domestic Greenhouse Gas Emissions Trading," http://www.ccap.org/pdf/TGHG.pdf

(LEED-ND) certification standards from the U.S. Green Building Council, now may be the time to consider something analogous for new development products. This is especially so if public funding—allowance revenue, gas tax revenue—is to be made available to support such "cooler growth." Public support should be coupled with some sort of guarantee of performance, whether in the form of standards or similar policy for new development.

Other options, such as a carbon tax, are also being debated and could also provide reinforcing price signals for VMT reduction and revenue for compact development and more transportation choices.

7.1.3 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."[38]

Transportation policy is climate policy. With another $300 billion to be reauthorized by Congress in 2009, it represents the largest category of federal infrastructure funding. As discussed in this book, how this money gets spent has a major impact on the nation's VMT and greenhouse gas emissions.

Accountability for GHG Impacts of Transportation Spending. Congress should require the U.S. Department of Transportation (US DOT) to assess the GHG impact of proposed reauthorization bills to determine conformity with national climate goals (i.e., a target percentage below 1990 levels by 2030, consistent with reaching 60-80 percent below 1990 GHG levels by 2050). This analysis would be based in large part on newly required regional scenario analyses conducted by Metropolitan Planning Organizations (MPO). If the transportation bill is expected to generate emissions that are inconsistent with national climate goals, then US DOT should develop a national climate plan that conforms to a mobile source GHG emissions budget and work with MPOs to modify their plans accordingly.

More Funding for Transportation Choices. A half-century ago, the U. S. adopted the Federal-Aid Highway Act of 1956, launching an unprecedented engineering project that quickly changed everything about the way Americans travel and build communities. Today, the Interstates are complete, and we need to invest in an equally ambitious effort to complete the rest of the nation's transportation system. While we work to maintain our world-class highway network, we must build other world-class systems, including public transportation and bicycling and pedestrian networks. These should be complemented by policies that encourage compact, mixed-use development, telecommuting, and pricing of auto use to better manage congestion and raise revenue for alternatives, such as New York City's proposed congestion pricing system.[39]

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[38] As proposed by the Center for Clean Air Policy, see http://www.ccap.org/transportation/smart.htm.

[39] http://www.nyc.gov/html/planyc2030/downloads/pdf/full_report.pdf.

Such investment is badly needed. Demand for New Starts funding is so great that most cities offer far more than the required local match to secure federal funds. Roughly 300 transit projects are authorized in the current federal transportation bill, yet funding is far below demand, producing only about a dozen projects every six years. The process to secure federal funding is also notoriously burdensome and time-consuming. Bicycle and pedestrian travel has also increased in the last decade, and is anticipated to rise. Currently, dedicated federal funding for these "non-motorized" choices stands at about 1.4 percent, even though bike and walking trips account for between 8 and 9 percent of all trips taken.

More Funding for Repair and Reconstruction. Making repair and reconstruction of existing infrastructure the top priority is consistent with climate change goals. Less money should be allocated to new or expanded highways, until deficiencies in critical facilities (e.g., those that threaten public health and safety) are eliminated and even then, only if highway projects can be shown to reduce greenhouse gas emissions and VMT.

"Fix-it-first" policies would establish powerful incentives for reinvestment in existing neighborhoods.[40] New infrastructure investment would stimulate infill development and opportunities for more transportation choices, shorter trips, and reduced GHG emissions. Investment in repairs will help ensure that our bridges, tunnels, and other facilities are safe to use. Such investments can be justified on cost-effectiveness grounds. For example, a recent report from the Sacramento Area Council of Governments found that providing infrastructure for sprawl developments costs an average of $20,000 more per unit than for smart growth developments. With regard to repair, deferred maintenance may reduce expenditures in the short term, but years of neglect create poorly performing infrastructure with much larger long-term repair and reconstruction costs. Deteriorating infrastructure in a community can also discourage private investment.

Increased investment would make up for the federal government's flagging contribution to infrastructure maintenance over the past several decades. The graphs below show that although both capital and operations & maintenance (O & M) spending have grown dramatically since 1980, the federal share of O & M has not risen at the same rate. This has increased pressure on state and local governments to make up the gap in funding needed to maintain aging infrastructure. The problem is particularly evident in older suburban neighborhoods where developers are seeking to build compact mixed-use projects but are facing resistance from residents concerned about their capacity to accommodate growth.

A fix-it-first policy can be implemented through several mechanisms. One option is to apply strict performance-based criteria to core funding programs (National Highway System, Interstate Maintenance, Surface Transportation Program, and Bridge Program) so that no funds can be spent on new roadway capacity until all critical facilities are brought up to minimum safety standards. Another alternative is to create minimum set-aside requirements for repair and reconstruction. For existing programs, like the Bridge and Interstate Maintenance programs, funding could be also increased to ensure that such set-aside requirements are practical.

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[40] The declaration of findings in the 1991 ISTEA legislation includes an emphasis on maintaining and enhancing system components before investing in new ones; similar State legislation enacted in New Jersey could provide a model to follow in other States.

To ensure that locales follow through with plans for redevelopment, a share of federal funds could be held back and rewarded only after infill-enabling policies are implemented successfully. Such a strategy has been used for infrastructure investment under Massachusetts' smart growth program.

The private sector can also be enlisted in the effort. Specifically, tax credits and low-interest revolving fund loans should be offered to privately financed projects that revitalize and retrofit public infrastructure. Such investments would not only benefit those projects, but would also catalyze investment in adjacent areas.

7.1.4 Replace Funding Formulas with Funding Based on Progress Toward National Goals

We recommend that transportation agencies develop a system of performance measures to meet specific national, state, and local goals pertaining to climate stabilization, energy security, accessibility for low-income and disabled persons, and safety. We believe that a mode-neutral plan to achieve such goals will result in several-fold increases in funding for public transportation, bicycling and pedestrian facilities, and reinforcing land-use changes. The kinds of programs that might see major increases include federal New Starts and Small Starts, federal Safe Routes to School, Transportation Enhancements, the Non-Motorized Pilot Program (which should be converted from a pilot to a regular program), and the Jobs Access and Reverse Commute Program.

Applying performance criteria to roadway infrastructure will likely result in a decrease of unnecessary and traffic inducing highway projects, because most projects have never been scored against any rigorous performance criteria. Many are among the 6,371 new earmarks from the 2005 SAFETEA-LU Act or are otherwise justified based on criteria that are much looser than those faced by transit proposals. Also, they are less likely to be able to compete as well with regard to the urgent national priorities of energy security and climate change discussed in this book.

To achieve a performance-oriented approach, our nation will have to fundamentally transform its transportation policies. Current funding formulas are based on VMT, fuel use and lane miles – thus rewarding increased GHG emissions. Moreover, gasoline tax revenues are dependent on the steady or increasing VMT levels and more funding is allocated to areas with more VMT. As long as our transportation industry is dependent on VMT levels being high, the task of reducing VMT will be extremely difficult. The current crisis in the federal transportation trust fund is actually an excellent opportunity to rethink how revenues are raised in light of national priorities for energy and climate.

States could require metropolitan transportation improvement programs (TIPs) to demonstrate their compliance with statewide measures, creating pots of money to use as rewards for meeting desired targets, and tracking the effectiveness of various VMT-reduction strategies. Potential measures to be achieved by 2030 might include:

- Reduce per capita VMT in a metropolitan region by 25 percent;
- Reduce statewide per capita VMT by 20 percent;
- Reach a state of good repair for roads and bridges to address safety and maintenance issues; and
- Double access to transportation alternatives and increased mode shares for transit, bicycling, walking, carpooling, or telecommuting to expand the transportation choices available to all Americans.

The original ISTEA legislation, as passed by the Senate in 1991 (and way ahead of its time), provides a model of how federal funding could be transformed to a performance-based system. This legislation would have created an Energy Conservation, Congestion Mitigation, and Clean Air Act Bonus program. The original language was as follows:

> This paragraph shall apply beginning in fiscal year 1993 and shall apply only to those States with one or more metropolitan statistical areas with a population of two hundred fifty thousand or more. The amount of each such State's Surface Transportation Program funds determined pursuant to section 133(b)(1)(A)(i) shall be reduced by multiplying such amount by a factor of 0.9 if the State's vehicle miles of travel per capita is more than 110 per centum of its vehicle miles of travel in the base year. Reductions in apportionments made pursuant to the preceding sentence shall be placed in a Surface Transportation Bonus Fund and shall be used, to the extent such funds are available, to increase the amount of Surface Transportation Program funds determined pursuant to section 133(b)(1)(A)(i) by a factor of 1.1 for each State affected by this paragraph, if such State's vehicle miles of travel per capita is less than 90 per centum of its vehicle miles of travel per capita in the base year. Funds remaining thereafter in the Surface Transportation Bonus Fund, if any, shall be apportioned to the States affected by this paragraph in proportion to each State's share of Surface Transportation Program funds determined pursuant to section 133(b)(1)(A)(i) among all such States prior to any adjustments made pursuant to this paragraph. Funds so apportioned shall be treated as funds pursuant to section 133(b)(1)(A)(i) area treated. For the purposes of this paragraph, the term "base year" shall mean the year 1990 for fiscal years 1993, 1994, and 1995, and shall mean the year 1995 for fiscal years 1996 and all subsequent fiscal years."

Such a bonus program could be administered either through state allocations and metropolitan suballocations, or better still, through direct allocations to MPOs (as described in the next section).

7.1.5 Provide Funding Directly to Metropolitan Planning Organizations

When MPOs were first established and formally recognized, a number of federal programs requiring regional planning came within their purview (Lewis and Sprague 1997). With the "new federalism" of the Reagan administration, MPOs lost most of the programs they briefly controlled (McDowell 1984). The one program remaining was transportation planning, but new regulations gave states full sway in determining the functions for MPOs. This meant that many MPOs were in the role of merely "rubber-stamping" decisions already made by state highway departments (Solof 1997).

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 reversed this trend, somewhat. ISTEA gave MPOs new authority and responsibilities. MPOs were to craft 20-year long-range transportation plans that were fiscally constrained to meet realistic revenue projections. They also had to adopt short-range transportation improvement programs to formally allocate federal transportation dollars to specific projects. They also now had some additional money to allocate. Before ISTEA, federal law mandated that states siphon off a tiny percentage (less than 1%) of their allocation of federal transportation dollars for MPOs. This money did not fund projects; it was to be used for MPO basic operations (staff, facilities, etc.). The funds for projects had to come through the state DOT, and hence was subject to the state's discretion and priorities.

ISTEA changed this by providing a minimum suballocation to MPOs (with 200,000+ population): in addition to providing some operating funds, states had to guarantee a minimal amount of project funding to their MPOs. Under the current transportation law, SAFETEA-LU, that amount is 5% of a state's federal highway allocation (Wolf, Puentes, Sanchez and Bryan 2007).

As important as these changes were, they have hardly made a dent in what is an increasingly inequitable distribution of transportation dollars. Metropolitan areas contain more than 80% of the nation's population and 85% of our economic output (Puentes and Bailey 2005). Investment by state DOTs in metropolitan areas lags far behind these percentages (Hill, Geyer, Puentes, et al 2005).

The issue is not just the *amount* of funding; it is also the authority to decide *how* the money is spent. More than one-third of the states that receive Congestion Management Air Quality funds—funds that by definition are to be used in MPO areas—do not suballocate those funds to their respective MPOs. Only 12 states suballocate federal Transportation Enhancement program dollars to MPOs. The state decides how these funds are to be spent. Even with the 5% of funds that are required to be suballocated to MPOs, many MPO staff report that the state DOT still wields substantial influence (Puentes and Bailey 2005).

What is necessary to remedy the long history of structural and institutional causes behind these inequities is a new system of allocating federal transportation funds directly to metropolitan areas. Instead of sending federal allocations to the states and expecting the states to "do the right thing" for metropolitan areas, future federal legislation should provide for the direct allocation funds to MPOs, without filtering funds through state DOTs.

Moreover, 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. A starting basis for making these calculations is the point-of-sale gas tax collection. Because different states have different relative demands for rural and interstate facilities, this formula could be adjusted on a state-by-state basis to reflect those variations.

7.1.6 Develop a National Blueprint Planning Process that Encourages Transportation Choices and Better System Management

Good planning is critical to the viability of alternative transportation modes and land use reforms at a regional scale. The State and Metropolitan Planning sections of the transportation reauthorization bill (Green-TEA) could require Land Use and Transportation Scenario Analyses for all regional transportation plans. Near-term Transportation Improvement Programs and Long Range Transportation Plans currently require alternatives analyses for specific large projects, but not for the full program or land use plans. It is difficult to discern the benefits from coordinated transportation land use policies on a project-by-project basis. Therefore, under the current system, innovative land use-based policies are more difficult to justify.

The next federal transportation bill should fix this problem by examining both the project scale and cumulative benefits of projects. It should also increase funding for coordinating regional transportation and land use planning to facilitate maximizing opportunities for transit-oriented development, intermodal transportation centers, and more compact, walkable neighborhoods. Scenario and visioning initiatives should also include robust public participation components. Efforts such as the California Blueprint Planning Grants and Blueprint Learning Network provide useful models for other states and regions.[41] Regions whose plans help attain performance goals should be able to access additional funding for implementation and other uses. A "Green-TEA" could establish a National Blueprint Learning Network and National Blueprint Planning Grants.

7.1.7 Place More Housing Within Reach

Many homebuyers "drive til they qualify," that is, they purchase a less expensive home further away from where they would ideally like to live.[42] With rising gasoline costs, the financial trade-off between a longer commute and cheaper housing is changing.[43] The potential savings from living in a convenient location with transportation choices is becoming a more important aspect of affordability.[44]

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[41] California Department of Transportation (2007), "Blueprint Learning Network." http://www.dot.ca.gov/hq/tpp/offices/orip/BLN.htm. Also see California Department of Transportation (2007), "California Regional Blueprint Planning Program." http://calblueprint.dot.ca.gov/

[42] Carrie Makarewicz, Tom Sanchez et. al. , Housing and Transportation Financial Tradeoffs and Burdens for Working Households in 28 Metropolitan Regions, Center for Neighborhood Technology and Virginia Tech, 2006, at H-T-Tradeoffs-for-Working-Families-n-28-Metros-FULL.pdf.

[43] Barbara Lipman (ed), A Heavy Load: The Combined Housing and Transportation Burdens of Working Families, Center for Housing Policy, National Housing Conference 2006 at www.nhc.org.

[44] Scott Bernstein, Carrie Makarewicz, Kevin McCarty; ***Driven to Spend***, Center for Neighborhood Technology and Surface Transportation Policy Partnership, 2005, at www.transact.org. Center for Neighborhood Technology and Center for Transit Oriented Development, The Affordability Index: A New Tool for Measuring the True

The Congressionally chartered Millennial Housing Commission has called for a dramatic increase in investment for housing that is affordable to a wide range of individuals and working families of modest means, including teachers, firefighters, nurses, and older Americans. Contrary to widespread beliefs, transit oriented development serves an extremely diverse population and will continue to do so.[45] Greatly expanding the supply of housing in walkable neighborhoods with high-quality transit is a way to satisfy this unmet demand and offer living arrangements that more people can afford. Recent studies for the Federal Transit Administration, the Dept. of Housing and Urban Development, and the Ford Foundation show that much of the need for housing over the next 30 years can be met within walking distance of the nation's 4,000 existing and development transit stations, with significant reduction of VMT.[46] Transportation investments, land development practices, and coordinated planning can also help achieve affordability and access goals while also reducing greenhouse gas emissions. Tax credits can provide a powerful incentive for investment in projects with coordinated land use and affordable housing.

Smart Location Tax Credit. The federal government and some state governments currently provide tax credits for hybrid vehicles, solar technology installation, and other technologies that reduce energy use. The same can be done for smart locations that inherently save energy from vehicle trips. The federal government should direct states to identify smart locations based on the "4D" performance criteria discussed in this book: density, diversity, design, and destination accessibility. Developers of new for-sale or rental units within the most efficient location tiers could qualify for a federal Smart Location Tax Credit. A portion of the incentive can be used to finance affordable units. The transportation choices available in these locations would reduce household transportation costs, an important cost saving to the people living in these homes.

Housing Rehabilitation Tax Credit: For existing housing, federal tax credits for rehabilitation should be provided to revitalize all existing housing units in neighborhoods that generate lower VMT per household than the regional average. As discussed above, federal guidelines would require each state to identify smart location zones that would benefit from the rehabilitation tax credit.

These tax credits serve multiple and critical national needs, from affordable housing to neighborhood reinvestment. They could be funded by reducing subsidies that are incompatible with a national focus on climate change, such as capping the tax-free parking benefit at its current level ($215 per month) or a reduced level (that is, capping it at $200 per month). Also, they could complement existing federal tax incentives that support affordable housing, reinvestment, and historic preservation. The value of tax credits could be increased when the Low Income Housing Tax Credit is also used to benefit smartly located and/or rehabilitation projects, which would help create housing choices for households of different income levels.

Affordability of a Housing Choice, Brookings Institution, 2006 at www.brookings.edu/metro/umi/pubs/20060127_aff**index**.htm.

[45] Preserving and Promoting Diverse Transit-Oriented Neighhborhoods, Center for Neighborhood Technology and Center for Transit Oriented Development, 2006 at http://www.cnt.org/repository/diverseTOD_FullReport.pdf.

[46] Hidden in Plain Sight: Meeting the Coming Demand for Housing Near Transit, Center for Transit Oriented Development 2005 at www.reconnectingamerica.org.

The federal Historic Preservation Tax Credit has been one of the most effective tools for revitalizing neighborhoods and repopulating older cities, suburbs, and towns. It should be strengthened and expanded to benefit a wider range of historic properties and to be combinable with other tax credits to facilitate more revitalization and affordable housing production.[47]

7.1.8 Create a New Program to Provide Funding to "Rewrite the Rules"

Builders, developers, and industry analysts have conducted market research studies that show a strong and growing demand for walkable, mixed-use neighborhoods with good transit access (see Chapter 1). However, outdated local development regulations (such as subdivision regulations, zoning, parking standards) often make this type of development the hardest thing for a developer to build. Ironically, creating neighborhoods that resemble some of our nation's most appealing places, such as the Georgetown neighborhood in Washington, D.C., or Charleston, South Carolina, is technically illegal in many places because such construction would violate current codes.

The problem is not lack of desire from cities, counties, or towns. In fact, many localities want to modernize their obsolete codes. However, limited planning funds make it hard to both run the development process and redesign it. The federal government provides vast technical assistance resources for everything from agricultural practices to homeland security. Congress should establish a new program to help communities update development rules to support more walkable, town-style, environmentally friendly development.

At the very least, such changes should allow smart growth and compact development a chance to compete by facing the same development process that conventional development must follow. Leveling the playing field would benefit consumers as they shop around for housing and development choices. Most communities already have a surplus of large-lot, single-family homes, and those that wish to change increasingly want to rewrite the rules to encourage compact development, much in the same way that conventional suburban development was subsidized and facilitated through federally discounted mortgages, infrastructure, planning and zoning rules, and other incentives. Changing the rules in just the 50 largest American metropolitan areas would quickly bring more housing, neighborhood, and transportation choices to about 168 million people, or more than half of all Americans.

7.2. State Policy Recommendations

In the absence of major federal action, many states are already moving ahead with plans to reduce CO_2 emissions. Some states have banded together in compacts like the Regional Greenhouse Gas Initiative and the Western Regional Climate Change Initiative to create cap-and-trade programs. In addition, twenty-nine individual states have created climate action plans; California and New York have some of the best defined plans.

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[47] Working with the Internal Revenue Service and State Historic Preservation Offices, the National Park Service in 2006 approved 1,253 rehabilitation projects that attracted a record-breaking $4.08 billion in private investment, which is equivalent to a more than 5 to 1 return on federal tax credits invested.

State climate plans in New York, Connecticut and Massachusetts include comprehensive VMT-reduction recommendations, though implementation has been mixed.[48] New York state requires its Metropolitan Planning Organizations to report GHG impacts of Transportation Improvement Programs and Long Range Transportation Plans (both are required to receive federal transportation funds).[49] Connecticut created an Office of Responsible Growth to promote transit-oriented development, provide transit alternatives, encourage walkable communities and target state funding to support development in designated Responsible Growth areas.[50] The California Energy Commission runs a working group tasked with developing recommendations on achieving GHG reductions from smart growth policies. In August 2007, the Commission released a set of policy recommendations on land use and climate change based on a comprehensive review of state and local efforts.[51]

Our recommendations for state policies incorporate development and land use as VMT and CO_2 reduction strategies and will work with or without the federal policies described above. They include:

1) Set state targets for VMT as part of a CO_2 reduction plan;
2) Adopt state transportation and land use policies that supports climate goals;
3) Improve transportation planning models to reflect the latest research on how the built environment affects travel behavior (regional travel forecasting, trip generation, etc.);
4) Align state spending with climate and smart growth goals;
5) Eliminate perverse local growth incentives; and
6) Create economic development incentives.

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[48] CCAP (2003) on Collaboration with the New York Greenhouse Gas Task Force, "Recommendations to Governor Pataki for Reducing New York State Greenhouse Gas Emissions." http://www.ccap.org/pdf/04-2003_NYGHG_Recommendations.pdf. See also CCAP(2004), "Connecticut Climate Change Stakeholder Dialogue: Recommendations to the Governor's Steering Committee." http://www.ccap.org/Connecticut.htm.

[49] ICF Consulting (2005), "Estimating Transportation-Related Greenhouse Gas Emissions and Energy Use in New York State." http://climate.dot.gov/docs/nys.pdf.

[50] Rell (2006), Executive Order 15. http://www.ct.gov/governorrell/cwp/view.asp?A=1719&Q=320908.

[51] California Energy Commission, "The Role of Land Use in Meeting California's Energy and Climate Change Goals," August 2007.
http://www.energy.ca.gov/2007publications/CEC-600-2007-008/CEC-600-2007-008-SF.PDF.

7.2.1. Set State Targets for Vehicle-Miles of Travel

Establish a GHG Reduction Plan That Includes a Target for VMT Reductions

If the federal government does not act to reduce GHG emissions and VMT, states can take the lead and establish their own goals. Whether federally or state driven, the state target should be allocated among local governments within the state, or, where localities are highly fragmented, to regional governments.

To achieve the targets, local and regional governments would submit plans to the state using the strategies that best fit their communities. States would then rate those plans and provide greater financial support and regulatory relief to those places with better implementation plans. Meeting VMT targets provides the opportunity to achieve significant co-benefits (e.g. greater housing and transportation choice, fiscal savings, providing services in underserved neighborhoods), so the state may also rate local plans according to their achievement of these benefits. To help communities meet these targets, the state can provide grants and technical assistance to help localities develop realistic plans that score better and become eligible for greater state aid. New federal transportation policy (Green-TEA) could help by providing supportive policies and incentives.

As explained in Section 7.1.1., this system is similar to the one currently employed to meet air quality standards under the Clean Air Act (CAA). Under the CAA, metropolitan regions must inventory their emissions sources and develop plans to bring those emissions in line with clean air standards. For example, most metro regions already inventory their VMT and associated emissions. They also project future VMT and develop strategies to reduce emissions from both current and future auto trips.

Washington State's Commute Trip Reduction program employs a similar strategy and is focused explicitly on reducing single-occupant vehicle commutes and greenhouse gases.[52] To achieve these goals, the state has set targets for reductions in single occupant vehicle commutes and VMT per commuter. Local jurisdictions must then set goals that are at least equal to the state goals and create plans for achieving the target measures. This program is described on the web site as follows:

> 1) **Program goals.** This section establishes the goals and targets for the CTR program that every city and county shall seek to achieve at a minimum for the affected urban growth area within the boundaries of its official jurisdiction. Every two years, the state shall measure the progress of each jurisdiction and region toward their established targets for reducing drive-alone commute trips and commute trip vehicle miles traveled per CTR commuter. Local and regional goals and measurement methodologies shall be consistent with the measurement guidelines established by WSDOT and posted on the agency's web site.

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[52] See the Washington Department of Transportation Web site at http://apps.leg.wa.gov/WAC/default.aspx?cite=468-63-030

2) **Statewide minimum program goals and targets.** The goals and targets of local jurisdictions for their urban growth areas shall meet or exceed the minimum targets established in this section.

a) The first state goal is to reduce drive-alone travel by CTR commuters in each affected urban growth area. This will help urban areas to add employment and population without adding drive-alone commute traffic. The first state target based on this goal is a ten percent reduction from the jurisdiction's base year measurement in the proportion of single-occupant vehicle commute trips (also known as drive-alone commute trips) by CTR commuters by 2011.

b) The second state goal is to reduce emissions of greenhouse gases and other air pollutants by CTR commuters. The second state target based on this goal is a thirteen percent reduction from the jurisdiction's base year measurement in commute trip vehicle miles traveled (VMT) per CTR commuter by 2011.

3) **Local program goals and targets.** Local jurisdictions shall establish goals and targets that meet or exceed the minimum program targets established by the state. The goals and targets shall be set for the affected urban growth area in the city or county's official jurisdiction, and shall be targets for the year 2011 based on the base year measurement for the urban growth area.

a) Each local jurisdiction shall implement a plan designed to meet the urban growth area targets. Progress will be determined every two years based on the jurisdiction's performance in meeting its established drive-alone commute trips and VMT targets. Local jurisdictions shall establish base year values and targets for each major employer worksite in the jurisdiction. However, the targets may vary from major employer worksite to major employer worksite, based on the goals and measurement system implemented by the jurisdiction. Variability may be based on the following considerations:

7.2.2. Adopt State Transportation and Land Use Policies That Supports Climate Goals

Guide Transportation Investments to Projects That Support the Creation of Walkable Communities, More Transportation Choices, and the Achievement of Climate Goals

The prevailing method of transportation planning—trying to keep up with demand by simply "projecting and providing"—has proved to be both more expensive and less successful than many would wish. In spite of large transportation investments, congestion nationally continues to worsen year after year. Further, future projected needs far outstrip any reasonable estimates of available funds. Finally, beyond fiscal constraints, climate change, an aging population, changing market demand, and other macro-trends suggest that a continuation of strategies that rely nearly exclusively on automobile transportation is untenable.

Instead, states can work with localities and the public to identify future land use and transportation scenarios that provide a wide and suitable array of transportation choices, manage the growth of VMT and emissions, reduce household and government transportation expenses, and support greater access and mobility for all citizens. The California Department of Transportation is currently supporting this approach through its BluePrint project where localities proactively examine future growth scenarios and make investments to achieve the desired scenario. Similar processes have worked in Utah (Envision Utah) and Oregon (The LUTRAQ project). In these latter cases, the preferred future growth scenarios reduced vehicle miles of travel, created better traffic outcomes and saved infrastructure costs. Both studies are included in the literature reviewed above.

Once a future land use/transportation scenario is identified, states can then direct every new investment toward building that scenario. This is substantially different from the current process, because rather than simply responding to land use changes transportation investments now help to shape those changes in a way that leads to better outcomes. Investing in a specific vision for a region's or community's future will ensure that the future is more than just the sum of individual projects, and that development decisions and policies help meet economic, environmental, community, and fiscal goals. State policy changes that implement this approach include:

- A shared state and local vision of the future transportation system;
- Evaluating the full range of options and outcomes in a mode-neutral way, including system and demand management, land use, and alternative modes;
- A State transit village program to coordinate state policy for growing transit locations and identify future transit-oriented development (TOD) opportunities (e.g., New Jersey);
- State standards to allow roads to adapt to the surrounding land use and the adoption of context-sensitive design more broadly (many states, including Montana, Ohio, Massachusetts, Texas, and Washington);
- State access management policies that are consistent with the future transportation system (e.g., managing highway access for new developments to better manage traffic loads; leading examples include policies in Colorado, Maryland, Florida, Oregon, and Delaware);
- State connectivity policies that rely more on a larger number of smaller, interconnected road facilities, with accompanying state funding for smaller-scale roads;
- A Fix-it-First infrastructure policy (e.g., New Jersey's Fix-it-First program for transportation);
- Adoption of a "complete streets" policy and an emphasis on providing a variety of attractive transportation options to the maximum number of people (e.g., St. Louis and San Diego);
- Elimination of state restrictions that prohibit gasoline tax revenues from being spent on public transportation and other modes (most states do not have such prohibitions); and
- Requirements for developers to assess and mitigate climate impacts of large projects (e.g., Massachusetts[53]; King County, Washington[54]).

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[53] Massachusetts Executive Office of Energy and Environmental Affairs (2007), "MEPA Greenhouse Gas Emissions Policy and Protocol." http://www.mass.gov/envir/mepa/pdffiles/misc/ghgemissionspolicy.pdf.

[54] King County (2007), "Executive Order on the Evaluation of Climate Change Impacts through the State Environmental Policy Act." http://www.metrokc.gov/exec/news/2007/pdf/climateimpacts.pdf.

Also, with successful trials around the globe, roadway pricing strategies will likely become a key tool in managing traffic congestion and raising revenue in the U.S. States will play a key role in approving metropolitan pricing schemes, as will the federal and local governments. Such efforts can have a major impact on VMT reduction and funding alternatives, such as infill development, cycling and walking infrastructure, transit operations and capital, and other priorities.

7.2.3. Align State Spending With Climate and Smart Growth Goals

Set Performance Standards for Discretionary and Formula-Allocated Spending, and Target Spending to Areas that Rank Better for Smart Growth

States should ensure that funding programs support climate and VMT reduction goals and should adopt policies to reward local governments that help to meet such goals. States should begin by inventorying all available discretionary funds in such areas as housing, economic development, infrastructure, water and sewer, schools, transportation, state facilities, and recreation. These funds can then be allocated to localities according to their performance in meeting state goals. This inventory should include not only state funds, but also federal funds passed through the state over which the state has discretionary control. These discretionary funds, if thoroughly identified and pooled, can amount to a significant incentive for counties and municipalities. When Massachusetts employed this approach, discretionary funds totaled roughly $500 million within an annual state budget of $27 billion.

After completing its inventory of discretionary funds, the state should develop a coordinated investment approach that would tie funding to local performance on the state's priorities for transportation, housing, tax reduction, and climate. One mechanism for judging performance is a scorecard modeled on the Commonwealth Capital Fund in Massachusetts. This scorecard system awards points when local governments change their development rules and funding to promote more compact, mixed-use, walkable neighborhoods. Communities that score well receive access to some funding when the rule changes are made, and receive access to the larger, remaining portion of funding when new development projects are permitted—tightly linking spending with results.[55] These incentives have lead directly to hundreds of changes to local zoning in Massachusetts cities and towns. These changes contributed to increased production of multi-family housing units from 3,800 to more than 7,000 units annually.

Another state scorecard system is used by the California Infrastructure and Economic Development Bank's Infrastructure State Revolving Fund Program. It rates applications on a 200-point scale that gives substantial preference to projects that:

1) are located in or adjacent to already developed areas and in a jurisdiction with an approved General Plan Housing Element;
2) are located in or adjacent to and directly benefit areas with high unemployment rates, low median family income, declining or slow growth in labor force employment, and/or high poverty rates; and
3) improve the quality of life by contributing to public safety, health care, education, day care, greater use of public transit, or downtown revitalization.

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[55] For more information on Massachusetts' Commonwealth Capital Fund and its scorecard, please see: www.mass.gov/?pageID=gov3topic&L=2&L0=Home&L1=Smart+Growth&sid=Agov3.

Unlike a state's discretionary funds, "formula funds" are distributed to localities on the basis of a formula that is applied annually to a given funding stream (e.g., gas tax revenues, housing funds). Thus, each locality is guaranteed a share of this money. Without changing the geographic allocation of these funds, states can ensure that these dollars are invested in projects that contribute to meeting state goals. The top priorities should be to minimize long-term costs of maintenance and maximize the safety and security of existing roads, bridges, transit, water systems, and other critical community infrastructure. In doing so, the state gets the additional and climate-friendly outcome of making infill and redevelopment more attractive. Therefore, states can designate that a certain percentage of "formula-funded" transportation, school, housing, or other funds to go to the operation and maintenance of existing transportation, water, and wastewater infrastructure.

The remaining funds can be made available to projects that perform best with respect to meeting state goals. Projects within a locality should compete for these funds based on performance, without a predetermined water treatment technology or transportation mode. With this "means neutrality" built in, more innovative projects will be able to successfully compete and become established in the market.

7.2.4. Create Economic Development Incentives

Modernize Incentives to Support Growth and Climate Goals

The average state enables and oversees more than 30 different kinds of company-specific economic development incentives. Most are effectively as-of-right (rather than competitive or discretionary), and many are granted by local or regional bodies. While a few (e.g., brownfield remediation credits) are *de facto* limited primarily to developed areas, they are not officially linked to state land use policy or to transportation planning through enabling legislation. Very few state incentives are harnessed to facilitate shorter commutes, transit-oriented development, or other efficient practices.

Maryland's Smart Growth Areas Act explicitly seeks to better coordinate economic development with planning. Enacted in 1997, the law designates Priority Funding Areas (PFAs), defined as those areas that are already served by water and sewer infrastructure or are planned to receive infrastructure (both urban and rural). The state will spend infrastructure and economic development money only within these PFAs. Areas outside the PFAs are ineligible for state assistance in the form of infrastructure spending or economic development incentives; if development happens there, it will happen without help from the state. The law is one of several Maryland initiatives to preserve rural lands and revitalize cities and towns.

Illinois' Business Location Efficiency Incentive Act, enacted in 2005, gives a small additional corporate income tax credit under one common state incentive (Economic Development in a Growing Economy) if the job site is accessible by public transportation and/or proximate to affordable workforce housing.[56] Companies seeking the additional credit at sites that do not initially qualify can later qualify with a site remediation plan that includes measures such as an employer-assisted housing plan, shuttle services, pre-tax transit cards, or carpooling assistance.

By virtue of their statutory control over both state tax credits and the most common kinds of local incentives, such as property tax abatements, tax increment financing districts, and enterprise zones, states have an enormous amount of unrealized power to recast economic development as a tool for efficient growth and reduced VMT.

7.2.5. Eliminate Perverse Local Growth Incentives

Reduce Competition Between Local Governments and Eliminate the "Fiscalization of Land Use" That Distorts Local Priorities

Local governments rely upon a variety of state-regulated revenue streams to fund local public services. But state policies sometimes depress one stream (e.g., property taxes) while enabling another (e.g., local sales tax increments), giving local governments a fiscal incentive to avoid, for example, residential land use and instead subsidize big-box retail projects. The result of these decisions can be the concentration of jobs far from workers, under-provision of affordable housing and housing for families, and attempts to export negative impacts of development to neighboring jurisdictions.

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[56] SB2855, at http://www.ilga.gov/legislation/BillStatus.asp?DocNum=2885&GAID=8&DocTypeID=SB&LegId=23994&SessionID=50, promoted by a coalition of public interest organizations including Good Jobs First, Center for Neighborhood Technology, Chicago Metropolis 2020 and other groups.

It is difficult for local governments to address these issues on their own. Those that are friendly to family housing or affordable housing can become overwhelmed if their neighbors seek to block these housing types. Localities that do not aggressively zone for commercial land use risk being out-competed by neighbors that do. While local governments in a few metro areas, such as Minneapolis/St. Paul and the City of Charlottesville and Albemarle County, Virginia, have developed pacts to deter intraregional competition, this is relatively rare.

States can eliminate the perverse incentives that local governments face in the development market. In Massachusetts, local governments were reluctant to permit housing for families, fearing that an influx of children would add to the cost of education. The state now provides towns with a hold-harmless guarantee: if education costs rise, the state makes up the difference. In Arizona, local government retail incentive packages became so large and so frequent that the state passed a law prohibiting them in the Phoenix metro area. For many New England states, property taxes are the dominant funding source, and property tax reform is seen as the potential solution. In parts of the West where property tax caps are more common, sales taxes can be a driver of land use decisions, and reform efforts must focus on this dynamic.

According to the National Association of Industrial and Office Properties' (NAIOP) web site, where localities have taken steps to reduce competition for tax base the following lessons can be drawn[57]:

- In the Twin Cities Region in Minnesota, this technique has notably reduced disparities among the localities included in the pool concerning their assessed non-residential property values per capita. When this arrangement was put into effect in 1975, the greatest disparity was 50 to 1; today it is 12 to 1. It is not clear whether this technique has greatly reduced competition among adjacent or nearby localities for added non-residential development projects.32
- In the Dayton, Ohio, region, this technique has made it possible for multiple municipalities to cooperate in promoting the economic development of the entire region, including the provision of affordable housing and cultural facilities serving the entire region.
- In the Hackensack Meadows District, in New Jersey, this technique has made it possible for a regional body to develop a land-use plan that is rational from the broader perspective of an entire region, even though that region encompasses parts of 14 municipalities and two counties, without causing fiscal disadvantages to any of the those 16 legal entities.
- In Rochester, New York, the city is able to collect more funds from the local option sales tax that flows through the county government than it could if it charged that tax only within its own boundaries.

[57] http://www.naiop.org/governmentaffairs/growth/rtbrs.cfm.

7.3. Regional and Local Policy Recommendations

Many local governments are committing to action to reduce greenhouse gas emissions; more than 650 mayors have signed on to the U.S. Conference of Mayors' Climate Protection Agreement,[58] and about 400 have signed on as "Cool Mayors" with ICLEI's Mayors for Climate Protection program.[59] The Sierra Club, in partnership with King County, Washington; Fairfax County, Virginia; and Nassau County, New York, recently launched the "Cool Counties" campaign. To achieve their greenhouse gas reduction goals, these localities will have to include policies that reduce VMT. The following policies can help local governments reach the CO_2 reductions they want, while also creating and supporting strong, healthy, diverse communities where people have more choices in where they live and how they get around:

1) Change the development rules to modernize zoning and allow mixed-use, compact development;
2) Favor location-efficient and compact projects in the approval process;
3) Prioritize and coordinate funding to support infill development;
4) Make transit, pedestrians, and bikes an integral part of community development; and
5) Invest in civic engagement and education.

7.3.1. Change the Development Rules

Examine the Rules and Regulations That Govern Development, and Determine if and how They Need to be Changed to Get Smart Growth That Reduces CO_2 Emissions

As discussed in the State Policy Recommendations section, many communities want to create mixed-use neighborhoods, integrate new development with transit stops, allow more density and more compact neighborhoods, offer more types of housing to allow people of different income levels to live in the same neighborhood, or require sidewalks, bike lanes, and other bicyclist and pedestrian amenities. But many find that their development rules do not allow them to get the type of development they want. Sometimes a community may even develop a vision of what its residents want from development, only to find that it simply is not possible to fulfill the vision under the existing regulations. Part of the strategy for reducing CO_2 emissions from vehicles is to make it easier to build more location efficient, compact developments that allow people to choose walking, bicycling, or public transit.

To achieve that goal, communities should examine their development rules and determine if and how they need to be changed to meet smart growth, CO_2 reduction, and other community goals. Several tools, such as scorecards and zoning code audits, are available to help communities figure out what they need to change to get the kind of development they want.[60] Some opportunities for reform include:

- zoning codes;
- subdivision regulations;

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[58] As of August 2007; see http://usmayors.org/climateprotection/listofcities.asp for the list of signatories.

[59] See http://www.coolmayors.com/common/directory/browse_mayors.cfm?clientID=11061 for the list of mayors.

[60] See, for example, the policy and code audit tools from the Smart Growth Leadership Institute at http://www.sgli.org/implementation.html and samples of scorecards from around the country at http://www.epa.gov/smartgrowth/scorecards/.

- street design standards;
- parking standards;
- annexation rules;
- design guidelines; and
- any other regulation that affects the location and design of development.

Rarely do these regulations require a complete overhaul to make smart growth projects permissible "by right"; many times, it can be done with tools like area plans or overlay zones.

For example, Nashville/Davidson County, Tennessee, had subdivision regulations that applied to rural, suburban, and urban areas equally. Therefore, building more dense and compact development in the central city was not possible. With assistance from the Smart Growth Leadership Institute, the county revised its subdivision regulations so that different standards could be applied to different areas.[61] Now the county can preserve the character of its rural areas while permitting the vibrant development it wants in more urban areas.

Such regulatory reform efforts are largely responding to market demand that is strong across the nation. A recent national survey of developers found that more than 60 percent agreed with the following statement about compact, walkable development: "In my region there is currently enough market interest to support significant expansion of these alternative developments," with a high of 70 percent in the Midwest and a low of 40 percent in the South Central region.[62]

State and local governments should also find ways to expedite and reward exemplary projects that meet the U.S. Green Building Council's LEED for Neighborhood Development (LEED ND) certification standards, and consider adopting those standards as their own. Illinois, for example, just passed "The Green Neighborhood Grant Act," which is the first state legislation to tie LEED ND standards to financial incentives. The Illinois program authorizes the Department of Commerce and Economic Opportunity to issue Requests for Proposals (RFPs) from model development projects that have received LEED ND certification, and award up to three grants to reimburse up to 1.5 percent of the total development costs.

7.3.2. Favor Good Projects in the Approval Process

Make It Easier, Faster, and More Cost Effective for Good Development Projects to Get Approved, and Offer Incentives and Flexibility to Get Better Development

Once communities have reformed their regulations to allow good development, they should make it easier for that good development to be approved. Predictability in the development process is valuable to everyone concerned: developers, local government, and community members. Laying out the guidelines and rules for what the local government considers a "good" development project makes the process more predictable and fair, as does defining the benefits developers will get from meeting or exceeding the community's standards. Two main ways to favor good projects are to offer them flexibility and to speed the approval process.

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[61] See http://www.nashville.gov/mpc/subdivregs/intro.htm and http://www.sgli.org/communities.htm#nashville

[62] Jonathan Levine and Aseem Inam, "The Market for Transportation-Land Use Integration: Do Developers Want Smarter Growth than Regulations Allow?" *Transportation*, Volume 31, Number 4, November 2004.

Flexibility in meeting requirements gives developers room for innovation and creativity, as well as cost savings. If a development project meets or exceeds the community's goals and vision, the developer should be rewarded with, for example, a density bonus that allows them to build more in exchange for providing an amenity the community wants, like affordable housing. Alternatively, local governments can calculate the traffic reduction benefits of a development and adjust accordingly how much parking, road improvements, or air-quality mitigation the developer needs to deliver.

Developers tend to favor an approval process in which projects that follow certain guidelines or are located in targeted areas get streamlined or fast-tracked approvals. Communities might guarantee review of the project within a certain amount of time, or they might coordinate the various departments that need to review development proposals so that review happens quickly and smoothly. Of course, the process must include several opportunities for meaningful public input and review and must ensure compliance with other environmental safeguards.

Some communities do this by setting out specific desirable criteria; any development that meets these criteria gets a fast track to approval. With the advent of the LEED-ND green development guidelines, communities have a good starting point for setting standards to define walkable, environmentally responsible neighborhoods.

In Austin, Texas, the city developed a matrix of smart growth criteria to help it analyze development proposals within areas where it wants to encourage development. The matrix measures how well the project meets the city's goals, including the location of the project, its mix of uses, its proximity to public transit, its pedestrian-friendly design, compliance with nearby neighborhoods' plans, and other policy priorities, including tax base increases. For projects that score above a certain level on the matrix, the city will waive some fees or invest public money in infrastructure for the development.[63]

In other places, an outside organization plays a similar role, setting up a list of criteria and offering public support for projects that meet those criteria. For example, the Greenbelt Alliance in the San Francisco Bay Area will endorse developments that are "pedestrian-oriented and transit accessible, use land efficiently, and provide affordable housing."[64] The Greenbelt Alliance will send a letter of support to the appropriate officials and actively support a project at public hearings if requested. Similar programs, with varying degrees of endorsement, are run through alliances in many other regions.[65] While this outside support doesn't guarantee a faster process, the stamp of approval from a neutral entity can help some projects get approved.

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[63] See http://www.ci.austin.tx.us/smartgrowth/default.htm.

[64] See http://www.greenbelt.org/whatwedo/prog_cdt_index.html.

[65] See, for instance, the Vermont Smart Growth Collaborative's Housing Endorsement Program (http://www.vtsprawl.org/Initiatives/sgcollaborative/VSGC_housingendorsement.htm) or the Urban Land Institute-supported Smart Growth Alliances Information Network. (http://www.uli.org/Content/NavigationMenu/MyCommunity/SmartGrowth/SmartGrowthAllianceInformationNetwork/Smart_Growth_Allianc.htm).

7.3.3. Prioritize and Coordinate Funding to Support Infill Development

Find Funding Sources to Support Infill Development, Coordinate Funding to Get the Most Impact, and Prioritize Infrastructure Projects to Determine Where the Investment will Do the Most Good

Just as at the federal and state levels, local governments should prioritize funding, including infrastructure spending, to support development that helps reduce CO_2 emissions and meets other community, economic, and environmental goals. By directing infrastructure funds to infill projects, whether to repair existing infrastructure or build new facilities, the community is investing in the type of development that can help reduce CO_2 emissions by creating more options for residents. Just as importantly, it is not subsidizing development in far-flung areas that will generate more vehicle trips. This money is a public investment, and it should be spent wisely and with the goal of doing the most good for the most people. As the Metropolitan Council of the Twin Cities region of Minnesota puts it:

> For the metropolitan transit and transportation system, putting growth where the infrastructure to support it already exists means roads that *don't have to be built*. Providing transportation options that include fast, convenient transit services means freeway lanes that *don't have to be added*. And, where new infrastructure is necessary, investments in more connected land-use patterns will be the most fiscally responsible use of limited public resources for transportation.[66] [emphasis theirs]

Scorecards are useful to set priorities for public spending. Similar to the scorecards mentioned previously in this chapter, communities can set up criteria based on location in an area designated for growth; proximity to transit, housing, workplaces, and other amenities; need for new infrastructure; and accommodation of automobiles, pedestrians, bicyclists, and transit. Infrastructure projects and other expenditures that score highly on the scorecard get priority, or get more public funding compared to projects that score poorly.

To get the most from their investments in infrastructure, transit, housing, and other expenditures, local governments should coordinate their land use policies with these investments. This means directing development to areas around transit stations, sharing parking among different uses, building new schools in places easily accessible to the neighborhoods they will be serving, and so forth.

7.3.4. Make Transit, Pedestrians, and Bikes an Integral Part of Community Development

Create a Comprehensive Vision and Plan for Creating Safe and Accessible Routes, Networks, Environments, and Linkages to Destinations. Rewrite Rules as Necessary, and Invest in Supportive Infrastructure.

If communities make it easier for people to walk, bike, or ride transit, they create new options for people besides driving. Making transit, bike, and pedestrian amenities part of planning guidelines creates predictability for developers and can help reduce traffic from new development, which is

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[66] *2030 Regional Development Framework*, Metropolitan Council, pp. 6-7, adopted January 14, 2004, amended December 14, 2006, http://www.metrocouncil.org/planning/framework/Framework.pdf.

a major concern of many of those who live in adjacent neighborhoods. Streets that are built with not only cars, but also bicycles, transit, and pedestrians in mind—often known as "complete streets"—are safer and make people feel more comfortable walking or biking. They are also often more attractive, with shade trees, benches, and other amenities. And they provide options for people who can't or choose not to drive, including children, older people, and people with disabilities.

Localities should adopt complete streets policies and design guidelines to create safe and welcoming environments for pedestrians, cyclists, and transit users. These policies require the accommodation of all users of the right of way, and set out new procedures for ensuring that construction, reconstruction, and maintenance projects balance the needs of all users. Accommodating new, walkable development on land that once held dead shopping centers or factories, or creating transit-oriented developments at rail stations, is likely to require investments in building or retrofitting a street network for pedestrians and cyclists.[67]

A great example of a place that has put all the elements together is Arlington County, Virginia, a suburb of Washington, D.C. Arlington County's master transportation plan includes elements for transit, bicycling, and walking.[68] The county has two subway lines, part of Washington's Metrorail system, and numerous bus routes. It has coordinated its land use with these transit investments, concentrating development along the subway lines and tailoring bus lines to key corridors. The county has emphasized safe and appealing walking and biking environments, putting in bike lanes, sidewalks, crosswalks (many with "countdown" pedestrian signals to let people know how much time they have left to cross the street), and bike and walking paths that connect to trails that go throughout the Washington metropolitan region. The county has also brought in car-sharing services to make it easier for residents to own one car instead of two, or to go without a car.

As a result of having all these transportation options, Arlington has some of the highest rates in the country of commuting by means other than personal automobile. Thirty-nine percent of Arlington residents commute by public transportation, twice the national average, and 6 percent walk to work, well above the national average of 1 percent.[69] The numbers are even higher in the subway corridors; in the Rosslyn-Ballston corridor, along Metrorail's Orange Line, 38 percent of residents who live within half a mile of a station take transit to work, and 73 percent of riders using these Metrorail stations walk to the stations. The foot traffic has fostered a lively commercial, retail, and residential corridor that comprises only 7.6 percent of the county's land area, yet produces about a third of its real estate tax revenue. Meanwhile, automobile traffic has been below projections as county population has grown, showing the benefits of these transportation options not only for the people who choose to bike, walk, or take transit, but also for those who drive.

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[67] See www.completestreets.org.

[68] See http://www.arlingtonva.us/Departments/EnvironmentalServices/dot/planning/mplan/MasterPlans.aspx for a copy of the master plan.

[69] Arlington Master Transportation Plan – Second Draft, Transportation Demand Management Element – November 2006, p. 9.

7.3.5. Invest in Civic Engagement and Education

Engage and Educate Citizens in Visioning Exercises, and Require Opportunities for Meaningful Citizen Participation in Development Decision-Making

For plans to be as successful as possible, the people who will be living and working in the community must be involved in creating them. This means that residents have to have opportunities to learn about the issues and give their input on decision-making. Education might mean public meetings, gathering and publishing data and maps in an easily understood format that's relevant to people's lives, or keeping a Web site up to date on local development issues. With a foundation of basic knowledge about these issues, people are better equipped to participate in development decisions and in guiding the future of their community. When residents are engaged in the decision-making process from the beginning and feel like their concerns and ideas are being heard and considered, they are less likely to fight new development. The extra money spent on these education and engagement efforts pays off in the long run in better development projects that move through the process more smoothly.

One popular form of engagement is a visioning exercise, usually held on a regional or local scale. Participants review various scenarios for the future of the region or community and choose the one that they prefer. Usually there is a "business as usual" scenario that shows how continuing along the current path will affect open space, traffic congestion, development, air and water quality, and other quality of life issues. Other scenarios illustrate what the future could look like with denser development, more transportation options, and development directed to certain areas to preserve open space.

Visioning exercises have been conducted all over the country. One of the best examples is the Sacramento Region's *Blueprint Transportation and Land Use Study*, which used an extensive public outreach process, cutting-edge Internet-accessible planning software, and a detailed business-as-usual baseline growth forecast to help participants to explore alternative growth scenarios through 2050. The adopted preferred scenario features sophisticated infill development and transportation investments that will produce 12.3 fewer daily vehicle-miles of travel per household by 2050, a 27 percent reduction below the baseline. Other well-known examples include Envision Utah, which began in 1997 and was the first large-scale scenario planning exercise in the nation, as well as Louisiana Speaks, which was launched to help coastal communities craft redevelopment plans after the devastation from Hurricanes Katrina and Rita and attracted over 27,000 participants.

Visioning exercises create general principles and strategies for development, but the public should also be engaged in making decisions on specific development projects. They need to be involved from the beginning for their input to be meaningful, and they need to know that their ideas and concerns are being listened to and taken seriously, even if they don't end up being incorporated into the project. Some of the tools communities use to get citizen input are design workshops, charrettes, public surveys, or public meetings.

In a planning ordinance approved in 2001, the town of Davidson, North Carolina, requires new development projects to hold a charrette to get public input. These workshops allow the developer and the town's residents to understand each other's concerns and goals and to work together to make sure the development meets the community's needs. The process gives citizens the chance to have their voices heard, and it lets developers deal with problems before they can hold up the project in the approval process. Gathering public support at this early stage makes the approval process smoother for developers. Davidson has found that holding these *charrettes* helps preserve its small-town character and makes it easier to achieve its goal of making bicycling and walking safer and more pleasant.

7.4. Developing a Comprehensive Policy Package

Such a comprehensive overhaul of America's development processes will be a mighty challenge. But it is on the same ambitious scale as other proposals that are being considered in the climate change debate, including efforts to switch to renewable fuels, dramatically increase vehicle efficiency, end oil imports from hostile nations, or renew investment in nuclear power.

The fact is, no gigaton of reduction will come very easily, and few methods are likely to take advantage of consumer demand as much as those discussed in this book. In fact, many of the reforms discussed here focus on making government rules and regulations more flexible to give people more of what they want. Also, most of the communities that have adopted these reforms have done so for a wide variety of self-interested reasons, like traffic management or financial rewards, and not because they wished to reduce greenhouse gas emissions. We are confident that these improvements to the built environment can offer tremendous win-win benefits, and hope that these types of policies do get implemented across the nation and the world. They should become a sensible complement to any other climate policies that focus on energy, vehicles, power plants, or other strategies.

8. Conclusion

With regard to urban development and travel demand management, this publication asks and answers three critical questions facing the urban planning profession, 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?

The answer to the first question is a 20 to 40 percent reduction in VMT for each increment of new development or redevelopment, depending on the degree to which best practices are adopted (see Chapter 3). The answer to the second question is a 7 to 10 percent reduction in total transportation CO_2 emissions by 2050 relative to continuing sprawl (see section 1.7). The answer to the third question is a set of dramatic policy changes at all three levels of government (see Chapter 7).

Unlike other vehicle emissions, CO_2 emissions have never been regulated. Given the difficulty of changing longstanding policies, development patterns and, ultimately, lifestyles, is the 7 to 10 percent reduction in CO_2 emissions worth the effort? The answer, we believe, is "yes," for three primary reasons:

- The U.S. transportation sector cannot reach a sustainable level of CO_2 emissions through vehicle and fuel technology improvements alone. It also needs to reduce VMT, as the third leg supporting the policy stool (see Chapter 2).

- The shift from sprawl to compact development will have many other economic, environmental, and quality-of-life benefits, so any "costs" of this CO_2 reduction strategy will be offset by additional quantifiable benefits (see sections 1.5 and 1.6).

- Reductions in VMT and CO_2 emissions with compact development are sizable and long lasting compared to reductions achievable with other available actions (see section 1.7 and Chapter 3).

- Compact development provides an insurance policy against the worst effects of climate change and oil price spikes. In the worst case, current or future residents of compact development will have a variety of viable transportation options, while the residents of sprawl will not.

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Constraints in household relocation: Modeling land-use/transport interactions that respect time and monetary budgets

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Abstract: Traditionally, integrated land-use/transportation models intend to represent all opportunities of travel and household location, maximize utilities and find an equilibrium in which no person or household could improve their satisfaction any further. Energy scarcity, higher transportation costs, and an increasing share of low-income households, on the other hand, demand special attention to represent constraints that households face, rather than opportunities for utility maximization. The integrated land-use model SILO explicitly represents various constraints, including the price of a dwelling, the travel time to work, and the monetary transportation budget. SILO ensures that no household makes choices that violate these constraints. Implementing such constraints helps SILO to generate more realistic results under scenarios that put current conditions under a stress test, such as a serious increase in transportation costs or severely increased congestion.

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1 Introduction

Households looking for a new place to live attempt to fulfill as many of their location preferences as possible. At the same time, however, households face a couple of constraints in a housing search. First and foremost, the price of a new dwelling is a constraint. Even though loans and mortgages allow households to afford places that exceed their immediately available budget, households have to get along with their income in the long run. This is why low-income households cannot afford moving into the most sought-after houses on the market. Income is an obvious constraint on housing choice for almost every household.

Another constraint households face when looking for a new dwelling is travel time. An analysis of the 2007-2008 Household Travel Survey for the Baltimore/Washington region revealed that 86 percent of all workers travel less than 60 minutes to work, and 99 percent travel less than 120 minutes to work. Commuting for no more than two hours, therefore, is another constraint for most households, at least on a daily basis. Suitable home locations are even more restricted if more than one household member is working. As the average time spent on commuting does not change much over time (Zahavi, Beckmann, and Golob 1981), this constraint is unlikely to change much in the future. As a consequence,

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average workers should be expected to move closer to their work location if congestion worsens, unless they have the opportunity to telework.

Another constraint is constituted by the total household budget. According to the Consumer Expenditure Survey[1], the average U.S. household spends 18.2 percent of its after-tax income on transportation. Should transportation become more expensive, households have to either adjust their travel behavior or reallocate their income. In reality, both happen. In some cases, particularly for low-income households, a steep increase in transportation costs may trigger a household relocation to a less expensive apartment to ensure that the household gets along with its income in the long run.

The literature review (Section 2) shows that the majority of land-use models do not represent such constraints explicitly. Section 3 introduces the land-use model SILO, and Section 4 explains how constraints are treated in SILO. Section 5 shows model validation results and Section 6 presents conclusions and recommendations for further research.

2 Literature review

One of the pioneering land-use models was designed by Herbert and Stevens (1960) in cooperation with Britton Harris as an equilibrium model simulating the distribution of households to residential land use. Lowry's model of metropolis (Lowry 1964, 1966) is often considered to be the first computer model that truly integrated land use and transportation. The Lowry model assumed the location of basic employment exogenously and generated an equilibrium for the allocation of non-basic employment and population. Over the last five decades, this popular model has been implemented many times (e.g., Batty 1976; Wang 1998; Mishra et al. 2011). At least equally influential was Forrester's Theory of Urban Interactions (1969). Even though it was an a-spatial model, this research on interactions between population, employment, and housing has influenced the design of many spatial land-use models developed since.

Putman developed the integrated transportation and land-use model package (ITLUP) (Putman 1983, 1991), where land use was modeled by the projective land-use model (PLUM) (Rosenthal, Meredith, and Goldner 1972; Goldner, Rosenthal, and Meredith 1972; Reynolds and Meredith 1972). Later, PLUM was replaced by the frequently applied disaggregated residential allocation model (DRAM) and an employment allocation model (EMPAL).

Wilson's entropy model (1967, 1970) generated an equilibrium by maximizing entropy of trips, goods flows, or the distribution of population. This model assumes a perfect equilibrium, which may never be reached in reality. Anas' (1982) model called the residential location markets and urban transportation created an equilibrium between demand, supply, and costs for housing. Anas' model, rather than follow the traditional deterministic approach that assigns each dwelling to the highest-paying buyer, instead applies stochastic variation to preferences and decisions.

The MEPLAN model developed by Echenique is an aggregated land-use transport model (Echenique, Crowther, and Lindsay 1969; Echenique et al. 1990; Abraham and Hunt 1999) that used the basic concept of the Lowry model as a starting point. The model can simulate a variety of both land-use and transport scenarios. MEPLAN has been applied to more than 25 regions worldwide (Hunt, Kriger, and Miller 2005, p. 332). Another modeling approach using the Lowry model as a starting point is the TRANUS model (de la Barra, 1989; de la Barra and Rickaby 1982; de la Barra, Perez, and Vera 1984) that simulates land use, transport, and its interactions at the urban and regional scale.

Martínez (2002, 1996) developed a land-use model under the acronym MUSSA in which location choice is modeled as a static equilibrium. Residential and commercial land-use developments compete for available land. MUSSA used the bid-auction approach based on the bid-rent theory where consumers try to achieve prices as low as possible and not higher than their willingness to pay (Martínez

[1]Available online at http://www.bls.gov/cex/#tables

1992). In the bid-rent theory, first introduced by Alonso (1964), land prices are an immediate result of the bid-auction process. In contrast, the discrete-choice approach—initially developed for housing choice by McFadden (1978)—models land being bought or rented with no instant effect on the price. Acknowledging that both approaches lead to similar results, Martínez argues elsewhere (1992) that the bid-auction approach and the discrete-choice approach should be integrated and seen as inseparable rather than opposed.

Wegener (1999, 1998b, 1982) developed the IRPUD model as a fully integrated land-use transport model. The household location choice is microscopic (Wegener 1984), simulating every household individually. The IRPUD model was one of the few early approaches that contradicted the common assumption that land-use models shall reach an equilibrium at the end of each simulation period (Wegener, Gnad, and Vannahme 1986). Land-use development aims at equilibrium constantly, but due to a continuously changing environment and slow reaction times of households, businesses, developers, and planners, this equilibrium stage is never reached. The price of a new dwelling and the commute distance to the household's main workplace are accounted for as true constraints in location choice. Similarly, the metroscope model for Portland, Oregon, (Conder and Lawton, 2002) compares expenditures for housing, transportation, food, health, and all other expenses to ensure that household budgets are not exceeded.

PECAS (Hunt and Abraham 2009, 2003) is another land-use model that represents an equilibrium of competing demand for developable land. Households relocate based on available floor space, prices, accessibilities, and other location factors. PECAS combines this bid-rent approach in a spatial economic model with a microscopic land-development model. DELTA (Simmonds and Feldman 2007) combines an economic model with households and job location model and a long-distance migration model.

Microsimulation was introduced by Orcutt et al. (1961) and subsequently applied to a series of modeling tasks, including travel behavior, demographic change, spatial diffusion, health and land use (Clarke and Holm 1987). The most influential microscopic land-use models include the California urban futures (CUF) model (Landis and Zhang 1998a, 1998b), the integrated land-use, transport and environment (ILUTE) model (Miller et al. 2004; Miller and Salvini 2001; Salvini and Miller 2003), the urban simulation (UrbanSim) model (Waddell 2002; Waddell et al. 2003), the learning-based transportation oriented simulations system (ALBATROSS) (Arentze and Timmermans 2000), predicting urbanization with multi-agents (PUMA) (Ettema et al. 2004), SimDELTA (Simmonds and Feldman, 2007) and the integrated land-use model and transportation system simulation (ILUMASS) (Strauch et al. 2005, Wagner and Wegener 2007). A common problem in microscopic modeling is stochastic variability between model runs. Gregor (2006) overcame this shortcoming in the land-use scenario developer (LUSDR) by running the same model hundreds of times and storing each model run as a potential future development.

Good overviews of operational land-use/transport models are given particularly by Hunt, Kriger, and Miller (2005), Wegener (2004, 1998a, 1994), Wegener and Fürst (1999), Timmermans (2003), Kanaroglou and Scott (2002), the U.S. Environmental Protection Agency (2000), and Kain (1987). The literature review showed that most land-use models do not explicitly represent constraints. The majority of models employ equilibrium methods to reach an "ideal" distribution of households and land uses. Commonly, land use is viewed as a decision-making process in which users optimize their utilities, rather than making choices among a limited set of alternatives. Notable exceptions are the IRPUD model and metroscope, which explicitly constrain households to move to dwellings that are within their respective price range.

3 The land-use model SILO

SILO was designed as a microscopic discrete choice model. Every household, person, and dwelling is treated as an individual object. All decisions that are spatial in nature (household relocation and development of new dwellings) are modeled with Logit models. Initially developed by Domencich and McFadden (1975), such models are particularly powerful at representing the psychology behind decision making under uncertainty. Other decisions (such as getting married, giving birth to a child, leaving the parental household, renovating a dwelling, etc.) are modeled with Markov models by applying transition probabilities.

SILO is integrated with the Maryland Statewide Transportation Model (MSTM) to fully represent interactions between land use and transportation. The model is built to work with less rigorous data collection and estimation requirements than traditional large-scale land-use models. Rather than requiring costly data collection and time-consuming model estimation, SILO takes advantage of national averages where possible and transfers parameters from models that have been implemented elsewhere. Figure 1 provides an overview of the SILO model.

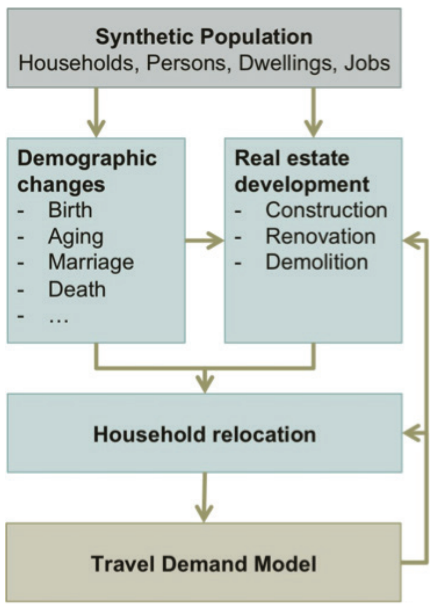

Figure 1: Flowchart of the land-use model SILO

At the beginning, a synthetic population is created for the base year 2000. The U.S. Census Public Use Micro Sample (PUMS) 5 percent dataset[2] is used to create this synthetic population. Using expansion factors provided by PUMS, household records including dwellings are duplicated until the population by PUMS zone (called a PUMA) matches 2000 census data. The location is disaggregated from PUMA to model zones using the zonal socioeconomic data of the MSTM as weights. Work places are created based on MSTM zonal employment data. For each worker, a work location is chosen within the recorded work-PUMA and based on the average commute trip length distribution found in the 2007-2008 Household Travel Survey for the Baltimore/Washington region. SILO simulates events that may occur to persons, households, and dwellings:

The housing market is modeled explicitly. Vacancy rates by five dwelling types and 31 regions are used as a proxy for additional demand. If vacancy rates drop, developers will add additional dwellings if zoning permits. To find the best locations for new dwellings, developers mimic the location choice

[2] Available for download at http://www2.census.gov/census_2000/datasets/PUMS/FivePercent/

behavior of households, and thereby, developers are likely to build the most marketable new dwellings. New dwellings are released into the housing market with a one-year delay to account for the time required for planning, approval, and construction. A hedonic price model is used to model changes in housing costs. Low vacancy rates lead to a fairly quick upward adjustment of prices, while high vacancies lead to a gradual price reduction. This reflects observed behavior that landlords use to attempt to keep prices high, even if demand is rather low.

Table 1: List of events simulated in SILO

Household	
Relocation	Buy or sell cars
Person	
Aging	Divorce
Leave parental household	Death
Marriage	Find a new job
Birth to a child	Quit a job
Dwelling	
Construction of new dwellings	Demolition
Renovation	Increase or decrase of housing price
Deterioration	

From one year to the next, certain events may trigger other events. For example, if a child is born, the household will have a higher probability of moving to a larger dwelling. Within one year, however, events are modeled in random order to avoid path dependency. A random number is assigned to each event. Events are sorted by this number in ascending order and executed in this sequence.

SILO is set to match observed land-use changes from 2000 to 2012 (so-called back-casting) and validated in 2012. Currently, the model runs to 2040. While the entire model is fully operational, the remainder of this paper focuses on household relocation for which constraints are implemented explicitly.

The model covers demographic changes, household relocation, and real estate changes. Workplaces and commercial floor space are not modeled explicitly at this point but exogenously given based on the Financially Constrained Long-Range Transportation Plan (CLRP). In the future, it is planned to add a sub-model that simulates the employment side.

SILO is open-source software and was initially developed with research funding by Parsons Brinckerhoff, Inc. The prototype application was implemented for the metropolitan area of Minneapolis-St. Paul, Minnesota. Currently, the Maryland Department of Transportation supports the implementation of an improved version for Maryland. The acronym stands for "simple integrated land-use orchestrator," as the model is meant to be implemented more easily than traditional large-scale models that require extensive model estimation. A visualization tool is included for the analysis of model results. Further information on model design and implementation can be found at www.silo.zone.

4 Modeling constraints

SILO distinguishes location factors that are desirable and those that are essential. Finding a place to live within someone's housing budget, for example, is considered to be an essential location factor. Having a particularly large apartment, on the other hand, is a desirable location factor only. If all other location factors are excellent, a household might compromise dwelling size.

In contrast to desirable utilities, essential utilities are assumed to be mandatory to be fulfilled. The three essential location factors represented by SILO include housing costs, commute travel times, and transportation costs. If one of these three utilities is 0, the utility for the entire dwelling has to be 0. This is achieved by using the Cobb-Douglas function that aggregates utilities by multiplication.

$$u_d = util_{p_d}^{\alpha} \cdot util_{ct_d}^{\beta} \cdot util_{tb_d}^{\gamma} \cdot util_{desFac_d}^{(1-\alpha-\beta-\gamma)} \quad (1)$$

where:

u_d	Utility of dwelling *d*
$util_{p_d}$	Utility of the price *p* of dwelling *d* (see Section 4.1)
$util_{ct_d}$	Utility of the commute time *ct* from dwelling *d* (see Section 4.2)
$util_{tb_d}$	Utility of the transportation budget *tb* required for dwelling *d* (see Section 4.3)
$util_{desFac_d}$	Utility of non-essential factors of dwelling *d* (see Section 4.4)
α, β, γ	Parameters as weights for each factor, set differently by household type

This way, it is ensured that households do not move into a place that violates a budget constraint. The following sections describe the three essential location factors (Sections 4.1 to 4.3) and desirable location factors (Section 4.4).

4.1 Housing cost constraints

The costs of a dwelling form an immediate constraint for any relocation choice. While households may exceed their housing budget temporarily, households have to get along with their income in the long run. The distribution of rent and mortgage payments in the base year, according to PUMS data, is used as guidance on how much households are willing to pay for housing. Figure 2 shows the aggregation to reveal the willingness to pay rent or to pay for a mortgage. As expected, higher income households tend to pay more for housing than low-income households.

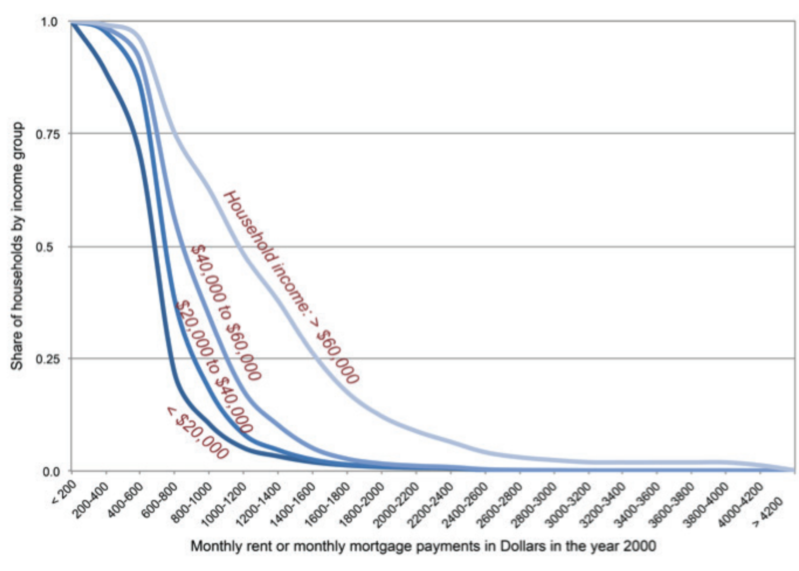

Figure 2: Willingness to pay rent by household income

Source: PUMS 2000 database

The relationship between income and housing expenses shown in Figure 2 is used to calculate the utility of a given price using equation 2.

$$util_{Pd} = 1 - \sum_{price_j}^{price_j < price_d} hhShare_{price\,j,inc} \qquad (2)$$

where:

$util_{pd}$	Utility of price *p* of dwelling *d*
$hhShare_{pricej,inc}$	Share of households with income inc who have paid $price_j$ in the base year

The higher the price, the lower the utility, and the utilities decline faster for low-income households than for high-income households. When the price is high enough that the share of households paying this amount for housing reaches zero, the utility becomes zero, and that dwelling becomes unavailable for this household type.

4.2 Commute travel time constraint

The travel time to work is a primary driver for household location choice. With the exception of workers who regularly work from home, the travel time from home to work is an important constraint when choosing a new place to live. Travel time to work is remarkably constant over time (Zahavi, Beckman, and Golob 1981; van Wissen, Golob, and Meurs 1991). The aforementioned household travel survey for the Baltimore-Washington region was analyzed for the time spent on home-to-work trips. Because respondents tend to round their travel time to even numbers (for example, 12 percent reported their commute to be exactly 30 minutes), the observed trip length frequency distribution is lumpy and needs to be interpolated. Figure 3 shows the estimated gamma functions representing the observed trip length frequency distribution in minutes for commute trips. The gamma functions were calibrated to match the reported average travel time.

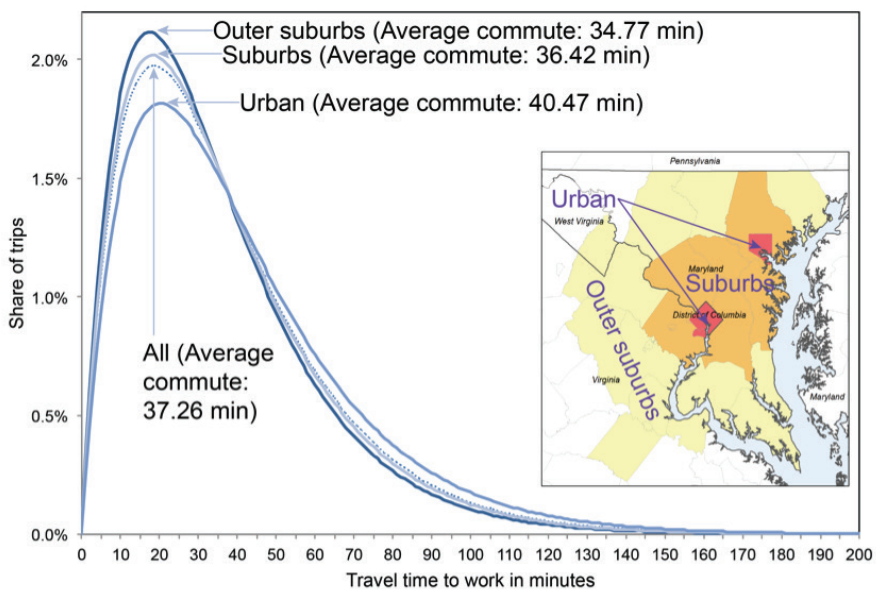

Figure 3: Estimated commute trip length frequency distributions in minutes for rural, suburban, and urban residents
Source: 2007-2008 household travel survey for the Baltimore-Washington region

Residents living in the urban counties in Baltimore, Washington, Arlington, and Alexandria have above-average commute times. Even though their average commute trip lengths of 9.8 miles is shorter than the average commute trip length of outer suburbs residents (15.5 miles), urban densities lead to more congestion, and therefore, residents need more time to get to work. Also, the transit share is much higher in urban areas, which often leads to longer travel times. The trip length frequency distributions in minutes are expected to not change significantly in the future.

When households look for a new housing location, the job locations of all household members are taken into account. As SILO is designed as a microsimulation, the work locations of all household members are known. Dwellings that would result in a commute of more than 200 minutes for any worker in a household are given a utility of zero. It was confirmed with the survey that the average travel time per worker is almost identical (within 3 percent) for single-worker households and multiple-worker households, which allows application of the same trip length frequency distribution probabilities for all households. The left map in Figure 4 shows an example of a work location in North Bethesda, Maryland (turquoise dot). The trip length frequency distribution in minutes is used to estimate the utility in terms of commute distance for every zone (shown in brown-to-yellow colors).

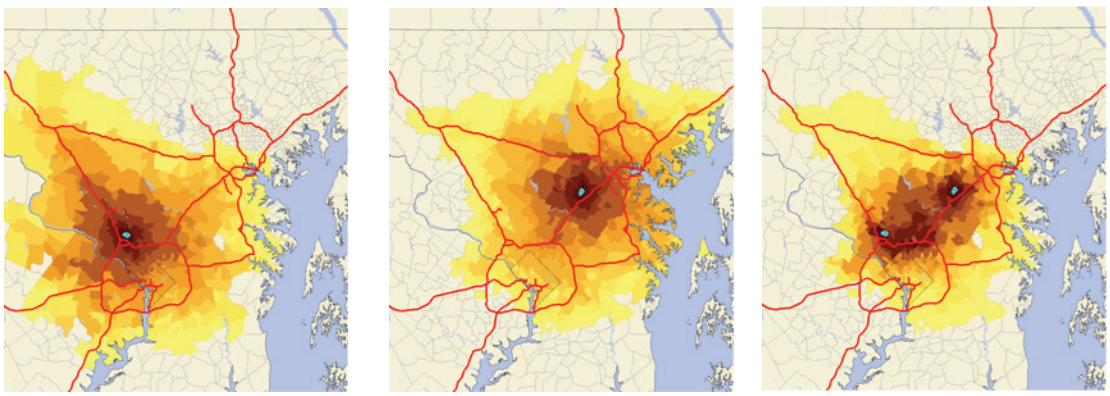

Figure 4: Likely housing locations for a household with workers in North Bethesda (left), Columbia (center), and both work locations (right)

The map in the center shows the home location probability for a person working in Columbia, Maryland. If these two persons lived in the same household, their joint area within a reasonable distance to their work locations is shown in the map on the right side of Figure 4. SILO explicitly represents this constraint when searching for a new housing location. The average commute trip length frequency in minutes shown in Figure 3 with a dotted line is scaled to values between 0 and 1 and applied as the commute distance utility.

Unfortunately, telework is not represented explicitly in SILO at this point. An employee working from home a few days per week is likely to be less constrained by the location of her or his employer and willing to accept longer commute travel times for the few days this person is actually commuting to work. It is planned to enhance the model to allow certain occupation types to telecommute, and thereby, offset some of their travel time budget.

Another shortcoming worth mentioning is that the constant travel time budget seems only to be reasonable with conventional modes of transportation. Should driverless cars become widely available, the value of time is expected to change substantially (Cyganski, Fraedrich, and Lenz 2015). Traveling in driverless cars may lessen the burden of commuting and thereby reduce this constraint in housing location in the future.

4.3 Household budget constraint

Another constraint explicitly reflected in SILO covers household expenditures. According to the Consumer Expenditure Survey[3] of the Bureau of Labor Statistics, households spent an average of 18.2 per-

[3] Data available online at http://www.bls.gov/cex/home.htm

cent of their after-tax income on transportation (fixed and variable costs) in 2000. Low-income households spent as much as 36.1 percent of their after-tax income on transportation. If transportation costs rise, these households will need to shift some expenses. While affluent households will simply reduce savings or discretionary spending to cover increased transportation costs, low-income households may struggle to cover substantially higher transportation costs. A household searching for a new home will at least roughly estimate transportation costs and consider carefully if transportation costs at a given home location are within the budget. A low-income household may decide to locate closer to the work location or choose a transit-friendly environment that may allow reducing the number of cars owned by the household.

Figure 5 compares average household income with average expenditures. The plot shows data for SILO's base year 2000, and data for 2005 and 2010 were analyzed and displayed very similar patterns. Interestingly, households in income categories with an annual after-tax income below $41,500 spent, on average, more money than they earned. According to the Bureau of Labor Statistics, such households draw on savings or borrow money. Students may get by on loans, and retirees may rely on savings[4]. As SILO does not trace debts, a household may temporarily accumulate; it simply acknowledges that households have access to money to cover their expenses. For example, a household with an after-tax income of $7,192 (left-most point in Figure 5) is assumed to have access to $15,703 to spend.

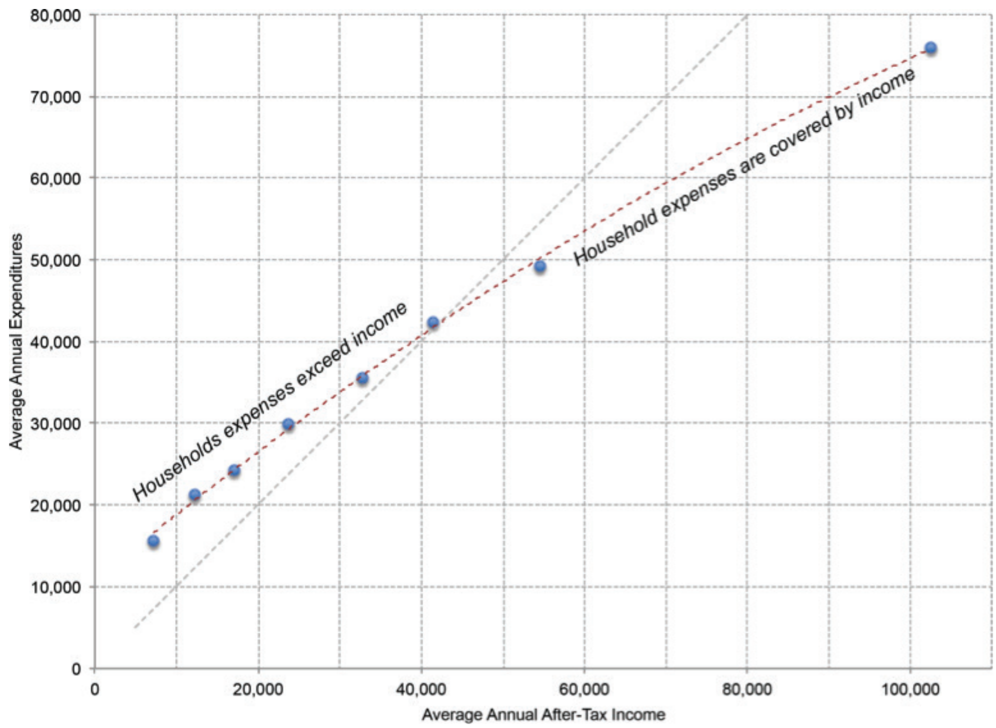

Figure 5: Household income and expenditures
Source: Consumer Expenditure Survey, BLS

A polynominal curve has been estimated to reflect the relationship between income and expenditures (shown with a red dashed line in Figure 5). For household incomes greater than $41,499 (whose income exceeds expenditures), the entire income is assumed to be available for expenditures, even though the average household at that income level saves some money.

4 For a more detailed discussion of this phenomenon compare http://www.bls.gov/cex/csxfaqs.htm#q21

$$e_h = \max\left[inc, \left(\alpha \cdot inc_h^2 + \beta \cdot inc_h + \gamma\right)\right] \quad (3)$$

where:

e_h	Budget available for expenditures of household *h*
inc_h	Income of household *h*
α, β, γ	Parameters, estimated to α = -2E-6, β = 0.8229 and γ = 10,794 [note that parameter names α, β and γ are reused in several equations even though they relate to different parameter sets]

Due to the parameter γ, the available money for expenditures can never drop below $10,794, even if the household income is reported as 0. According to the Consumer Expenditure Survey, expenses for gasoline and motor oil make up between 2.6 percent (for high income) and 3.9 percent (for low income) of all household expenses. Though this may not seem high, an increase of travel costs may become a serious burden for low-income households. Litman (2013) suggested that fuel price elasticity is between -0.1 and -0.2 for short-run and between -0.2 and -0.3 for medium-run adjustments. Short-run adjustments include choosing different trip destinations and switching the mode, while long-run adjustments (which typically apply after one to two years) include the purchase of more fuel-efficient vehicles and selecting more accessible home and job locations. Because a household move is part of a medium- to long-run adjustment, the higher elasticity with an average of -0.25 was chosen in SILO; should gas prices increase by 10 percent, travel demand is expected to decline by 2.5 percent. Transportation costs *tc* are calculated based on auto-operating costs (set to 8.1 cents per mile in the base scenario), the distance to work, and transportation required for other purposes such as shopping, dropping off children at childcare, doctor visits, etc. For a scenario that analyzes the impact of higher fuel costs, the adjusted transportation expenditures are calculated by:

$$et_h = tc_s\left(1 + \frac{tc_s - tc_r}{tc_r} \cdot el\right) \quad (4)$$

where:

et_h	Expenditures of household *h* for transportation
tc	Transportation costs (*r* for reference case and *s* for alternative scenario)
el	Elasticity of travel demand on transportation costs, set to -0.25

Currently, the elasticity is held constant, even though it is commonly assumed that elasticities rise as fuel prices increase. However, no data were readily available to quantify this relationship. Depending on future improvements in vehicle technology, the price per mile might drop, though increasing energy prices may offset technological advances. Currently, transportation costs per mile are kept unchanged from 2000 to 2040.

Costs for transit are not considered at this point, but auto travel costs are used as a proxy for the costs transit riders would face. This simplification is used for two reasons. First, the MSTM does not provide reliable transit fare values. In the future, general transit feed specification (GTFS) data are planned to replace existing transit networks, which is expected to overcome this shortcoming. Secondly, SILO does not know which mode of transport is going to be used by each traveler in the MSTM. While assumptions for zero-car households are easy (most of them will use transit), modal predictions for other households are difficult. However, given that transit fares are considered to be comparatively high in this region, the auto operating costs appear to be a reasonable proxy for transportation costs even for transit riders.

In addition to adjusting travel behavior and locations, many households will need to rebalance

[5] Assumed data points for income/discretionary spending: [$0/$100; $20,000/$1000; $40,000/$2200; $100,000/$10,000; $150,000/$20,000]

expenditures if transportation costs rise. Figure 6 shows the relative size of various expenditure types. The total expenditure is identical to the expenditure line shown in Figure 5, and the shares of various expenditure categories were also estimated by polynominal functions using observations of the Consumer Expenditures Survey. A certain share of "other expenditures" is assumed to be discretionary (such as going out for dinner, going to the movie theater, vacationing, etc.) and could be used to offset increased transportation costs. No data were available to quantify discretionary spending, and a few data points[5] were assumed to estimate a smooth curve for the discretionary spending shown in Figure 6.

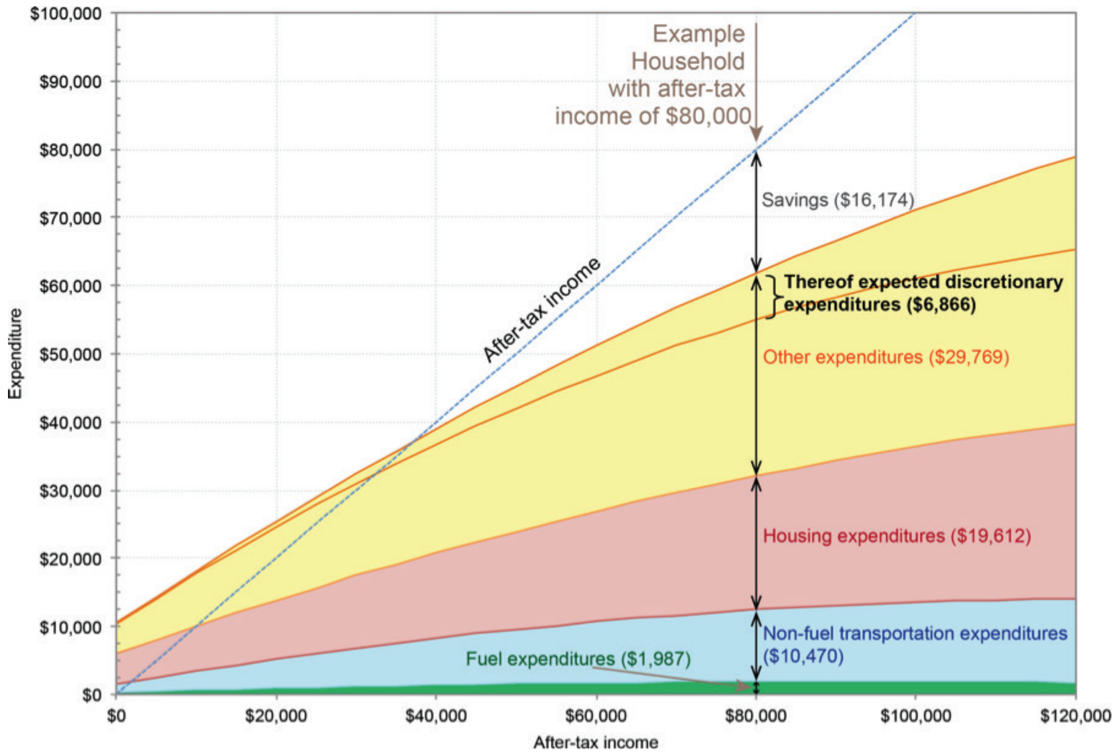

Figure 6: Share of expenditure types by household income

Source: Consumer Expenditure Survey, BLS

A binomial logit model (equation 5) is used to calculate the utility for transportation costs. If the discretionary income and savings are insufficient to cover the transportation costs of a given dwelling, the utility for transportation costs at this dwelling is set to 0.

$$\text{if } (e_{dis,h} + s_h < \text{tc}): \quad util_{tb_d} = 0 \tag{5}$$

$$\text{if } (e_{dis,h} + s_h < \text{tc}): \quad util_{tb_d} = \frac{1}{1+\exp\left(\beta \cdot \frac{e_{dis,h}+s_h}{tc}\right)}$$

where:

$util_{tbd}$ Utility of dwelling d for transportations budget tb

β Parameters describing sensitivity of increased transportation costs

$e_{\text{dis,h}}$ Discretionary expenditures of household *h*

s_h Savings of household *h*

For high-income households, this utility will always be close to 1, as an increase in transportation costs is insignificant for these households. Households with a lower income, however, will find a lower utility if transportation costs at a given dwelling are high. Should transportation costs exceed the discretionary income plus savings, the utility for the dwelling will be set to 0, which prevents this household from moving into this dwelling.

4.4 Desirable location factors

In addition to housing costs, commute travel times, and transportation costs (described in Sections 4.1 to 4.3), a number of further location attributes are included that are deemed to be desirable but nonessential. Such location factors include the size and the quality of the dwelling, the accessibility to population and employment by auto and transit, low crime rates, and the quality of schools in the school district of a dwelling. While these location factors are desirable, one strong attribute may compensate for another weak attribute. For example, a house in the suburbs may be weak in terms of accessibility but strong in terms of size. In contrast, urban apartments tend to be weaker in size, but provide excellent accessibilities. A strong attribute may offset a weak attribute, depending on the household preferences. Those location factors are combined by weighted addition.

$$util_{desFac_d}=\alpha\cdot u_{size_d}+\beta\cdot u_{quality_d}+\gamma\cdot u_{autoAcc_d}+\delta\cdot u_{transitAcc_d}+\varepsilon\cdot u_{schoolQual_d}+(1-\alpha-\beta-\gamma-\delta-\varepsilon)\cdot util_{crimeIndex_d} \quad (6)$$

where:

$util_{desFac_d}$ Utility of desirable (but nonessential) factors for dwelling d

$\alpha, \beta, \gamma\ldots$ Parameters, set differently by household types

u_{factor_d} Utility of attribute of dwelling *d* (currently implemented: size, quality, auto accessibility, transit accessibility, school quality, and county-level crime index)

5 Sensitivity testing and model validation

Validating land-use models tends to be more challenging than validating transportation models. While counts are generally perceived as sufficiently accurate to validate transportation models, no comparable dataset exists for land-use models. Two approaches were applied to validate SILO. First, sensitivity tests were conducted in which single parameters were modified and the changed model results were analyzed for reasonability. This is not considered to be a true validation in the traditional sense of comparing observed with modeled data, but it is rather a reasonability check. Such sensitivity tests have been completed for many variables, including parameters to calculate housing utilities, marriage and divorce probabilities, probability to leave the parental household, birth probabilities, initial housing vacancy rates, in-migration and out-migration assumptions, land capacity for future development, accessibility parameters, and auto-operating costs. Changes in model results were small and moved in the expected direction of change.

Secondly, rather than starting the model in a current base year, "back-casting" from 2000 to 2012 was applied. Figure 7 shows a scatter plot that compares observed and modeled number of households by county ($R^2 = 0.991$, RMSE = 10,107, Percent RMSE = 12.6). Modeled population numbers are the result of simulating 12 years in one-year increments, and observed population was collected from the five-year population estimate of the American Community Survey (ACS). Several counties in Maryland are slightly overestimated by the model, while Fairfax County (including Fairfax City and Falls Church City) falls short by 10 percent. This deviation along the state line is largely due to the fact that Maryland and Virginia have different methodologies of accounting for redevelopment opportunities (including greenfield development and infill development). Maryland traditionally has promoted denser development and has provided higher development capacity numbers than Virginia. Hence, the model expects more opportunities for growth in Maryland than in Virginia. It is investigated currently whether development capacities can be calculated by a unique method for the entire study area.

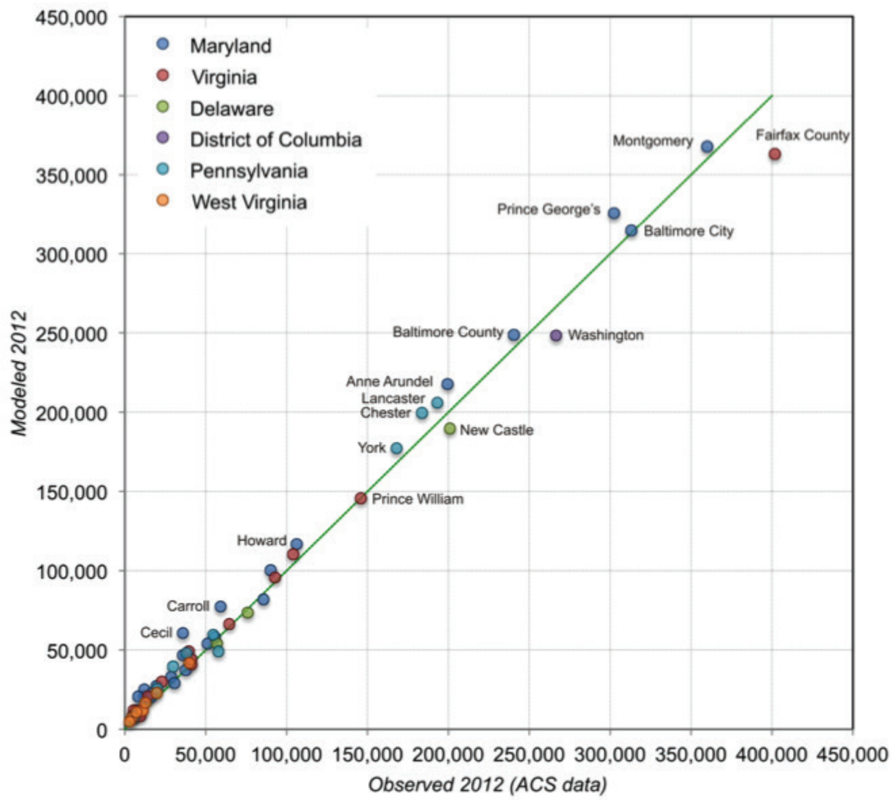

Figure 7: Validation of SILO results against 2012 ACS population data by county

SILO results were also compared at the zonal level against 2012 data from transportation models for Baltimore, Washington, DC, and Delaware. At this zonal level, an RMSE of 1123 and a Percent RMSE of 9 were found. The provenance of their zonal data is unknown, which is why this comparison does not count as validation but only as another reasonability check.

6 Conclusions

Many land-use models focus on representing utility maximization, finding equilibriums, and optimally allocating limited resources. The famous Lowry model was built to reach an equilibrium between location of work places and location of households every simulation period (Lowry 1964). Similarly, most models using Alonso's bid-rent approach (Alonso 1964) assume an immediate equilibrium between land prices and demand for land. Dynamic urban models, in contrast, explicitly represent time delay and limited information that lead to imperfect equilibriums (Harris and Wilson 1978; Wegener 1986). While bid-rent models are assumed to better represent land prices, discrete choice models often are expected to more realistically represent delays as they happen in reality. For example, newly demanded housing is not available to move into right away, as planning, obtaining building permits, and construction may take more than a year from when the demand is realized to when the first household may move in.

Wegener (2014, p. 753-755) identified three principal challenges for land-use modeling: represent environmental impacts, decline rather than growth, and the impacts of the future energy crises. Testing policies that address environmental impacts, such as carbon taxes, road pricing, or energy-efficient buildings have an immediate impact on household budgets. Planning for decline requires reallocating limited resources, including closing of schools or redevelopment of brownfield sites. A future energy crisis may limit the availability of fossil fuels for transportation or heating and cooling, with an immediate impact on household mobility and budgets. If these challenges hold true, representing constraints will become even more important. If models miss representing changes in travel behavior and location choice under increasing transportation costs, model results will be less realistic and difficult to defend. If congestion worsens and people spend more time traveling, models that miss adjusting destination choice, mode choice, and trip chaining will produce unlikely results. Representing constraints rather than the entire map of opportunities will become more important in a scarce energy future.

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WHAT'S AT STAKE?

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MASSPIRG Education Fund

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EXECUTIVE SUMMARY

Imagine two futures for the transportation system of the Commonwealth of Massachusetts.

In one, the air is cleaner. It is more convenient to use an improved public transit system and to drive less, so most households only own one car. There are fewer traffic jams because fewer people travel via automobile. There are more sidewalks and bike lanes, so many people walk or bike to their jobs, schools, and other destinations. People feel a little richer with extra money in their pocket, due to less spending on gasoline, parking, and auto maintenance. Bay Staters are healthier as a result of reduced pollution and increased physical activity.

In the second future, imagine the opposite trends. More cars are on the road, increasing traffic congestion, pollution, and emissions that cause global warming. Public transit is less convenient and less available because it is often broken down and hasn't expanded with the economy. Walking and bicycling infrastructure remains unimproved. More collisions result in more deaths and injuries. We spend more filling up our tanks and repairing our vehicles more frequently, and the state spends more to repair the increased wear on roads. Bay Staters have less money, less time, and are less healthy.

The benefits of reduced driving are sometimes difficult to see, but hugely important. Many dramatic gains remain unrecognized because they are indirect, gradual, or result from avoided collisions and health problems that people don't expect will happen to them in the first place. In our daily lives, it is difficult to assess the value of reduced costs that would have been borne by others or consequences that didn't occur.

To make these benefits clear, this report quantifies the gains that would be enjoyed by the Commonwealth and its residents resulting from a one percentage point reduction in the growth rate of driving. Starting with the state's official driving forecasts, a one percentage point reduction in the growth rate of driving from 2015 to 2030 would bring major economic, environmental, and public health benefits, with annual savings increasing each successive year.

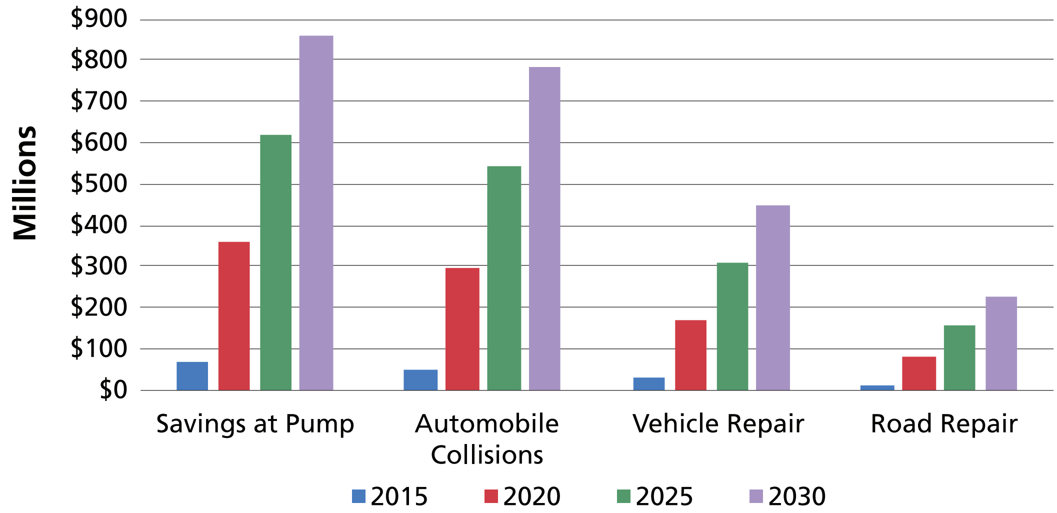
By 2030, the combined savings would reach $2.3 billion annually, consisting of:

- $857 million less spent at the pump
- $785 million less spent on fewer automobile collisions and resulting consequences
- $446 million less spent on vehicle repair
- $224 million less spent on road repair

Figure ES-1 illustrates these annual benefits and how they grow over time.

Tallying up the benefits that would result over the course of the next 15 years, the combined economic savings resulting from a one percentage point reduction in the

Figure ES-1: Annual Economic Savings, 2015-2030



The combined economic savings resulting from a one percentage point reduction in the driving growth rate are estimated to reach $20.1 billion.

driving growth rate below official forecasts are estimated to reach $20.1 billion, consisting of:

- $7.7 billion less spent at the pump
- $6.7 billion less spent on fewer automobile collisions and resulting consequences
- $3.8 billion less spent on vehicle repair
- $1.9 billion less spent on road repair

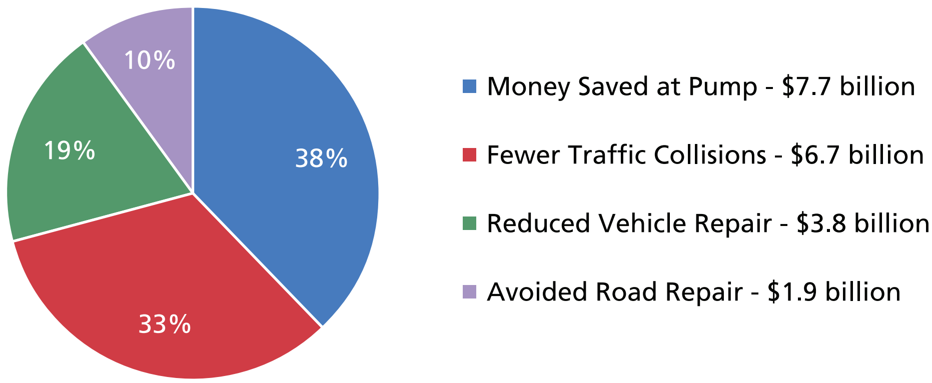
To put these sums in context, the total economic savings of a one percentage point reduction in the VMT growth rate from 2015 to 2030 is enough to provide any one of the following:

- Groceries for 180,455 American households for the entire period;[1] or
- Daycare costs for 81,558 Massachusetts infants in daycare fulltime for the period;[2] or
- Mortgage payments for 92,746 average Massachusetts households for the period.[3]

Figure ES-2 demonstrates where the savings come from. The greatest economic savings are expected to result from avoided gasoline expenses, followed by savings resulting from fewer automobile collisions, reduced vehicle repair costs, and avoided road repairs costs.

A one percentage point reduction in the vehicle-miles traveled (VMT) growth rate would also result in 267.6 million fewer gallons of gas consumed annually by 2030, and 2.6 billion fewer gallons of gas consumed cumulatively over the course of the next 15 years. This is the equivalent of every household in Massachusetts saving nearly a thousand gallons of gasoline over the period.[4]

Figure ES-2: Economic Savings from a One Percentage Point Reduction in the Driving Growth Rate, 2015-2030



All values represent billions of dollars in savings for a 1 percent decrease in the growth rate of vehicle-miles traveled compared to official Massachusetts Department of Transportation forecasts.

This reduction in gasoline consumption would prevent an estimated 2.4 million metric tons of carbon dioxide from being released into the atmosphere annually by 2030, and an estimated 23.3 million metric tons of carbon dioxide cumulatively from being emitted from 2015 to 2030. According to the U.S. Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator, the annual carbon emissions savings by 2030 would be equivalent to taking more than 500,000 cars off the road that year. [5]

The carbon savings are especially important because the transportation sector has been the biggest and fastest growing source of carbon-related emissions in Massachusetts in recent decades.[6] Addressing transportation sector emissions by reducing the number of driving miles will significantly improve our ability to meet the Commonwealth's commitment to curb global warming, as set forth by the Massachusetts Global Warming Solutions Act of 2008.

Furthermore, there are significant public health benefits from reduced driving miles.

The criteria for selecting which transportation projects receive priority for state investment should be revised to prominently consider the reduction of VMT, to give greater weight to public health and environmental factors, and toensure that the most useful projects receive priority, regardless of the mode of transportation the project utilizes.

Burning less gasoline reduces the amount of pollution released into the atmosphere. Air particulate matter associated with the transportation sector has been linked to nearly 53,000 premature deaths a year in the United States, according to a recent study conducted by the Massachusetts Institute of Technology.[7] As individuals drive less, studies also find they are more physically active and less likely to be obese, or suffer from other chronic illnesses linked to physical inactivity, such as cancer, diabetes, and heart disease.[8] The good news is that increased walking, bicycling, and use of public transportation can help offset these risks.

The State has adopted a goal of tripling the number of public transit, walking, and bicycling trips by 2030. State and local transportation decisions should be oriented around attaining this goal and enabling reduced driving more generally. The criteria for selecting which transportation projects receive priority for state investment should be revised to prominently consider the reduction of VMT, to give greater weight to public health and environmental factors, and to ensure that the most useful projects receive priority, regardless of the mode of transportation the project utilizes.

While it has long been a transportation holy grail to accurately measure the VMT impacts of certain transportation choices, that does not mean it is not a worthwhile endeavor. Capturing the benefits of reduced driving between now and 2030 will require resources and new state and local policies and incentives to enable Bay State residents to drive less and take advantage of other forms of transportation more. Finally, the state should regularly publicly disclose its progress in meeting these goals.

Now, more than ever, it is imperative that we introduce policies that reduce driving miles, as total vehicle miles have drifted upwards recently, after years of decline. This report shows that even a modest reduction in driving miles will deliver large benefits to the economy, the environment, and public health.

A great deal is at stake.

INTRODUCTION

Transportation connects people and places. The transportation choices we make today profoundly shape our quality of life in Massachusetts for decades to come. This is why the Commonwealth has made a commitment to triple the portion of miles people travel by walking, bicycling, and riding public transit by 2030.[9] An improved transportation system will enable Bay State residents to drive fewer miles, but just how significant are the benefits?

This report measures the future improvements to our quality of life in Massachusetts from even a small downward shift in driving trends.

The benefits to Bay Staters from reduced driving have been substantial, but often unrecognized because they represent costs that were *not* incurred. People feel the negative effects from auto crashes and the cost of fueling up on their weekly budget, but notice less when costs are avoided, when costs are borne by others, or when costs take the form of invisible emissions or crashes we think didn't anticipate harm from in the first place.

Recent national and Massachusetts increases in per-capita driving the last few years make clear that the reductions in driving that had occurred since 2005 are not inevitable if smart policies and investments are not pursued.

Many in the Bay State want the ability to choose not to drive, and to live in places where they can walk, bike, or ride public transportation to jobs, recreation, and to run errands. Individuals and businesses seek to reside in places like Massachusetts partly because the Commonwealth provides these options. With greater investments in our transportation system, the Commonwealth will continue to experience dividends, as the brightest minds and most innovative companies will increasingly view Massachusetts as a favorable place to be located.

This report measures the future improvements to our quality of life in Massachusetts from even a small downward shift in driving trends. For a one percentage point of driving below present forecasts, the report measures the expected benefits in terms of reduction in gallons of gas consumed, savings at the pump, fewer auto collisions, reduced road maintenance, and millions of metric tons of avoided CO_2.

THE BENEFITS OF REDUCED DRIVING

There are numerous benefits to achieving reductions in driving. Some are obvious to consumers, such as fewer trips to the pump, but most benefits are not as easy to see. For example, driving fewer miles means:

- Fewer automobile collisions, which not only saves lives and prevents injuries, but also avoids substantial economic costs and lost worker productivity;
- Less gasoline consumed, which saves money at the pump, limits air pollution, and reduces emissions of pollutants that cause global warming; and
- State and municipal governments spend less money repairing roads and bridges.

Since the benefits of fewer driving miles mainly represent costly or damaging outcomes that did *not* happen, they are less readily recognized. Measuring each benefit of reduced driving separately helps demonstrate its full impact.

FEWER GLOBAL WARMING EMISSIONS

Transportation in Massachusetts generates 38 to 48 percent of total carbon dioxide emissions statewide, depending on the measure.

The U.S. Energy Information Administration estimates that 19.64 pounds of CO_2 are released into the atmosphere for every gallon of standard non-ethanol based gasoline burned, and about 22.38 pounds of CO_2 are released for every gallon of diesel fuel burned.[10] The combustion of fossil fuels such as gasoline and diesel to transport people and goods is the second largest source of CO_2 emissions nationwide, accounting for about 27 percent of the United States' total CO_2 emissions in 2013.[11] In Massachusetts, the share of CO_2 emissions from transportation is even higher. The latest available data from the Energy Information Administration show that in Massachusetts, CO_2 emissions totaled 59 million metric tons in 2012, with 28.1 million metric tons coming from the transportation sector—nearly 48 percent.[12]

It is important not to underestimate the role that reducing VMT plays in combating global warming. While there is a tendency to think about global warming chiefly through the lens of the energy sector, or to think of reductions in the burning of petroleum as resulting chiefly from cleaner fuels or more fuel-efficient automobiles, reducing VMT can be centrally important to curbing greenhouse emissions. A study by the President's Council of Economic Advisors recently examined how official projections of petroleum consumption from 1970 out to 2030 have been so much lower than originally anticipated. They found changes in the transportation sector accounted for 80 to 90 percent of the total reduction in anticipated petroleum consumption.[13] Within the transportation sector, reducing VMT accounted for 75 percent of the total shift - three times more than the benefits of improved vehicle fuel efficiency, making reducing VMT the single most important factor in declining petroleum usage.[14]

Taking an active role in reducing greenhouse gas emissions from its residents, the state of Massachusetts passed legislation in 2008, adopting a plan to reduce statewide greenhouse gas emissions to 80 percent less than 1990 levels by 2050.[15] Achieving this goal and intermediary benchmarks will require bold action in every sector, especially transportation.

LESS AIR POLLUTION AND FEWER DEATHS FROM POLLUTION

Air pollution from road transportation in the U.S. causes about 53,000 premature deaths a year.

Air pollution and related deaths are another significant cost associated with driving. As cars burn gasoline, potentially dangerous emissions are released into the atmosphere and ultimately inhaled into our lungs.

Researchers from Massachusetts Institute of Technology's Laboratory for Aviation and the Environment have recently released sobering data on air pollution's impact on Americans' health. The study tracked ground-level emissions from sources such as industrial facilities, vehicle tailpipes, marine and rail operations, and commercial and residential heating throughout the United States. They found that such air pollution causes nearly 200,000 early deaths each year. According to the study, emissions from road transportation are the most significant contributor, causing nearly 53,000 premature deaths each year.[16]

FEWER AUTOMOBILE-RELATED DEATHS

Each year, four times more people are killed in auto crashes than the death tolls of U.S. soldiers in the entire Afghanistan and Iraq wars combined.

According to the National Highway Traffic Safety Administration, at least 32,719 people were killed in the United States in automobile related crashes in 2013 alone.[17] In the same year, a Massachusetts resident was killed on the road almost every day, a total of 326 deaths for the year.[18]

Further, a recent study conducted by the Task Force for Child Survival and Development, found that on average, for every road traffic death, there are four cases of "severe, permanent disabilities, typically to the brain, spinal cord or lower limb joints; 10 cases requiring hospital admission and 30 requiring treatment in an ER."[19]

The number of deaths each year on our roads is so high that it is hard to believe the sum is considered "normal." If the carnage occurred from a disaster or attacks from external enemies, the nation would stop to grieve in disbelief over the loss. The annual death toll on the roads is nearly equivalent to the total number of United States combat deaths in the entire Korean War (1950-1953),[20] and is more than half of the total American deaths in the two decades-long Vietnam War (1955-1975).[21] The annual body count is more than four times the total death of United States soldiers in the entire Afghanistan and Iraq wars combined – *and this occurs each year*.

FEWER AUTOMOBILE-RELATED INJURIES

On average, roughly 106 Massachusetts residents are injured in automobile crashes each day.

Reduced fatalities are only a part of the health benefits from reduced driving. According to collision data from National Highway Traffic Safety Administration, there were nearly 5.7 million police reported automobile collisions in the United States in 2013, 1.6 million of which resulted in injuries to some 2.3 million people on public roadways.[22]

While 2.3 million injuries on public roadways is staggering, it is far from a full representation of the number of crash-related injuries. The Congressionally-chartered National Safety Council estimates that when factoring in injuries occurring during crashes on private roadways such as parking lots and driveways, the number of total annual injuries for 2013 was actually closer to 3.8 million in the United States. In other words, in a single year, on average across the United States, one in every 83 residents experiences an injury from an auto collision.[23]

The most recent injury data available for Massachusetts dates back to 2012. That

Other Modes of Transportation Are Comparatively Safer Than Driving

Driving an automobile is far more dangerous than other modes of travel. Research by Todd Litman in the *Journal of Public Transportation* in 2014 examined data on automobile fatalities in the United States, and found that riding a bus is about 60 times safer than driving per mile traveled. Similarly, riding various forms of intercity rail, light rail, or commuter rail is around 20 to 30 times safer than driving per mile traveled.

year, 38,799 people were injured in automobile related incidents, and 4,384 of those resulted in injuries requiring hospitalization.[24] These statistics boil down to approximately 106 injuries each day, 12 of which require hospitalization.[25]

Estimates show that the total cost of auto-related fatalities, injuries, and property damage that occurred in 2013 (factoring in medical expenses, employer costs, lost wages, property damage, and related expenses), tallies up to a whopping $267.5 billion nationally.[26] On an individual level, this adds up to approximately $2,184 per household in the United States each year.[27] As we can see, reductions in VMT, translate into huge savings for Americans every year through avoided collisions.

LESS PROPERTY DAMAGE FROM COLLISIONS

Property damage from auto collisions costs about $240 per person annually in the United States, and drivers in Boston, Worchester, and Springfield file claims at especially high rates.

Reducing VMT decreases the overall number of collisions, and therefore reduces resulting property damage. According to the National Highway Traffic Safety Administration, roughly four million automobile collisions in the United States in 2013 resulted *only* in property damage.[28] Based on an extrapolation of National Highway Traffic Safety Administration's analysis, these collisions [29] resulted in an estimated cost of $73.3 billion in 2013, or approximately $230 per person living in the United States.[30]

Massachusetts is notorious for being a place where drivers get into collisions. This is not just folklore of people complaining about infamous "Boston drivers" or "Massholes" on the road. Allstate Insurance's study of auto insurance claims in 200 major cities found Boston to be the worst in the country, followed by Worchester, with Springfield as the fifth worst in the nation, measured by frequency of claims for collision damage.[31] Boston drivers are about two and a half times as likely to file a claim from a collision than the average American driver.

MONEY SAVED AT THE PUMP

Federal Highway Data Show Massachusetts drivers consumed approximately 2.4 billion gallons of gas in 2014, at an estimated cost of $8.6 billion.

While it may seem obvious, one of the single biggest benefits from reduced driving is the resulting reduction in the total cost of gasoline consumed each year. Purchasing gas costs consumers and businesses thousands of dollars annually.[32] According to the Energy Information Administration, Americans consumed 136.8 billion gallons of gasoline nationwide in 2014.[33] In Massachusetts in 2012, 2.6 billion gallons were consumed at an estimated cost of $9.6 billion.[34] Meaning, that on average, each registered Massachusetts driver consumed an estimated 10.6 gallons of gasoline per week, at an average cost of $39.30.[35]

A major benefit of not consuming all of this gas is that it is less costly for household budgets. The price of gas fluctuates, but it has remained well above the levels that were typical during the 1990s or the early part of the 2000s. From 2006 to 2014, gasoline cost consumers in Massachusetts a total of approximately $74 billion, representing a massive transfer of wealth out of the hands of local consumers and businesses, and into the hands of big oil companies.[36]

REDUCED VEHICLE REPAIR COSTS

The American Automobile Association estimates that, on average, Americans spend over 5 cents per mile on vehicle maintenance.

More driving also leads to additional wear and tear on vehicles. Owning and operating a vehicle is expensive. In 2015, the American Automobile Association estimated that vehicle repair costs the average family as much as $767 a year, or an average of 5.11 cents per mile.[37]

To put the per-mile cost of repairs in perspective, data from the Massachusetts Department of Transportation projects total VMT in the Commonwealth to reach 57.3 billion miles in 2015. Thus, at the national average of approximately 5.11 cents of repairs for each mile driven, Massachusetts drivers will spend roughly $2.9 billion in 2015 on vehicle repair cost alone.[38]

REDUCED ROAD REPAIR

The Commonwealth of Massachusetts spent more than $240 million annually on road repair between 2009 and 2011.

As anyone who has hit a pothole could guess, as people drive more, they do more damage to the roads. More driving means worse roads, and ultimately makes more repair necessary. The more road repair, the higher the cost of maintaining roads.

Repairing our roads is a major expense for state government. A report by Smart Growth America found that in 2011, states would have needed to collectively spend $45.2 billion to bring roads rated in "poor" condition to a state of good repair, while also maintaining their existing systems.[39] This figure is roughly three times the amount that states actually spent repairing and maintaining the road system.

In fact, on a scale of "good," "fair," or "poor," 13 percent of Massachusetts's roads were in "poor" condition in 2011, while only 10 percent of roads were in "good" condition that year.[40] Meanwhile, according to the same report, the Commonwealth spent $241 million annually on average on road repair from 2009 to 2011.[41]

Wellness Benefits of Reduced Driving

Other benefits from reduced driving may be more difficult to quantify on a per-mile basis, but are just as important to the well-being of Massachusetts residents. Those who drive less have lower rates of obesity, and decreased risk of cancer, diabetes, and heart disease.

Reduced health care costs

Weight and physical inactivity related health issues in the United States account for a large percentage of heath care spending each year. Each year, $117 billion, or 11.1 percent of health care costs, are spent treating illnesses associated with inadequate levels of physical activity.[42] When inadequate physical activity is taken to the extreme, that price tag gets even bigger. Obesity in the United States costs an estimated $190.2 billion a year, or nearly 21 percent of annual medical spending in the United States.[43] Childhood obesity alone is responsible for $14.1 billion in direct medical costs.[44]

In a study of 187 American cities and their obesity rates, the direct costs connected with obesity and obesity-related diseases are roughly $500 per resident.[45] If the 10 most obese cities cut their obesity rates down to the 2009 national average (26.5 percent), the combined savings to their communities would be $500 million in health care costs each year.[46] If all 187 cities were able to decrease their obesity rates to 15 percent, it would save the United States roughly $32.6 billion in health care costs each year, calculating out to approximately $102 in savings per person each year.[47]

In considering these numbers, it is important to note that, at 23.6 percent, Massachusetts already has an obesity rate that is far below the national average, and is currently the third least obese state in the nation.[48] While there are a number of factors that contribute to this, the availability of active modes of transportation such as walking, bicycling, and public transit are, at least in part, responsible.[49] Past investments in creating walkable communities, bikeable neighborhoods, and the ready availability of public transit have paid dividends.

Reduced risk of obesity, cancer, diabetes, and heart disease

The average American commuter spends roughly 51.8 minutes a day commuting to and from work.[50] Whether or not people sit in their cars while commuting to work is a serious health concern.

Large amounts of time spent in cars contributes to the high levels of obesity found among Americans. Studies that compare VMT to obesity find a strong correlation among individuals.[51] More driving corresponds to sedentary lifestyles, rather than burning calories from walking or bicycling to a destination. For many people, the short regular walk to and from the bus stop can be their most regular exercise.

Recent studies also link cancer, diabetes, and heart disease to low levels of physical activity, due, in part, to time we spend physically inactive, traveling in automobiles. It is estimated that inadequate physical activity contributes to roughly 200,000 premature deaths in the U.S. each year.[52] The Surgeon General recently issued a call to action on walking and walkability to address the issue of physical inactivity in America. In a report backing the call to action, the Surgeon General states that 117 million Americans are living with chronic diseases, such as coronary heart disease, diabetes, and cancer.[53]

The report advocates physical activity as a way to reduce the risk of chronic disease, stating that engaging in physical activity for roughly 30 minutes per work day can reduce the risk of contracting a chronic disease by 30 percent.[54] The average American walking commute takes 23 minutes per day, and the average bicycling commutes lasts 38.6 minutes per day.[55] If more Americans could commute by walking, bicycling, or public transit, the risk of chronic disease would decrease substantially.

Improved mental health

Beyond the physical benefits that come from an active lifestyle, there are mental health benefits attributed with getting the appropriate amount of exercise. The Surgeon General's call to action states that "physical activity is associated with improved quality of life, emotional well-being, and positive mental health."[56] Further, a study has shown that long commutes in cars tend to lead to negative mental health outcomes, including poor sleep, anxiety, social isolation, and depression.[57] Finally, in the long term, studies that also show that physical activity may postpone cognitive decline in older adults.[58] If commuters could spend less time in their cars and more time commuting by foot, bike, or public transit, they could fulfill the recommended physical activity set forth by the Surgeon General and realize greater physical and mental health impacts.

QUANTIFYING A REDUCTION IN DRIVING

What follows uses Massachusetts Department of Transportation's official forecasts as a baseline, and then examines what a one percentage point reduction in the VMT growth rate would mean.

As the Commonwealth looks to the future, even relatively small reductions in the growth rate of driving volume will offer significant benefits to our economy, our environment, and our quality of life.

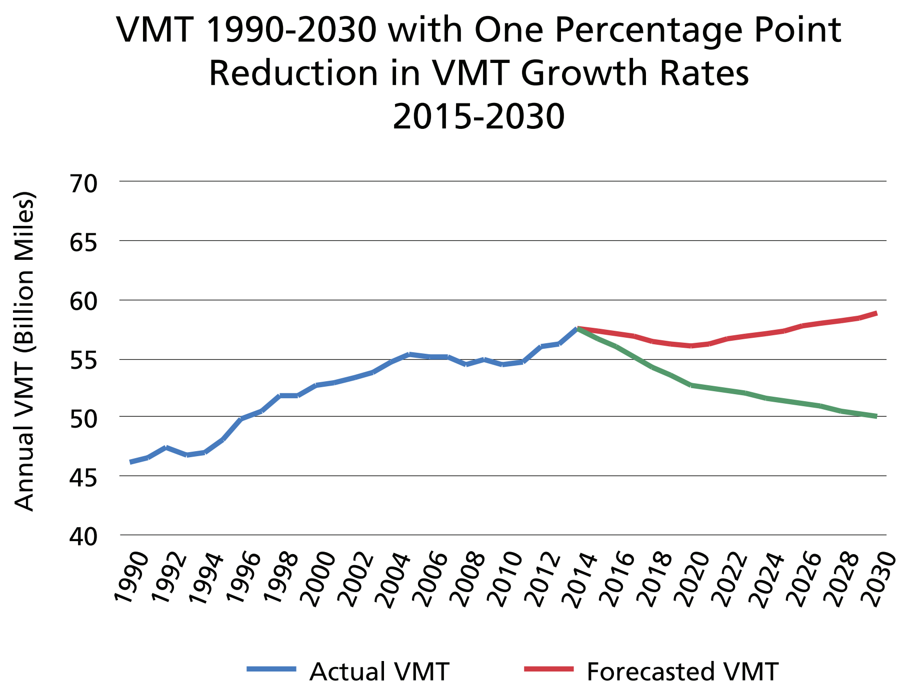
This section examines the expected result of a one percentage point reduction in the VMT growth rate below official forecasts by the Massachusetts Department of Transportation between 2015 and 2030. The Massachusetts Department of Transportation's projections of future driving demand reflect recent socio-economic data, surveys of trip making behavior, and actual traffic count data.

What follows uses Massachusetts Department of Transportation's official forecasts as a baseline, and then examines what a one percentage point reduction in the VMT growth rate would mean. For instance, whereas the Massachusetts Department of Transportation's baseline forecast is for a 0.43 percent reduction in VMT between 2015 and 2016, the one percentage point reduction scenario below forecast instead shows a reduction of 1.43 percent. Likewise, the Massachusetts Department of Transportation forecasts a 0.49 percent increase in VMT between 2020 and 2021, and the one percentage point reduction scenario shows a 0.51 percent reduction in VMT instead.

THE SIGNIFICANT IMPACT OF A 1% REDUCTION IN THE DRIVING GROWTH RATE

A single percentage point reduction in the growth rate of VMT would decrease VMT by 575.5 million miles in 2015, compared to the sum that the Massachusetts Department of Transportation forecast last year. By 2030, a one percentage point reduction below that forecast would result in 8.7 billion fewer miles traveled for that year. Cumulatively, a one percentage point reduction for the 2015-2030 time period would result in 74.5 billion fewer vehicle miles of driving during that span.

Figure 1: Comparing MassDOT Forecast of Future VMT in Massachusetts to a One Percentage Point Growth Reduction Below Forecast



A one-percent reduction would merely represent a return to levels of total VMT observed during the late 1990's.[59] The comparison between the current Massachusetts Department of Transportation forecast of future VMT and an alternative scenario with a one percentage point reduced growth rate is shown in Figure 1.

Table 1: Forecast VMT and Reduction in VMT from a One Percentage Point Reduction in VMT Growth Rate[60]

Year(s)	Forecasted VMT (Billions of Miles)	1 Percentage Point Reduction Scenario (Billions of Miles)	Change (Billion Miles)
2015	57.304	56.728	-0.576
2020	56.060	52.765	-3.295
2025	57.419	51.408	-6.011
2030	58.777	50.057	-8.720
2015-2030	915.636	841.112	-74.524

ENVIRONMENTAL BENEFIT — REDUCED CO_2 EMISSIONS

The combustion of each gallon of gasoline releases 19.64 pounds of CO_2 into the atmosphere.[61] Therefore, a one percentage point reduction in the VMT growth rate below the Massachusetts Department of Transportation's forecasts, when applied to the reduction in gasoline consumed, would result in 226.3 thousand metric tons of CO_2 not emitted in 2015, rising to 2.4 million metric tons in 2030, and 23.3 million metric tons for the period.

The U.S. Environmental Protection Agency provides some needed context. According to the agency's Greenhouse Gas Equivalencies Calculator 2015, estimated annual carbon emissions savings are equivalent to taking 47,653 cars off the road for one year.[62] Similarly, 2030 annual savings are equivalent to taking 501,958 cars of the road for one year.

ECONOMIC BENEFIT — REDUCED GASOLINE CONSUMPTION AND MONEY SAVED AT THE PUMP

As previously discussed, if driving decreases, we would expect similar reductions in the number of gallons of gasoline consumed and the costs of purchasing this gasoline. The rate at which reductions in driving decreases these outcomes depends on the fuel efficiency of cars and the cost of gasoline.[63]

Taking projections of both the fuel efficiency of cars and the cost of gasoline into account, in 2015, a one percentage point reduction in driving growth rate would result in the consumption of 25.4 million fewer gallons of gasoline. That amount of annual savings is calculated to increase steadily over the period. By 2030, we would expect to use 267.6 million fewer gallons than the amount based on currently forecast driving miles, while the total decrease in gas consumption for the period from 2015 to 2030 would equate to 2.6 billion gallons.

Table 2: Reduced CO_2 Emissions Associated with a One Percentage Point Reduction in the VMT Growth Rate

Year	Marginal Reduction in VMT with 1 Percentage Point Decrease in Driving Growth Rate (Billion Miles)	Gasoline Not Consumed (Billion Gallons)	CO2 Not Emitted (Million Metric Tons)
2015	-0.576	0.025	0.226
2020	-3.295	0.131	1.170
2025	-6.011	0.209	1.865
2030	-8.720	0.268	2.384
2015-2030	-74.524	2.612	23.272

Table 3: One Percentage Point Reduction in VMT Growth Rate and Associated Decreases in Gasoline Consumption and Money Spent at the Pump

Year(s)	Marginal Reduction in VMT with 1 Percentage Point Decrease in Driving Growth Rate (Billion Miles)	Resulting Decrease in Gas Consumption (Billion Gallons)	Resulting Decrease in Money Spent at the Pump (EIA Future Price Estimates)
2015	-0.576	0.025	$0.071
2020	-3.295	0.131	$0.360
2025	-6.011	0.209	$0.618
2030	-8.720	0.268	$0.856
2015-2030	-74.524	2.612	$7.698

Using less gasoline would result in big savings for consumers each year at the pump. A one percentage point reduction in driving growth below forecast in 2015 would mean consumers would save an additional $71.1 million on gasoline for the year. By 2030, Massachusetts consumers would save an additional $856.5 million, based on Energy Information Administration forecasts of likely per-gallon prices. For the period from 2015 to 2030 cumulatively, consumers would save an additional $7.7 billion.

To better understand the magnitude of these savings, it is helpful to think about them on a more personal scale. For instance, if the savings were distributed equally among every one of the 4.7 million drivers licensed in to drive in the Commonwealth as of 2012,[64] the savings would equate to roughly $1,628 per driver for the period.[65]

ECONOMIC BENEFIT — REDUCED AUTOMOBILE COLLISION COSTS

The National Safety Council, estimates the total cost of automobile collisions nationwide in 2013 at approximately nine cents per mile.[66] This includes the lifetime cost of medical expenses, employer costs, lost wages, and property damage from automobile collisions occurring in 2013.

Applying this per-mile cost to the decrease in VMT associated with a one percentage point reduction scenario shows decreased costs for 2015 to be $51.8 million, growing to $784.8 million in 2030, and cumulatively reaching $6.7 billion for the period from 2015-2030.

Table 4: Increased Massachusetts Savings on Automobile Related Collisions Associated with a One Percentage Point Reduction in VMT Growth Rate.

Year(s)	Marginal Reduction in VMT with 1 Percentage Point Decrease in Driving Growth Rate (Billion Miles)	Benefits Associated with Fewer Automobile Related Collisions (Billion $)
2015	-0.576	$0.052
2020	-3.295	$0.297
2025	-6.011	$0.541
2030	-8.720	$0.785
2015-2030	-74.524	$6.707

ECONOMIC BENEFIT — REDUCED AUTOMOBILE MAINTENANCE COSTS

In addition to the reduced cost of gasoline, automobile collisions and injuries, and state road repair, reduced driving also means reduced automobile repair for the average Massachusetts automobile owner. The Automobile Association of America found that the average cost of vehicle maintenance is 5.11 cents per mile.[67] Therefore, a one percentage point decrease in the VMT growth rate below the Massachusetts Department of Transportation's forecasts would result in $29.4 million saved on auto repair in 2015,[68] and would climb to $445.6 million in 2030,[69] with $3.81 billion in cumulative savings for the period from 2015-2030.[70]

Table 5: Benefits of Automobile Maintenance Associated with a One Percentage Point Reduction in the VMT Growth Rate in Massachusetts

Year(s)	Marginal Reduction in VMT with 1 Percentage Point Decrease in Driving Growth Rate (Billion Miles)	Benefits Associated with Decreased Auto Repair (Billion $)
2015	-0.576	$0.029
2020	-3.295	$0.168
2025	-6.011	$0.307
2030	-8.720	$0.446
2015-2030	-74.524	$3.808

ECONOMIC BENEFIT — REDUCED STATE ROAD REPAIR COSTS

For the benefits of reduced driving for state road repair in the Commonwealth, this report applies the 2.57 cents per mile estimate, derived from estimates of high and low traffic repair needs on roads by the Federal Highway Administration.[71] With a one percentage point reduction in the VMT growth rate below the Massachusetts Department of Transportation's forecasts, the additional savings to Massachusetts on state road repair would be $14.8 million in 2015,[72] rising to $224.1 million in 2030,[73] and a cumulative $1.9 billion for the period from 2015 to 2030.[74]

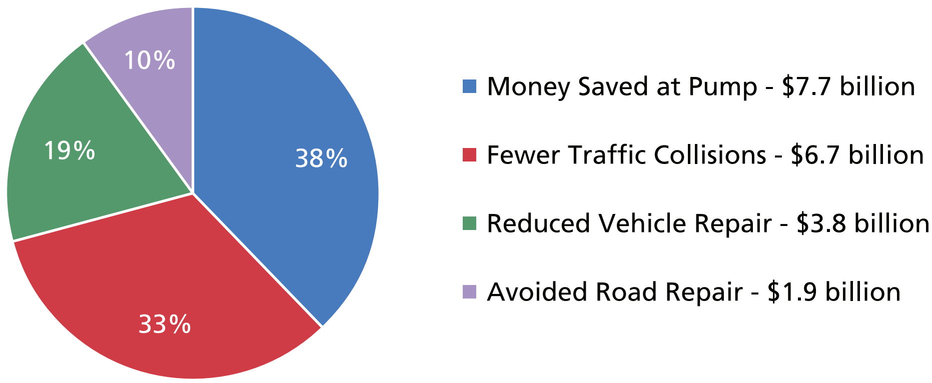
Table 6: Reduced Cost of State Road Repair Associated with a One Percentage Point Reduction in the VMT Growth Rate.

Year(s)	Marginal Reduction in VMT with 1 Percentage Point Decrease in Driving Growth Rate (Billion Miles)	Benefits Associated with Decreased State Road Repair (Billion $)
2015	-0.576	$0.015
2020	-3.295	$0.085
2025	-6.011	$0.154
2030	-8.720	$0.224
2015-2030	-74.524	$1.915

TOTAL COMBINED ECONOMIC BENEFITS

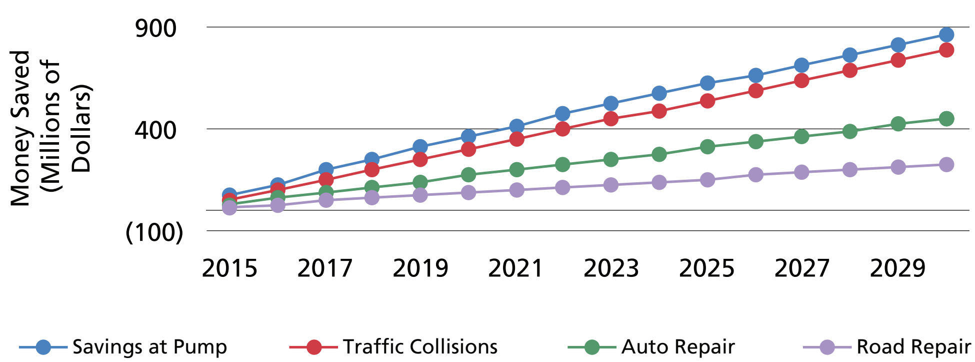
Factoring in the economic cost of gas consumption, automobile related collisions and injuries, automobile repair, and road repair, we can derive a total economic surplus of these driving related costs and externalities. Adding these figures together, we arrive at a combined total savings in 2015 of $167.1 million ($71.1 million in gas consumption $51.8 million in collisions, $29.4 million in auto repair, and $14.8 million in road repair). In 2030, the combined economic cost equates to $2.3 billion ($856.5 million in gas consumption, $784.8 million from automobile collisions, $445.6 million from auto repair, and $224.1 million from road repair). For the period from 2015-2030, cumulative economic savings equates to $20.1 billion ($7.7 billion in gas consumption, $6.7 billion from automobile collisions, $3.8 billion from auto repair, and $1.9 billion from road repair).

Figure 2: Below illustrates the breakdown of total economic saving for the period from 2015-2030.



All values represent billions of dollars in savings for a 1 percent decrease in the growth rate of vehicle-miles traveled compared to official Massachusetts Department of Transportation forecasts.

Figure 3: Reduced Expenses Per Year from a 1 Percentage Point VMT Growth Rate Reduction, 2015-2030



As indicated in Table 8 below, the cumulative savings of a one percentage point reduction in VMT below the current forecast from the Massachusetts Department of Transportation is $20.129 billion for the period from 2015-2030.

For context, the total economic savings of a one percentage point reduction in the VMT growth rate from 2015-2030 is enough to provide for the period any of the following:

- Groceries for almost 180,455 American households;[75]
- Daycare costs for 81,558 Massachusetts infants in daycare fulltime;[76]
- The average Massachusetts mortgage payment for 92,746 households.[77]

Table 8: Annual Benefits of Reduced Automobile Collisions, Auto Repair, State Road Repair, and Gasoline Consumption

Year	Reduced Costs Associated with Gasoline Consumption (Billion $)	Reduced Costs Associated with Auto Related Collisions (Billion $)	Reduced Costs Associated with Auto Repair (Billion $)	Reduced Costs Associated with State Road Repair (Billion $)	Combined Benefits (Billion $)
2015	$0.071	$0.052	$0.029	$0.015	$0.167
2020	$0.360	$0.297	$0.168	$0.085	$0.909
2025	$0.618	$0.541	$0.307	$0.154	$1.620
2030	$0.856	$0.785	$0.446	$0.224	$2.311
2015-2030 Combined	$7.698	$6.707	$3.808	$1.915	$20.129

RECOMMENDATIONS

The choice ahead is clear. Capturing the benefits of reduced driving between now and 2030 will require prompt changes to state and local policies and creating incentives to encourage Bay State residents to drive less, and to use other forms of transportation more. Achieving a one percentage point reduction in the VMT growth rate will require the Commonwealth's project selection process to make VMT reduction a major priority. It will require more adequate funding, preferably from revenue sources that also encourage non-driving modes of transportation. And new systems will need to be established for regular public assessments of the state's success in reducing VMT.

In the past few years, the state has taken some positive steps on which we can build. There is a new state goal of tripling the shares of trips made by transit, walking, and biking between 2012 and 2030. Under the Healthy Transportation Policy Directive, the Massachusetts Department of Transportation incorporates non-driving modes within or adjacent to state projects as much as possible.[78] Massachusetts's Department of Environmental Planning recently set forth regulations that require the Massachusetts Department of Transportation and Metropolitan Planning Organizations to evaluate and track the greenhouse gas emissions and impacts of investment decisions while prioritizing greenhouse gas impacts when making these decisions.[79] The GreenDOT implementation plan has a series of recommendations aimed at fostering a shift from driving to other modes.

Yet, there is more that we should do. The recommendations below identify the top three efforts the state can make to help move us further down the road to reducing VMT, which will lead to the significant environmental, economic, and public health savings outlined in this report.

1) CHOOSE TRANSPORTATION INVESTMENTS THAT REDUCE DRIVING

Decisions about what types of investments to prioritize will greatly influence future levels of driving. The post-World War II era increase in driving partly resulted from heavy investment in new and wider roads and ever more sprawling development. In the Bay State and across the nation, new highways have been constructed over the last half-century in ways that encouraged people to live further from their jobs, the services they need, and their pastimes, leading to increased driving. For decades new off-ramps in previously rural communities fueled real estate development in distant suburbs and exurbs consisting largely of housing subdivisions, office parks, and shopping centers while many older cities were neglected.

The 2013 transportation finance law created a Project Selection Advisory Council to establish criteria for investment decisions.[80] The Council's June 2015 report to the legislature recommended criteria to screen future transportation investments. The Council's report is a great first step. It creates a group of objective criteria for project selection, which is a dramatic improvement over how project decisions were made in the past. The new criteria now include public health, environmental, and social and regional equity factors, yet they are given too little weight in the scoring.

As the criteria are implemented, the state should amend them to explicitly make reducing VMT a major criteria for evaluating which investments should be prioritized for funding.

Investments that would contribute to a reduction in VMT include improving walking and bicycling trails, modernizing and enhancing capacity on public transportation lines, improving and expanding intercity rail service, purchasing newer and more reliable buses, introducing bus rapid transit, and favoring projects that encourage land-use patterns such as compact development that entail shorter auto trips. Private-sector transportation demand management strategies should be encouraged to complement these investments, such as shuttles and carpooling programs. Moreover, scoring projects based on their impact on VMT will help avoid wasteful spending on new and wider highways that would lead to less efficient land use, requiring additional spending on other infrastructure to service far-flung development, and drastically increase the costs stemming from VMT.

The Commonwealth must make new investments to enable better transportation choices, while maintaining a state of good repair of those we already have - including public transportation, sidewalks, bike lanes, and trails and paths. The goal should be to make the combination of multiple modes of transportation serve as more than the sum of their parts to make it viable for households to drive less, or to reduce the number of automobiles they own. Strategies to accomplish this include incorporating car-sharing and bike-sharing into plans and designing bike racks and crosswalks at transit stops. Investments should also support "complete streets" that are designed to enable safe walking, bicycling, and transit use.

2) RAISE REVENUES THAT PAY FOR OUR TRANSPORTATION NEEDS WHILE PREFERABLY ALSO REDUCING DRIVING

Sufficient resources to pay for important investments are necessary. Despite some progress in transportation funding in 2013, most experts agree that more funding is necessary to make the types of investments that our state needs to make. There is no shortage of innovative revenue sources that policy makers can embrace. While gas taxes have waned in recent years due to improved fuel efficiency and inflation, there are other ways of raising transportation revenue that would also encourage reductions in driving. One of these could be a road usage charge, or fee, based on VMT. But whether we use that method or another, the guiding principal should be that we must provide sufficient revenue to address our transportation needs, while doing what we can to disincentive costly over reliance on driving.

Those incentives need not just be public sector based. A private-sector incentive to reduce driving would be to allow "pay-as-you-drive" (PAYD) insurance. Instead of paying auto insurance as a fixed cost, PAYD insurance links the monthly fee that a customer pays for car insurance with the distance that he or she drives. This provides motorists with more insurance options that better reflect actual economic costs, and encourages fewer driving miles.[81] Massachusetts is currently one of only sixteen states that prohibit PAYD insurance.

At the same time, we should encourage transit use by keeping public transit fares low. Large fare hikes would both decrease the mobility of people with low incomes and cause riders with access to an automobile to drive more.

3) SET GOALS AND TRACK PROGRESS

The Commonwealth already evaluates transportation performance using a number of important measures including asset conditions and on-time performance. Yet, a successful investment strategy should also reduce driving. The Massachusetts Department of Transportation should work toward including VMT reduction as an explicit performance measure. Reporting on this measure should be done on a public dashboard on the Massachusetts Department of Transportation's website and included in quarterly and annual performance and accountability reports. The Performance and Asset Management Council established by the 2013 transportation finance law should also include VMT benchmarks in its recommendations.

CONCLUSION

Together the benefits of just a one percentage point reduction in the growth rate of VMT will yield $2.3 billion yearly by 2030, and $20.1 billion combined from 2015-2030, a sum that is understated because it includes only those benefits that can be readily quantified in dollar terms per mile driven excluding benefits such as lower carbon emissions and public health benefits such as reduced obesity.

There is much to gain, with even small reductions in the future number of VMT in Massachusetts. Even relatively small decreases in the growth in the volume of driving translates into large benefits for the people of Massachusetts. As we have seen, these include physical benefits, such as reduction in loss of life or other injury from collisions; economic benefits, such as reduced road and vehicle maintenance, increased work time, and medical savings; environmental benefits, such as reduced CO_2 emissions and reduced air pollution; and public health benefits, such as decreased obesity. Together the benefits of just a one percentage point reduction in the growth rate of VMT will yield $2.3 billion yearly by 2030, and $20.1 billion combined from 2015-2030, a sum that is understated because it includes only those benefits that can be readily quantified in dollar terms per mile driven, excluding benefits such as lower carbon emissions and public health benefits such as reduced obesity.

We can save money, save lives, prevent injury, and protect the environment by focusing on smarter transportation policies, and promoting regulations and incentives that further these choices. There is much at stake, and much to gain.

APPENDIX I - METHODOLOGY

Reduced Vehicle-Miles Traveled (2015-2030)

We calculate the reduction in VMT in Massachusetts between 2015 and 2030 with a one percentage point reduction in the VMT growth rate below the forecast made by the Massachusetts Department of Transportation. In order to calculate this, we take the VMT growth rate for a given year between 2015 and 2030 as predicted by the Massachusetts Department of Transportation, and subtract one percentage point from the growth rate. For instance, if the growth rate was projected to be 0.75 percent, under a one percentage point reduction scenario, the derived growth rate would be -0.25 percent. The report then applies the new, reduced growth rate to the Massachusetts Department of Transportation's VMT estimate for that year. The result is the number of VMT with a one percentage point reduction in the projected VMT growth rate. The annual figures are then summed to calculate the total number of miles driven under a one percentage point reduced growth rate scenario from 2015 to 2030. That number is then subtracted from the sum of the Massachusetts Department of Transportation's projections over the same span of years, which produces the difference in VMT between the two projections. This results in 74.5 billion fewer miles driven in Massachusetts between the years 2015 and 2030 if the VMT growth rate is reduced by one percentage point.

Source:

- Massachusetts Department of Transportation, Travel Demand Model. Office of Transportation Planning. *Massachusetts Vehicle-Miles Traveled Statistics and Projections*, 2014.

Economic Benefit – Decreased Automobile Collisions (2015-2030)

To calculate the economic implications of fewer automobile collisions from 2015 to 2030, we use the process described in the preceding section, "Reduced Vehicle-Miles Traveled (2015-2030)," to determine the number of vehicle-miles not traveled in Massachusetts during that span. This figure is then multiplied by a derived per-mile cost of 9.0 cents per mile for each year. Annual figures are then summed to determine economic savings from avoided automobile collisions for the period. The result is $6.7 billion saved from 2015 to 2030. To determine the per-mile cost of automobile collisions, 9.0 cents per mile, we use data obtained from the National Safety Council, which estimates the total economic cost of automobile collisions nationwide in 2013 at $276.5 billion, and divide that figure by the total VMT that year, 2.972 trillion, to reach a 9.0 cent per mile cost.

Source:

- National Safety Council. *National Safety Council Estimates Traffic Deaths Down Three Percent in 2013*. Retrieved from http://www.nsc.org/NewsDocuments/2014-Press-Release-Archive/2-12-2014-Traffic-Fatality-Report.pdf.
- U.S. Department of Transportation, Federal Highway Administration, Office of Highway Policy Information (2014, November). *Travel Monitoring and Traffic Volume*. Retrieved from https://www.fhwa.dot.gov/policyinformation/travel_monitoring/13dectvt/index.cfm

Economic Benefit – Decreased Automobile Repair (2015-2030)

To calculate the economic implications of a one percentage point reduction in VMT growth rate and the resulting saving from auto repair costs during the 2015 to 2030 period, we first use the process described in the previous section, "Reduced Vehicle-Miles Traveled (2015-2030)," to determine the number of vehicle-miles not traveled in Massachusetts during that span. This figure is then multiplied by a 5.11 cent per vehicle-mile repair cost, as reported by the American Automobile Association in 2015. Resulting annual values are then summed to determine the total economic implications for the period, which comes to $3.8 billion.

Source:

- American Automobile Association (2015, April 28). *Annual Cost to Own and Operate a Vehicle Falls to $8,698, Finds AAA*. Retrieved from http://newsroom.aaa.com/2015/04/annual-cost-operate-vehicle-falls-8698-finds-aaa/

Economic Benefit – Decreased Road Repair (2015-2030)

To calculate the economic implications of a one percentage point reduction in VMT growth rate and the resulting savings from road repair costs during the 2015 to 2030 period, we first use the process described in the previous section, "Reduced Vehicle-Miles Traveled (2015-2030)," to determine the number of vehicle-miles not traveled in Massachusetts during that span. This figure is then multiplied by a 2.57 cent per mile road repair cost. Resulting annual values are then summed to determine the total economic benefits for the period, which comes to $1.9 billion not spent on road repair from 2015 to 2030. The 2.57 cent per mile figure is derived first by finding the difference in driving miles for a span of 20 years, from 2010 to 2030, using two scenarios for a change in VMT growth rate (this report uses scenarios with a 1.36 percent increase in VMT growth rate and with a 1.85 percent increase). We then divide the amount of money spent on road repair in that timespan by the difference in VMT for each scenario, which is equal to 2.57 cents per mile.

Source:

- Massachusetts Department of Transportation, Travel Demand Model. Office of

Transportation Planning. *Massachusetts Vehicle-Miles Traveled Statistics and Projections*, 2014.

- U.S. Department of Transportation, Federal Highway Administration, Policy and Governmental Affairs (2014, November 7). *2013 Conditions and Performance Report, Ch. 7*, exhibit 7-2. Retrieved from http://www.fhwa.dot.gov/policy/2013cpr/chap7.cfm

Economic Benefit – Decreased Gasoline Consumption (2015-2030)

To calculate the decrease in gasoline consumption from of a one percentage point reduction in VMT growth rate during the 2015 to 2030 period, we first use the process described in the previous section, "Reduced Vehicle-Miles Traveled (2015-2030)," to determine the number of vehicle-miles not traveled in Massachusetts during that span. These annual figures are then divided by the Light Duty Stock Fleet Mix MPG, as reported by the Energy Information Administration, for the chosen year of calculation. The result is the number gallons of gasoline that would be consumed in Massachusetts in those years if the projected number of vehicle-miles driven was reduced by one percentage point. Those totals are then subtracted from the gallons of gas which would be consumed based on the Massachusetts Department of Transportation's projected VMT for the same period. The annual totals are summed to provide a total number of gallons of gasoline not consumed as a result of a one percentage point reduction in VMT, 2.6 billion gallons of gasoline.

Source:

- U.S. Energy Information Administration. *Annual Energy Outlook 2015*. Retrieved from http://www.eia.gov/beta/aeo/#/?id=7-AEO2015&region=0-0&cases=ref2015&start=2012&end=2040&f=A&linechart=~7-AEO2015.28.&map=&ctype=linechart

Economic Benefit – Decreased Money Spent at the Pump (2015-2030)

To calculate the economic implications of a one percentage point reduction in VMT growth rate and the resulting reduction in money spent at the pump during the 2015 to 2030 period, we first use the process described in the previous section, "Economic Benefit – Decreased Gasoline Consumption (2015-2030)," to determine the number of gallons of gasoline not consumed during that span. The resulting annual figures were then multiplied by the average annual price per gallon of gasoline as projected by the Energy Information Administration for the chosen year of calculation. Resulting annual values are then summed to determine the total economic implications for the period, which comes to $7.7 billion not spent at the pump from 2015 to 2030.

Source:

- U.S. Energy Information Administration (2015, April 14). *Annual Energy Outlook 2015: Energy Prices*, Fig. 4. Retrieved from http://www.eia.gov/forecasts/aeo/section_prices.cfm.

Total Combined Economic Benefits (2015-2030)

The total economic implications from a decrease in automobile collisions, road repair, automobile repair, and gasoline consumption as a result of a one percentage point reduction in the projected VMT growth rate from 2015 to 2030 is $20.1 billion. We calculated the money saved from fewer collisions, less road repair, and less automobile repair for a given year as described in the previous sections, "Economic Benefit – Decreased Automobile Collisions (2015-2030)," "Economic Benefit – Decreased Automobile Repair (2015-2030)," "Economic Benefit – Decreased Road Repair (2015-2030)," and "Economic Benefit – Decreased Money Spent at the Pump (2015-2030)." The process is repeated for every year between 2015 and 2030, and the final sum is equal to the total amount of money saved due to decreased automobile collisions, automobile repair, road repair, and gasoline consumption, $20.1 billion.

Environmental Benefit – Reduced CO_2 Emissions (2015-2030)

We calculated the reduction in CO_2 emissions from 2015 to 2030 due to a one percentage point reduction in the projected VMT growth rate to be 23.3 million metric tons. To obtain this value, the report first calculates the gallons of gasoline not consumed for a given year between 2015 and 2030 due to a one percentage point reduction in the projected VMT growth rate, as described in the above section, "Decreased Gasoline Consumption (2015-2030)." This number is then multiplied by the standard conversion factor for pounds of CO_2 emitted per gallon of gasoline combusted, 19.64 pounds per gallon, as provided by the Energy Information Administration. This number is then converted from pounds of CO_2 to metric tons of CO_2. The process is then repeated for every year between 2015 and 2030. Finally, the annual figures are summed to provide the final value for the reduction in CO_2 emissions from 2015 to 2030, 23.3 million metric tons.

Source:

- U.S. Energy Information Administration (2015, July 7). *Frequently Asked Questions, How much carbon dioxide is produced by burning gasoline and diesel fuel*. Retrieved from http://www.eia.gov/tools/faqs/faq.cfm?id=307&t=10

APPENDIX II - DATASHEET

	Year	Annual VMT[1]	Growth Rates in Orginal Forecast[2]	VMT Growth Rate with 1 Percent Lower Growth Scenario[3]	VMT with 1 Percent Lower VMT Growth Rate than Forecast[4]
Post-Driving Boom (Forecasted)	**2015**	57,304,000,000	-0.43%	-1.43%	56,728,480,000
	2016	57,055,000,000	-0.43%	-1.43%	55,914,695,976
	2017	56,806,000,000	-0.44%	-1.44%	55,111,525,543
	2018	56,557,000,000	-0.44%	-1.44%	54,318,837,745
	2019	56,309,000,000	-0.44%	-1.44%	53,537,463,612
	2020	56,060,000,000	-0.44%	-1.44%	52,765,344,788
	2021	56,332,000,000	0.49%	-0.51%	52,493,705,857
	2022	56,603,000,000	0.48%	-0.52%	52,221,303,668
	2023	56,875,000,000	0.48%	-0.52%	51,950,034,832
	2024	57,147,000,000	0.48%	-0.52%	51,678,981,244
	2025	57,419,000,000	0.48%	-0.52%	51,408,165,549
	2026	57,690,000,000	0.47%	-0.53%	51,136,714,606
	2027	57,962,000,000	0.47%	-0.53%	50,866,449,668
	2028	58,234,000,000	0.47%	-0.53%	50,596,487,671
	2029	58,506,000,000	0.47%	-0.53%	50,326,849,419
	2030	58,777,000,000	0.46%	-0.54%	50,056,695,070
Cum. 2015-2030		915,636,000,000			841,111,735,247

Post-Driving Boom (Forecasted)

Year	Difference in VMT between - Orginal Forecast vs. 1 Percent Lower VMT Growth Scenario[5]	Avoided Traffic Accidents (Benefits Associated with 1 Percentage Point Reduction in VMT Growth Rate, 2015-2030 ($))[6]	Auto Repair (Benefits Associated with 1 Percentage Point Reduction in VMT Growth Rate, 2015-2030 ($))[7]	State (Not Local) Road Repair (Benefits Associated with 1 Percentage Point Reduction in VMT Growth Rate, 2015-2030 ($))[8]
2015	-575,520,000	-$51,796,800	-$29,409,072	-$14,790,864
2016	-1,140,304,024	-$102,627,362	-$58,269,536	-$29,305,813
2017	-1,694,474,457	-$152,502,701	-$86,587,645	-$43,547,994
2018	-2,238,162,255	-$201,434,603	-$114,370,091	-$57,520,770
2019	-2,771,536,388	-$249,438,275	-$141,625,509	-$71,228,485
2020	-3,294,655,212	-$296,518,969	-$168,356,881	-$84,672,639
2021	-3,838,294,143	-$345,446,473	-$196,136,831	-$98,644,159
2022	-4,381,696,332	-$394,352,670	-$223,904,683	-$112,609,596
2023	-4,924,965,168	-$443,246,865	-$251,665,720	-$126,571,605
2024	-5,468,018,756	-$492,121,688	-$279,415,758	-$140,528,082
2025	-6,010,834,451	-$540,975,101	-$307,153,640	-$154,478,445
2026	-6,553,285,394	-$589,795,685	-$334,872,884	-$168,419,435
2027	-7,095,550,332	-$638,599,530	-$362,582,622	-$182,355,644
2028	-7,637,512,329	-$687,376,110	-$390,276,880	-$196,284,067
2029	-8,179,150,581	-$736,123,552	-$417,954,595	-$210,204,170
2030	-8,720,304,930	-$784,827,444	-$445,607,582	-$224,111,837
Cum. 2015-2030	-74,524,264,753	-$6,707,183,828	-$3,808,189,929	-$1,915,273,604

	Year	Avoided Traffic Accidents, Vehicle Repair, and State Road Repair Combined (Benefits Associated with 1 Percentage Point Reduction in VMT Growth Rate, 2015-2030 ($))[9]	Avoided Traffic Accidents, Vehicle Repair, State Road Repair, and Savings at Pump Combined (Benefits Associated with 1 Percentage Point Reduction in VMT Growth Rate, 2015-2030 ($))[10]	Fleet Mix MPG[11]	Gasoline Consumption (Benefits Associated with 1 Percentage Point Reduction in VMT Growth Rate, 2015-2030 (gallons))[12]
Post-Driving Boom (Forecasted)	**2015**	-$95,996,736	-$167,139,439	22.7	2,504,453,990.34
	2016	-$190,202,711	-$320,291,383	23.1	2,425,431,656.79
	2017	-$282,638,339	-$477,388,050	23.5	2,345,959,242.51
	2018	-$373,325,464	-$625,674,253	23.9	2,268,278,426.47
	2019	-$462,292,270	-$767,695,629	24.5	2,184,978,925.90
	2020	-$549,548,489	-$909,332,468	25.1	2,102,955,416.74
	2021	-$640,227,463	-$1,055,048,516	25.7	2,040,727,298.88
	2022	-$730,866,948	-$1,199,029,640	26.4	1,978,577,776.36
	2023	-$821,484,190	-$1,341,071,882	27.1	1,916,352,958.57
	2024	-$912,065,529	-$1,480,974,296	27.9	1,854,080,461.79
	2025	-$1,002,607,186	-$1,620,108,312	28.7	1,790,247,505.90
	2026	-$1,093,088,004	-$1,758,479,210	29.5	1,730,730,881.26
	2027	-$1,183,537,795	-$1,894,062,672	30.4	1,675,525,513.12
	2028	-$1,273,937,056	-$2,031,904,288	31.1	1,625,026,309.62
	2029	-$1,364,282,317	-$2,169,942,210	31.9	1,578,750,990.78
	2030	-$1,454,546,862	-$2,310,999,078	32.6	1,536,326,989.23
Cum. 2015-2030		-$12,430,647,361	-$20,129,141,327		31,558,404,344.26

	Year	Gasoline Consumption Avoided (Gasoline Conumption Avoided Associated with 1 Percentage Point Reduction in VMT Growth Rate, 2015-2030 (gallons))[13]	Average Annual Price of Gasoline MA Annual Averages (EIA Estimates of Future Gas Prices 2015-2030 (Estimate))[14]	Money Spent at Pump (Projected Money Spent at Pump under 1 Percent Decrease Scenario (EIA estimated gas prices))[15]
Post-Driving Boom (Forecasted)	**2015**	(25,408,108.25)	$2.80	$7,012,471,172.95
	2016	(49,463,373.26)	$2.63	$6,378,885,257.37
	2017	(72,129,522.37)	$2.70	$6,334,089,954.77
	2018	(93,462,514.48)	$2.70	$6,124,351,751.46
	2019	(113,112,355.20)	$2.70	$5,899,443,099.94
	2020	(131,308,021.41)	$2.74	$5,762,097,841.86
	2021	(149,216,206.23)	$2.78	$5,673,221,890.90
	2022	(166,015,138.96)	$2.82	$5,579,589,329.35
	2023	(181,674,018.13)	$2.86	$5,480,769,461.50
	2024	(196,175,437.22)	$2.90	$5,376,833,339.18
	2025	(209,322,415.40)	$2.95	$5,281,230,142.41
	2026	(221,797,068.76)	$3.00	$5,192,192,643.78
	2027	(233,725,288.26)	$3.04	$5,093,597,559.87
	2028	(245,296,838.69)	$3.09	$5,021,331,296.73
	2029	(256,579,583.92)	$3.14	$4,957,278,111.05
	2030	(267,641,317.50)	$3.20	$4,916,246,365.52
Cum. 2015-2030		-2,612,327,208.05	NA	$90,083,629,218.65

	Year	Money Saved At Pump (Projected Savings at Pump under 1 Percent Reduction Scenario (EIA estimated gas prices))[16]	Co2 Emissions (million metric tons) (Reflecting a 1 Percentage Point Reduction in VMT Growth Rate, 2015-2030)[17]	CO2 Avoided/Added (Additional CO2 Associated with 1 Percent Reduction in VMT, 2015-2030 (million metric tons))[18]
Post-Driving Boom (Forecasted)	**2015**	-$71,142,703.09	22,311,090.51	(226,349.78)
	2016	-$130,088,671.67	21,607,114.94	(440,647.66)
	2017	-$194,749,710.40	20,899,129.79	(642,570.52)
	2018	-$252,348,789.09	20,207,105.21	(832,616.86)
	2019	-$305,403,359.04	19,465,026.22	(1,007,668.74)
	2020	-$359,783,978.67	18,734,314.48	(1,169,766.01)
	2021	-$414,821,053.33	18,179,951.26	(1,329,302.23)
	2022	-$468,162,691.86	17,626,288.22	(1,478,956.61)
	2023	-$519,587,691.86	17,071,954.40	(1,618,454.75)
	2024	-$568,908,767.93	16,517,195.83	(1,747,641.58)
	2025	-$617,501,125.44	15,948,535.81	(1,864,762.29)
	2026	-$665,391,206.28	15,418,328.11	(1,975,893.55)
	2027	-$710,524,876.33	14,926,527.51	(2,082,156.86)
	2028	-$757,967,231.56	14,476,652.09	(2,185,242.77)
	2029	-$805,659,893.52	14,064,405.41	(2,285,755.83)
	2030	-$856,452,216.01	13,686,468.45	(2,384,300.00)
Cum. 2015-2030		-$7,698,493,966.07	281,140,088.23	(23,272,086.06)

Appendix II: Notes and Sources

1. The annual Vehicle Miles Traveled (VMT) represented above, show forcasted VMT for the years 2015-2030. Massachusetts Department of Transportation, Office of Project Oriented Planning. (2014). Travel Demand Model. Massachusetts vehicle-miles traveled Statistics and Projections.

2. The growth rate is calculated by subtracting the forecasted annual VMT for the previous year by the forecasted annual VMT for the current year and then dividing by the forecasted annual VMT for the previous year.

3. To calculate VMT Growth Rate with one percent lower growth, we took the growth rate from the original forecast and subtracted one full percentage point.

4. To calculate one percent lower VMT growth rate, we first started with the actual VMT from 2015 and multiplied by the projected VMT growth rate under the one percent lower scenario for 2015 to achieve a projected one percent lower VMT. We then multiplied each projected VMT with the subsequent year's projected growth rate.

5. To calculated the difference in VMT between original forecast versus the one percent lower VMT growth scenario, we simply subtracted each year's one percent lower scenario from the original forecast to achieve a difference in VMT between the two projections.

6. We derived a per mile cost of 9.0 cents per mile by taking National Safety Council's cost of collisions nationwide in 2013 [267.5 billion], and dividing by Federal Highway Administration's data for total miles driven in 2013 [2.972 trillion]. We then multiplied 9.0 cents per mile to the difference in VMT between the original forecast and the one percent lower VMT scenario to find the avoided traffic accident cost. National Safety Council (2014, February 12). National Safety Council Estimates Traffic Deaths Down Three Percent in 2013, National Safety Council. Retrieved from http://www.nsc.org/NewsDocuments/2014-Press-Release-Archive/2-12-2014-Traffic-Fatality-Report.pdf. See also, U.S. Department of Transportation, Federal Highway Administration, Office of Highway Policy Information (2014, November). Travel Monitoring and Traffic Volume. Retrieved from https://www.fhwa.dot.gov/policyinformation/travel_monitoring/13dectvt/index.cfm.

7. 2015 driving cost study on per-mile costs of operating a sedan foun that it costs 5.11 cents per mile to maintain a vehicle. To calculate auto repair costs avoided, we multiplied 5.11 cents per mile to the difference in VMT between the original forecast and the one percent lower VMT scenario. American Automobile Association (2015, April 28). Annual Cost to Own and Operate a Vehicle Falls to $8,698, Finds AAA. Retrieved from http://newsroom.aaa.com/2015/04/annual-cost-operate-vehicle-falls-8698-finds-aaa/. Note: Values reflect average repair costs for sedans of all sizes. AAA's estimates are based upon the cost to maintain a vehicle and perform needed repairs for five years and 75,000 miles, including labor expenses, replacement part prices and the purchase of an extended warranty policy.

8. The 2.57 cents per mile figure for expected cost of existing state road repair is calculated using data from FHWA for both vehicle-miles traveled estimates [4.2 trillion miles from 2010-2030] and expected cost of maintenance [$108 billion], and then extrapolating out a per-mile cost based on total costs of maintenance divided by total miles. For projections between 2015-2030, we multiplied the difference in VMT between original forecast and one percent lower VMT growth scenario to 2.57 cents per mile to derive avoided road repair costs. U.S. Department of Transportation, Federal Highway Administration, Policy and Governmental Affairs (2014, November 7). 2013 Conditions and Performance Report, ch. 7, exhibit 7-2. Retrieved from http://www.fhwa.dot.gov/policy/2013cpr/chap7.cfm

9. This column calculates the total economic benefit of avoided accidents, vehicle repair, and road repair. Totals are based upon summation of component parts i.e. the sum of avoided costs from traffic accidents, avoided vehicle repair costs, and avoided road maintenance costs.

10. This column calculates the total economic benefit of avoided accidents, vehicle repair, road repair and savings at the pump. Totals are based upon summation of component parts i.e. the sum of avoided costs from traffic accidents, avoided vehicle repair costs, avoided road maintenance costs, and money saved at the pump.

11. Fleet Mix numbers reflect values for "Light Duty Stock" MPG - the closest approximation of "on the road" MPG for a typical light duty fleet nationwide. Light Duty Stock reflects the combined "on-the-road" estimate for all types of cars and light trucks. All values come from Energy Information Administration- Annual Outlook Report. Values for 2015 -2030 are estimates provided by EIA in their 2015 AEO.U.S. Energy Information Administration.

12. To calculate gas consumption we took the total miles projected (2015-2030) and divided by annual MPG values for "light duty stock" as the best indicator of real world MPG.

13. To calculate gas consumption avoided we used previously calculated values for VMT avoided since the end of the Driving Boom, and divided by "light duty stock" fleet mix MPG for the corresponding year.

14. Values for 2015 -2030 are estimates provided by EIA in their 2015 AEO.U.S. Energy Information Administration.

15. To calculate values we used EIA's values for the predicted average annual cost of gas and multiplied by our previously calculated number of gallons.

16. For estimates of money saved at pump from 2015-2030, we took values for gasoline consumption avoided under a one percent VMT decrease and multiplied that by the EIA projected gas prices.

17. To calculate projected Co2 emissions, we calculated the projected gallons of gasoline consumed under a one percent decrease scenario by 19.64 to achieve CO2 emissions projected, and then divided by 2204.63 million metric tons to achieve projected CO2 emissions. 1 Gallon of gas equates to 19.64 pounds of Co2. U.S. Energy Information Administration (2015, July 7). Frequently Asked Questions, How much carbon dioxide is produced by burning gasoline and diesel fuel. Retrieved from http://www.eia.gov/tools/faqs/faq.cfm?id=307&t=10

18. To calculate CO2 avoided we took values for gasoline consumption avoided and multiplied by 19.64 - the standard 1 gallon of gas to CO2 conversion, and then divided by 2204.62 to achieve million metric ton units provided by Energy Information Administration. U.S. Energy Information Administration (2015, July 7). Frequently Asked Questions, How much carbon dioxide is produced by burning gasoline and diesel fuel. Retrieved from http://www.eia.gov/tools/faqs/faq.cfm?id=307&t=10

ENDNOTES

1 This figure is derived by dividing the total economic savings from 2015-2030 ($20.1 billion) by the average monthly grocery cost per U.S. household in 2015 ($618.80) over 15 years ($111,385). The resulting figure, 180,455, is the equivalent number of households (as defined above) that could purchase 15 years' worth of monthly groceries. U.S. Department of Agriculture (2015, April). *Official USDA Food Plans: Cost of Food at Home at Four Levels, U.S. Average*. Retrieved from http://www.cnpp.usda.gov/sites/default/files/CostofFoodApr2015.pdf. Note: Data reflects national average monthly grocery bill for a male and female households of two with partners between the ages of 19 and 50.

2 This figure is derived by dividing the total economic savings from a one percentage point decrease in the vehicle-miles traveled growth rate from 2015-2030 ($20.1 billion) by the 2012 average annual infant daycare cost per child in Massachusetts ($16,430) calculated over 15 years ($246,450). The resulting figure (81,558) represents the number of infants that could be provided fulltime daycare for 15 years. Tran, A.B. (2014, July 2) Map: The average cost of child care by state. *Boston Globe.* Retrieved from https://www.bostonglobe.com/2014/07/02/map-the-average-cost-for-child-care-state/LN65rSHXKNjr4eypyxT0WM/story.html.

3 This figure is derived by dividing the total economic savings from a one percentage point decrease in the vehicle-miles traveled growth rate ($20.1 billion) by the average Massachusetts monthly mortgage payment ($1,204) expanded over 15 years ($216,720). The resulting figure (92,746) represents the number of mortgage payers whose mortgages could be paid for 15 years. Grueling, M. (2012, December 1). National Average Monthly Mortgage Payment by State. *LendingTree.com*. Retrieved from https://www.lendingtree.com/mortgage/2011-2012-national-average-monthly-mortgage-payment-article. Note: This figure uses data obtained from 2011-2012.

4 To achieve this figure, we divided the number of gallons of gas to be saved over the next 15 years (2.6 billion gallons) by the number of households in Massachusetts in 2014 (2,828,492) to achieve 923 gallons of gas not consumed per household between the years 2015 and 2030. U.S. Census Bureau (2015). *State & County QuickFacts: Massachusetts*. Retrieved from http://quickfacts.census.gov/qfd/states/25000.html

5 To acquire this data, one must enter the aforementioned metric tons into the "Carbon Dioxide or CO2 Equivalent" form field, then hit "Calculate." This results in a host of equivalents, including equivalent number of greenhouse gas emissions from passenger vehicles. U.S. Environmental Protection Agency. (2015). *Greenhouse Equivalencies Calculator*. Retrieved from http://www.epa.gov/cleanenergy/energy-resources/calculator.html

6 Massachusetts Energy Information Administration. *Massachusetts Carbon Dioxide Emissions from Fossil Fuel Consumption(1980-2012)*. Retrieved from http://www.eia.gov/environment/emissions/state/excel/massachusetts.xlsx

7 Caiazzo, F., Ashok, A., Waitz, I.A., Yim, S.H.L., and Barrett, S.R.H. (2013, May 31). Air pollution and early deaths in the United States. Part I: Quantifying the impact of major sectors in 2005. *Atmospheric Environment Journal*, *79*, 198-208, 203. Retrieved from http://lae.mit.edu/wordpress2/wp-content/uploads/2013/08/US-air-pollution-paper.pdf

8 Jacobson, S.H., King, D.H., Yuan, R. (2011). A note on the relationship between obesity and driving. *Journal of Transport Policy*, 1-5. Retrieved from http://www.ahtd.info/yahoo_site_admin/assets/docs/A_note_on_the_relationship_between_obesity_and_driving.173153035.pdf. Note: The study found that vehicle use (measured in annual vehicle-miles traveled) correlated as high as 99 percent with annual obesity rates

9 Massachusetts Department of Transportation (2012, December 12). *GreenDOT Implementation Plan*. Retrieved from http://www.massdot.state.ma.us/Portals/0/docs/GreenDOT/finalImplementation/FinalGreenDOTImplementationPlan12.12.12.pdf

10 U.S. Energy Information Administration (2015, July 7). *Frequently Asked Questions, How much carbon dioxide is produced by burning gasoline and diesel fuel*. Retrieved from http://www.eia.gov/tools/faqs/faq.cfm?id=307&t=10

11 U.S. Environmental Protection Agency (2015, April 15). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013*, p. 2-28. Retrieved from http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2015-Main-Text.pdf

12 Massachusetts Energy Information Administration. *Massachusetts Carbon Dioxide Emissions from Fossil Fuel Consumption(1980-2012)*. Retrieved from http://www.eia.gov/environment/emissions/state/excel/massachusetts.xlsx

The Massachusetts Department of Environmental Protection offers a slightly different, but similarly useful analysis that relies on using gross emissions. Its estimate also includes emissions from agriculture and waste, as well as other industrial processes, thereby slightly diluting the transportation sector's share of total emissions. By this method, Massachusetts Department of Environment Protection estimates that the transportation sector will account for 38 percent of all statewide emissions in 2015. Regardless of whether we accept federal or state estimates, what is clear is that the transportation sector is a major contributor to global warming causing emissions both nationally and here in Massachusetts. Without meaningful policy reforms that help reduce the number of vehicle miles traveled (VMT), transportation sector emissions could easily jeopardize gains made in other sectors.

13 President's Council of Economic Advisors. (2015, June). *Explaining the U.S. Petroleum Consumption Surprise*, pg. 2. Retrieved from https://www.whitehouse.gov/sites/default/files/docs/explaining_us_petroleum_consumption_surprise_final.pdf

14 President's Council of Economic Advisors. (2015, June). *Explaining the U.S. Petroleum Consumption Surprise*, pg. 14. Retrieved from https://www.whitehouse.gov/sites/default/files/docs/explaining_us_petroleum_consumption_surprise_final.pdf

15 Greenhouse Gas Emissions Limits. 21N M.G.L.A. § 3(b) (2008).

16 Caiazzo, F., Ashok, A., Waitz, I.A., Yim, S.H.L., and Barrett, S.R.H. (2013, May 31). Air pollution and early deaths in the United States. Part I: Quantifying the impact of major sectors in 2005. *Atmospheric Environment Journal*, *79*, 198-208, 203. Retrieved from http://lae.mit.edu/wordpress2/wp-content/uploads/2013/08/US-air-pollution-paper.pdf. Note: Air pollution causes acute respiratory problems, temporary decreases in lung capacity, and inflammation of lung tissue. In addition, it impairs the body's immune system, reduces the release of oxygen to body tissues, and increases a person's risk of cancer-related death.

17 U.S. Department of Transportation, National Highway Traffic Safety Administration (2014, December). *2013 Motor Vehicle Crash: Overview*, 1-6, 1. Retrieved from http://www-nrd.nhtsa.dot.gov/Pubs/812101.pdf

18 U.S. Department of Transportation, National Highway Traffic Safety Administration (2014, December). *2013 Motor Vehicle Crash: Overview*, 1-6, 1. Retrieved from http://www-nrd.nhtsa.dot.gov/Pubs/812101.pdf

19 Giles, L.P, Hayes, E.S., & Rosenberg, M.L. (2005, June 1). Road Traffic Injuries: Can We Stop A Global Epidemic? *The Doctor will see you Now*. http://www.thedoctorwillseeyounow.com/content/emergencies/art2104.html. Note, these statistics represent worldwide data.

20 33,686 U.S. service members died of battle deaths. Rhem, K.T. (2000, June 8). U.S. Department of Defense. Korean War Death Stats Highlight Modern DoD Safety Record. *DoD News*. Retrieved from http://archive.defense.gov/news/newsarticle.aspx?id=45275

21 National Archives (2013, August). *Statistical Information about Fatal Casualties of the Vietnam War*. Retrieved from http://www.archives.gov/research/military/vietnam-war/casualty-statistics.html

22 U.S. Department of Transportation, National Highway Traffic Safety Administration (2014, December). *2013 Motor Vehicle Crash: Overview*, 1-6. Retrieved from http://www-nrd.nhtsa.dot.gov/Pubs/812101.pdf

23 Using 2013 U.S. Census population data, the number of U.S. citizens experiencing a car crash injury each year (3.8 million) was divided by the population of the U.S. in 2013 (316.5 million) to achieve statistic that one in 83 Americans is injured in a car crash each year. U.S. Census Bureau. *U.S. and World Population Clock*. Retrieved from http://www.census.gov/popclock/

24 Massachusetts Executive Office of Public Safety and Security, Highway Safety Division, *Commonwealth of Massachusetts Highway Safety Plan*, p. 16. Retrieved from http://www.nhtsa.gov/links/StateDocs/FY15/FY15HSPs/MA_FY15HSP.pdf

25 Massachusetts Executive Office of Public Safety and Security, Highway Safety Division, *Commonwealth of Massachusetts Highway Safety Plan*, p. 16. Retrieved from http://www.nhtsa.gov/links/StateDocs/FY15/FY15HSPs/MA_FY15HSP.pdf

26 National Safety Council (2014, February 12). National Safety Council Estimates Traffic Deaths Down Three Percent in 2013, *National Safety Council*. Retrieved from http://www.nsc.org/NewsDocuments/2014-Press-Release-Archive/2-12-2014-Traffic-Fatality-Report.pdf

27 This number is derived by dividing $267.5 billion by 122,459,000 U.S. households in 2013, as reported by the U.S. Census Bureau (2013). *America's Families and Living Arrangements: 2013: Households (H table series) – Households by Type and Tenure of Householder for Selected Characteristics*. Retrieved from https://www.census.gov/hhes/families/data/cps2013H.html

28 U.S. Department of Transportation, National Highway Traffic Safety Administration (2014, December). *2013 Motor Vehicle Crash: Overview*, 1-6, 3. Retrieved from http://www-nrd.nhtsa.dot.gov/Pubs/812101.pdf

29 These property damage-only collisions can range from simple fender-benders to severe damage that totals a vehicle, damages building exteriors, or creates prolonged traffic congestion. While some crashes may only require minor repairs, others can result in the need to totally replace nearby structures, including neighboring properties, utility poles, guardrails, and more.

30 While National Highway Traffic Safety Administration does not yet have available data on the estimated costs of these 4 million collisions, a 2010 National Highway Traffic Safety Administration study (updated in May of 2015) found that there were 3.9 million property damage-only car crashes that year, resulting in $71.5 billion in estimated costs. Based on this data, 2013 costs would be estimated at $73.3 billion, or approximately $230 per person living in the United States as of 2013. U.S. Department of Transportation, National Highway Traffic Safety Administration. (2015, May). *The Economic and Societal Impact Of Motor Vehicle Crashes, 2010 (Revised)*, p. 2. Retrieved from http://www-nrd.nhtsa.dot.gov/pubs/812013.pdf

31 Based on Allstate customers in 2012 to 2013. Allstate. (2015). *America's Best Divers Report.* Retrieved from https://www.allstate.com/resources/Allstate/attachments/tools-and-resources/ABD-Report-2015.pdf

32 Massachusetts Energy Information Administration. *Massachusetts Carbon Dioxide Emissions from Fossil Fuel Consumption(1980-2012)*. Retrieved from http://www.eia.gov/environment/emissions/state/excel/massachusetts.xlsx U.S. Energy Information Administration. (2014, December 16). *Average annual household expenditures on gasoline and motor oil (2000-2015)*. Retrieved from http://www.eia.gov/todayinenergy/detail.cfm?id=19211

33 U.S. Energy Information Administration (2015, March 12). *Frequently Asked Questions: How much gasoline does the United States Consume?* Retrieved from http://www.eia.gov/tools/faqs/faq.cfm?id=23&t=10

34 Consumption costs are calculated by multiplying the number of gallons of gasoline consumed in 2012 as reported by Massachusetts to the FHWA, an then applying an average cost per gallon of $3.72, which represents the average cost of a gallon of gasoline in Massachusetts in 2012 as reported by Energy Information Administration. *See*, Massachusetts Department of Transportation, Office of Transportation Planning. (2014). Travel Demand Model. *Massachusetts vehicle-miles traveled Statistics and Projections*; U.S. Energy Information Administration, *Weekly Retail Gasoline and Diesel Prices,* Retrieved from http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_sma_a.htm. Data is retrieved by selecting "Massachusetts" from the "Area" drop down list, and "Annual" from the "Period" drop down list, then looking to the "2014" column.

35 Number of gallons of gasoline burned per week are derived by dividing the total number of gallons of gasoline consumed in Massachusetts in 2012 (2,600,479,912) as reported by the Federal Highway Administration, by 52 weeks, and further dividing that number by the number of licensed drivers in Massachusetts in 2012 (4,734,000 licensed drivers). *See*, Massachusetts Department of Transportation, Office of Transportation Planning. (2014). Travel Demand Model. *Massachusetts vehicle-miles traveled Statistics and Projections*; Office of Highway Policy Information, Federal Highway Administration, U.S. Department of Transportation (2014). *State Statistical Abstracts 2012*, *Massachusetts*. Retrieved from http://www.fhwa.dot.gov/policyinformation/statistics/abstracts/2012/ma.cfm. Total estimated cost per week is calculated by multiplying the derived number of gallons of gas consumed each week by the average cost of a gallon of gasoline in Massachusetts in 2012 as reported by the Energy Information Administration. *See*, U.S. Energy Information Administration, *Weekly Retail Gasoline and Diesel Prices,* Retrieved from http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_sma_a.htm. Data is retrieved by selecting "Massachusetts" from the "Area" drop down list, and "Annual" from the "Period" drop down list, then looking to the "2014" column.

36 To obtain the figure for the total cost of gasoline in Massachusetts from 2006 to 2014, we first calculate the gallons of gasoline consumed each year from 2006 to 2014 and multiply by average prices for those years. This is derived by first calculating vehicle-miles traveled in Massachusetts for each year, as reported by the Massachusetts Department of Transportation, divided by the average number of miles per gallon of the automobile fleet. Fleet MPG is obtained using the "Light Duty Stock Fleet Mix MPG" for each year, as reported by the Energy Information Administration in their 2008, 2011, and 2014 Annual Energy Outlook reports. By this method, the total cost of gasoline in Massachusetts from 2006 to 2014 is $73.2 billion. "Light Duty Stock Fleet Mix MPG" uses the Corporate Average Fuel Efficiency (CAFE) standard. *See* U.S. Energy Information Administration, *Annual Energy Outlook 2008* (Table A7. Transportation Sector Key Indicators and Delivered Energy Consumption. MPG for "Light Duty Stock."). Retrieved from http://www.eia.gov/oiaf/aeo/pdf/tables.pdf; U.S. Energy Information Administration, *Annual Energy Outlook 2011*, *Transportation Sector Key Indicators and Delivered Energy Consumption* (MPG for "Light Duty Stock"). Retrieved from http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2014ER&subject=0-AEO2014ER&table=7-AEO2014ER&region=0-0&cases=full2013-d102312a,ref2014er-d102413a; U.S. Energy Information Administration. *Annual Energy Outlook 2014*, *Transportation Sector Key Indicators and Delivered Energy Consumption* (MPG for "Light Duty Stock"). Retrieved from http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2014ER&subject=0-AEO2014ER&table=7-AEO2014ER&region=0-0&cases=full2013-d102312a,ref2014er-d102413a. For the price of gasoline, we use the annual gas price average as reported by the Energy Information Administration. *See*, U.S. Energy Information Administration, *Petroleum and Other Liquids, Annual Retail Gasoline and Diesel Prices, History 2003-2014*. Retrieved from http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EMM_EPM0_PTE_SMA_DPG&f=A. While the future of gas prices is difficult to know, this report uses the forecasts of the federal Energy Information Agency's 2015 Annual Energy Outlook for future years.

37 American Automobile Association (2015, April 28). *Annual Cost to Own and Operate a Vehicle Falls to $8,698, Finds AAA*. Retrieved from http://newsroom.aaa.com/2015/04/annual-cost-operate-vehicle-falls-8698-finds-aaa/

38 This figure is derived by taking total projected VMT in 2015 (57.30 billion) and multiplying by 5.11 cents per mile, which represents the nationwide average cost of repair per mile. Massachusetts Department of Transportation, Office of Transportation Planning. (2014). Travel Demand Model. *Massachusetts vehicle-miles traveled Statistics and Projections*.

39 Smart Growth America and Taxpayers for Common Sense (2014, March). *Repair Priorities 2014: Transportation Spending Strategies to Save Taxpayer Money and Improve Roads*. Retrieved from http://www.smartgrowthamerica.org/documents/repair-priorities-2014.pdf

40 Smart Growth America and Taxpayers for Common Sense (2014, March). *Repair Priorities 2014: Transportation Spending Strategies to Save Taxpayer Money and Improve Roads*, p. 18. Retrieved from http://www.smartgrowthamerica.org/documents/repair-priorities-2014.pdf. *Citing* Federal Highway Administration Highway Statistics (2011). *Functional System Length - 2011 Miles By Measured Pavement Roughness*, Tbl. HM-64. Retrieved from http://www.fhwa.dot.gov/policyinformation/statistics/2011/hm64.cfm; Federal Highway Administration Highway Statistics (2011). *Functional System Length - 2011 Miles By Measured Pavement Roughness/Present Serviceability Rating*, Tbl. HM-63. http://www.fhwa.dot.gov/policyinformation/statistics/2011/hm63.cfm

41 Smart Growth America and Taxpayers for Common Sense (2014, March). *Repair Priorities 2014: Transportation Spending Strategies to Save Taxpayer Money and Improve Roads*, p. 9. Retrieved from http://www.smartgrowthamerica.org/documents/repair-priorities-2014.pdf

42 Carlson, S.A., Fulton, J.E., Pratt, M., Yang, Z., & Adams, E.K. (2015). Inadequate Physical Activity and Health Care Expenditures in the United States. *Progress in Cardiovascular Diseases, 57*; 315-327, 317. Retrieved from http://www.onlinepcd.com/article/S0033-0620(14)00123-6/pdf

43 T.H. Chan, Harvard School of Public Health. *Economic Costs*. Retrieved from http://www.hsph.harvard.edu/obesity-prevention-source/obesity-consequences/economic/#references; *citing* Cawley J, Meyerhoefer C. (2012), Journal of Health Economics. *The medical care costs of obesity: an instrumental variables approach*. Accessed at: http://www.sciencedirect.com/science/article/pii/S0167629611001366.

44 Trasande L. & Chatterjee S. (2009). The Impact of Obesity on Health Service Utilization and Costs in Childhood. *Obesity, 17*(9):1749-54, 1749. Retrieved from http://onlinelibrary.wiley.com/doi/10.1038/oby.2009.67/epdf

45 Gallup Business Journal (2011, January 27). The Cost of Obesity to US Cities, *Gallup*. Retrieved from http://businessjournal.gallup.com/content/145778/cost-obesity-cities.aspx#1

46 Gallup Business Journal (2011, January 27). The Cost of Obesity to US Cities, *Gallup*. Retrieved from http://businessjournal.gallup.com/content/145778/cost-obesity-cities.aspx#1

47 Gallup Business Journal (2011, January 27). The Cost of Obesity to US Cities, *Gallup*. Retrieved from http://businessjournal.gallup.com/content/145778/cost-obesity-cities.aspx#1

48 United Health Foundation. (2014). *America's Health Rankings 2014: Massachusetts*. Retrieved from http://cdnfiles.americashealthrankings.org/SiteFiles/StateSummaries/Massachusetts-Health-Summary-2014.pdf

49 Walk Boston. *Walking Agenda*. Retrieved from http://www.walkboston.org/policy-positions/walking-agenda

50 McKenzie, B. (2014, May). Modes Less Traveled – Bicycling and Walking to Work in the United States: 2008-2012. *U.S. Census Bureau*. Retrieved from http://www.census.gov/hhes/commuting/files/2014/acs-25.pdf

51 Jacobson, S.H., King, D.M., Yuan, R. (2011). A note on the relationship between obesity and driving. *Journal of Transport Policy*. Retrieved from http://www.ahtd.info/yahoo_site_admin/assets/docs/A_note_on_the_relationship_between_obesity_and_driving.173153035.pdf. Note: The study found that vehicle use (measured in annual vehicle-miles traveled) correlated as high as 99 percent with annual obesity rates, when measuring VMT/licensed driver over a six year lag period.

52 Litman, T. (2010, June 14). *Evaluating Public Transportation Health Benefits*. Retrieved from http://www.apta.com/resources/reportsandpublications/Documents/APTA_Health_Benefits_Litman.pdf. *Citing*, College of Health & Human Performance (2004). Physical Activity Facts and Figures. *East Carolina University.*

53 U.S. Department of Health and Human Services, Office of the Surgeon General. (2015). *Step It Up! The Surgeon General's Call to Action to Promote Walking and Walkable Communities*, p. 3. Retrieved from http://www.surgeongeneral.gov/library/calls/walking-and-walkable-communities/call-to-action-walking-and-walkable-communites.pdf. *Citing*, Ward, B.W., Schiller, J.S., & Goodman, R.A. (2014). Multiple chronic conditions among U.S. adults: a 2012 update. *Prev Chronic Dis*.

54 U.S. Department of Health and Human Services, Office of the Surgeon General. (2015). *Step It Up! The Surgeon General's Call to Action to Promote Walking and Walkable Communities*, p. 4. Retrieved from http://www.surgeongeneral.gov/library/calls/walking-and-walkable-communities/call-to-action-walking-and-walkable-communites.pdf. *Citing,* Physical Activity Guidelines Advisory Committee, U.S. Dept of Health and Human Services (2008). *Physical Activity Guidelines Advisory Committee Report, 2008*. Note: the Surgeon General's Report states that Americans should be walking for 2 hours and 30 minutes over a seven day week. For our purposes, we calculated this number over a five day period, as we are concerned with Americans commuting during the work week.

55 McKenzie, B. (2014, May). Modes Less Traveled – Bicycling and Walking to Work in the United States: 2008-2012. *U.S. Census Bureau.* Retrieved from http://www.census.gov/hhes/commuting/files/2014/acs-25.pdf

56 U.S. Department of Health and Human Services, Office of the Surgeon General. (2015). *Step It Up! The Surgeon General's Call to Action to Promote Walking and Walkable Communities*, p. 5. Retrieved from http://www.surgeongeneral.gov/library/calls/walking-and-walkable-communities/call-to-action-walking-and-walkable-communites.pdf

57 For a review, see Hoehner, C.M., Barlow, C.E., Allen, P., & Schootman, M. (2013, June 1). Commuting Distance, Cardiorespiratory Fitness, and Metabolic Risk. *American Journal of Preventative Medicine, 42(6)*, 571-8. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3360418/

58

59 Massachusetts Department of Transportation, Office of Transportation Planning. (2014). Travel Demand Model. *Massachusetts vehicle-miles traveled Statistics and Projections*.

60 A One-percentage point reduction in VMT is calculated by backing out the current projected growth rate as estimated by MASSDOT, and subtracting one percentage point. For instance, if the current growth rate was positive 0.25 our recalculated reduced growth rate was negative 0.75. This was done for each year. By subtracting one percent from the growth rate rather than subtracting one percent from the forecasted amount of VMT, we seek to measure a relatively constant effort. The policy effort necessary to turn a half-percent increase in the rate of growth into a half-percent decrease in growth rate is likely similar to the policy effort required to move from a half percent decrease to a one and a half percent decrease in the growth rate. By contrast, a one percent reduction of larger increases likely request less effort than turning a small increase into a small decrease in VMT.

61 U.S. Energy Information Administration (2015, July 7). *Frequently Asked Questions, How much carbon dioxide is produced by burning gasoline and diesel fuel*. Retrieved from http://www.eia.gov/tools/faqs/faq.cfm?id=307&t=10

62 U.S. Environmental Protection Agency. (2015). *Greenhouse Equivalencies Calculator*. Retrieved from http://www.epa.gov/cleanenergy/energy-resources/calculator.html

63 Future fuel efficiency of automobiles is expected to increase. To estimate the future fuel efficiency of Massachusetts's automobile fleet, this report relies on nationwide average forecasts provided by the U.S. Energy Information Administration in their 2015 Annual Energy Outlook Report. For 2015, the Energy Information Administration estimates that the "on the road" average fuel efficiency for automobiles and light duty trucks (collectively known as "Light Duty Stock") was 22.7 MPG.

The U.S. Energy Information Agency's forecasts slow increases in gasoline prices through 2040. This report uses the agency's Annual Energy Outlook 2015 reference forecast of future gasoline prices. These values are likely to understate the future cost of gasoline because gasoline in the Bay State tends to be somewhat more expensive than the national average. For 2015, the report uses the Massachusetts price of gasoline for June 2015 ($2.80 per gallon), which has already exceeded the official forecast.

64 Office of Highway Policy Information, Federal Highway Administration, U.S. Department of Transportation (2014). *State Statistical Abstracts 2012*, *Massachusetts*. Retrieved from http://www.fhwa.dot.gov/policyinformation/statistics/abstracts/2012/ma.cfm

65 To calculate the savings per licensed driver for the period, we took the total savings for 2015-2030 (-$7.7 billion), and divided that by the number of licensed drivers in 2012 (4.73 million), which resulted in $1,628 in savings per licensed drivers in Massachusetts for 2015-2030. Office of Highway Policy Information, Federal Highway Administration, U.S. Department of Transportation (2014). *State Statistical Abstracts 2012*, *Massachusetts*. Retrieved from http://www.fhwa.dot.gov/policyinformation/statistics/abstracts/2012/ma.cfm

66 We derived a per mile cost of 9.0 cents per mile by taking National Safety Council's cost of collisions nationwide in 2013 (267.5 billion), and dividing by Federal Highway Administration's data for total miles driven in 2013 (2.972 trillion). National Safety Council (2014, February 12). National Safety Council Estimates Traffic Deaths Down Three Percent in 2013, *National Safety Council*. Retrieved from http://www.nsc.org/NewsDocuments/2014-Press-Release-Archive/2-12-2014-Traffic-Fatality-Report.pdf. *See also*, U.S. Department of Transportation, Federal Highway Administration, Office of Highway Policy Information (2014, November). *Travel Monitoring and Traffic Volume*. Retrieved from https://www.fhwa.dot.gov/policyinformation/travel_monitoring/13dectvt/index.cfm

67 American Automobile Association (2015, April 28). *Annual Cost to Own and Operate a Vehicle Falls to $8,698, Finds AAA*. Retrieved from http://newsroom.aaa.com/2015/04/annual-cost-operate-vehicle-falls-8698-finds-aaa/

68 In order to calculate the associated savings on automobile maintenance resulting from a one percentage point decrease in driving volume in 2015, this report takes the marginal decrease in driving volume for 2015 (575.52 million miles, see appendix II) and multiplies this value by a per-mile cost of automobile maintenance (5.11 cents per mile). The resulting figure ($29.41 million) represents the associated savings on reduced automobile maintenance for that year. American Automobile Association (2015, April 28). *Annual Cost to Own and Operate a Vehicle Falls to $8,698, Finds AAA*. Retrieved from http://newsroom.aaa.com/2015/04/annual-cost-operate-vehicle-falls-8698-finds-aaa/

69 In order to calculate the associated savings on automobile maintenance resulting from a one percentage point decrease in driving volume in 2030, this report takes the marginal decrease in driving volume for 2030 (8.72 billion miles, see appendix II) and multiplies this value by a per-mile cost of automobile maintenance (5.11 cents per mile). The resulting figure ($445.61 million) represents the associated savings on automobile maintenance for that year. American Automobile Association (2015, April 28). *Annual Cost to Own and Operate a Vehicle Falls to $8,698, Finds AAA*. Retrieved from http://newsroom.aaa.com/2015/04/annual-cost-operate-vehicle-falls-8698-finds-aaa/

70 To calculate the associated savings on automobile maintenance resulting from a one percentage point decrease in driving volume for the period from 2015-2030, this report takes the yearly values calculated using the process described above for each year in the period and sums the values to produce a cumulative total for the period ($3.81 billion).

71 The 2.57 cents per mile figure for expected cost of existing state road repair is calculated using data from FHWA for both vehicle-miles traveled estimates (4.2 trillion miles from 2010-2030) and expected cost of maintenance ($108 billion), and then extrapolating out a per-mile cost based on total costs of maintenance divided by total miles. To calculate the VMT estimate from 2010-2030 (4.2 trillion miles) this report takes the difference between a high VMT growth scenario (1.85 percent growth) and a low VMT growth scenario (1.36 percent growth), and sums the annual differences over a projected 20 year period from 2010-2030. To calculate the expected cost of road maintenance from 2010-2030 ($108 billion) this report takes the expected repair costs associated with a future high VMT growth scenario (1.85 percent growth) and future low VMT growth scenario (1.36 percent growth) which equates to $5.4 billion, and expands that cost estimate over a projected 20 year period from 2010-2030 to reach a total of $108 billion. U.S. Department of Transportation, Federal Highway Administration, Policy and Governmental Affairs (2014, November 7*). 2013 Conditions and Performance Report*, ch. 7, exhibit 7-2. Retrieved from http://www.fhwa.dot.gov/policy/2013cpr/chap7.cfm

72 To calculate the economic benefit of a reduction in state road repair associated with a one percentage point decrease in driving volume in 2015, this report takes the value for the reduction in the amount of miles traveled in 2015 under a one percent decrease scenario (575.52 million miles, see appendix II) and multiplies by the per-mile cost of state road repair (2.57 cents per mile). The resulting figure ($14.79 million) is the associated savings on state road repair for the time period. U.S. Department of Transportation, Federal Highway Administration, Policy and Governmental Affairs (2014, November 7*). 2013 Conditions and Performance Report*, ch. 7, exhibit 7-2. Retrieved from http://www.fhwa.dot.gov/policy/2013cpr/chap7.cfm

73 To calculate the economic benefit of a reduction in state road repair associated with a one percentage point decrease in driving volume in 2030, this report takes the value of the reduction in the amount of miles traveled in 2030 (8.72 billion miles, see appendix)II and multiplies by the per-mile cost of state road repair (2.57 cents per mile). The resulting figure ($224.11 million) is the associated cost of state road repair for the time period. U.S. Department of Transportation, Federal Highway Administration, Policy and Governmental Affairs (2014, November 7*). 2013 Conditions and Performance Report*, ch. 7, exhibit 7-2. Retrieved from http://www.fhwa.dot.gov/policy/2013cpr/chap7.cfm

74 To calculate the economic benefit of a reduction in state road repair associated with a one percentage point decrease in driving volume for the period from 2015-2030, this report calculates the annual values using the process described above and then sums all resulting values for each year. The result is the associated savings on state road repair ($1.92 billion) for the period from 2015-2030.

75 This figure is derived by dividing the total economic savings from 2015-2030 ($20.1 billion) by the average monthly grocery cost per U.S. household in 2015 ($618.80) over 15 years ($111,385). The resulting figure, 180,455, is the equivalent number of households (as defined above) that could purchase 15 years' worth of monthly groceries. U.S. Department of Agriculture (2015, April). *Official USDA Food Plans: Cost of Food at Home at Four Levels, U.S. Average*. Retrieved from http://www.cnpp.usda.gov/sites/default/files/CostofFoodApr2015.pdf. Note: Data reflects national average monthly grocery bill for a male and female households of two with partners between the ages of 19 and 50.

76 This figure is derived by dividing the total economic savings from a one percentage point decrease in the vehicle-miles traveled growth rate from 2015-2030 ($20.1 billion) by the 2012 average annual infant daycare cost per child in Massachusetts ($16,430) calculated over 15 years ($246,450). The resulting figure (81,558) represents the number of infants that could be provided fulltime daycare for 15 years. Tran, A.B. (2014, July 2) Map: The average cost of child care by state. *Boston Globe.* Retrieved from https://www.bostonglobe.com/2014/07/02/map-the-average-cost-for-child-care-state/LN65rSHXKNjr4eypyxT0WM/story.html.

77 This figure is derived by dividing the total economic savings from a one percentage point decrease in the vehicle-miles traveled growth rate ($20.1 billion) by the average Massachusetts monthly mortgage payment ($1,204) expanded over 15 years ($216,720). The resulting figure (92,746) represents the number of mortgage payers whose mortgages could be paid for 15 years. Grueling, M. (2012, December 1). National Average Monthly Mortgage Payment by State. *LendingTree.com*. Retrieved from https://www.lendingtree.com/mortgage/2011-2012-national-average-monthly-mortgage-payment-article. Note: This figure uses data obtained from 2011-2012.

78 MassDOT Implements New Healthy Transportation Policy Directive. Accessed at: https://www.massdot.state.ma.us/main/tabid/1075/ctl/detail/mid/2937/itemid/350/MassDOT-Implements-New-Healthy-Transportation-Policy-Directive--Prioritizes-Inclusion-of-Bicycle--Transit--Walking-Options.aspx

79 Global Warming Solutions Act Requirements for the Transportation Sector and the Massachusetts Department of Transportation (310 CMR 60.05). Accessed at: http://www.mass.gov/eea/docs/dep/air/laws/greendot-fs.pdf

80 Project Selection Advisory Council. Accessed at: https://www.massdot.state.ma.us/BoardsCommittees/ProjectSelectionAdvisoryCouncil.aspx

81 A study conducted at the Massachusetts Institute of Technology estimated a 9.5 percent reduction in vehicle-miles traveled if all drivers in Massachusetts switched to a strictly per-mile PAYD insurance plan. Joseph Ferreira, Jr and Eric Minikel, Massachusetts Institute of Technology, *Pay-As-You-Drive Auto Insurance In Massachusetts: A Risk Assessment and Report On Consumer, Industry And Environmental Benefits.* Accessed at: http://web.mit.edu/jf/www/payd/PAYD_CLF_Study_Nov2010.pdf.

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March 2017

A White Paper from the National Center for Sustainable Transportation

Kevin Fang, University of California, Davis
Jamey Volker, University of California, Davis

National Center for Sustainable Transportation

ITS UC DAVIS INSTITUTE OF TRANSPORTATION STUDIES

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NCST

Cutting Greenhouse Gas Emissions Is Only the Beginning: A Literature Review of the Co-Benefits of Reducing Vehicle Miles Traveled

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NCST

Introduction

Traditional evaluation of the transportation system focuses on automobile traffic flow and congestion reduction. However, this paradigm is shifting. In an effort to combat global warming and reduce greenhouse gas (GHG) emissions, a number of cities, regions, and states across the United States have begun to deemphasize vehicle delay metrics such as automobile Level of Service (LOS). In their place, policymakers are considering alternative transportation impact metrics that more closely approximate the true environmental impacts of driving. One metric increasingly coming into use is the total amount of driving or Vehicle Miles Traveled (VMT).

Since passing the seminal Global Warming Solutions Act (AB 32) in 2006, California has enacted two major laws over the past decade that are spurring efforts to reduce VMT: Senate Bill 375 (2008) and SB 743 (2013). SB 375 addresses regional GHG emissions reductions from passenger travel. For each region in the State with a metropolitan planning organization (MPO), the law requires the California Air Resources Board (ARB) to set and regularly update per capita GHG emissions reduction targets for 2020 and 2035. To achieve those targets, SB 375 requires each MPO to adopt a "sustainable communities strategy" (SCS) as part of its regional transportation plan. VMT reductions are a key strategy in SCSs.

Senate Bill 743 (2013) directs the Governor's Office of Planning and Research (OPR) to revise the guidelines for determining the significance of transportation impacts during analyses conducted under the California Environmental Quality Act (CEQA). SB 743 requires a replacement metric that will "promote the reduction of greenhouse gas emissions, the development of multimodal transportation networks, and a diversity of land uses." It mandates that "automobile delay, as described solely by [LOS] shall not be considered a significant impact on the environment" under CEQA, except in "locations specifically identified in the guidelines, if any." VMT is OPR's currently recommended replacement metric (OPR, 2016).

While state goals for reducing GHG emissions have been one motivation for the shift to VMT measures, reductions in VMT produce many other potential benefits, referred to as "co-benefits," such as reductions in other air pollutant emissions, water pollution, wildlife mortality, and traffic congestion, as well as improvements in safety and health, and savings in public and private costs. Such benefits may provide additional justification for reducing VMT. In this paper, we review the literature to explore the presence and magnitude of potential co-benefits of reducing VMT, providing California-specific examples where available.

Figure 1 shows the conceptual framework guiding our literature review. Items shaded in green indicate characteristics that can influence VMT. Items shaded in red indicate co-benefits potentially sensitive to VMT.

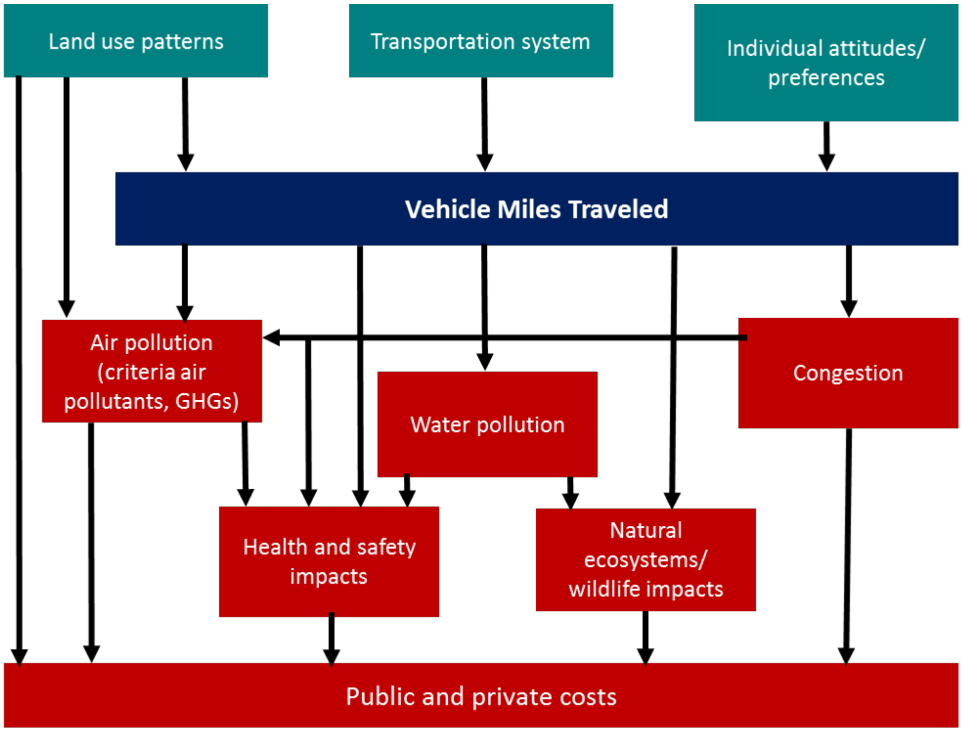

Figure 1. Conceptual Framework

Air Pollutant Emissions

GHG and Criteria Air Pollutant Emissions from Vehicular Operation

Motor vehicles emit pollutants into the atmosphere as by-products of combustion (tailpipe emissions) and through other mechanisms such as fuel evaporation, tire and brake wear, and creation of road dust from the wearing of pavement. Emissions of major concern include greenhouse gases and criteria air pollutants, each of which is a major policy concern in California. Reducing the State's GHG emissions has been state priority for over a decade, as reflected by the aforementioned AB 32, SB 375 and SB 743. Criteria air pollutants are substances for which national and state standards have been set on the basis of human health. California has long standing air quality problems, with large areas of the state unable to attain national ambient air quality standards (NAAQS) for criteria pollutants. Of 52 counties, 39 are in non-attainment for at least one pollutant. Four counties are in non-attainment for five pollutants, and nine counties are in non-attainment for four pollutants.

Transportation is a major source of emissions. Table 1 shows emissions of criteria air pollutants and GHGs from the operation of on-road vehicles in California (not including life-cycle emissions). For criteria air pollutants, operation of on-road vehicles are the source for a majority of carbon monoxide (CO), a near majority of nitrogen oxides (NOx), and a double-digit percent share of particulate matter (PM) 2.5. For greenhouse gases, approximately 33 percent of carbon dioxide equivalent (CO_2e) emissions comes from the operation of on-road vehicles.

Estimates of vehicles nationwide project that the average passenger vehicle emits approximately 5.5 metric tons of CO_2e per year (US Environmental Protection Agency, 2005). This equates to approximately 1.01 pounds of CO_2e per mile.

Table 1. Criteria air pollutant/greenhouse gas emissions from on-road transportation operations in California and potential emissions reduction[1]

	Emissions (Tons/yr)							
	ROG	**CO**	**NOx**	**SOx**	**PM**	**PM 10**	**PM 2.5**	**CO_2e**
Total	634,596	2,690,886	768,555	38,354	928,560	532,849	152,574	486,670,304
From on-road transportation*	147,278	1,437,220	373,585	1,964	15,764	28,309	15,721	159,559,517
Share of emissions from road transportation*	23.2%	53.4%	48.6%	5.1%	1.7%	5.3%	10.3%	32.8%
If on-road transportation emissions decreased by…	**Emissions (tons/yr) would decrease by…**							
	ROG	**CO**	**NOx**	**Sox**	**PM**	**PM 10**	**PM 2.5**	**CO_2e**
1%	1,473	14,372	3,736	20	158	283	157	1,595,595
5%	7,364	71,861	18,679	98	788	1,415	786	7,977,976
10%	14,728	143,722	37,358	196	1,576	2,831	1,572	15,955,952
15%	22,092	215,583	56,038	295	2,365	4,246	2,358	23,933,927
If on-road transportation emissions decreased by…	**Total statewide emissions would drop by…**							
	ROG	**CO**	**Nox**	**Sox**	**PM**	**PM 10**	**PM 2.5**	**CO_2e**
1%	0.2%	0.5%	0.5%	0.1%	0.0%	0.1%	0.1%	0.3%
5%	1.2%	2.7%	2.4%	0.3%	0.1%	0.3%	0.5%	1.6%
10%	2.3%	5.3%	4.9%	0.5%	0.2%	0.5%	1.0%	3.3%
15%	3.5%	8.0%	7.3%	0.8%	0.3%	0.8%	1.5%	4.9%

*Includes tailpipe and other operational emissions (e.g. evaporation, brake dust, tire wear) from mobile transportation sources. Does not include other transportation-related lifecycle emissions (e.g. vehicle manufacturing, fuel refining)

Table 1 also shows potential mass reductions of pollutants if on-road transportation emissions decreased by modest percentages. There could be reductions of up to millions of tons of reduced CO_2e emissions and up to hundreds of thousands of tons of criteria air pollutant emissions.

State targets for some emissions (e.g. CO_2) require a steep reduction over the coming years and decades. In order to reach those targets, improvements in vehicle efficiency, fuels, and VMT will each need to contribute substantially. If per-capita VMT does not decline, VMT increases (through population growth) would likely preclude achieving GHG reduction goals by outweighing improvements in vehicle efficiency and fuel carbon content (California Air Resources Board, 2016). Thus, while improvements in vehicle efficiency and fuel pollutant content will mean each reduced mile of vehicle travel eliminates less pollution in an absolute

[1] Criteria air pollutant emissions from California Air Resources Board (2013) – California Almanac of Emissions and Air Quality [2012 data]
CO_2e emissions from California Air Resources Board (2016) – California Greenhouse Gas Inventory [2014 data]

sense, steeply reducing targets mean that, for the foreseeable future, VMT reduction will continue to provide a substantial share of the needed emissions reduction to hit targets. Vehicles which have no tailpipe emissions (e.g. plug-in hybrid and fully electric vehicles) still lead to some air pollutant emissions, through the electricity generation required for charging. Emissions can be substantially less depending on the carbon content of the energy grid (McLaren, et al. 2016). California has a relatively high proportion of energy generated from renewables; however, a substantial (though shrinking) share of electricity used in California is generated from sources that emit GHGs or criteria air pollutants (California Energy Commission, 2016). Thus, reducing even the VMT driven by zero tailpipe emissions vehicles would reduce GHG and local air pollutant emissions.

A potential confounding factor when discussing potential emissions benefits of reduced VMT is travel speed, as emissions of several criteria air pollutants and GHGs are sensitive to travel speed (Transportation Research Board, 1995; Barth and Boriboonsomsin, 2009). In conventional vehicles, powered by internal combustion engines (ICEs), greater per-mile emissions tend to take place at higher speeds (e.g. 60 mph or greater) where more energy is required to move a vehicle, as well as at lower speeds (e.g. less than 30 mph average travel speeds), where the stop-and-go conditions of congestion cause extra acceleration cycles, energy lost to braking, longer vehicle operation time.

The effect of speed is different on hybrid and battery electric vehicles. Nikowitz, et al. (2016) show that unlike ICEs, which have greatest energy use (and in turn emissions) at low and high speeds, hybrid and battery electric vehicles have greatest energy use under high speed and aggressive driving scenarios (see Table 2). Emerging advanced vehicle technologies such as regenerative braking recovers some of the energy lost in stop and go conditions. Electric motors in battery electric and hybrid vehicles shut off when the vehicle is stopped. Similar “start-stop” technology is increasingly common in ICE-powered vehicles. Increased deployment of technology points to a decreased sensitivity of emissions reductions to the speed of VMT in the future.

Table 2. Relative energy consumption for internal combustion, hybrid, and battery electric vehicles under different drive cycle scenarios[2]

		Scenario		
		City driving	**Highway driving**	**Aggressive driving**
Test cycle		UDDS	HWFET	US06
Test cycle parameters		19.59 mph average speed, frequent stops and starts	48.3 mph average speed, one start/stop	48.4 mph average speed, some stops, rapid acceleration
Make	**Vehicle type**	**Energy consumption relative to lowest energy consumption**		
2012 Ford Focus	Internal Combustion Engine	32% greater	Lowest	37% greater
2010 Toyota Prius	Hybrid	Lowest	4% greater	60% greater
2012 Nissan Leaf	Battery electric	Lowest	19% greater	72% greater

Life Cycle Emissions

Beyond reducing tailpipe emissions, VMT reduction also reduces life cycle emissions, such as those from fuel refining, vehicle manufacture, roadway construction, and roadway maintenance (Chester and Horvath, 2009; Chester and Madanat, 2010, Chehovitz and Galehouse, 2010; Hendriks, et al., 2004). These additional sources increase estimates of GHG emissions from road vehicles by approximately 63 percent over tailpipe emissions alone, and increase estimates of criteria air pollutant emissions from 1.1 to 800 times greater. To the extent that VMT reductions (1) reduce fuel purchases, (2) cause or are the result of decisions of would-be drivers to sell their vehicles or forego purchasing an additional vehicle, or (3) reduce roadway repair burdens, they reduce life-cycle emissions.

Emissions from Building-Related Energy Use

Compact development is a key VMT reduction strategy, as it leads to both shorter trip distances and greater use of alternative modes (Ewing and Cervero, 2010, Transportation Research Board 2009). Stone et al. (2007) estimate that building compact development to reduce VMT would also reduce criteria air pollutant and carbon dioxide emissions at a regional level between five and six percent over a conventional growth scenario, even when accounting for changes in travel speeds.

Compact development can also promote air pollutant and GHG emissions reductions through decreased building energy use. More compact housing units have a smaller volume of air to heat and cool. Additionally, attached housing units have less exposed surface area through which energy is lost. Overall, Ewing and Rong (2008), estimate households living in compact counties use approximately 20 percent energy than households living in sprawling counties, even while taking into account other factors such as income, and the urban heat island effect.

[2] Drive cycles – US Environmental Protection Agency (2016)
Energy consumption – Adapted from Nikowitz, et al. (2016)

Water Pollution

Motor vehicle travel can cause deposition of pollutants onto roadways, which can then be carried by stormwater runoff into waterways. Fuel, oil, and other liquids used in motor vehicles can leak from vehicles onto the ground (Delucchi, 2000). Brake dust and tire wear can further cause particles to be deposited onto the ground (Thorpe and Harrison, 2008). Brake pads and tire compounds are made out of compounds that include metal. One study estimates that approximately half of all copper in San Francisco Bay could have originated from brake pads (Nixon and Saphores, 2003). In California as a whole, up to 232,000 pounds of copper, 13,280 pounds of lead, and 92,800 pounds of zinc in stormwater are attributable to brake pad dust (Nixon and Saphores, 2003).

Motor vehicles require roadways for travel. Paved roadways are generally impervious surfaces which prevent infiltration of storm water in the ground. Impervious surfaces can increase the rate, volume, speed, and temperature of stormwater runoff (US Environmental Protection Agency, 2003), and can transport pollutants via that runoff into waterways. Wearing down of roadways can further cause particles to be deposited onto the ground (Thorpe and Harrison, 2008).

Most motor vehicles also consume liquid fuel, the storage and handling of which can result in fuel tank leaks and spills (Delucchi, 2000). California has had at least 38,000 confirmed cases of leaks from underground storage tanks (Nixon and Saphores, 2003). Reducing VMT cuts consumption of fuel and could reduce fuel spillage risks. These reductions would be additional to reductions gained through greater vehicle efficiency and adoption of alternative fuel vehicles.

The Victoria Transportation Policy Institute (2015) estimates that motor vehicle-related water pollution from roadway runoff, oil spills, and road salting cost approximately 42 billion dollars per year or 1.4 cents per mile.

Health and Safety

Vehicle Collisions and Fatalities

A plurality of “unintentional injury deaths” (deaths not caused by old age, disease, suicide and homicide) are transportation related (Savage, 2013). According to the National Highway Traffic Safety Administration’s Fatality Analysis Reporting System (FARS), 32,675 individuals were killed in motor vehicle crashes in 2014 (NHTSA, 2015). 3,074 of these fatalities occurred in California, 7.9 fatalities per every 100,000 people per year. These fatalities are not just borne by motor vehicle occupants, but by other users as well. In California, more than one quarter of those killed in motor vehicle collisions are pedestrians, bicyclists, or users of other non-motorized modes.

Where there is more driving, there are more vehicle-related fatalities. Comparing motor vehicle fatalities by state from FARS and VMT data from the Bureau of Transportation Statistics (2015) shows a strong positive correlation (r = 0.82) between VMT per capita and fatalities from motor vehicle crashes per capita (authors calculation, see Figure 3).

Data also indicates that each mile driven is also more dangerous in areas with high VMT. Again comparing data from FARS and the BTS, there is a moderately strong positive correlation (r = 0.50) between VMT per capita and deaths per mile traveled (authors calculation, see Figure 4). If the number of vehicle-related fatalities were purely a matter of exposure, every mile traveled should have the same amount of risk regardless of where that mile was driven. There would thus be no correlation between VMT per capita and fatalities per mile. However, states with higher VMT tend to have more motor vehicle crash deaths per mile than lower VMT states. Since increasing VMT is associated with more vehicle-related fatalities per capita and per mile, residents of states where they can fulfill their travel needs with fewer or shorter vehicle trips (and thus with lower VMT) enjoy reduced transportation safety risks.

Using public transit alternatives is associated with less risk than motor vehicle travel. Savage (2013) estimates that drivers or passengers of cars or light trucks experienced 7.28 fatalities per billion miles traveled from 2000-2009. Comparatively, riders of Amtrak, commuter rail, urban mass transit rail systems, buses, and commercial aviation experience 0.43 fatalities per billion miles traveled or fewer.

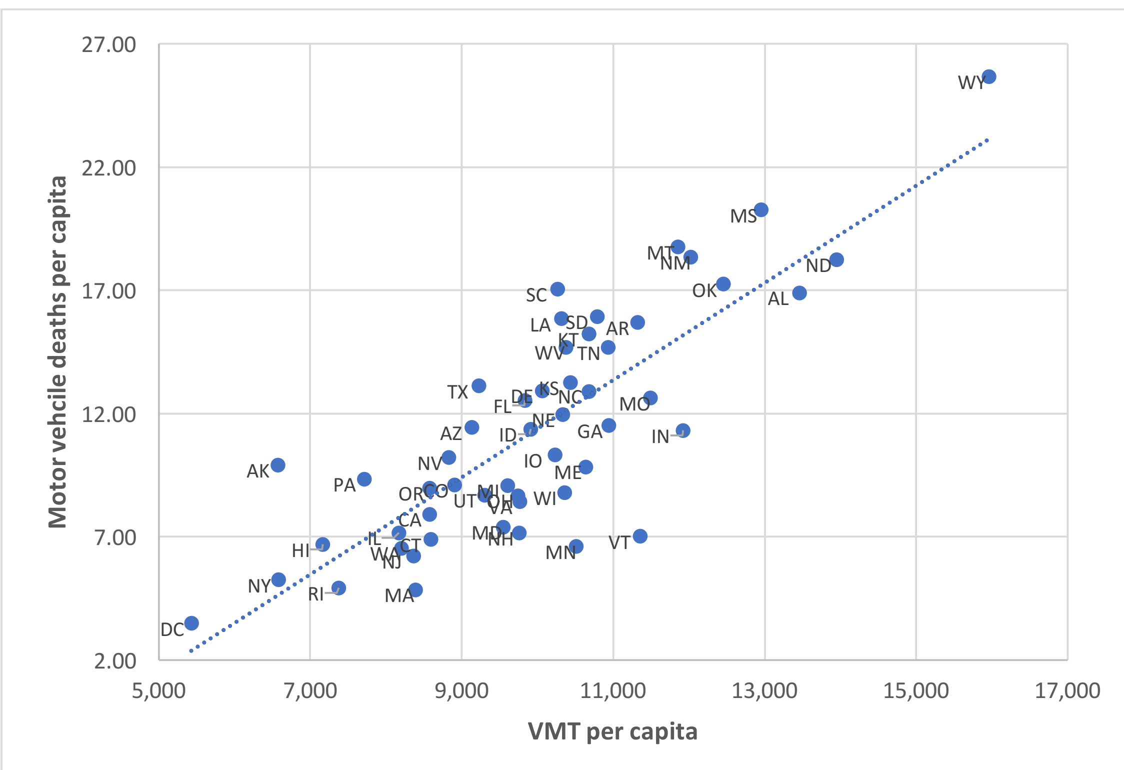

Figure 2. Motor-vehicle related deaths per capita increases as VMT per capita increases

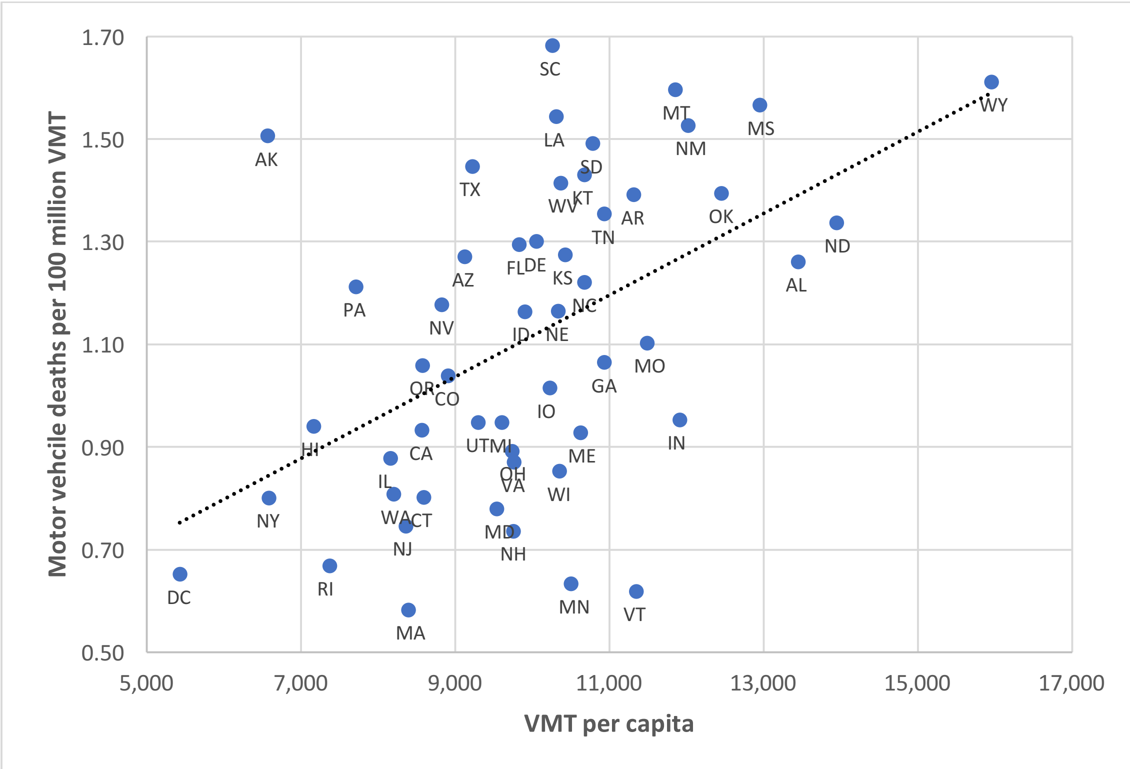

Figure 3. Motor-vehicle related deaths per mile increases as VMT per capita increases

Physical Health

Driving or riding in motor vehicles is a sedentary behavior. Several studies find associations between VMT and weight. For example, obesity and Body Mass Index (BMI) are positively associated with VMT per licensed driver (Jacobson and King, 2009; Behzad, King, and Jacobson, 2012). Geographic areas with high VMT per capita are also associated with poorer health outcomes resulting from reduced physical activity. Residents of counties in the United States with high VMT per capita are less likely to walk for leisure, more likely to be obese, have higher BMI levels, and have a greater prevalence of hypertension (Ewing, et al. 2003). Among California counties, those with the highest mean obesity also tend to have the highest mean VMT per capita (Lopez-Zetina, Lee, and Friis, 2006). Potentially contributing to this pattern are more nights with insufficient sleep and higher smoking rates found with increased driving time (Ding, et al. 2014).

While transit users also ride in motorized vehicles, transit users are more likely to engage in significant physical activity, walking to and from transit stops. Besser and Dannenberg (2012) found that bus and rail users walk an average of 24 minutes per day to and from transit. More than a quarter of transit riders fulfill the US Surgeon General's recommendation of 30 minutes of physical activity per day just from walking to/from stops and stations. On the other hand, increased time driving is significantly associated with not meeting the physical activity recommendation (Ding, et al. 2014).

Users of non-motorized modes by definition engage in physical activity while traveling. The Caltrans Strategic Management Plan (CSMP) sets a goal of doubling 2010 walking and transit levels, and tripling bicycling levels by 2020. An epidemiological analysis of that CSMP describe that achieving this goal would reduce chronic disease and "would constitute a major public health achievement on par with California's successful efforts at tobacco control." (Maizlish, 2016, p. 5).

Health Impacts of Air Pollution

As discussed previously, road transportation and VMT contribute to air pollutant emissions. Criteria air pollutants can lead to a variety of health effects. For example, nitrogen oxides and volatile organic compounds react with oxygen in the air to create ozone, which can have several negative health effects including chest pain, coughing, throat irritation, airway inflammation, reduced lung function, and aggravation of other respiratory conditions (US Environmental Protection Agency, 2016a). Particulate matter poses particularly acute health impacts as small particulates (less than 10 µm in diameter) can enter the lungs or bloodstream and cause or exacerbate heart and lung issues, and even lead to premature death (US Environmental Protection Agency, 2016b). California has especially poor air quality attainment for both ozone and particulate matter.

Table 3 shows per mile estimates of the cost of motor vehicle-related air pollution by McCubbin and Delucchi (1999). Costs range from several cents per mile for most ozone, carbon monoxide, nitrogen oxides, and air toxics, to more than 12 dollars per mile for particulate matter. The higher estimate for particulate matter reflects the greater health effects, including mortality, that can be triggered by particulate matter.

Table 3. Gasoline-powered motor vehicle air pollution cost per mile[3]

	PM	O_3	CO	NO_2	Air Toxics
Cost (2015 $)	12.60	0.08	0.08	0.65	0.05

*Original data in 1991 dollars. Data above is average of low/high estimate from original study. Costs include emissions from tailpipe, upstream fuel and vehicle production, and road dust.

Mental Health

In addition to physical health, long driving commutes can also have a negative impact on mental health. Hennessy (2008) identifies several examples from studies associating long driving commutes with poor mental health outcomes and related consequences, including stress, negative mood, poor concentration, driver error and traffic collisions. Hennessy also

[3] Based off McCubbin and Delucchi (1999)

finds that as stress drivers experience while driving increases, workplace hostility and obstructionism rise among men. Other studies corroborate Hennessy's findings. Gee and Takeuchi (2004), for example, find that traffic stress correlates with depressive symptoms. Ding, et al. (2014) find the more total time a person spends driving per day, the more likely they are to report a poor/fair quality of life, high/very high physiological distress, being stressed for time, and that their health interferes with social activities.

In addition to negative mental health outcomes for drivers, VMT can also cause worse mental health for people in the neighborhoods where that driving occurs or originates. A review of literature by Pohanka and Fitzgerald (2004) notes that residents of dispersed, and thus generally auto-dependent, suburban areas can face increased blood pressure, headaches, and social isolation, which is disadvantageous as the presence of social relationships is positively correlated with health. Additionally, the aforementioned depressive symptoms identified by Gee and Takeuchi are significantly worse in neighborhoods with a high “vehicular burden”, which increases with motorized transport in an area. Built environments that reduce automobile dependence and promote walking can result in lower rates of dementia (Xia et al., 2013).

Wildlife Impacts

Many of the same roadway impacts that affect the health of people can also affect wildlife. Forman and Alexander (1998) outline several potential ecological impacts of roads. For instance, vehicles can directly harm wildlife in “roadkill” events, with an estimated one million vertebrates killed per day on US roads. Shilling and Waetjen (2016) discuss that in California, 5,950 wildlife-related incidents were reported to the California Highway Patrol from a one-year period between 2015 and 2016. Additionally, about 7,000 reports of animal carcasses are made annually to the volunteer California Roadkill Observation System. Overall, Shilling and Waetjen estimate that reported and unreported animal-vehicle collisions cost California approximately $225 million per year. Due to varying avoidance of roadways, impacts differ by species types. Amphibians and reptiles are especially at risk on narrow, low-traffic roads, larger mammals are at risk on narrow, high-speed roads, and birds and small mammals at risk on wide, high-speed roads, Forman and Alexander (1998).

Roadway avoidance is itself an impact, with lower populations of species adjacent to roadways Forman and Alexander (1998). Species can be affected and deterred by characteristics such as road noise, air pollution, altered or polluted water runoff, and nighttime lighting. Roadway avoidance tends to be higher adjacent to higher speed and higher traffic roads. Due to the impacts of roadkill and road avoidance, roadways also act as barriers for species movement. Roadways cutting through habitat can isolate populations of species into smaller groups. Isolated populations have a higher risk for extinction and can have negative impacts on genetic diversity (Coffin, 2007; Holderegger and DiGiulio, 2010).

More compact development patterns that are associated with lower VMT would consume less land and conceivably subject less territory to road avoidance and potential habitat fragmentation. A comparison of various development scenarios across the Sacramento and San Francisco Bay Areas predicted that the most compact growth scenario would save nearly 50 percent of agriculturally sensitive land acreage and steep-sloped areas, and close to 100 percent of wetland areas (Landis, 1995).

Congestion and Accessibility

Broadly, congestion occurs when the free-flow capacity of a roadway is either exceeded by demand (e.g. freeways entering central business districts during peak-hour commutes) or impeded (e.g. when there are auto accidents, roadwork or other road closures). In either case, congestion increases as more vehicle travel is loaded onto the roadway (Falcocchio and Levinson, 2015; Downs, 2004). Conversely, reducing total VMT in a region can reduce congestion on the regional road network, albeit subject to temporal and spatial caveats.

From a temporal standpoint, unless there is an explicit cost imposed on using congested roadways (e.g. a congestion charge) or driving passenger vehicles in general, congestion reductions on those roadways will commonly increase the demand for using them and ultimately cause congestion to rebound to near-preexisting levels in the long-term. This is called the "Principle of Triple Convergence" – some trip makers in the region change their travel locations (routes), times and/or modes to take advantage of the reduced congestion on the roadways in question (Downs, 2004). This "triple convergence" is the reason why roadway expansions often do not reduce congestion in the long-term (Handy and Boarnet, 2014), and why, according to Downs (2004, p. 22]), "building light rail systems or subways rarely reduces peak-hour traffic congestion."

However, recent research indicates that transit may cause a more sizeable and enduring reduction in peak-hour congestion than previously thought. Anderson (2014) used a choice model, calibrated using data from the Los Angeles metro area, that unlike most previous studies accounted for the heterogeneity in congestion levels on roadways in the region, which increased the predicted congestion-reducing effects of transit by six times. As Anderson (2014, p. 2764) explains, since "drivers on heavily congested roads have a much higher marginal impact on congestion than drivers on the average road," and since transit riders are often those who would have to drive on "the most congested roads at the most congested times," transit has a "large impact on reducing traffic congestion."

Spatially, VMT reductions alleviate congestion in the specific locations where net vehicle travel is curtailed. And even where urban (or suburban) densification increases net localized vehicle travel and congestion despite reducing per capita (or even net regional) VMT, it generally increases local *accessibility* to jobs and other desired destinations, decreasing the time and cost of reaching those destinations. In a study of congestion and accessibility in the Los Angeles region, Mondschein et al. (2015, p. v) found that "high-density areas in the region provide better access to jobs than those areas where traffic conditions are relatively less congested." Similarly, for Los Angeles firms, they found that "physical proximity to other firms, rather than area congestion levels, is the primary component of firms' ability to access other similar firms" (Mondschein et al., 2015, p. viii).

In sum, increasing regional VMT, all else equal, will increase regional congestion. And conversely, reducing regional VMT can reduce regional congestion, though congestion levels may rebound somewhat in the long-term. Even where VMT-reducing densification increases local congestion, it tends to improve local accessibility.

Fiscal Matters

Reducing VMT also has major fiscal impacts. It has both direct and indirect impacts on both household and public costs. VMT can also have major impacts on governmental revenues.

Household Costs – Direct Impacts

American households pay more for transportation than any other category of household expenditures except housing (Haas et al., 2013). According to Bureau of Labor Statistics data, households spent nearly 20 percent of their income on transportation on average in both 2000 (18%) and 2010 (16%) (Moeckel, 2017; Haas et al., 2013). A major reason for that is auto ownership and use are expensive – "the most expensive component of transportation cost is auto ownership" – and many U.S. households live in suburban and exurban areas with poor accessibility and transit connectivity (Haas et al., 2013, 20). Reducing household VMT (and car ownership) can thus reduce total household costs both directly and indirectly.

The direct cost reductions of driving less are well known, and include reduced fuel use and parking costs, lower maintenance costs averaged over time, and, for those households that reduce their VMT enough to sell one of their vehicles, license, registration, insurance, and additional maintenance cost savings (Levinson and Gillen, 1998; Cui and Levinson, 2016). The cost of alternatives to driving vary greatly by location, alternative, value of time, and other factors Active transportation options like walking and bicycling can be much cheaper for shorter trips than driving because they have lower capital and operating costs (e.g. the cost of walking shoes or a bicycle versus the cost of a vehicle and gasoline). And transit (e.g. buses and commuter rail) can be cheaper than driving for longer trips. Keeler et al. (1975), for example, estimated the comparative costs of a hypothetical commute in the San Francisco Bay Area by driving (1.5 passengers per auto), riding Bay Area Rapid Transit (BART), and riding a bus. They concluded that both bus and rail transit can be cheaper for the user on an average basis than driving at sufficiently high passenger densities. However, the potential for a given household to reduce its transportation costs by reducing VMT largely depends on availability of sufficient regional transit connectivity, accessibility to jobs and other amenities (Haas et al., 2013; Haas et al., 2008; Renne and Ewing, 2013).

Household Costs – Indirect Impacts

As is frequently discussed in both the academic literature and California policy circles, one way to reduce VMT – and achieve the associated household cost savings – is to increase residential and employment densities within existing urban areas, and especially near transit stations (Ewing and Cervero, 2010). For residences, a benefit of this type of “smart growth” is that it can substantially reduce household costs, particularly transportation costs. Haas et al. (2008), for example, developed a model for estimating average household transportation costs by Census block based on annual household VMT, household car ownership and annual household transit use. They tested their model in the Minneapolis-St. Paul metropolitan region and found that reductions in average annual household transportation costs correlated with decreasing VMT, decreasing auto ownership, increasing transit trips and denser, more transit- and job-accessible areas. From that original model, the Center for Neighborhood Technology (CNT) developed the Housing + Transportation Index. CNT has since expanded and refined the model, but its results continue to show that residential density is the single largest predictor of auto ownership and use, and thus household transportation costs (Haas et al., 2013).

Households in denser and more accessible urban areas often also demand less energy and water because they have smaller units and lots (Litman, 2016; Busch et al., 2015). When all the cost savings of living in denser urban areas are combined, the available evidence shows that they “more than offset” the increased housing costs in those areas (Litman, 2016, p. 19; Ewing and Hamidi, 2014). In other words, when all costs are considered, rather than just housing costs, living in smart growth communities is generally less expensive than living elsewhere.

With specific respect to California, one recent study estimated that if 85 percent of new housing and jobs added in the state until 2030 were located within existing urban boundaries, it would reduce per capita VMT by about 12 percent below 2014 levels (Busch et al., 2015). That combination of reduced VMT and more compact development would, in turn, result in an estimated $250 billion in household cost savings cumulative to 2030 (with an average annual savings per household in 2030 of $2,000) (Busch et al., 2015). Household costs analyzed in the study include auto fuel, ownership and maintenance costs, as well as residential energy and water costs.

Public Costs – Indirect Impacts

In addition, denser development usually reduces the per capita costs of providing many types of public infrastructure and services. Denser development can, among other things, reduce road and utility line lengths, and in turn reduce travel distances needed to provide public services like police, garbage collection, emergency response and transporting school children (Litman, 2016; Busch et al., 2015; Burchell and Mukherji, 2003). Indeed, in his review of the literature, Litman (2016) found that “[n]o credible, peer-reviewed studies demonstrate that comprehensive Smart Growth policies fail to significantly reduce public infrastructure and service costs.”

With specific respect to California, the recent Busch et al. (2015) study estimated that if 85 percent of new housing and jobs added in the state through 2030 were located within existing urban boundaries, it would result in $8.2 billion in avoided public health costs and $18.5 billion in infrastructure cost savings cumulative to 2030 (Busch et al., 2015). Public health costs considered include those related to passenger vehicle air pollutant emissions, such as respiratory-related ER visits, mortality, etc. Infrastructure costs estimated include "one-time capital costs for building local roads, water and sewer infrastructure; and ongoing annual operations and maintenance costs" (Busch et al., 2015). All cost savings estimates are in 2015 dollars.

Government Revenues – Direct Impacts

VMT reduction can reduce public revenues from volumetric gas taxes or VMT fees, if those fees are held constant per gallon or mile. As VMT declines, so does the volume of gas consumed or miles tolled, and, correspondingly, the amount of revenue received. However, decreases in gas tax or potential future VMT tax revenue could be made up by increasing the tax rates. And as between volumetric gas taxes and VMT-based taxes, revenue stability would likely be more easily achieved with a VMT-based fee, given the rapidly advancing shift to electric and more fuel-efficient vehicles that are reducing liquid fuel consumption (National Highway Traffic Safety Administration, 2014; California Energy Commission, 2016). That is one reason states including California have been studying VMT fees (California Department of Transportation, 2016). A VMT fee would also be one of the "most effective way[s] to change behavior" to reduce VMT (Chapple, 2015). However, fees, like taxes, are commonly politically unpopular, even those with immense social benefit (Bedsworth et al., 2011).

Government Revenues – Indirect Impacts

As with household and governmental costs, VMT-reducing "smart growth" land use patterns also impact governmental revenues. Litman (2016) surveyed the literature and found that "Smart Growth tends to increase economic development, including productivity, business activity, property values and tax revenue." For example, the Chicago Metropolitan Agency for Planning (CMAP) (2014) concluded, based on a comparison of Chicago-area residential project case studies, that "denser projects drive higher revenues." Per capita gross domestic product (GDP) also tends to decline with rising VMT and increase with per capita transit ridership, which in turn can increase tax revenues (Kooshian and Winkelman, 2011).

Most studies look primarily at either the cost impacts or the revenue impacts of smart growth and reducing VMT, not both. But in two recent studies of Madison, Wisconsin and West Des Moines, Iowa, respectively, Smart Growth America (SGA) did a more comprehensive fiscal impact analysis (SGA, 2015a, 2015b). In the studies, SGA calculated both costs and revenues – the net fiscal impact – to the cities and their associated school districts across a range of high- and low-development density scenarios.

The West Des Moines study assessed the fiscal impact of the estimated residential and commercial growth in the city over 20 years using four different density scenarios (holding the product mix constant), and estimated that the net fiscal benefit for the city and the local school district would be 50 percent greater for the most compact development scenario as compared to the base density scenario (current West Des Moines density) (SGA, 2015a).

The Madison study was narrower in scope. It analyzed the fiscal impact of developing a 1,400-acre site across a range of development densities and product mixes. Comparing the baseline density and product mix scenario to the more compact development scenario with the same product mix, the study estimated that the latter – compact development – would have a slightly greater (about 5 percent) net fiscal benefit. However, the authors also concluded that their model likely underestimated the net fiscal benefit of the more compact scenario (SGA, 2015b).

Conclusion

Reducing VMT can provide many additional benefits beyond reducing GHG emissions. Studies show a broad array of co-benefits including environmental, human, and fiscal health. VMT reductions can provide these co-benefits directly (e.g. lowering air pollutant emissions and operating costs of vehicles with reduced use) and indirectly (e.g. realizing the benefits of alternatives to driving). As noted, there are some variations in the depth of these benefits (e.g. spatial differences in impacts, and impacts dependent on other factors in addition to VMT), but the evidence is clear that, overall, VMT reductions can help forward multiple goals in addition to GHG reduction. Additional research measuring costs and benefits of transportation on a per distance traveled basis, which was not yet available for all impacts reviewed in this paper, would be helpful in further ascertaining the depth and breadth of potential co-benefits of VMT reductions.

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The Economic Benefits of Vehicle Miles Traveled (VMT)-Reducing Placemaking: Synthesizing a New View

November 2017

A White Paper from the National Center for Sustainable Transportation

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The Economic Benefits of Vehicle Miles Traveled (VMT)-Reducing Placemaking: Synthesizing a New View

A National Center for Sustainable Transportation Research Report

November 2017

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The Economic Benefits of Vehicle Miles Traveled (VMT)-Reducing Placemaking: Synthesizing a New View

EXECUTIVE SUMMARY

This paper analyzes evidence on the economic benefits of placemaking efforts that prioritize pedestrian and non-motorized access and that, at times, reduce vehicle miles traveled. The previous literature on the economic impacts of transportation has focused on theorizing and gathering evidence on ways that transportation infrastructure generates economic benefits at large geographic scales – often states or nations. That literature overlooks many of today's transportation projects which are at the scale of a neighborhood and which typically include non-motorized transportation. We summarize evidence on how those more locally oriented placemaking efforts are associated with benefits that accrue to residents and firms. There is a high degree of evidence that there are economic benefits, on commercial property values, residential property values, business sentiment, and productivity, from density that are summarized as they relate to neighborhood oriented placemaking transportation policies. We conclude by suggesting a systems view of metropolitan transportation that has a hierarchy of networks, from high-throughput metropolitan arteries to local, multi-modal, neighborhood planning with connections between the different levels of the system.

Introduction

California cities, and regions across the world, are embarking on a sea of change in transportation policy. Movements to limit the automobile, reduce driving, and support transit and non-motorized travel are now popular worldwide. This change is motivated in part by environmental regulations. California, for example, encourages local governments to reduce vehicle miles traveled (VMT) to comply with state regulations for greenhouse gas (GHG) emission reduction. But the trend toward lower VMT, and policies that are aimed at reducing VMT, goes deeper than compliance with environmental regulations. VMT-reducing planning – programs that include complete streets, pedestrian neighborhoods, bicycle infrastructure, or transit – is part of a movement to reconnect transportation to place and placemaking, and to view transportation not simply as a mobility tool but as an integral part of the built environment in our communities.

> The Project for Public Spaces defines placemaking as… "the collaborative, community-based process by which we can shape our public realm in order to maximize shared value. More than just promoting better urban design, Placemaking facilitates creative patterns of use, paying particular attention to the physical, cultural, and social identities that define a place and support its ongoing evolution." (Project for Public Spaces, 2009)

In this paper, we examine how VMT-reducing placemaking can help boost local (i.e. neighborhood) economies. This is a new question in two ways. First, the link between economic development and transportation has been largely a link from increased mobility – at times from increased VMT – to economic growth. Second, the academic literature on economic benefits and transportation has been regional and national, and rarely neighborhood focused.

Changing the focus to the economic role of less VMT and shifting the geography from the metropolitan area to the neighborhood are both challenging shifts. The increasing policy importance of multi-modal transportation, often with an explicit goal to reduce VMT, requires a better understanding of how VMT-reducing placemaking is, or could be, linked to neighborhood economic benefits. This paper addresses that gap for policymakers and researchers.

This paper proceeds in the following sections. In Section II, we discuss the motivation for a new view of VMT-reducing placemaking and the link to local economic benefits. Section III articulates both the old (or traditional) view of how transportation influences economic development, and a new view that we argue should be synthesized. The two views, we note, are not mutually exclusive, but rather focus on different problems at different geographic scales. Sections IV through VI articulate different categories of benefits from plans that reduce VMT in neighborhoods. Section IV summarizes evidence on agglomeration benefits (i.e. increases in business productivity), Section V discusses resident benefits that accrue from VMT-reducing placemaking, and Section VI summarizes business benefits. We close with conclusions in Section VII.

II. Why Study the Economic Benefits of Placemaking?

California has a policy interest in encouraging alternatives to automobile travel. Senate Bill (SB) 375 (The Sustainable Communities and Climate Protection Act of 2008) requires that metropolitan planning organizations (MPO's) meet GHG reduction targets for the ground transportation sector. SB 375 does not require VMT reduction *per se* (the target is GHG emissions), but SB 375 has accelerated discussion about the co-benefits of policies that reduce GHG emissions, and those co-benefits are often related to quality-of-life attributes associated with reduced driving.[1] Additionally, in response to SB 743 (2013), the California Governor's Office of Planning and Research has proposed shifting the criteria for transportation impacts for California Environmental Quality Act (CEQA) review from level-of-service – a congestion criterion – to VMT, which will favor projects that reduce current levels or future growth of VMT.

At the sub-state level, cities and municipalities are increasingly pursuing policies that are consistent with VMT reduction. Los Angeles Mayor Eric Garcetti's Great Streets program has been a signature of his administration.[2] Complete streets – streets that accommodate pedestrians and bicyclists, that are environmentally sustainable, and that integrate the street space and associated sidewalks into public life – have been a priority in many California communities for some years.[3] Traffic calming is increasingly popular and is related to complete streets and pedestrianization. All of these reflect a policy context that has shifted from viewing streets and highways solely as mobility infrastructure to viewing those roadways as public space and hence valuing policies that favor lower levels of VMT.

For purposes of this paper, we define VMT-reducing placemaking as efforts that have two broad characteristics.

(1) VMT-reducing placemaking projects link transportation infrastructure to place, such that the transportation project becomes a neighborhood amenity. Examples include but are not limited to complete streets, pedestrianized streets or malls, highway caps, bike lanes and bicycle sharing.

(2) VMT-reducing placemaking projects have the effect of reducing VMT, either through purposeful efforts (e.g. traffic calming) or through a concomitant of the project (e.g. infrastructure that supports bicycle or walking travel.)

We focus on neighborhood scale geographies, because that is the scale for many VMT-reducing or similar placemaking projects, and because smaller communities (or small locales within

[1] See the set of 25 policy briefs developed for the California Air Resources Board. Each brief includes a section on co-benefits. Here: https://arb.ca.gov/cc/sb375/policies/policies.htm.

[2] See LA Great Streets Initiative website for more information on this program, here: http://lagreatstreets.org/.

[3] See, e.g., the proceedings of a 2011 UCLA conference, available here: http://www.lewis.ucla.edu/wp-content/uploads/sites/2/2015/02/2011-Complete-Streets-for-Los-Angeles.pdf.

larger cities) have often been most concerned about whether and how VMT-reducing placemaking will affect their local economy. Our research aims to inform other researchers and local policymakers on the effects of neighborhood scale VMT-reducing placemaking.

III. How Might VMT Reduction Contribute to Neighborhood Vitality and Neighborhood Economies?

The idea that VMT reduction can have economic benefits might seem odd at first – particularly so after decades of practice and scholarship that focused on ways that mobility (and hence at times increased VMT) is associated with economic growth. In this sub-section, we discuss two things. First, we will discuss the traditional literature on transportation and economic development, to provide both a benchmark and lessons, and then theoretical perspectives on why and how VMT-reducing placemaking can have positive local (neighborhood) economic outcomes.

A. The Old View: Transportation and Economic Development

The link between transportation and economic growth began, intuitively enough, with the idea that better transportation improves economic development. Increasing market access, by building transportation infrastructure, improves trade and increases economic growth. That is particularly true for the early stages of infrastructure construction which can have large impacts on the geographic scope of markets. Donaldson (2010) and Donaldson and Hornbeck (2016) found that early railway construction in both the U.S. and India in the 1800s led to economic growth. Those early railroads connected market towns and far-flung locations that, often, were not previously readily or reliably connected to the larger market.

The construction of the Interstate Highway system in the 1950s and 1960s provided another opportunity to examine the link between large-scale transportation infrastructure investment and economic growth. Nadiri and Manuneas (1996, p. 110) examined how highway capital is related to total factor productivity (TFP) for 35 industries in the U.S. They found that from 1964 through 1972, 25 percent of TFP growth in those industries was associated with increases in the stock of highways, but that in later years, when the Interstate Highway network was largely complete, the effect was smaller. From 1973 through 1979, highway capital accounted for two percent of TFP growth in the industries studied by Nadiri and Manuneas (1996). Like the railroads before them, the construction of a new, national transportation network was associated with economic growth (in this case measured by growth in productivity.) But the effect of additional changes to the transportation network is smaller when the network is mature.

Mohring and Harwitz (1962) examined the impact of the early Interstate Highway system and developed a critique which still applies today. In some cases, improvements in transportation infrastructure shift economic activity from one location to another. Distinguishing between aggregate growth and shifts in activity across the landscape is an important issue. A good piece of intuition, which is consistent with theory and evidence, is that large investments in new national infrastructure (railways in the 1800s, highways in the mid-1900s), by connecting large numbers of previously poorly linked markets, can generate aggregate economic growth. Once the network matures, the economic impact of transportation investment is more likely to shift economic activity from one location to another, as businesses move to take advantage of the new pattern of transportation accessibility.

This has led to the double counting critique, first formalized by Mohring (1961) in a different context (land prices). Applied to economic growth, the double counting critique cautions us to be careful to distinguish between two cases: (1) when transformative new networks connect previously unconnected places, and hence lead to new economic growth, and (2) when more marginal changes in transportation infrastructure advantage some locations, shifting economic activity from one location to another. The double counting critique has been a mainstay of academic thinking on transportation and economics. The critique implies that new jobs near highways or rail stations ought not be counted as economic impacts, because those jobs moved from somewhere else, and hence are countervailed by job losses elsewhere. This critique has led many, including this paper's first author (Boarnet, 1997), to be skeptical of the role that highway building, or by extension, any improvement in transportation access in a mature system in a developed economy, can have on aggregate economic growth.

Yet there is one more nuance, and a potentially important one. Knowledge-based economies, relying on access within metropolitan areas, benefit from smooth transportation. Hymel (2007) found that traffic congestion is associated with lower rates of employment growth in a sample of U.S. metropolitan areas. The dampening effect of congestion on employment growth is larger at higher levels of congestion (Hymel, 2007, p. 134). Starting from a less congested network, in San Diego, a 10% reduction in travel time gives a 2.48% increase in employment growth. In the more congested Los Angeles - Orange County network a 10% reduction in travel time gives a 4.6% increase in employment growth.

This result has been reproduced by computable general equilibrium (CGE) models that examine how transportation investment is related to economic growth within a metropolitan area. The Southern California Association of Governments (SCAG) is the metropolitan planning organization for the greater Los Angeles region, a six-county area that is home to over 18 million persons. Beginning in the 2012 Regional Transportation Plan, and continuing with the 2016 plan, SCAG has modeled how transportation spending in the greater Los Angeles region will increase employment. The results show that the 2016 Regional Transportation Plan, a program of over $500 billion in transportation investments over 25 years, can create an average of 539,000 annual jobs from 2016-2040, of which 188,000 jobs in each year will be from the construction, operation, or maintenance of transportation projects. The other 351,000 annual jobs flow from increased economic competitiveness (SCAG, 2016).[4] This is similar to the market

[4] "Annual jobs" in the SCAG (2016) analysis is job years. One job for a duration of one year is one "annual job."

area results of Donaldson (2010) and Donaldson and Hornbeck (2016), but it reflects advantages within the metropolitan area that likely go beyond simple one-for-one shifts in economic activity from one location to another.

This result applies at the regional (metropolitan or county) level (the unit of analysis in Hymel's study and similar research) not at the neighborhood level. The research results suggest that improved regional transportation access, of the sort that would flow from congestion pricing or improved access to jobs, is associated with regional economic growth, while at the neighborhood level knowledge-based industries benefit from density and hence often congestion. The research literature does not give evidence that neighborhood congestion is a factor in local economic growth, but the literature (summarized below) does support the idea that VMT reduction can boost neighborhood economic growth.

Summarizing, the following results are important:

1. Most research has focused on how more transportation, often measured as more infrastructure, relates to economic growth. The results are twofold: (a) New networks, often built to respond to new transportation technologies, can connect far-flung markets, increasing market access, trade, and hence economic growth. (b) After the initial network construction, marginal changes (for example, adding a link to the network or expanding capacity by adding a lane) often have no or at best little relationship to economic growth.

2. Recent evidence (e.g. Hymel, 2007, SCAG, 2016) has linked congestion reduction to economic growth. Congestion reduction, however, is not the same as simply investing in more transportation infrastructure. In large, congested, metropolitan areas, evidence indicates that adding more highway lane miles induces more driving (Duranton and Turner, 2011). Managing the system, including pricing congestion, will be important for the relationship between transportation access and economic growth, particularly so in mature networks and systems.

3. The practice community should beware of double counting. In the early stages of network construction, the economic benefits from increased connectivity likely extend broadly and hence economic gains are likely to go beyond simply moving activity from one location to another. But as the network matures, continued improvements in transportation access most often shift economic activity from one location (with relatively poor access) to another, more accessible, location. Seeing a new office park develop near an intersection of two highways, or in a transit-oriented development (TOD), does not imply that all those jobs are new. Much of that economic activity might have located elsewhere absent the new freeways or TOD.

4. Double counting applies most clearly to cases where the economy is constant returns to scale – in simple terms, cases where doubling economic inputs leads to twice as much economic output. Knowledge economies rely on learning that is facilitated by interaction,

and is performed by workers who value amenities. Such economies may be characterized by increasing returns to scale if, as is often the case, firms become more productive when they and their employees interact with each other. This is the key to why congestion reduction in heavily congested locations is associated with more employment growth.

What does this all mean? We should draw two distinctions – between metropolitan and neighborhood geographies, and between efficiency of movement (access) and simply building more infrastructure. The evidence suggests that improving connections across a metropolitan area can increase economic activity (e.g. Hymel, 2007; SCAG, 2016). This is not a formula for simply building more infrastructure, but a call to build infrastructure wisely. The evidence suggests that ease of movement across a metropolitan area can be important, and in dense cities, such movement is usually multi-modal, requiring in part the higher passenger throughput that rail transit (particularly heavy rail) can provide. At the same time, foot traffic and inviting streetscapes are important for neighborhoods, and are likely increasingly valued by residents and business visitors alike. All of this suggests a place for a new view of transportation and economic development, which has a role for placemaking that can, at times, be linked to reductions in VMT rather than increases in driving.

B. A New View: VMT, Placemaking, and the Value of Place

The idea that place is valuable is not new in planning. It is at the core of the field. But it is arguably new to transportation planning – at least new in the way we are currently asking the question and in the policy debates that the question informs. The purpose of this white paper is to summarize the evidence in ways that can inform policy.

There are three ways that VMT-reducing placemaking can enhance the value of and the economy in a neighborhood: (1) amenities associated with placemaking aspects of transportation policies or projects, (2) increased residential property values which reflect improved resident quality of life, and (3) increased business activity or economic benefits that flow from the VMT reduction. Each is described below.

1. Public or External Benefits

VMT reduction can have many positive effects. Lower VMT, or the reduced car travel speeds that are often associated with lower VMT, can lead to lower accident rates, increased physical activity (from pedestrian and bicycle programs and projects), improved air quality, and amenities that range from inviting streetscapes to sidewalk cafes to walking neighborhoods that may be desired by local residents and shoppers. Some of these effects are reductions in what economists would call negative externalities. A negative externality is a cost to persons who did not buy a good but who are affected by others who purchase (or sell) the good. Emissions from cars are negative externalities, because persons who did not drive breath the emissions generated by trips from other drivers. Following that logic in reverse, improvements in local air quality from reduced driving are external benefits. Increased physical activity, to the extent that physical activity produces or reflects societal benefits that are not fully captured by the individual (e.g. reduced societal healthcare costs) can be external benefits. Accident reduction, particularly when individuals cannot perfectly insure against the full effect of traffic accidents, can be external benefits.

There is a large literature on each of these topics, and for that reason this paper will not go into depth on each effect. These summaries cover the link between VMT reduction and neighborhood amenities: For driving speed and accidents, see Aarts and Schagen (2006); for VMT reduction and physical activity, see Frank et al. (2007) and Sallis et al. (2004); for driving and air quality, see Zhang and Batterman (2013).

All of these things are neighborhood amenities. As such, the benefits will be dispersed throughout the neighborhood – no single private actor can be expected to capture the full value. Having said that, a common way to measure amenities is to look for how those amenities are reflected in land values. If these impacts – lower accidents, improved air quality, inviting streetscapes, and a neighborhood that is visually attractive – are valued by residents, that value should be reflected in higher land prices and hence, holding all else equal, higher home prices. This is a time-honored concept – places with higher amenities have higher home values. The theory behind this dates to the pioneering urban economics work of Alonso (1960), Muth (1968) and Mills (1972), and large literatures have demonstrated that place based amenities are reflected in land values and home values. For a review of the literature on house prices and transit-oriented developments, see Bartholomew and Ewing (2011).

2. Resident Benefits

Residents value living in neighborhoods with more desirable amenities. That value should be reflected in higher land prices and hence higher house values. Hence a common way to measure resident benefits is to measure increases in home prices. Those home prices will measure the overall package of amenity benefits – the combination of, for example, slower vehicle movement, pedestrianization, business activity, and inviting streetscapes, in addition to school quality, access to jobs, and a host of other factors. Some studies disentangle the effect of individual amenities on home prices, while other studies examine the effect of a package of amenities by measuring the house price premium associated with a neighborhood or specific kind of neighborhood without separating the effect of the several amenities in the neighborhood.

3. Business benefits

Non-motorized and public transportation, pedestrianization, and traffic calming measures can increase retail business benefits by doing three different things. First, increased pedestrian activity and accessibility for customers can lead to more opportunities for walk-by or pass-by customer visits to retail businesses. That increase in retail sales can lead to an increase in commercial property values. Lastly, walkable business districts with links to high-throughput transit can increase pedestrian activity and transportation access in ways that might lead to more business interactions and hence higher business productivity.

We summarize the literature on each impact in turn. We first discuss ways that neighborhood-scale placemaking can lead to higher business productivity, then we summarize studies that measure resident benefits, followed by studies of retail sales and business property values.

IV. Placemaking and Agglomeration Benefits

There is consensus in both the theoretical and empirical economic literature that increased urban density is beneficial for local economic growth. The phenomenon is called "agglomeration economies" and refers to the finding that firms are more productive, on average, when they locate near other firms. Several studies on agglomeration economies are summarized in Table 1.

Agglomeration benefits decline sharply with distance. For some industries, most of the productivity benefits from locating near other firms accrue within 1-5 miles (Rosenthal and Strange, 2003). In other words, firms are typically more productive when they locate near other firms in the same industry, but that effect operates over small distances, as small as 1 to 5 miles (Rosenthal and Strange, 2003). An older study that measured the effect of train stations on employment centers finds that the positive influence of stations on employment declines sharply, dropping at a rate of 20-25% per mile (McMillen and McDonald, 1998). In general, there is evidence that agglomeration benefits are strongest over short distances (McMillen and McDonald, 1998).

The Rosenthal and Strange (2003) study finds that small firms (1-20 people) benefit the most from co-locating near each other. Moreover, they find that some industries benefit more from co-locating. Firms in creative industries, such as software and fashion apparel, benefited more from co-locating near other similar firms, suggesting the importance of knowledge spillovers as a source of agglomeration economies. A series of studies finds that traffic congestion is negatively related to economic growth. For example, workers who spend more time commuting need to be compensated with higher wages (Wheaton and Lewis, 2002). As a result, if congestion leads to commute times that are excessively long, it is in the interest of firms to move closer to their employees to reduce commute times. One way to mitigate this shuffling is to allow for mixed-used zoning that enables firms and employees to co-reside (Wheaton and Lewis, 2002). Another study that modeled traffic flow in urban areas reached a similar conclusion that mixing land-use inside commercial districts, increasing density, and improving road network connectivity in order to stem congestion helps economic efficiency and spatial equity (Tsekeris and Geroliminis, 2013). Another study examined Britain's largest cities and found that congestion and increasing housing prices negatively affect economic growth (Hanlon and Miscio, 2017). These conclusions are consistent with those of Gordon, Richardson, and Wong (1986) who find that cities such as Los Angeles are highly polycentric, meaning that traffic congestion is encouraging firms to move closer to employees in order to reduce their commuting times. However, firm relocations to places outside of the urban core may also reduce the benefits of agglomeration unless enough firms choose to locate in the same area. As a result, the Los Angeles area may not be as productive as it could be. Similarly, Hymel (2007) finds that high congestion reduces employment growth.

Importantly, benefits to firms from locating near each other do not benefit everyone equally. Services, shopping, and knowledge industries benefit the most from agglomeration (Graham, 2007b). Bacolod, Blum, and Strange (2009) find that agglomeration benefits accrue most to sectors requiring high cognitive and social skills. In a similar analysis, Rosenthal (2008) and Rosenthal (2001) find that benefits accrue from human capital spillovers as evidenced by high agglomeration effects among college educated workers. All of this is consistent with a view that agglomeration benefits – the benefits of firms and employees quickly interacting with each other – are strongest in creative and knowledge-based industries.

Although no studies examined agglomeration effects at the neighborhood level, presumably due to lack of appropriate data, some inferences can be made from the studies on agglomeration that may apply at the neighborhood level. First, for industries requiring social and cognitive skills, density leads to higher productivity. Second, congestion reduces productivity at all surveyed geographic levels and increases the spread of firms which can reduce agglomeration benefits. Combining these findings, we can surmise that shopping or high-skilled industry clusters would benefit from VMT reductions if high density transport alternatives (i.e., walking, cycling, transit) could enable retailers and firms to co-locate at the neighborhood level.

Table 1. Summary of Studies on Agglomeration Economics

Author (Year)	**Results**
Bacolod, Blum, and Strange (2009)	Urban wage premium is a premium on cognitive and social skills.
Graham (2007a)	Transport infrastructure increases firm and residential density.
Graham (2007b)	All tested sectors experience positive returns from agglomeration. In the study, manufacturing has the lowest agglomeration benefits. The industries that benefits most from agglomeration economies are: public services, business services, and banking finance and insurance.

Author (Year)	Results
Hanlon and Miscio (2017)	Congestion, measured through commuting times, has a negative effect on city growth.
Hymel (2007)	High levels of congestion reduce employment growth in urban areas.
McMillen and McDonald (1998)	Average employment density decreases by 34% to 35% per mile from employment subcenters.
Rosenthal and Strange (2001)	For agglomeration benefits, labor market pooling works at the zip code level while knowledge spillovers work at the county level.
Rosenthal and Strange (2003)	The benefits of co-locating diminish rapidly with distance. For example, for software firms, 100 additional software workers within one mile is associated with 0.04 new software firm births and 1.17 additional employees at each firm.
Rosenthal and Strange (2008)	Being located closer to an employment center increases wages. Human capital spillovers are especially important for college educated workers.
Tsekeris and Geroliminis (2013)	Improving road network connectivity can reduce congestion and increase economic efficiency.
Wheaton (2004)	In a general equilibrium model with agglomeration economies and commuting costs, firms locate in a polycentric pattern to obtain agglomeration benefits while reducing commuting costs.
Wheaton and Lewis (2002)	A 1% increase in worker specialization leads to a 23% increase in wages. Specialization leads to 30% wage increases at the MSA level with variation between industries and occupations.

V. Resident Benefits

Benefits to residents can be capitalized into increased house prices or rental values. Those benefits would be of two types:

1. Benefits from accessibility created by projects associated with reduced VMT. Multi-modal transportation projects, improved non-motorized access, and clustering of destinations near residences might all increase transportation access while reducing VMT.
2. Benefits from larger "quality of life" impacts or amenities related to improved access.

Examining house prices or rental rates will capture both benefits, and most studies in the literature cannot disentangle the effect of accessibility from other quality of life or placemaking benefits.

One method for understanding if a characteristic is capitalized into property values is by performing hedonic house price models. Due to data availability, most studies use house prices rather than rents, and we summarize those studies here.

Hedonic house price models use property values as the dependent variable with a variety of environmental and home characteristics as the independent variables. The literature on hedonic house pricing models published since 2000 was reviewed. The studies looked at both commercial and residential property values as the dependent variable. Most of the studies used proximity (distance) to a transit station as the measure of accessibility. The measurement of walkability differed slightly; some studies used Walk Score, while others used neighborhood characteristics such as sidewalk density or the slope of sidewalks.

The impact of transit- and pedestrian-oriented development on property values varied across studies, likely due to geographical differences, walkability measurement differences, and other model-related factors. The studies and their results are listed in Table 2. The pattern in Table 2 aligns with the findings of the meta-analysis by Debrezion, Pels, and Rietveld (2007), who looked at the impact of transit railway stations on commercial and residential property prices.

Debrezion et al. (2007) find that accessibility to a market or central business district (CBD), measured as railway station proximity, is associated with property values. However, there is variability in the results of studies that attempt to measure that impact; some hedonic pricing analyses find statistically significant small, positive, and modest impacts, while others find negative or statistically insignificant impacts (Debrezion et al., 2007). Debrezion et al. (2007) performed a meta-analysis of 57 studies to better understand why there is variation in results. This analysis concludes that six features of the analyzed studies could explain the variation: type of property, type of railway station, type of model used, the presence of specific variables related to accessibility, demographic features, and the timing of the data. More detailed findings of the meta-analysis include (Debrezion et al., 2007):

- Properties near commuter railway stations show consistently and significantly higher values, controlling for other factors, compared to light and heavy rail stations.
- Commercial property values located within a 0.25-mile range from a railway station are, on average, 16.4 percent more expensive. As Debrezion et al. (2007, p. 176) explain, "…when the office is within walking distance of the station, it benefits, otherwise the station is of little use…"
- Residential home prices increase 2.4 percent for every 250 meters closer to a railway station.
- Omitted variable bias may occur. If a study leaves out highways in its regression, the regression can overestimate the impact of station access on property values.

Most research found that walkability is positively associated with home prices. Additionally, Matthews and Turnbull's (2007) research found that the design of the transportation network can affect the magnitude of walkability benefits; grid-like street patterns increased home values. Pivo and Fisher (2011) studied different types of properties and their values across the United States between 2001 and 2008 to understand how walkability affects different property types. Their study found that apartment properties with high Walk Scores were associated with a 6 percent increase in market value, while office and retail properties saw a 54 percent increase (Pivo and Fisher, 2011). In Cortright's 2009 CEO for Cities paper on the effect of Walk Scores on housing prices, he found a range of price impacts depending on the city studied. Looking at the California results, Fresno, Stockton, San Francisco and Sacramento each saw positive associations between Walk Score and house prices, while Bakersfield saw a negative association of Walk Score with house prices, , where a 1-point increase in walkability was associated with a $112 decrease in home value. However, the result for Bakersfield was not statistically significant at the .1 (two-tailed) level. For a 1-point change in Walk Score, the price of a home in Fresno increased $675, Stockton increased $795, San Francisco increased $2,985, and Sacramento increased $2,642 (Cortright, 2009, Table 5).

Resident Benefits in Guerrero Street, San Francisco, CA

In the quickly transforming Mission District in San Francisco, residents along Guerrero Street came together in an effort to make their street more pedestrian-friendly. With speeding cars along its six traffic lanes and eight unsignalized intersections, the community called for Guerrero Street to be included in traffic calming plans (Project for Public Spaces, pg. 58). The citizen's organization, San Jose/Guerrero Coalition to Save Our Streets, successfully advocated for the following pedestrian-friendly improvements:

- Changed the street from three lanes of traffic each way to two lanes of traffic with a bicycle lane
- Created wider medians
- Installed new traffic lights

These changes resulted in residents feeling safer to walk in their neighborhood and a reduction in driving speeds (Roth, 2009).

Images:

After traffic calming, before greening: http://pavementtoparks.org/wp-content/uploads//2015/10/plaza-guerrero-park-before.jpg

After greening: https://www.flickr.com/photos/54560762@N04/22199523316

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Several studies observed that transit-oriented developments coupled with pedestrian-friendly neighborhood environments are associated with higher home sales prices (Bartholomew and Ewing, 2011; Duncan, 2011). Duncan (2011) examined whether proximity to transit adds more value to a condominium property in a good pedestrian environment than it does in a bad pedestrian environment. His study focused on San Diego and measured good pedestrian environments in neighborhoods with three variables: density of commercial activity, flat path to a station, and well-connected street network (intersection density). Results found that transit stations in pedestrian-friendly neighborhoods see higher market values (estimated premium of $20,000) than transit stations in poor pedestrian environments (Duncan, 2011, p. 120). This supports the use of a more holistic land use and design approach to transit station projects, to ensure pedestrian-oriented projects are provided. Duncan's results also emphasize the value that residents place on good pedestrian accessibility in TOD's.

The study by Boyle, Barilleaux, and Scheller (2013) differs from the more general trend of positive associations between home prices and pedestrian character. Using data from Miami, Boyle, Barilleaux, and Scheller (2013) used fixed effects to control for unobserved heterogeneity in the data. Walkable neighborhoods might be valuable for reasons that are correlated with the walkability (such as, possibly, better access to downtown job centers), rather than the pedestrian character itself. The Boyle, Barilleaux, and Scheller (2013) study attempted to control for neighborhood characteristics other than walkability by including controls for the subdivision, one square mile section, and zip code of each house in the data, and when any of those geographic controls were included (to measure neighborhood characteristics), the Walk Score variable in their hedonic house price regression was insignificant. While the data were cross-sectional, the use of these "fixed effects" to control for neighborhood characteristics is a strong analytical approach, and so the results provide some caution. Duncan (2011) also used neighborhood controls in his San Diego study – in his case, using dummy variables for neighborhoods ranging from 0.5 to 4 square kilometers to control for neighborhood quality. Duncan found a strong and statistically significant house value premium for pedestrian characteristics in locations within a half kilometer of a rail transit station. Good pedestrian characteristics increase home prices within a half kilometer of rail transit stations by 15 percent, according to Duncan (2011). On the whole, the methodological quality of studies in this literature varies, with two of the strongest studies – Boyle, Barilleaux, and Scheller (2013) and Duncan (2011) – reaching opposing conclusions.

Summarizing, the hedonic house price models that focused on measuring the impact of transit saw less consistent results than did the studies examining pedestrian-oriented development. This suggests there is a premium associated with the quality of life amenities found in walkable neighborhoods, and that effect of a walkability house price premium is more robust in the literature than the evidence for transit access and house prices. With the exception of the Boyle, Barilleaux, and Scheller (2013) study, the evidence on pedestrian environments and house prices supports the idea that placemaking characteristics associated with VMT reduction bring residential and quality of life benefits. It must be acknowledged that property owners will be the primary beneficiaries of increased property value and there are displacement and gentrification impacts of placemaking amenities. These equity concerns are important and deserve further research.

Table 2. Summary of Studies of Hedonic House Price Models

Author (Year)	Study Area	Methodology	Walkability Results	Transit Results
Bartholomew and Ewing (2011)	Meta-analysis summarizing several studies	Survey and summary of existing literature	Transit-oriented development paired with pedestrian-oriented development increases home values	Transit-oriented developments result in varying impacts due to differing magnitudes of amenities and disamenities
Boyle, Barilleaux, and Scheller (2013)	Miami, FL	Linear hedonic fixed effects regression	Walkability (measured by Walk Score) was not associated with home values using a fixed effects method to control for unobserved heterogeneity	
Cervero (2002)	Santa Clara County, CA			Commercial retail values increased by 23 percent for a typical commercial parcel near a light rail station Commercial retail values increased by 120 percent located within 0.25 miles of a commuter rail station

Author (Year)	Study Area	Methodology	Walkability Results	Transit Results
Cortright (2009)	Multi-city	Log-linear hedonic OLS regression	Thirteen out of fifteen cities showed positive impact of Walk Score on house prices.	
Debrezion, Pels, and Rietveld (2007)	Meta-analysis summarizing several studies	Meta-regression model with the effect size of the impact of railway station proximity as the dependent (Y) variable		Commercial properties within 0.25 mile of a rail station see a larger price gap from properties located outside that range than do residential properties - on average, commercial properties have a 16.4% price increase whereas residential properties have a 4.2% price increase Commuter railway stations have a consistently higher positive impact on property values compared to light rail station or bus stop

Author (Year)	Study Area	Methodology	Walkability Results	Transit Results
Duncan (2011)	San Diego, CA	Linear hedonic fixed effects regression	Home values increased when transit station distance was interacted with pedestrian-oriented development (measured by sidewalk slope, intersection density, and population-serving businesses)	
Li et al. (2015)	Austin, TX	Cliff-Ord spatial hedonic regression (also known as General Spatial Model)	Home values increased in areas of high walkability (measured by Walk Score and sidewalk density) Walkability premium on home prices is higher areas with: more college residents, higher proportion Hispanic residents, higher income residents, lower crime rates.	

Author (Year)	Study Area	Methodology	Walkability Results	Transit Results
Matthews and Turnbull (2007)	King County, WA	Linear hedonic OLS regression	Pedestrian-oriented neighborhoods with a more gridiron-like street pattern associated with higher home values	
Pivo and Fisher (2011)	Various across U.S.	Linear hedonic OLS regression	Using 2001-2008 real estate performance data from the National Council of Real Estate Investment Fiduciaries, found walkability (measured by Walk Score) increased the market values of office (54 percent), retail (54 percent) and apartment (6 percent) properties Walkability had a statistically insignificant effect on industrial properties	

Author (Year)	Study Area	Methodology	Walkability Results	Transit Results
Song and Knaap (2003)	Washington County, OR	Semi-log hedonic OLS regression, data from 1990 to 2000	Pedestrian walkability has mixed effects on home values: 1) single family units within a quarter-mile of commercial uses have higher prices; and 2) single family units within a quarter-mile of a bus stop have lower values, controlling for other characteristics	
Seo, Golub, and Kuby (2014)	Phoenix, AZ	Translog (ln-ln) hedonic OLS regression including spatial lag and spatial error model (to mitigate hetero-skedasticity and spatial dependence)		Home values increased near light-rail transit nodes

Author (Year)	Study Area	Methodology	Walkability Results	Transit Results
Wang (2016)	Seattle, WA	Linear hedonic OLS regression; before, during, after TOD construction time periods		After the construction period, transit-oriented development has a positive impact on single-family home values located within 0.25 to 0.5 miles from a light rail station

VI. Business Benefits

In some instances, neighborhoods reduce VMT in business districts through traffic calming, closing streets to vehicle traffic, or supporting alternatives to driving. There are multiple ways that VMT reduction can benefit neighborhood businesses. For instance, increased pedestrian activity and accessibility for customers can lead to more visiting opportunities for retail businesses which can increase property values and retail sales if the increased foot traffic or longer "lingering" times offsets the effect of reduced automobile accessibility. It is possible that closing streets might not reduce automobile accessibility much, if nearby streets remain open to vehicle traffic as is typically the case. The studies in this section include street closures and other efforts that install pedestrian or bicycle amenities or calm traffic while keeping streets open.

Several studies surveyed businesses on their perception of the impact of pedestrianization (including street closures) and walkability. (For a list of the studies reviewed, see Table 3.) In these studies, the sample size ranged from 9 to 777 firms. Surveys and questionnaires were used both before and after periods of different pedestrianization and traffic calming measures, some of which spanned years. The studies varied in their research period, with some examining timeframes being as early as the 1990's and the more contemporary studies being in the 2010's.

Some of the studies analyzed policies that close off streets from vehicle traffic or that limited vehicle traffic. Initially, businesses were concerned that the reduction in automobile traffic would hurt their business. The studies showed that business owners shifted to a positive perception after the traffic calming policies or street closures were instituted. For instance, after the implementation of bicycle lanes on Valencia Street in San Francisco, 66% of merchants surveyed indicated that they believed that bike lanes had a generally positive effect on business and/or sales and would support more traffic calming (Drennan and Kelly, 2003). At times, business owners' positive perception led them to attribute several benefits such as increased public safety and increased business revenue to the traffic calming policies (Wooller et al., 2012; Kumar 2006). The retail gains of the business owners varied in each study but showed increases in the majority of studies. In the Khao San Road project (a street closure and pedestrianization in Bangkok, Thailand), 47% of retail shops reported an increase in sales volume (or turnover) with 35% reporting no change (Kumar, 2006). Similarly, in Hong Kong, the pedestrianization of a two-way street retail area led to an approximately 17% increase in retail sales on average (Yiu, 2011). Hass-Klau's (1993) work mirrored these findings. Hass-Klau (1993) conducted a cross-country study of retail businesses in Germany and the United Kingdom. In addition to increased retail sales, better pedestrian flow, and improved perception of pedestrian streets, the Hass-Klau study found that pedestrianization led to increases in house prices and rents in the pedestrian street areas after the policies were implemented (Hass-Klau, 1993).

Complete Streets in Lancaster, CA

The City of Lancaster, located in Los Angeles County, wanted to revitalize its downtown. Part of the problem in attracting people and businesses was due to the dangerous and un-walkable nature of Lancaster Boulevard. A four-lane road with many traffic signals, cars sped by at 50 miles per hour, making it inhospitable to pedestrians and shoppers (National Complete Streets Coalition, 2012, p. 22). The City began its revitalization efforts in 2006 and in 2008 the City Council passed its final plan which included a $10 million Complete Streets design. The goals of the project were to improve walkability, increase pedestrian safety and reduce speeds (George, 2013, p. 65).

The following changes were made to Lancaster Boulevard as part of its Complete Streets design:

- Reduced the number of lanes from four to two, removed several traffic signals, installed a roundabout
- Created a central "rambla" (resembling the famous Barcelona street) which includes pedestrian-friendly infrastructure, parking spaces, and a community event space
- Widened and repaved sidewalks, added street lighting, and landscaped with more greenery.

Lancaster Boulevard is now branded as "The BLVD." The Complete Streets design has spurred economic development in the downtown by improving roadway safety for pedestrians. More than 40 new businesses opened following the redesign, private investment is estimated to be $125 million in downtown, and sales tax revenue increased 26 percent (National Complete Streets Coalition, 2012, p. 22).

Images:

https://i.ytimg.com/vi/pojylzK2uSM/maxresdefault.jpg
https://www.huduser.gov/portal/casestudies/images/artist_hsg/Image_10.jpg
https://www.cnu.org/sites/default/files/LancasterBoulevard_streetscape.jpg

Sources:

George, Sherie. (June 2013). "A Complete Streets Analyis and Recommendations Report for the City of Bakersfield." Accessed: http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=2037&context=theses

National Complete Streets Coalition Local Government Commission. (February 2012). "It's a Safe Decision: Complete Streets in California." Accessed: https://www.smartgrowthamerica.org/app/legacy/documents/cs/resources/cs-in-california.pdf

The BLVD website: http://www.theblvdlancaster.com/downtown-lancaster.html; City Council of the City of Lancaster. (2010). "Resolution No. 10-68, [Downtown Lancaster Specific General Plan]." Accessed: http://www.cityoflancasterca.org/home/showdocument?id=12940

According to Weisbrod and Pollakowski (1984), pedestrian projects increased the entry of new businesses into downtown areas. Increased property value was associated with pedestrianization and walkability initiatives in Toronto, Canada and Washington D.C. (Prokai, 1991; Alfonzo et. al, 2012). Alfonzo et. al (2012) studied 71 neighborhoods within the Metropolitan Washington D.C. area and found that more walkable places perform better economically. On average, more walkable places had $6.92/sq. ft. per year higher retail rents and generated 80 percent more in retail sales when compared to the places with fair walkability (Alfonzo et. al, 2012). In addition, an increase in walk score resulted in an increase in retail sales, office rents, and residential property values (Alfonzo et. al, 2012).

Union Square North, Manhattan, New York City

Union Square in Manhattan, New York City (an area that is about 9 acres or a little less than 400,000 square feet) is a constantly traversed area, "sometimes seeing up to 200,000 pedestrians on peak summer days" (NYC Press Release, 2010). It is a popular destination known for its Greenmarket, shops, restaurants, street chess, and being a gathering point for social and political activism.

In 2010, the New York City Department of Transportation (NYCDOT) announced its street redesign project for Union Square. The goal was to improve pedestrian safety and park access while maintaining economic vitality in an area that had 95 pedestrian injury crashes from 2004 to 2008 (NYC Press Release, 2010).

The project, developed with input from the community, supported by the area's Community Board and backed by the Union Square Partnership and local businesses, was able to implement the following (NYC Press Release, 2010 and Union Square Project Proposal, 2010):

- Converting portions of 17th Street to one-way traffic
- Adding pedestrian areas
- Reducing through traffic lanes on Broadway from 23rd to 18th Streets to one lane with safety islands and protected bike path
- Simplified traffic signals to improve pedestrian safety.

The street redesign project allowed Union Square to remain a vibrant neighborhood while also becoming more safe (NYC Press Release, 2010). An NYCDOT evaluation in 2012 found that injury crashes in Union Square had dropped 26 percent while commercial vacancies had dropped by 49 percent.

Sources:

NYCDOT (2012) Measuring the Street: New Metrics for 21st Century Streets http://www.nyc.gov/html/dot/downloads/pdf/2012-10-measuring-the-street.pdf

NYC DOT Announces Completion of Union Square Redesign, Improving Safety and Park Access Press Release. http://www.nyc.gov/html/dot/html/pr2010/pr10_043.shtml

Union Square Project Proposal. New York City Department of Transportation. 6/21/2010. http://www.nyc.gov/html/dot/downloads/pdf/20100610_broadway_union_square.pdf

When analyzing the studies, the type of pedestrian project and the location of the efforts should be considered. When analyzing how downtown revitalization projects affected retail sales, Weisbrod and Pollakowski (1984) discovered that revitalization of downtowns had little to no impact on employment growth of existing retail business in the area but revitalization efforts did increase new business openings in the downtown areas. The studies of full street closures are outside of the U.S., and we caution that the evidence of positive impacts of pedestrian projects in the U.S. is largely from projects that increase pedestrian and non-motorized travel, rather than full street closures. Pedestrianization efforts in Toronto, Canada saw an increase in vacancy rates even though prior literature had shown a negative relationship between pedestrianization and vacancy rates (Prokai, 1999).

Summarizing, there are relatively few studies in this area, but the surveys of business owners suggest that initial business concerns about pedestrian projects shifted to a positive attitude after the project was completed. Studies of property values, while relatively few in number, suggest that when implemented in areas of high foot traffic (or high potential foot traffic), pedestrianization is associated with increased sales and, through that, increased commercial property values.

Table 3. Summary of Economic/Retail Benefits of Pedestrianization

Author (Year)	**Study Area**	**Methodology**	**Results**
Alfonzo, et. al (2012)	Walkable Places and Economic Performance, Metropolitan Washington, D.C.	Hedonic regression analysis using Walk Score and Irvine-Minnesota Inventory to measure walkability	Higher Walk Score locations performed better economically. Walk Score correlated with increases in retail sales, office rents, and residential housing values. In addition, higher Walk Score locations benefitted from being near other high Walk Score locations.
Drennen and Kelly (2003)	Economic Effects of Traffic Calming on Urban Small Businesses on Valencia Street in San Francisco	Interviews with street merchants, N=27	66% of merchants believed that the bike lanes have had a positive effect on business and/or sales. They stated they would support more traffic calming on Valencia Street. 37% of surveyed business owners believe that sales

Author (Year)	Study Area	Methodology	Results
			increased due to new customers from outside the neighborhood being able to visit their business because of traffic calming policies
Hass-Klau (1993)	How does pedestrianization affect retail in United Kingdom and Germany	Survey, Germany N=777 UK N=400	Increases in pedestrian flow were associated with business turnover. Housing rents/costs increase in pedestrian areas after traffic calming measures
Kumar (2006)	Khao San Road, Bangkok. Effects of pedestrianisation on commercial and retail sales. Business types categorized by food stalls, shops, guest houses, and travel agencies	Survey, N=110	47% of retail shops had increase in revenue sales, 35% had no change, while 18% had a reduction 65% increase in favorability of pedestrian project after development from 20% favorability (before) to 85% favorability (after)
New York City DOT (2012)	New York City	Post-project metrics of economic vitality	Union Square North in Manhattan saw 49% fewer retail vacancies after the addition of a new pedestrian plaza and protected bicycle lanes. Pearl Street in Brooklyn saw 172% increase in retail sales after pedestrian plaza

Author (Year)	Study Area	Methodology	Results
Prokai (1999)	Impacts of pedestrian friendly streetscape improvements on two retail areas in Toronto, Canada	Indicator Analysis of Trends and Distribution, Often Simple Before-After Comparison of Data without Statistical Controls	Property values were higher where streetscape improvements were done. Studies indicated an increase in vacancy following pedestrian projects.
Robertson (1991)	Examines the city centers of six Swedish cities to help better understand the extent to which pedestrian streets have changed over time in terms of retail trends.	Interviews	Interviewees' believed that pedestrian streets helped to strengthen the commercial cores of Swedish cities. Prior to the expansion of central pedestrian district, downtown merchants had a negative perception of central pedestrian districts.
Weisbrod and Pollakowski (1984)	Effects of Downtown Improvement Projects on Retail Activity	Regression of data for 14 shopping malls that were part of downtown pedestrian revitalization projects	Downtown revitalization projects sometimes had no statistically significant impact on observed growth or exits of existing establishments. Revitalization projects did have a statistically significant positive effect on rates of new establishment entry into revitalization areas.

Author (Year)	Study Area	Methodology	Results
Wooller, Badlam, and Schofield (2012)	Pedestrianization Benefits, New Zealand	Semi-Structured Interviews, N=9	Perception of interviewees was that pedestrianization encouraged leisure business. Perception of co-benefits included public safety, accessibility, and exercise
Yiu (2011)	Pedestrianization and Retail Rents, Hong Kong, China	Two-street, Two-period Regression Model	Pedestrianization increased the retail rental value of the street by approximately 17%.

VII. Discussion: Synthesizing a Systems View of the Economic Benefits of Transportation

The literature on economic benefits of transportation falls into two parts – what we called the "old" and the "new" views – with little cross-talk or connections between those two literatures. The different views evolved at different times (roughly the early and mid-Interstate Highway era for the old view versus the past two decades for the new view), focusing on different policy questions (increased VMT versus neighborhood placemaking) and different geographic scales (metropolitan areas or larger geographies versus neighborhoods). We first summarize the results from the "new" view studies surveyed here, and then suggest a policy synthesis.

The studies on residential benefits of VMT-reducing placemaking provide evidence that house prices are higher, controlling for other factors, in neighborhoods with good pedestrian characteristics. Higher neighborhood Walk Score (indicating better pedestrian access to destinations) is associated with higher house values, suggesting that persons value the package of amenities that is associated with walkable neighborhoods. Transit access also is associated with higher house values, although that effect varies across studies and the transit house price premium is larger in more walkable neighborhoods.

Business surveys indicate that businesses in locations where streets were closed or where traffic lanes were reduced had a generally positive view of the impact on their retail sales. Some evidence indicates that increases in commercial property prices are associated with pedestrianization. Some of these business impact studies might be subject to "survivor bias", surveying firms that remained in the neighborhood after the pedestrianization project was completed and hence missing firms whose business could not adapt and that thus left the neighborhood or ceased operations. Yet some of the survey studies contacted firms before and after pedestrian improvements, and those surveys showed large increases in business favorability from before-project to after the project was completed.

One caution for both the residential house price and business impact studies is that the research might have focused on places where pedestrianization and placemaking was most likely to have a positive impact. Policy activity often focuses on locations that are primed to benefit, and researchers might also choose neighborhoods where the placemaking activity was likely to provide benefits, if for no other reason than that such places are more visible to researchers. While the results suggest positive impacts on residents and businesses, it would be premature to generalize that every place will benefit. We suggest that the evidence is best interpreted as showing that thoughtfully applied placemaking activity has positive impacts; not that any and every VMT-reducing placemaking in any location will produce benefits.

The studies on agglomeration show that the benefits from businesses locating near other businesses is often a short distance phenomenon – in some cases at a scale of from one to five miles. Knowledge industries and creative activities particularly benefit from agglomeration economies, and hence transportation plans that allow firms, employees, and customers to interact quickly and seamlessly, often in a face-to-face fashion, will be important for the economic health of cities. The evidence does not indicate that those interactions need be at a walking scale, and the geographic scope of agglomeration benefits, while covering short distances, is larger than the scale of many neighborhoods.

The most applicable “old view” studies are those more recent works that show economic benefits from reduced congestion in a metropolitan area (e.g. Hymel, 2007; SCAG, 2016). These works indicate that increasing access within a metropolitan area is important for economic growth – a finding consistent with the literature on agglomeration economies. But building highways is not a fruitful way to increase access in metropolitan areas. Studies have shown that in congested metropolitan areas, additional highway capacity leads to induced travel, such that new highway capacity does not reduce congestion (e.g. Duranton and Turner, 2011). For that reason, congestion reduction is not nearly as simple as building more highways – and highway building alone will not lead to lower congestion levels in large metropolitan areas.

Overall, these results suggest a systems approach (Figure 1). At the scale of a metropolitan area, economic growth flows from transportation policies that reduce congestion and/or increase access, thus allowing more seamless business interactions and more easy reach from firms to output and labor markets. Many neighborhoods will benefit from policies that reduce VMT while producing placemaking amenities, but creating an entire metropolitan area of slow-moving traffic in pedestrianized places would not allow the high throughput that metropolitan areas need to increase accessibility. A hierarchy of transportation links is the best approach. High throughput routes, ideally congestion priced, should connect neighborhoods within metropolitan areas, while those neighborhoods should, as often as possible, support multiple travel modes that have amenities associated with walkable locales. There will still be a role for suburban office parks with easy automobile accessibility (not every place can be an urban neighborhood), but even in those more suburban places planners should include the amenities and transportation options that, research has shown, produce value for residents and firms.

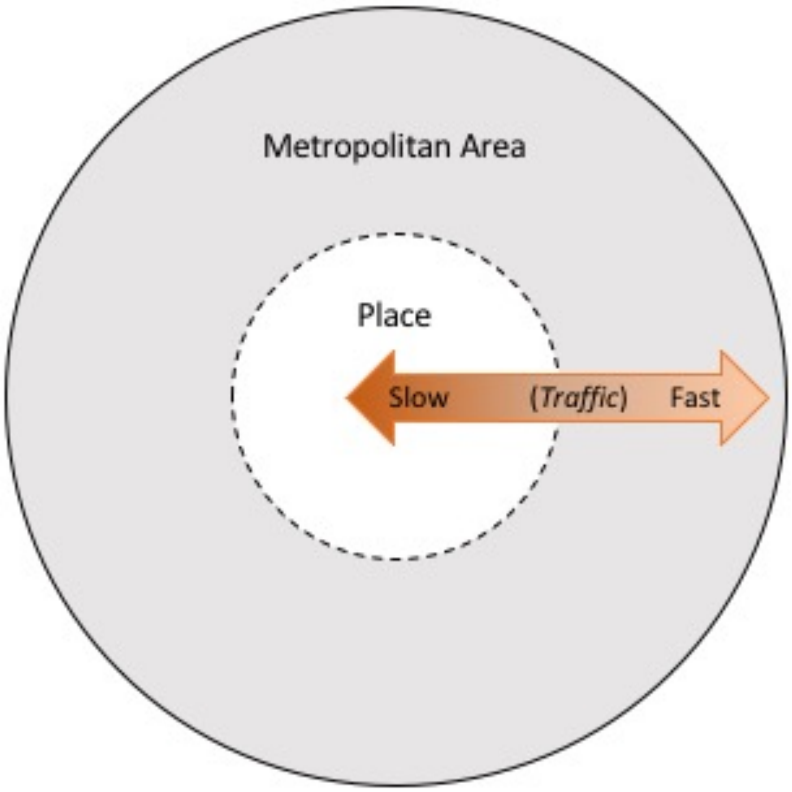

Figure 1. Systems approach to transportation policy promoting economic benefits in both place and larger metropolitan area

Can a car-only transportation system support this hybrid of regional accessibility and neighborhood placemaking? We believe the answer is "no", particularly in larger metropolitan areas. The walking-oriented design elements and pedestrian neighborhoods that help create placemaking benefits are often seamlessly associated with alternatives to automobile travel. Those designs are often associated with first-last mile transit access or with plans to increase non-motorized travel. There is a role for the car, but a car-only metropolitan transportation plan leaves little room for walkable placemaking at the neighborhood scale. The best approach is the one being pursued in many cities – travel options and alternatives that view the automobile as one of many ways to travel, but not the only travel mode. In large metropolitan areas, a systems view will require high throughput transit that can support densities that highways cannot support (e.g. the central business districts in Los Angeles or San Francisco), ideally congestion priced highways and major transit links, and careful focus on first-last mile neighborhood accessibility that has a robust role for placemaking amenities.

Neighborhood placemaking, in this view, is a concomitant of transportation systems based on a backbone of high throughput intra-metropolitan connectors that link to neighborhoods through a range of modes that include transit, walking, and bicycling. The transportation system, in this view, is about more than movement. It connects people and firms at the metropolitan scale, while focusing on providing amenities and weaving into the urban fabric at the neighborhood scale. Transportation planning, in this view, includes urban design, human interaction, and accessibility.

Equity considerations will be important in a placemaking-oriented view of transportation planning. Higher income neighborhoods are often the places with the resources and political clout to pursue placemaking initiatives. Pedestrianized streets, traffic calming, and bicycle lanes are more commonly found in high-income than low-income places. One risk of neighborhood-led planning is that those neighborhoods with the resources to engage in placemaking will do so, leaving other neighborhoods behind. For that reason, placemaking should have a strong role for equity, with purposeful efforts to bring placemaking to neighborhoods that may not have the resources or political power to pursue such initiatives by themselves. Such an equity-focused placemaking should empower local communities. The best placemaking is typically organic and informed by local needs, and hence it would be unwise to foist a placemaking view on a neighborhood from the outside. As neighborhoods become more important in transportation planning, transport planners will have to shift from top-down approaches to methods that empower and engage communities.

Overall, the evidence suggests that placemaking initiatives, pursued in ways that reduce neighborhood VMT, bring benefits that are valued by residents and firms. Placemaking will require a more multi-modal transportation planning, focusing on neighborhood context and engaging and empowering communities while building system backbones that increase access throughout the metropolitan area. This synthesis is appropriate and necessary for an era in which the automobile, while still important, cannot meet all our accessibility needs. There is a need for more research that further explores the impacts of small scaled placemaking and its effects on local economies and redefining accessibility.

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Are Vehicle Travel Reduction Targets Justified?

Evaluating Mobility Management Policy Objectives Such as Targets to Reduce VMT and Increase Use of Alternative Modes

30 May 2022

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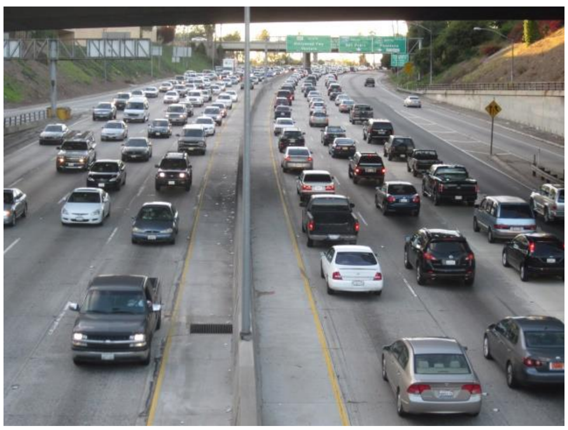



Automobile dependency and sprawl force people to drive more than is economically efficient. VMT reduction targets provide a framework for policy and planning reforms that help create more accessible, multi-modal communities where less driving is needed to meet people's needs.

Abstract

This report investigates whether transportation policies should include targets to reduce vehicle travel and encourage use of alternative modes, called *mobility management* or *transportation demand management* (TDM). Such objectives may be justified on several grounds: they help solve various problems and provide various benefits; they help insure consistency between short- and long-term planning decisions; and they help prepare for future travel demands. Many mobility management strategies are market reforms that increase transport system efficiency and equity. Mobility management criticism tends to reflect an older, automobile-oriented planning paradigm that considers a limited range of objectives, impacts and options. More comprehensive analysis tends to favor mobility management. Appropriate mobility management can reduce vehicle travel in ways that minimize costs and maximize benefits to consumers and society.

This report expands on the article
Todd Litman (2013), "Comprehensive Evaluation of Energy Conservation and Emission Reduction Policies," *Transportation Research A*, Vol. 47, January, pp. 153-166

Introduction

Many jurisdictions have targets to reduce vehicle travel and increase use of non-auto modes (walking, bicycling, public transit, etc.) to achieve various economic, social and environmental goals. For example, California state law requires that per capita vehicle travel be reduced 15% by 2050 (GOPR 2018). Washington State requires 30% reductions by 2035 and 50% by 2050 (WSL 2008). New Zealand's target is to reduce light-duty vehicle travel 20% by 2035 (NZMoE 2022). British Columbia's target is to reduce light-duty vehicle travel 25% between by 2030 and approximately double walking, bicycling and public transit half of all trips by 2050 (CleanBC 2021). Colorado state law requires that all major transportation projects support emission reduction targets (Degood and Zonta 2022). Israel's goal is to cut car travel in half (Zagrizak 2022). Minnesota's goal is to reduce vehicle travel 20% by 2050 (Bellis 2021). The United Kingdom's goal is that half of all urban journeys will be by active modes by 2030 (DfT 2020). Scotland has a target to reduce vehicle travel by 20% by 2030 (Reid 2020). Many cities also have VMT reduction targets. Guides and tools are available for designing and evaluating VMT reduction plans (Byars, Wei and Handy 2017; Caltrans 2020; TransForm 2009).

Examples of Local VMT Reduction Targets (ACEEE 2019; Klein 2020; PBOT 2021; Thorwaldson 2020 Zagrizak 2022)

- **Boston:** put every home within 10 minutes of public transport, bike share, and car share by 2050.
- **Columbus:** Create "smart mobility hubs," to help residents travel without a car.
- **Minneapolis:** reduce VMT 40% by 2040 through walking, bicycling, public transit and compact development.
- **Orlando:** most local trips are done on foot, bike, carpooling, or transit.
- **Phoenix:** by 2050, 90% of residents live within a half-mile of transit, and 40% commute by non-auto modes.
- **Portland:** reduce vehicle travel and associated emissions by 45%.
- **San Antonio:** reduce average daily vehicle-miles per capita from 24 now to 19 by 2040.

Some critics argue that such targets are misguided. Highway advocacy groups (HUA 2009), activist organizations (Poole 2009; O'Toole 2009; Cox 2009), and some transport policy experts (Pisarski 2009a) argue that VMT reduction policies are costly, unfair, and harmful to consumers and the economy. Some environmental advocates argue that "clean vehicle" strategies, such as shifting to hybrid and electric vehicles, are more effective at reducing emissions than VMT reductions (Hawken 2017). Poole (2009a) calls VMT reduction goals "a terrible idea" and challenges proponents to prove they are cost effective. I accept that challenge.

VMT reduction policies are not necessarily the most effective way of achieving any single goal but are often cost effective considering all impacts (benefits and costs). They can:

- Help achieve multiple community goals including congestion reduction, facility cost savings, consumer savings, investment fairness between drivers and non-drivers, public health, traffic safety, improved mobility for non-drivers, energy conservation and emissions reductions.
- Align policies between different levels of government and organizations, for example, to ensure consistency between local, state and federal policies.
- Respond to changing travel demands and community priorities (ITF 2021a).

This report investigates these issues. It discusses justifications for VMT reduction targets and evaluates criticisms of these policies. It discusses how mobility management objectives can help create a transport system that better responds to future needs.

Accessibility versus Mobility

To understand this issue it is useful to consider the distinction between *accessibility* (people's ability to reach desired goods, services and activities) and *mobility* (physical movement). Accessibility is the ultimate goal of most transportation activity, excepting the small portion of travel for which movement is an end in itself such as jogging or cruising; even recreational travel usually has a destination such as a picnic site or resort (Litman 2003; Sundquist, McCahill and Brenneis 2021). The key question in this analysis is whether it is possible to achieve accessibility with less mobility.

Planning decisions often involve tradeoffs between different types of access accessibility. For example, wider roads and increased traffic volumes and speeds reduce pedestrian access, and therefore public transit access since most transit trips involve walking links; automobile-oriented land use patterns (dispersed, urban fringe development with abundant parking) tends to be difficult to access by walking, cycling and public transit); and resources devoted to automobile transport are unavailable for alternative modes.

VMT reduction critics tend to assume that *transportation* means automobile travel, so any reduction in vehicle travel reduces accessibility. VMT reduction advocates tend to consider a broader range of accessibility factors, so VMT reductions need not reduce accessibility if implemented with improvements to alternative modes and more accessible land use development. They argue that appropriate VMT reduction strategies can improve overall accessibility, transport system efficiency, and user benefits.

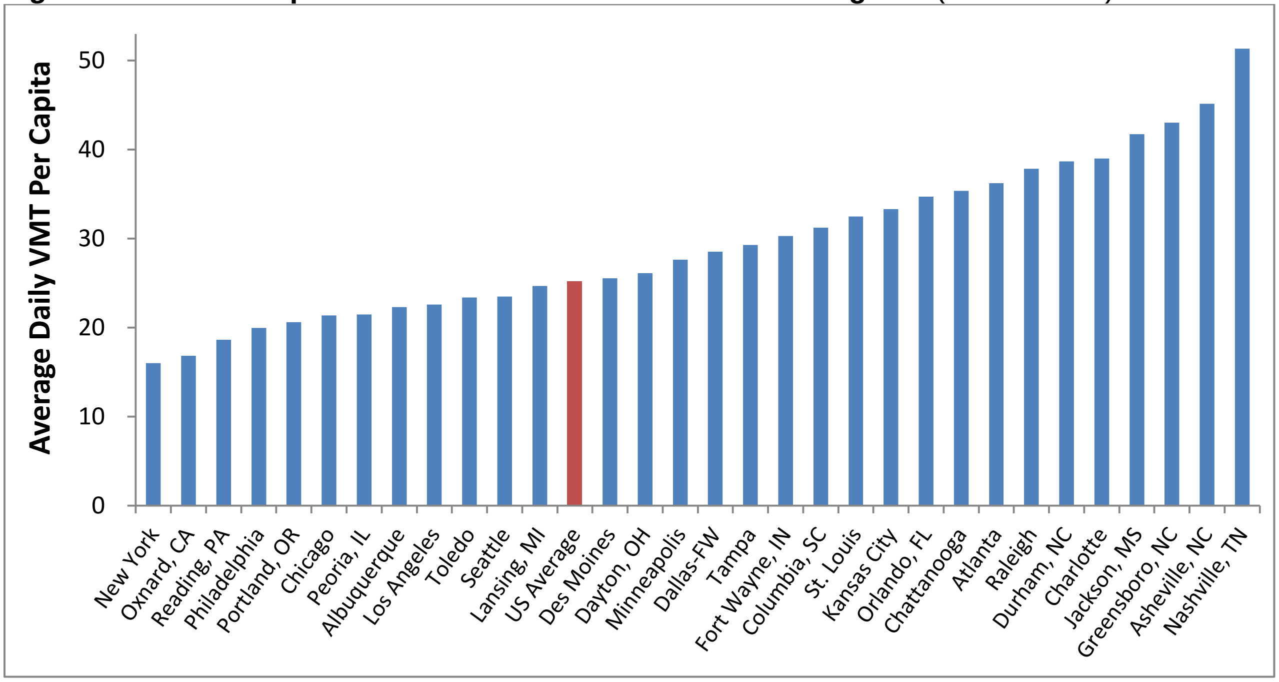
VMT reduction advocates argue that current planning practices are distorted in various ways that favor automobile dependency, and therefore result in economically excessive vehicle travel, that is, vehicle travel for which total costs exceed total benefits (Boarnet 2013; Garceau, et al. 2013; Levine 2006). For example, automobile travel is significantly underpriced (road, parking, insurance and fuel prices do not reflect marginal costs); a major portion of transport funding is dedicated to roads and parking facilities and cannot be used for other modes or mobility management strategies even if they are more cost effective overall; and many land use planning practices discourage compact, mixed, infill development (Litman 2014a). Correcting these distortions tends to reduce automobile travel in ways that increase economic efficient and benefits consumers overall (Clarke and Prentice 2009).

California state law, SB 743 (2013), requires that transportation project environmental impacts be evaluated based on their vehicle miles travelled (VMT) rather than roadway level of service (LOS), which is sometimes called a shift from LOS to VMT (Lee and Handy 2018). Governor Executive Order (EO) N-19-19 (2019) requires state agencies to reduce greenhouse gas emissions. The California State Transportation Agency (CalSTA 2021) and the Northern California Institute of Transportation Engineers (ITE SB 743 Task Force 2021) have developed guidelines for applying these policies to transportation planning decisions. These policies support a shift from mobility-based to accessibility-based planning, which recognizes that improvements to non-auto modes and more accessible land use development policies can increase accessibility while reducing mobility. For example, these policies recognize the important roles that walking, bicycling and public transit play in an efficient and equitable transportation system; reform transportation funding favor efficient modes; and favor infill development over urban expansion.

How Much Vehicle Travel Do People Need?

Per capita vehicle travel varies significantly among U.S. urban regions, as illustrated below.

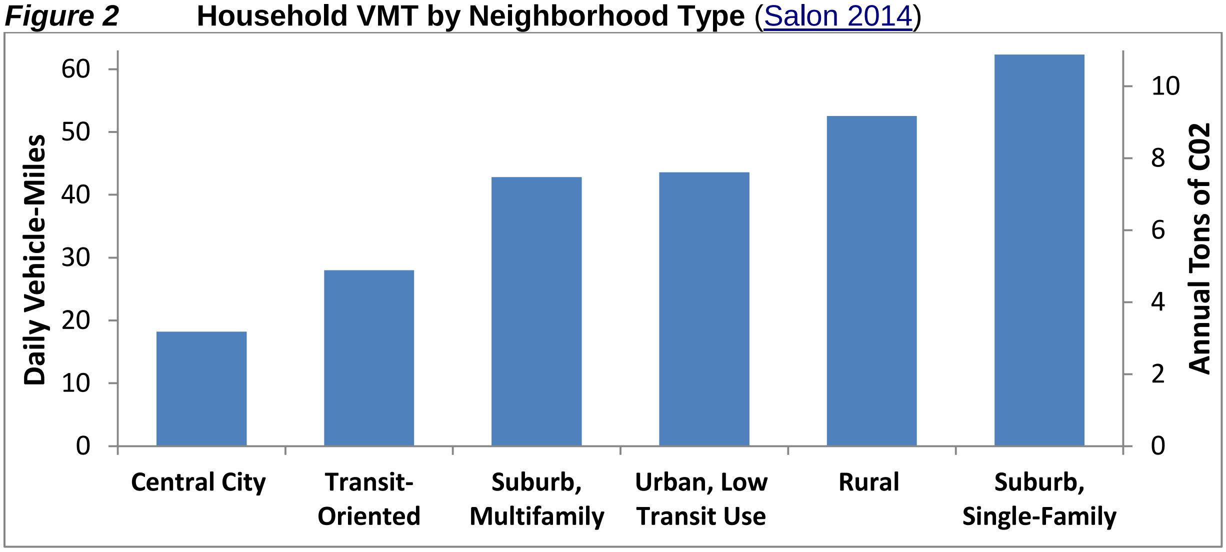
Figure 1 **Per Capita Vehicle Travel in Selected Urban Regions** (FHWA 2018)



Per capita daily vehicle-miles range from less than 16 to more than 50 among U.S. urban regions.

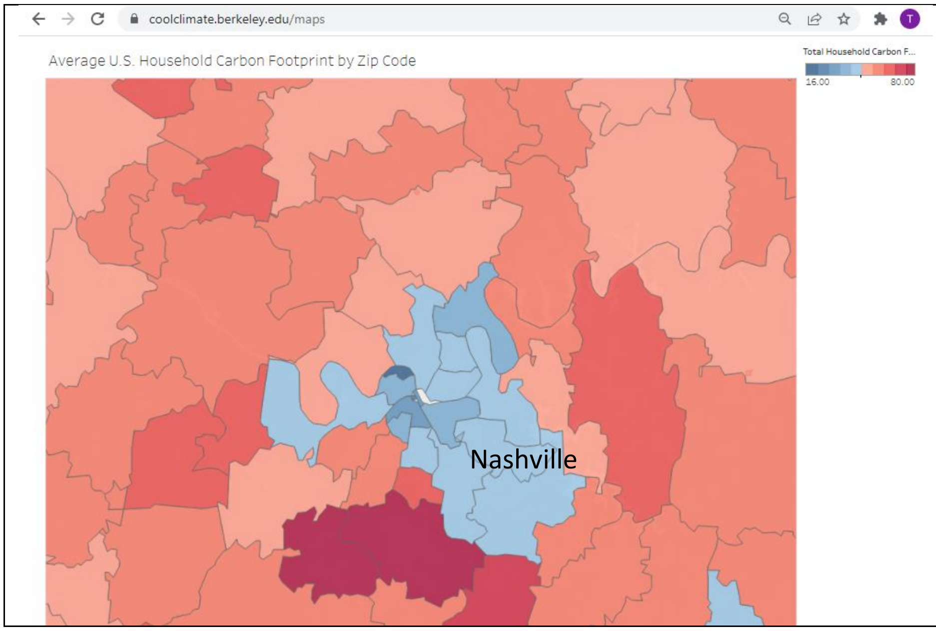
There are similar ranges within an urban region. Daily VMT are about three times higher in suburban locations than in compact, multimodal neighborhoods, as illustrated below.

Figure 2 **Household VMT by Neighborhood Type** (Salon 2014)



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

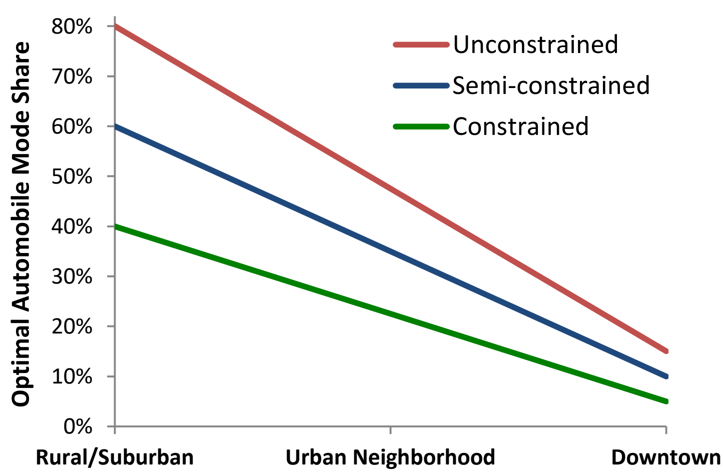
Figure 3 **Household Climate Emissions, Nashville, TN** (Cool Climate Maps)



Cool Climate Maps show average climate emissions from transportation, housing and goods consumption by geographic location. This example shows the much lower emissions typical of central neighborhoods compared with automobile-dependent, sprawled areas, due largely to lower vehicle travel.

These studies indicate that vehicle travel is highly variable, depending on geographic and economic factors. There is no evidence that residents of high vehicle-miles communities access more activities or are more productive than lower vehicle-miles communities. In fact, lower vehicle-miles communities tend to have more economic productivity and residents spend less total time travelling than in higher vehicle-miles areas, as described later in this report. In other words, you can say that automobile-dependent areas provide less efficient access: residents must travel further to reach desired services and activities. This is not to say that automobile dependency is bad, but it is costly in terms of time and travel expenses.

Figure 4 **Optimal Automobile Mode Shares** (Litman 2014b)



The optimal level of automobile travel declines with density and poverty. In affluent, sprawled suburbs, most trips can be by automobile, but this should decline as densities or poverty increases, and should be less than 30% in most urban neighborhoods. Various demand management strategies can be used to favour more space-efficient and affordable modes over private automobiles.

The key issue for this discussion is whether, given better transportation options and incentives, transportation systems could become more efficient, so people can meet their accessibility needs with fewer vehicle-miles. To justify high rates of automobile travel, VMT reduction critics sometimes describe a type of trip that is best made by automobile. "You can't move furniture by bicycle," or "It would take me three times longer to commute by public transit than by car." This may be true, but does not prove that vehicle travel reductions are infeasible. The fact that *some* trips are best made by automobile does not mean that *all* trips should be made by automobile, or that current levels of vehicle travel are optimal.

Evidence discussed later in this report indicates that, given better options and incentives, a major portion of vehicle travel could be reduced in ways that are cost-effective overall. The key is to focus on the most changeable trips. Some people assume that there are few ways to reduce mileage, for example, arguing that vehicle travel reductions are only achievable in large cities with high quality public transit, and are therefore infeasible in rural area. However, motorists actually have many ways to reduce mileage, by choosing closer destinations, consolidating trips, shifting modes, and using mobility substitutes (telecommunications and delivery services). Since rural residents currently drive relatively high annual miles, they are often able to achieve relatively large mileage reductions. New technologies can significant improve non-auto accessibility. For example, the COVID pandemic demonstrated that telecommunications and delivery services can substitute for many vehicle trips, studies suggest that e-bikes could substitute for 10-30% of local trips, and integrated navigation and payment apps can make ridesharing, and public transit services more convenient for many trips.

There are two related challenges to vehicle travel reductions. First, although automobiles are expensive to own, their variable costs are low, typically costing just 10-15₵ per vehicle-mile. After spending thousands of dollars a year in fixed expenses, vehicles, owners often feel that they should maximize their mileage in order to get their money's worth from their large investments. In addition, for many people driving is more prestigious than other modes; they feel embarrassed walking, bicycling or using public transit. As a result, motorists often drive even when they have good alternatives, such as to local destinations within convenient walking and bicycling distance, and on urban corridors with frequent public transit services.

The second challenge is that mobility options have strong economies of scale. If most people in a community rely on automobiles, other modes are likely to be inefficient and stigmatized. For most of the last century, most communities have experienced a self-reinforcing cycle of automobile-oriented transportation planning and sprawled development patterns which create automobile-dependent communities.

Mobility Management Defined

Mobility management (also called *transportation demand management* [TDM] and *VMT reduction strategies*) refers to policies and programs that change travel activity to increase transport system efficiency (VTPI 2008; ICAT 2020; TfA and SGA 2020). Table 1 lists common mobility management strategies.

Table 1 **Mobility Management Strategies** (ICAT 2020; ITF 2021; VTPI 2008)

Improved Options	Incentives	Land Use Policies	Programs
Transit improvements	Congestion pricing	Smart growth	Commute trip reduction programs
Walking and cycling improvements	Distance-based fees	New urbanism	School and campus transport management
Rideshare programs	Parking cash out	Parking management	Freight transport management
Flextime	Parking pricing	VMT developer fees	TDM marketing
Telework	Pay-as-you-drive vehicle insurance	Transit oriented development	
Carsharing	Fuel tax increases	Car-free planning	

This table lists various mobility management strategies.

Mobility management is more than individual solutions to individual problems, such as road pricing to reduce congestion and transit improvements to reduce pollution; it is most effective if implemented as an integrated program that includes improved transport options and incentives to use the most efficient option for each trip. It is supported by professional organizations such as the Institute of Transportation Engineers and the Federal Highway Administration. Even roadway expansion advocates often support some mobility management strategies such as efficient road and parking pricing (Staley and Moore 2008). It reflects a paradigm shift, as summarized in Table 2.

Table 2 **Transport Planning Paradigm Shift** (Litman and Burwell 2006)

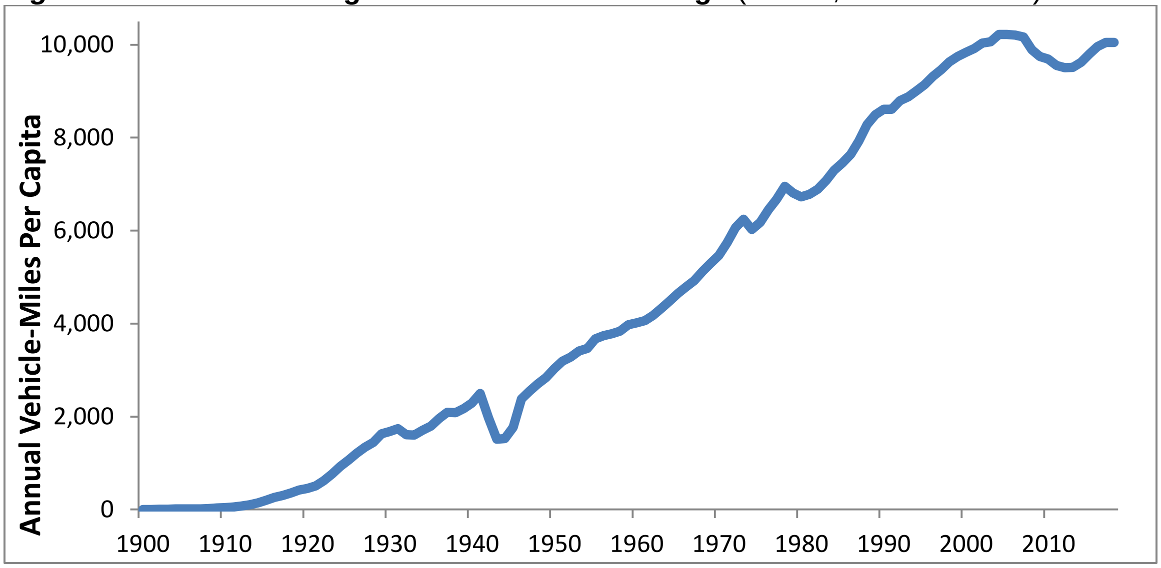
Factor	Old Paradigm	New Paradigm
Definition of transportation	Vehicle travel – mobility	Accessibility (ability to reach desired goods, services and activities)
Modes considered	Automobile and truck	All modes (walking, cycling, public transit, automobile, telework, etc.)
Land use development	Low-density, automobile-dependent	Compact, mixed, multi-modal
Performance indicators	Vehicle traffic speeds, roadway Level-of-Service	Multi-modal Level-of-Service, overall accessibility
Favored improvements	Expanded road and parking capacity, increased traffic speeds	Multi-modal improvements, mobility management,

A paradigm shift is changing the way transportation problems are defined and solutions evaluated.

Disagreements about the merit of mobility management often reflect differences in analysis scope – the range of benefits and costs considered. Critics generally consider just one or two benefits, while proponents consider more, including some often overlooked in conventional transport project evaluation such as parking cost savings, vehicle ownership cost savings, and health impacts. For example, Poole (2009) and Pisarski (2009a) criticize VMT reduction policies as an inefficient way to reduce pollution emissions; such criticism would be justified if pollution reduction was the only benefit these policies provide, but when other impacts are considered mobility management is often cost effective overall.

Critics often assume that everybody (at least, everybody who matters) drives, and so ignore the benefits of improving mobility for non-drivers. They tend to assume that past vehicle travel growth rates will continue into the future. They ignore current demographic and economic trends (aging population, rising fuel prices, increased urbanization, increasing traffic congestion, and increased health and environmental concerns) which are reducing VMT growth and increasing the value of alternative modes (NAR 2020).

Figure 5 **U.S. Average Annual Vehicles Mileage** (FHWA, Various Years)



Per capita motor vehicle travel increased during the Twentieth Century but peaked about 2000. Many current demographic, economic and technical trends are reducing vehicle travel demand.

Mobility management critics often ignore *rebound effects* (also called *takeback* or *induced travel* effects) the additional vehicle travel that results from roadway expansion and increased vehicle fuel economy (Moshiri and Aliyev 2017). Ignoring these effects exaggerates the value of highway expansion and fuel efficiency standards and so undervalues mobility management solutions. Critics often argue that mobility is very inelastic, citing research Small and Van Dender (2007) which implies that even large price increases have little effect on vehicle travel. But that study was based on U.S. data from 1960 to 2000, a unique period of rising vehicle ownership, increasing employment and real incomes, declining real fuel prices, highway expansion, declining transit service quality, and suburbanization. More recent analysis indicates that motorists are becoming more price sensitive (Brand 2009; Litman 2010).

Mobility Management Justifications

This section discusses justifications for mobility management and therefore VMT reduction targets.

Helps Solve Multiple Problems and Provide Multiple Benefits

The old planning paradigm was reductionist: each problem was assigned to a profession or agency with narrowly defined responsibilities: transportation agencies were responsible for reducing traffic congestion, health agencies for improving public fitness and health, and environmental agencies for reducing pollution. This can result in those organizations rationally implementing solutions that contradict other community goals, and tends to undervalue solutions that provide multiple benefits. The new paradigm is more comprehensive, and so searches for win-win solutions that help achieve multiple community goals, such as congestion reduction strategies that also increase public fitness and reduce pollution.

Mobility management tends to provide many benefits (VTPI 2008). Although a particular mobility management strategy may not be the most cost effective solution to a single problem, it is often the most beneficial strategy overall, considering all impacts. For example, considering just short-term congestion impacts, highway widenings often seem justified, and considering just emission reductions, alternative fuel vehicle subsidies often seem justified, but those strategies provide a limited range of benefits, and tend to induce additional vehicle travel, which reduces their intended benefits and increases other problems. By reducing congestion delays, urban roadway expansions tend to induce additional vehicle travel, which over the long run increases downstream congestion, crashes and pollution emissions. Similarly, by reducing fuel costs, efficient and alternative fueled vehicles tend to increases total vehicle travel and therefore congestion, infrastructure costs, crashes and sprawl-related costs. Mobility management strategies tend to achieve many planning objectives, as illustrated in Table 3.

Table 3 **Comparing Strategies** (Litman 2011)

Planning Objective	Roadway Expansion	Fuel Efficient Vehicles	Mobility Management
Motor Vehicle Travel	*Increased*	*Increased*	*Reduced*
User convenience and comfort	✓		✓
Congestion reduction	✓	×	✓
Road and parking cost savings	×	×	✓
Consumer savings		✓/×	✓
Reduced traffic accidents	×	×	✓
Improved mobility options			✓
Energy conservation		✓	✓
Pollution reduction	×	✓	✓
Physical fitness & health			✓
Economic development	?	?	✓
Land use objectives	×	×	✓

(✓ = Achieve objectives. × = Contradicts objective.) Roadway expansion and more fuel efficient vehicles provide a limited range of benefits, and by increasing total vehicle travel they can exacerbate other problems such as congestion, accidents and sprawl. Win-Win Solutions tend to reduce total vehicle travel and increases economic efficiency, which helps achieve many planning objectives.

Increases Efficiency and Fairness

Mobility management includes various reforms that increase economic efficiency and equity. An efficient transport system should reflect these principles:

- *Consumer options.* Consumers have a variety of transport and location options so they can choose the combination that best meets their needs and preferences.
- *Efficient pricing*. The prices that consumers pay for a good reflect the full marginal costs of supplying that good, unless a subsidy is specifically justified.
- *Economic neutrality*. Public policies and planning practices are not arbitrarily biased in favor of one good over others.

Current policies and planning practices are distorted in various ways that tend to increase motor vehicle travel beyond what is economically optimal, as summarized in Table 4.

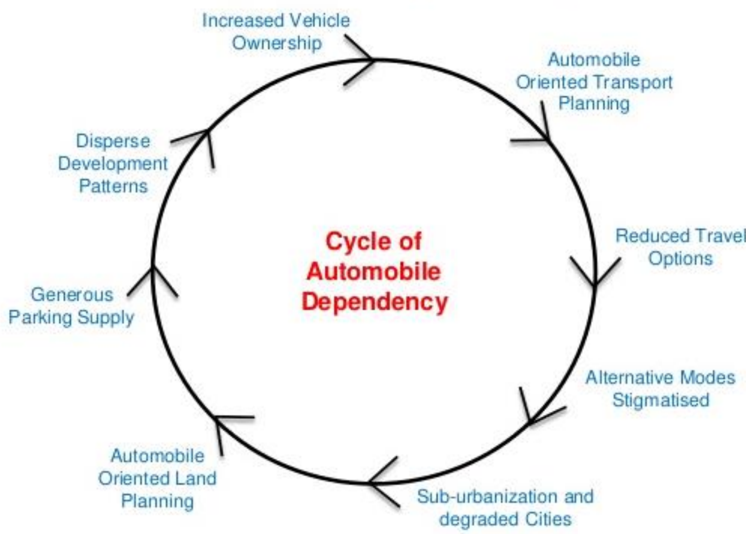
Table 4 **Transport Planning Distortions** (Clarke and Prentice 2009; Litman 2006)

	Description	Examples	Potential Reforms
Inadequate consumer options	Consumers often have limited alternatives to automobile transportation and automobile-oriented location.	Poor walking and cycling conditions. Inadequate public transit service. Lack of housing in accessible, multi-modal locations.	Improve alternative modes such as walking, bicycling, public transit and carsharing. Integrate alternative modes. More affordable housing in accessible locations.
Efficient Pricing	Many motor vehicle costs are fixed or external.	Unpriced roads. Unpriced parking. Fixed insurance and registration fees. Low fuel prices.	As much as feasible, charge marginal prices for roads, parking and emissions, and convert fixed costs, such as insurance and registration fees, into variable costs.
Transport Planning Practices	Transportation planning and investment practices favor automobile-oriented improvements, even when other solutions are more cost effective.	Dedicated roadway funding. Transportation system performance indicators based on vehicle traffic conditions. Incomplete impact analysis.	Apply least-cost planning. Fund alternative modes and mobility management whenever cost effective. Apply multi-modal transport performance indicators.
Land Use Polices	Current land use planning policies encourage lower-density, automobile-oriented development.	Parking minimums. Restrictions on development density and mix. Development and utility fees that fail to reflect the higher costs of dispersed locations.	Smart growth policy reforms that support more accessible, multi-modal land use development. Location-based development and utility fees.

This table summarizes various transportation market distortions and potential reforms.

These distortions help create a self-reinforcing cycle of increased automobile dependency and sprawl (Figure 6). Mobility management tends to correct these distortions, leading to more balanced and efficient transport systems.

Figure 6 **Cycle of Automobile Dependency and Sprawl**



This figure illustrates the self-reinforcing cycle of increased automobile dependency and sprawl. Establishing objectives to reduce vehicle travel and increase use of alternative modes can help correct existing market distortions that lead to inadequate transport options, economically excessive automobile travel, and sprawled land use patterns.

Various policy and planning reforms are justified on economic efficiency and planning principles, such as more efficient road, parking, insurance and fuel pricing; more comprehensive and integrated planning; least-cost funding and neutral tax policies. Transportation professionals categorize these reforms as mobility management strategies.

Critics might argue that VMT reductions should be an outcome of market reforms rather than planning objectives. They could suggest, "Let's just implement efficient pricing and let consumers decide how much to reduce their mobility." But the first step in reforming outdated policies is to establish new goals and performance targets. VMT reduction targets are often the best way to begin implementation of economically-justified policy and planning reforms; they focus political and institutional actions toward reform. For example, VMT reduction targets encourage legislative changes to support efficient road and parking pricing, and for transportation agencies to apply least-cost investments and develop more multi-modal planning practices. Similarly, these targets encourage local governments to reform zoning codes and implement more efficient parking management.

Least-Cost Planning (Lindquist and Wendt 2012)
Least-cost planning is a planning framework that implements the most cost-effective solution to a problem, considering all impacts (costs and benefits), giving equal consideration to demand management as capacity expansion. This tends to justify far more implementation of mobility management solutions than what occurs under current planning practices which consider a limited set of planning goals and have dedicated funds for facility improvements that cannot be used to implement mobility management strategies.

Provides Strategic Guidance for Individual Policy and Planning Decisions

A fundamental principle of good planning is that individual, short-term decisions should be consistent with strategic, long-term goals. Current transportation policies often fail to reflect this principle: individual planning decisions often contradict strategic objectives, resulting in inefficiency. Mobility management objectives can help guide individual policy and planning decisions so they are more integrated. For example, mobility management objectives encourage policy makers to choose efficient pricing and investments, transportation agencies to develop mobility management programs, and transportation professionals to learn about mobility management techniques.

Many policy and planning decisions affect the amount of mobility that occurs in an area, as summarized in Table 5. Although individually decisions that stimulate automobile travel may seem modest and justified, their impacts are cumulative and synergistic. People who live or work in automobile-oriented areas typically drive 40-60% more annual miles and rely less on alternative modes than they would in more multi-modal communities (Pratt 1999-2009; Ewing, et al. 2007; VTPI 2008; TransForm 2009).

Table 5 **Examples of Policy and Planning Decisions That Affect Mobility**

Transport Policies	Land Use Policies
Fuel taxes and prices	
Road tolls	Location of facilities and activities (jobs, housing, services, etc.)
Roadway supply and design	
Sidewalk and path supply and quality	Land use density and mix
Public transit service supply and quality	Parking supply and price
Mobility management programs	Building orientation

Many policy and planning decisions affect the amount and type of mobility that occurs in an area.

Conventional planning often ignores these long-term impacts. Many transport and land use policy decisions are based on narrow, short-term objectives with little consideration of strategic goals. For example, transportation agencies often expand roadways to reduce congestion, although this induces additional vehicle travel which increases downstream traffic and parking congestion, crashes, energy consumption and pollution emissions, although other congestion reduction strategies are available. Similarly, most local governments have generous minimum parking requirements, although this induces additional vehicle traffic, which increases traffic congestion, accidents, energy consumption and pollution emissions. VMT reduction targets encourage decision makers to choose the congestion reduction strategies that also help reduce parking problems, and the parking solutions that also help reduce congestion problems. Such comprehensive, strategic planning maximizes efficiency and benefits.

Some jurisdictions are starting to reform transportation policies to better support strategic goals. For example, the U.K.'s Department for Transport (DfT) has warned local authorities that major road projects will not receive central government funding if they are likely to increase carbon emissions or fail to support walking, bicycling and public transit (Reid 2022). This decision partly reflects research showing that highway expansions tend to increase vehicle traffic, which reduces their congestion reduction benefits, leading to poor benefit to cost ratios (BCRs), often much lower than for non-auto modes. For example, DfT found BCR's for bicycling projects up to 35 to 1, much higher than the 4.7 average BCR's for highway improvements.

Responds to Changing Travel Demands
Many demographic, economic and technical trends are reducing demand for automobile travel and increasing demand for other mobility and accessibility options.

Trends Shifting Travel Demands (Litman 2006)

- *Vehicle saturation.* During the last decade per capita vehicle ownership and annual mileage have reached saturation levels. Although total traffic may increase somewhat in areas with rapid population growth, growth rates will be much lower than what occurred during the last century and many areas will experience no growth or even negative VMT growth.
- *Aging population.* As the Baby Boom generation retires per capita vehicle travel will decline and their demand for alternatives will increase.
- *Rising fuel prices.* This will increase demand for energy efficient travel options such as walking, cycling and public transit, and more accessible land use development.
- *Increasing urbanization.* As more people move into cities the demand for urban modes (walking, cycling and public transportation) increases.
- *Increasing traffic and parking congestion.* This increases the relative value of alternative modes that reduce urban traffic congestion.
- *Rising roadway construction costs.* This reduces the feasibility and economic justification of major urban highway expansion.
- *Shifting consumer preferences.* Various indicators suggest that an increasing portion of consumers prefer multi-modal urban neighbourhoods and alternative modes.
- *Increasing health and environmental concerns.* Many individuals, organizations and jurisdictions plan to reduce pollution and increase physical fitness.
- *Technological innovations that improve alternatives.* Many new transportation technologies and services (telework, vehicle sharing services, multi-modal navigation and payment apps, delivery services, etc.) help residents reduce their vehicle ownership and use.

As a result of these trends, per capita annual automobile travel has peaked in most wealthy countries (Figure 4), and demand for alternatives is growing.[1] This is not to suggest that automobile travel will disappear, but vehicle travel demand will grow much less than in the past and demand for alternative modes will increase. It is sensible for transportation policies to reflect these changes, which means creating more diverse and efficient transportation systems, and more accessible, multi-modal communities. Mobility management objectives are a practical way to help implement these changes.

[1] In public lectures I often ask the audience, "Compared with your current travel patterns, how many of you would prefer to drive more than you currently do, and how many would prefer to drive less, provided that alternative modes are convenient, comfortable and affordable?" In virtually every case most audience members indicate that they would prefer to drive less and few want to drive more than they currently do.

Evaluating Criticisms

This section evaluates specific criticisms of mobility management objectives.

Harms Consumers

Critics argue that, since consumers freely choose automobile travel and automobile-dependent locations, they must be harmed by vehicle travel reduction and smart growth policies (Pisarski 2009a and 2009b; Moore, Staley and Poole 2010). This is not necessarily true: many mobility management strategies use positive incentives that directly benefit consumers by improving travel options or rewarding vehicle travel reductions (Table 6), and real estate market research indicates that consumers increasingly prefer smart growth home locations (NAR 2020).

Table 6 **Mobility Management Strategy Impacts** (VTPI 2008)

Positive Incentives	Mixed	Negative Incentives
Public transit improvements	Smart growth	
Walking and cycling improvements	New urbanism	
Rideshare and carshare programs	Parking management	
Flextime and telework	Transit oriented development	Road tolls
Pay-As-You-Drive pricing	Car-free planning	Parking pricing
Parking cash out and unbundling	Traffic calming	Fuel tax increases

This table categorizes mobility management strategies according to user impacts. Far more provide positive than negative incentives, and even negative incentives, such as road pricing, can benefit users overall if revenues are used to reduce other taxes or provide new valued services.

Even negative incentives, such as higher fees or traffic calming, can benefit consumers overall. For example, people who drive less due to higher road tolls, parking fees or fuel prices may be better off overall if revenues are used to reduce other taxes or provide new valued services, or if they benefit from reduced congestion, accident risk, pollution exposure, or less need to chauffeur non-driving relatives and friends (Litman 2007b).

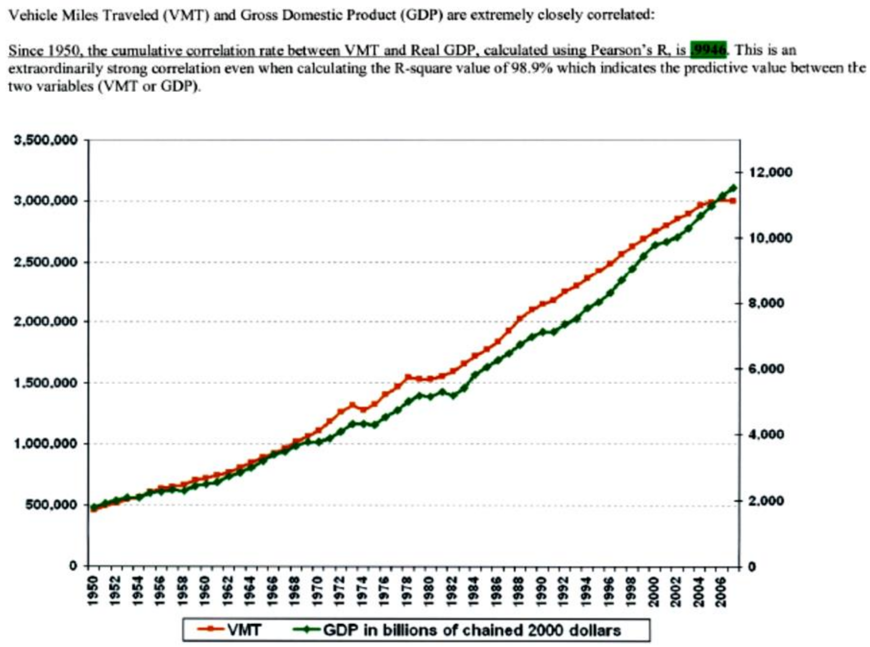
Although it would be inefficient to reduce vehicle travel arbitrarily, for example, by randomly forbidding vehicle trips or closing roads, efficient mobility management improves the convenience of higher value automobile trips (by reducing congestion when motorists are willing to pay directly for road and parking use) while giving consumers incentives to reduce low-value automobile travel, such as trips that provide little benefit or that can easily shift to alternative modes or destinations.

To the degree that mobility management objectives help create a transportation system that better responds to future travel demands, applies positive incentives and efficient pricing, resulting vehicle travel reductions can maximize consumer benefits and minimize consumer costs.

Harms the Economy

Some critics argue that because vehicle travel tends to increase with economic development, any effort to reduce vehicle travel is economically harmful. For example, the Highway Users Alliance (HUA 2009) claims that the graph below proves that, because VMT and GDP are correlated, efforts to reduce vehicle travel must reduce economic productivity.

Figure 7 **US VMT and GDP Trends** (HUA 2009)

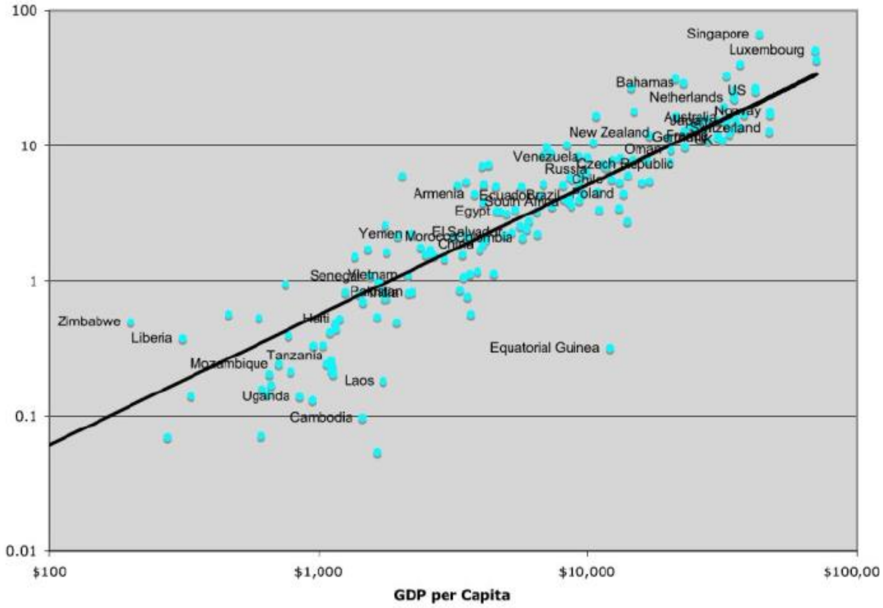


The Highway Users Alliance claims that this graph proves that a reduction in vehicle travel will reduce economic productivity, but correlation does not prove causation.

Similarly, economist Randall Pozdena claims that Figure 7 proves there is a strong positive relationship between income and energy use, and that because recessions often follow petroleum price spikes, efforts to reduce per capita vehicle travel reduce economic productivity. He concludes that, "a one percent change in VMT/capita causes a 0.9 percent change in GDP in the short run (2 years) and a 0.46 percent in the long run (20 years)." This analysis misrepresents these issues in important ways.

The log-log format in Figure 8 is a visual trick that exaggerates the relationships between energy and economic development. For example, although the U.S. and Norway are located close together, Norwegians actually consume about half as much fuel per capita as U.S. residents. The graph includes countries with very different levels of industrialization. An increase in per capita vehicle travel in very poor countries such as Zimbabwe and Liberia has a very different productivity impacts than in wealthy, industrialized countries. Similarly, although oil price spikes harm oil consumers, gradual and predictable fuel tax increases can be economically beneficial by encouraging energy conservation and reducing the wealth transferred to oil producers.

Figure 8 **Per Capita GDP Versus Barrels of Oil** (Pozdena 2009)



Pozdena claims this graph proves that increased energy consumption increases economic productivity. A log-log graph such as this exaggerates such relationships.

Certainly energy use, vehicle travel and GDP tend to increase together, as figures 3 and 4 indicate, but this reflects several factors:

1. Motor vehicle travel can increase economic productivity, particularly when used for high value transport such as freight and service delivery, business travel and emergency trips.
2. Increased wealth tends to increase vehicle ownership and use, although marginal impacts decline as illustrated in Table 7.

Table 7 **Annual Per Capita Vehicle Mileage by Income Quintile** (BLS 2007)

Income Quintile:	1	2	3	4	5
Income before taxes	$6,195	$12,579	$18,485	$24,986	$49,496
Annual mileage	4,733	6,182	7,440	7,926	8,885
Mileage increase per $1,000 additional income	*764*	*227*	*213*	*75*	*39*

Increased wealth causes declining marginal mileage increases.

3. Increased wealth allows some wealthy households to choose more accessible locations, allowing them to reduce their vehicle travel.
4. Vehicle travel imposes external costs (congestion, accident damages, import exchange burdens, pollution emissions) that can reduce economic productivity.
5. Increased vehicle travel tends to create more automobile-dependent transport system and dispersed land use patterns which increases the amount of travel needed to maintain a given level of accessibility. This tends to reduce economic productivity.

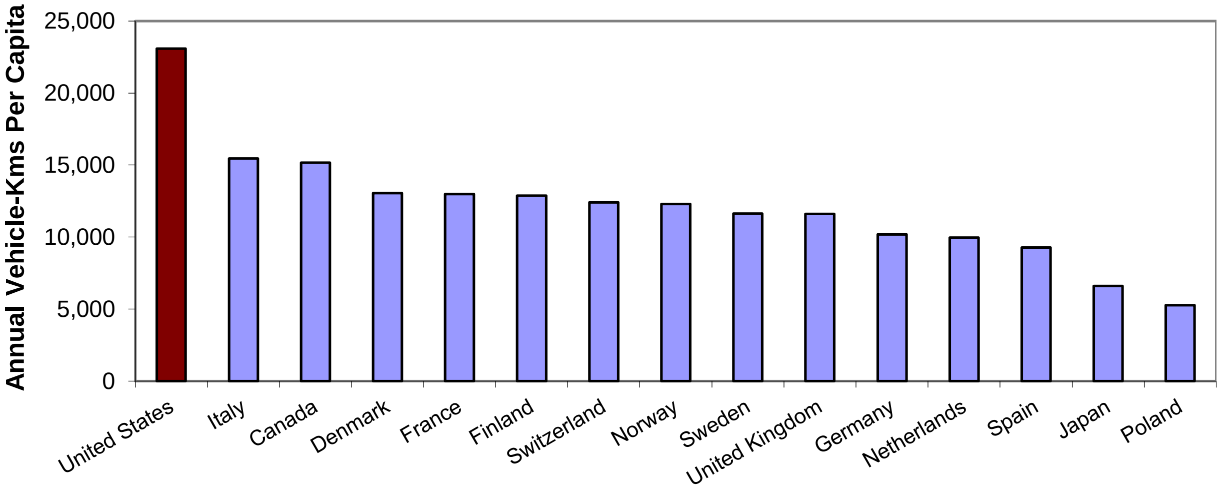
Only Factor 1 *causes* wealth to increase with VMT, while factors 2-5 *result from* increased wealth. Factors 1 and 2 cause *positive* relationships between VMT and GDP, while factors 3, 4 and 5 cause negative relationships. Because these effects vary, the overall relationships between vehicle travel and economic productivity depend on specific conditions, including a region's level of development, economic factors such as the costs of importing fuel, and the policies that are applied.

It is unsurprising that VMT and GDP correlate since vehicle expenditures account for a significant portion of household, business and government consumption (typically 15-25% in automobile-oriented regions), so all else being equal, doubling VMT increases GDP about 10%. However, this does not necessarily reflect increased social welfare: it could simply reflect an increase in costs. For example, policies that stimulate sprawl will increase both VMT and GDP, since residents must drive more annual miles, spend more on vehicles and fuel, although consumers and society could be worse off overall. In such situations, VMT reductions can support economic development (Zheng, et al. 2011).

Researchers find weak or negative relationships between personal vehicle travel and economic productivity (Angel and Blie 2015; Ecola and Wach 2012; Kooshian and Winkelman 2011; McMullen and Eckstein 2011). Empirical evidence suggests that increasing from very low to moderate levels of mobility increases productivity since motor vehicles are used for high-value trips, but at higher levels of per capita VMT, marginal benefits decline and eventually becomes negative as external costs and inefficiencies increase (Kooshian 2011; Zheng, et al. 2011). An international study found that per capita vehicle ownership peaks at about $21,000 (1997 U.S. dollars) annual income (Talukadar 1997). Similarly, a World Bank study found that beyond an optimal level (about 7,500 kilometers annual motor vehicle travel per capita, with considerable variance due to geographic and economic factors), vehicle travel marginal costs outweigh marginal benefits (Kenworthy, et al. 1997). The researchers conclude that, "*there are no obvious gains in economic efficiency from developing car dependence in cities*," and, "*There are on the other hand significant losses in external costs due to car dependence.*"

Among wealthy countries there is considerable variation in per capita vehicle travel. Although per capita VMT grew during most of the last century, it has saturated in most wealthy countries and the level at which this saturation occurs varies depending on transport and land use policies (Millard-Ball and Schipper 2010). The U.S. averages more than twice the per capita vehicle travel as most other OECD countries, as indicated in Figure 8. Of particular interest is Norway, which produces petroleum but maintains high fuel prices and has other policies to discourage vehicle travel and support alternative modes. These policies minimized domestic fuel consumption, leaving more oil to export. As a result, Norway has one of the world's highest incomes, a competitive and expanding economy, a positive trade balance, and the world's largest legacy fund.

Figure 9 **Per Capita Annual Vehicle Travel By Country** (OECD 2009)



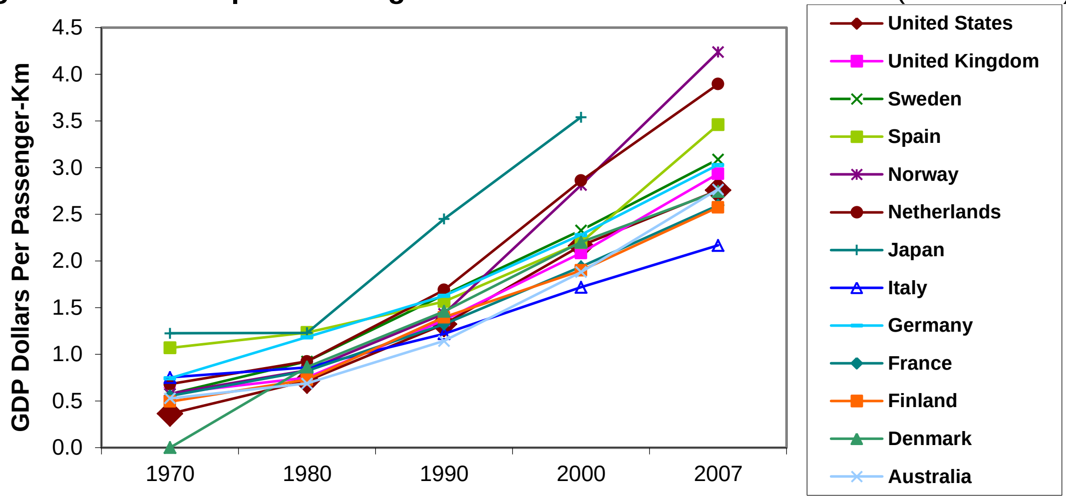
Per capita vehicle mileage is significantly higher in the U.S. than in other industrialized countries. Residents of wealthy countries such as Switzerland, Norway and Sweden drive about half as much as in the U.S. due to policies and planning practices that increase transport system efficiency.

Similarly, annual per capita vehicle mileage varies significantly among U.S. cities, from fewer than 6,000 average annual vehicle-miles per capita to more than 15,000, as indicated in Figure 1. Although many factors influence these differences, they result, in part from transport and land use policies that affect the travel options available, travel incentives, and land use patterns. There is no evidence that lower VMT cities such as Redding, Sacramento, Chicago and Portland, are less economically successful or have inferior quality of life than higher VMT cities such as Atlanta, Houston, Birmingham or Durham; in fact, the lower VMT cities tend to have higher per capita GDP, as indicated later in this report.

The data presented by HUA and Pozdena do not really prove that increased energy consumption and vehicle travel necessarily support economic development. For example, although in an undeveloped country, transport system improvements that cause average per capita annual vehicle travel to rise from 1,000 to 2,000 VMT may increase economic productivity, this does not prove that VMT reduction policies in a developed country, such as more efficient road and parking pricing, and greater investments in alternative modes, which cause average annual vehicle travel to decline from 16,000 to 15,000 VMT reduce productivity, although this is what Pozdena implies. Per capita annual vehicle travel varies widely among wealthy countries due to differences in pricing and planning practices. By reducing costs (congestion, road and parking facility costs, fuel expenses, accident and pollution damages, etc.) they can increase productivity.

Described differently, the amount of vehicle travel and energy required per unit of GDP varies widely. Virtually all developed countries are increasing GDP per unit of energy and mobility, and some extract far more productivity (material wealth and income) per unit of mobility and energy than others, as illustrated in Figure 10, due, in part, to transport policies. All else being equal, policies that increase transport efficiency increase economic productivity and competitiveness. This is sometimes called *decoupling* (Mraihi 2012; OECD 2006).

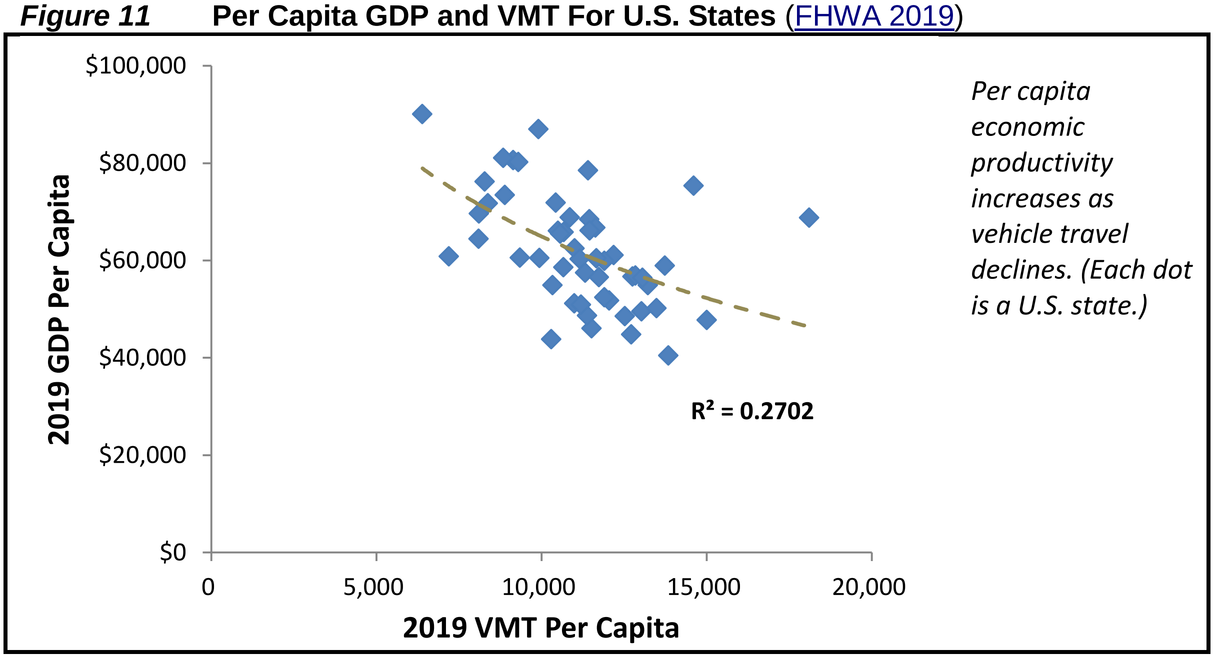
Figure 10 **GDP per Passenger-Kilometer for Various Countries** (OECD 2009)



Most countries are increasing GDP per passenger-mile, some much more than the U.S.

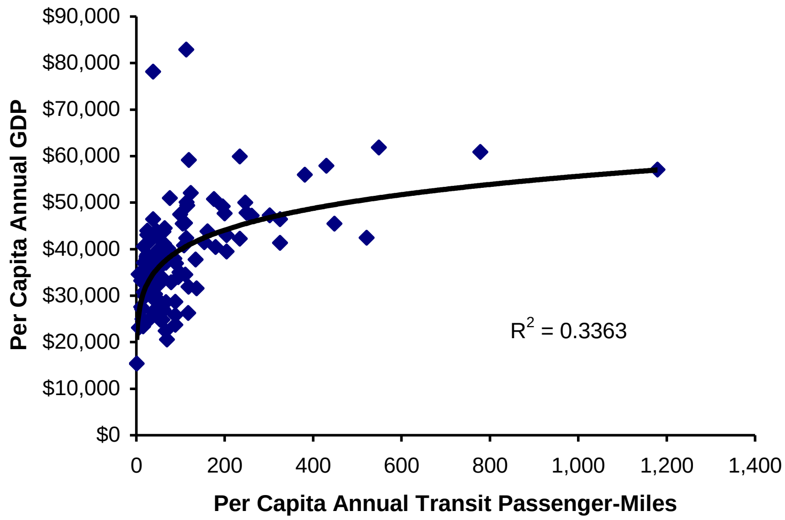
A rigid relationship between mobility and economic productivity implies that economies are inflexible: there is only one efficient way to produce goods, and that economic development requires ever more energy and movement. A flexible relationship between mobility and economic productivity implies that economies are responsive and creative: if energy and mobility are cheap, businesses and consumer use a lot, but if prices increase or other policies encourage conservation, the economy becomes more efficient. Within developed countries there is a negative relationship between vehicle travel and economic productivity as illustrated in the following figures (also see Kooshian 2011).

Figure 11 **Per Capita GDP and VMT For U.S. States** (FHWA 2019)



Similarly, *GDP tends to increase with public transit travel*, as illustrated in Figure 9.

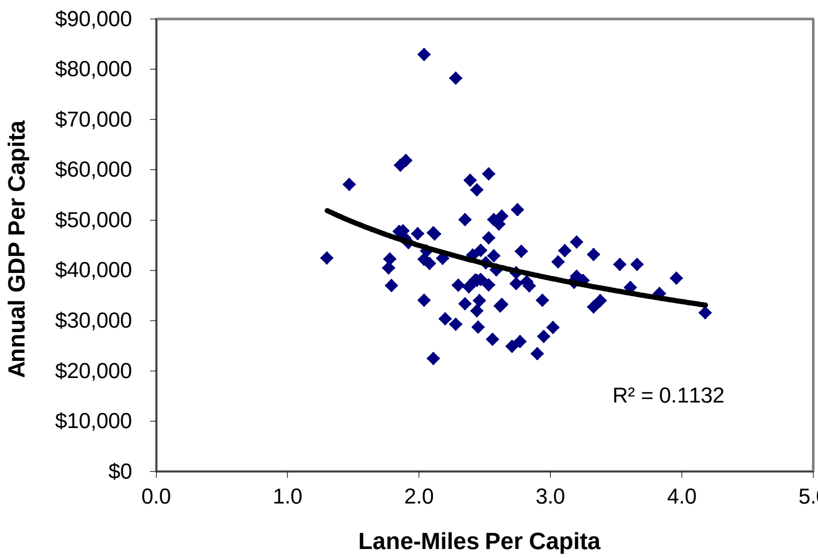
Figure 12 **Per Capita GDP and Transit Ridership** (VTPI 2009)



GDP tends to increase with per capita transit travel. (Each dot is a U.S. urban region.)

Per capita GDP tends to decline with roadway lane miles, as illustrated in Figure 13.

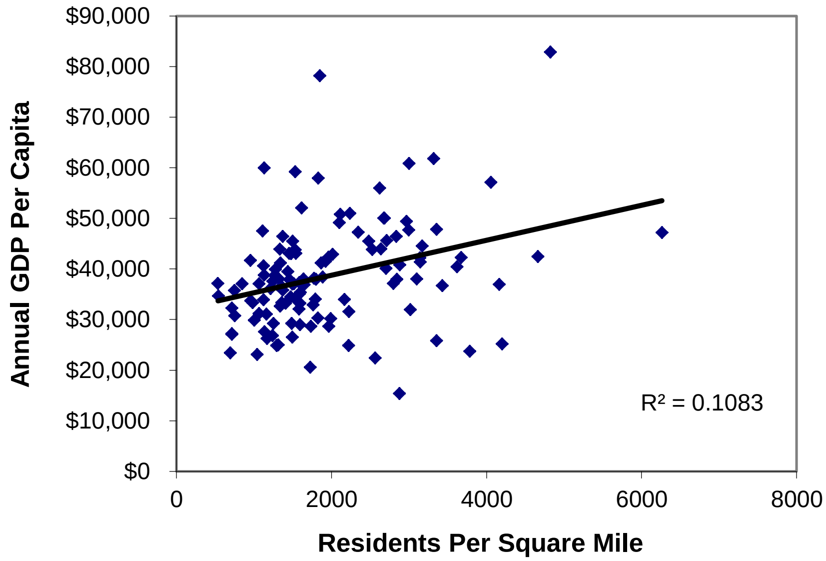
Figure 13 **Per Capita GDP and Road Lane Miles** (VTPI 2009)



Economic productivity declines with more roadway supply, an indicator of automobile-oriented transport and land use patterns. (Each dot is a U.S. urban region.)

Per capita GDP tends to increase with population density, as illustrated in the following figure. These *agglomeration efficiencies* reflects the benefits that result from improved land use accessibility (reduced distances between activities) and increased transport system diversity, which both tend to increase with density.

Figure 14 **Per Capita GDP and Urban Density** (BTS 2006 and BEA 2006)

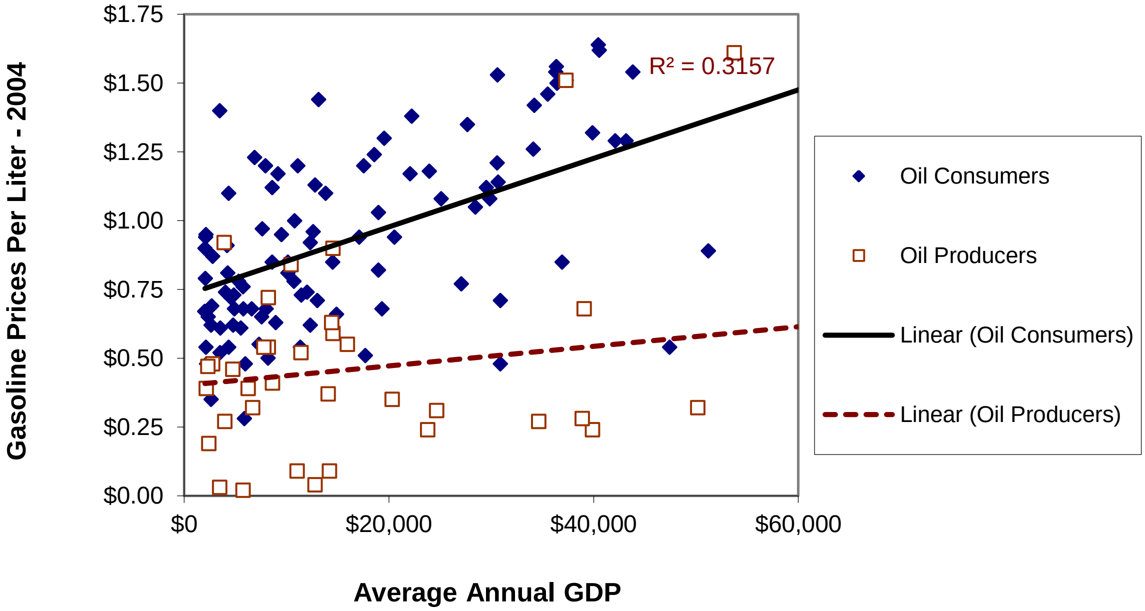


Productivity tends to increase with population density. (Each dot is a U.S. urban region.)

Zheng, et al. (2011) find similar results: per capita economic productivity tends to be higher in states with less automobile-dependent transport systems. Chapple and Makarewicz (2010) analyzed business growth trends in California between 1990 and 2005. They find that most expanding firms locate near transportation infrastructure, such as highways and major airports, but the majority of growth occurred near existing infrastructure in urban areas rather than expanding to undeveloped sites at the urban fringe. They conclude that policies that encourage infill development need not reduce economic development, and may support economic development by improving affordable and accessible housing.

The following figure shows that per capita GDP increases with fuel prices, particularly among oil importing countries ("Oil Consumers"). This suggests that, contrary to popular belief, high fuel prices (and therefore, high vehicle operating costs) increase economic productivity and development by increasing transport system efficiency and reducing the wealth lost to importing fuel.

Figure 15 **GDP Versus Fuel Prices, Countries** (Metschies 2005)[2]



Economic productivity tends to increase with higher fuel prices, indicating that substantial increases in vehicle fees can be achieved without reducing overall economic productivity.

Two factors help explain why GDP tends to decline at high levels of VMT:

1. Marginal productivity benefits decline as a declining portion of travel is for productive uses, such as freight and service delivery, and business travel.
2. The additional VMT imposes increasing economic costs (vehicle expenses, road and parking facility costs, traffic service costs, accident and pollution damages, etc.).

[2] Fuel price (www.internationalfuelprices.com), GDP (http://en.wikipedia.org/wiki/List_of_countries_by_GDP_(PPP)_per_capita), petroleum production (http://en.wikipedia.org/wiki/Petroleum); excluding countries with average annual GDP under $2,000.

Summary of Pozdena Critique
Pozdena's 2009 paper makes the following errors:

- Correlations between energy use, VMT and GDP do not prove causation. Increased wealth often increases energy use and vehicle travel. This does not mean that increases in vehicle travel will increase wealth or reductions in vehicle travel reduce wealth.
- The log-log graph exaggerates the perceived correlation. There is actually considerable variation in per capita energy use and vehicle travel between countries and cities with comparable GDP due to differences in energy and transportation policies.
- Pozdena's evidence (international data including very low-income countries, long-term trends beginning at the start of the automobile age, and the effects of oil shocks) are not relevant for evaluating the economic impacts of typical mobility management strategies.
- Most experts agree with Pozdena that transportation policy reforms should reflect economic principles, but he only considers congestion and pollution problems, and therefore only supports congestion pricing and carbon taxes. He ignores other market distortions such as inefficient pricing of roadway facilities and crash risk, and underinvestment in non-auto modes. More comprehensive analysis justifies additional mobility management strategies, such as parking and insurance pricing reforms, more comprehensive planning and least-cost funding.
- Pozdena argues that "excessive" fuel taxes, VMT fees, or disincentives to driving are unjustified, although, until other impacts are efficiently priced they can be justified on second-best grounds. For example, until comprehensive road pricing is implemented, higher fuel taxes, VMT fees and parking pricing will provide some congestion and road cost saving benefits.
- Pozdena implies that VMT reductions are implemented primarily by regulations, but most VMT reduction strategies reflect market principles and good planning: more efficient pricing for roads, parking, insurance and fuel; more multi-modal planning and least-cost investment practices; land use planning reforms. This may reflect a semantic confusion: VTM reduction policy targets themselves can be considered a type of regulation, but most of the specific mobility management strategies applied to achieve these targets are not; they are planning and pricing reforms that can be justified for economic efficiency and equity.
- Pozdena assumes that Smart Growth primarily involves new regulations, although it actually involves a variety of policy reforms, many of which reduce regulations or simply shift development location and design, and that this does not reduce vehicle travel (he claims, incorrectly that "there is no evidence to support implied causality flowing from density to VMT"), reduce transport costs or increase economic productivity. His criticism assumes that consumers dislike compact communities so urban living necessarily harms consumers and society. Abundant research indicates otherwise (Levine 2006; Carlson and Howard 2010; NAR 2020).

Transportation market distortions encourage economically inefficient transportation activity, in which marginal costs exceed marginal benefits. More neutral planning and efficient pricing increase economic productivity. For example, more efficient road and parking pricing encourage travelers to use alternative modes under congested conditions, which reduces congestion and parking costs borne by businesses. Even sub-optimal reforms, such as fuel tax increases, can be justified on second-best ground, until optimal policies, such as time- and location-based fees, are fully implemented.

Ignores Mobility Benefits

Critics sometimes argue that motor vehicle travel provides benefits that are overlooked by advocates of VMT reduction targets, but this is generally untrue. Most public officials and planners are quite aware of the benefits of mobility to people and businesses, and its importance in a successful economy. However, they are also aware of the direct and indirect costs that result from excessive motor vehicle travel and the benefits that can result from a more diverse and efficient transportation system. Table 8 indicates mobility management benefits and costs.

Table 8 **Mobility Management Benefits and Costs**

Benefit Categories	Cost Categories
Direct user benefits (from positive incentives) Revenues (from pricing strategies) Congestion reduction Roadway costs savings Parking cost savings Consumer savings Reduced chauffeuring burdens Accident reductions Improved mobility options Energy conservation Pollution reduction Physical fitness and health	Reduced mobility benefits Subsidies User fees Transaction costs (costs to pay and collect fees, and any additional enforcement costs)

This table indicates the categories of benefits and costs that should be considered when evaluating mobility management cost effectiveness.

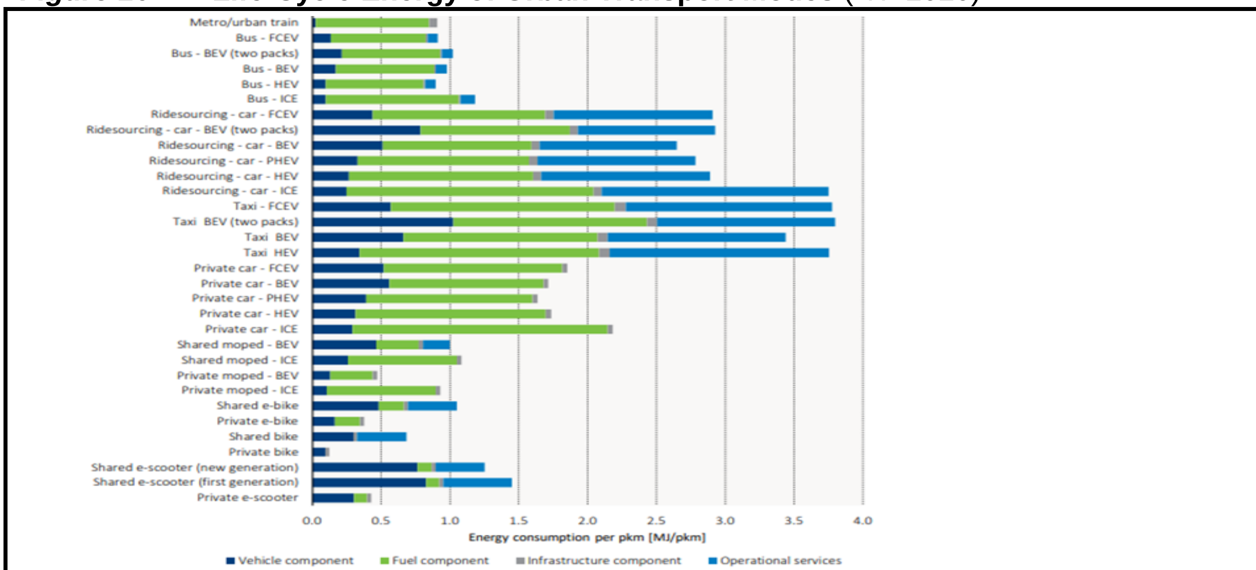
As discussed earlier, the ultimate benefit of transportation is *accessibility*. If transportation is defined only as mobility the only solution to traffic and parking congestion is to expand roads and parking facilities. Defining transportation based on accessibility allows a much broader range of solutions to be considered, including improvements to alternative modes and mobility substitutes, pricing incentives, and more accessible land use. Better management can increase the benefits provided by mobility, for example, by reducing traffic and parking congestion so there is less delay when people do drive, and improving travel options so motorists are not required to spend as much time chauffeuring non-driver friends and family members.

Pollution Reduction Cost Efficiency

Critics argue that reducing vehicle travel is an inefficient way to reduce pollution emissions (Poole 2009). This might be true if emission reductions were the only benefit, but VMT reductions can provide many co-benefits and so can be very cost effective considering all impacts. Vehicle travel reductions tend to reduce consumer costs, congestion, infrastructure, crash and sprawl-related costs, while renewable fuel vehicles tend to increase these costs because their lower operating expenses induce additional vehicle travel (Alarfaj, Griffin and Samaras 2021; Litman 2005; Vaughan 2019).

Although electric and hydrogen vehicles are often called “zero emissions,” they actually produce significant emissions over their lifecycle, including their fuel, vehicle and infrastructure production. The figure below compares estimated lifecycle energy consumption of various modes, measured per passenger-kilometer. The results indicate that bicycles (including e-bikes) are most energy efficient, followed by mopeds, public transit, and private cars. The least efficient modes are shared vehicles (ridehailing and taxis) due to their additional deadheading travel (empty vehicle-miles required to pick up and drop off passengers). In addition, because they have lower fuel costs, efficient and alternative fuel vehicle owners typically drive 10-30% more annual miles than they would with equivalent fossil fuel vehicles, further reducing their emission reductions and increasing other external costs. This indicates that it would is wrong to assume that shifts to more efficient and alternative fuel vehicles will solve our transportation problems.

Figure 16 **Life-Cycle Energy of Urban Transport Modes** (ITF 2020)



Notes: BEV = battery electric vehicle; HEV = hybrid electric vehicle; ICE = internal combustion engine; FCEV = fuel cell electric vehicle; PHEV = plug-in hybrid electric vehicle.

Several recent studies conclude that VMT reductions will be needed to achieve emission reduction targets (Manjoo 2021; McCahill 2021; Yudkin, et al. 2021; Vaughan 2019). “Electrification of Light-Duty Vehicle Fleet Alone Will Not Meet Mitigation Targets,” (Milovanoff, Posen and MacLean 2020) concludes that fleet electrification is an inefficient way to achieve emission reductions due to slow fleet turnover, and the economic and environmental costs of producing the required batteries and accommodating the additional electrical demand.

Some mobility management strategies are particularly effective at achieving environmental goals (Burbank 2008; Cambridge Systematics 2009). For example, fuel tax increases, distance-based insurance and registration fees, more efficient parking management, and land use policy reforms often have modest incremental costs and substantial economic and environmental benefits (CBO 2003; Parry 2005). Efficient road pricing reduces VMT and congestion, providing extra emission reductions. Aviation transport management reduces high altitude pollution emissions which have particularly severe climate change impacts. Freight transport management can reduce travel by heavy vehicles that have high emission rates per vehicle-mile.

Crowding

Critics argue that smart growth land use policies cause crowding. This is generally untrue and reflects a misunderstanding of the concept. Although smart growth increases *density* (people per acre) it does not necessarily increase crowding (people per square foot of interior building space). For example, in a typical 1,800 square foot house requires a 10,000 square foot (quarter acre) lot if it is single-story with a large garage and yard, but the same size house needs only 2,000 square foot if it is three stories with a single car garage and a small yard.

Current and projected market trends favor smart growth (NAR 2020). Demand for dispersed, automobile-dependent housing is declining while demand for housing in more accessible, multi-modal neighborhoods is growing due to factors such as aging population, rising fuel prices and shifting consumer preferences (Thomas 2009). Since sprawl has been the primary development pattern for the last half-century there is still plenty of low-density, single-family, sprawled housing available for people who want it (Leinberger 2008) but the demand for accessible, multi-modal housing will be inadequate (Reconnecting America 2006). Past development policies (such as generous minimum parking requirements and building setbacks, and excessive limits on development density and mix) caused sprawl; it makes sense to change these policies to encourage more urban infill and multi-modal development patterns (Levine 2006).

Consumer Sovereignty

Consumer sovereignty means that consumers are able to choose the goods that best meet their needs. This principle suggests that transportation policies should allow consumers to choose how and how much to travel without external intervention. Critics argue that mobility management and smart growth policies constitute violates this principle. The Highway User Association claims that mobility management attempts to "alter behavior and personal choice" (HUA 2009), and Pisarski (2009a and 2009b) argues that such policies prevents consumers from choosing the lifestyles they prefer.

But many current policies and planning practices tend to favor automobile travel over other modes and more dispersed land use development, depriving consumers of options that involve alternative modes or more compact locations. To the degree that current levels of automobile dependency and sprawl result from market distortions, mobility management and smart growth policies help achieve modal neutrality and consumer sovereignty. These policies tend to improve travel and housing options, allowing consumers to choose the combination that best meets their needs. They do not eliminate driving and single-family housing, even with programs that critics consider aggressive and "radical," automobile travel would continue to have the largest mode share, Americans would continue to drive more than residents of peer countries, and most residents would live in single-family homes in most communities.

Harms Poor People

Some studies indicate that economically disadvantaged workers (such as former welfare recipients) tend to work and earn more if they have an automobile, and motor vehicles can provide access to basic services such as medical care and shopping (Baum 2009; Blumenberg and Pierce 2012; Smart and Klein 2015). This leads some people to conclude that vehicle ownership increases social equity, so vehicle travel reduction policies are unfair and harmful to low-income households (Pisarski 2009a). This misinterprets the issues.

The additional income provided by vehicle ownership is, on average, far less than the additional costs, making households financially worse off overall (Smart and Klein 2015). Other studies indicate that high quality public transit also increases labor participation (CTS 2010), even in automobile-oriented cities such as Houston, Texas (Yi 2006). Analysis by Gao and Johnston (2009) indicates that transit improvements provide greater total benefits to all income groups than subsidizing automobiles for lower-income groups.

Automobile subsidies only benefit a subset of disadvantaged people, those able to drive, and incur significant direct and indirect costs. Low income motorists must typically spend $250 to $500 per month to own and operate a vehicle. Their insurance premiums tend to be high, and the older vehicles they own tend to be unreliable, imposing large repair costs. As a result, much of the additional income provided by automobile ownership must be spent on vehicle expenses, reducing net gains. Automobile travel incurs other user costs, including accident risk and reduced physical fitness (APHA 2010; Lachapelle, et al. 2011), and increases external costs imposed on disadvantaged communities including traffic congestion, road and parking facility costs, accident risk, and pollution emissions.

Increased vehicle travel does not necessarily increase overall economic productivity or employment. On the contrary, productivity rates (per capita GDP) tend to increase with transit ridership and decline with automobile use, indicating that a more multi-modal transport system support community economic development (Litman 2010a).

An automobile dependent transportation system is inherently inefficient and inequitable. Subsidies intended to help lower-income people own and operate automobiles treat one symptom but exacerbate other problems. Creating a more diverse and efficient transport system addresses the root of the problem, which provides the greatest total benefits to society, including increased social equity by improving mobility and accessibility for physically, economically and socially disadvantaged people (Alexander, Alfonzo and Lee 2021).

This analysis indicates that although automobile use can benefit some disadvantaged people, other transport improvement strategies are often more cost effective and beneficial overall. These include improved walking and cycling conditions, improved rideshare and public transit services, carsharing, distance-based vehicle insurance and registration fees, and more affordable housing in accessible locations (Sullivan 2003; Litman 2010c). These solutions tend to benefit all residents, and especially those who are physically, economically or socially disadvantaged.

Summary of Mobility Management Impacts

Table 9 evaluates the impacts of various mobility management strategies. Most strategies increase economic efficiency, and many provide direct consumer and equity benefits.

Table 9 Impacts of Mobility Management Strategies

Strategy	Efficiency	Consumer (Users)	Equity
Incentives to Choose Efficient Modes			
Congestion pricing	Positive. Reflects efficient pricing.	Mixed. Increases motorists' costs but reduces congestion	Mixed. Benefits some people but burdens others
Cost-recovery road tolls	Positive. Reflects efficient pricing.	Mixed. Increases motorists' costs but provides revenues.	Positive. More equitable than most other funding.
Distance-based registration fees	Positive. Reflects efficient pricing.	Positive. Gives motorists a new way to save money.	Positive. Charges users for the costs they impose.
Cost-recovery parking fees	Positive. Reflects efficient pricing.	Mixed. Increases motorists' costs but provides revenues.	Positive. Charges users for the costs they impose.
Fuel tax increases	Positive if raised gradually and predictably.	Mixed. Increases motorist costs but provides revenues.	Positive if taxes internalize costs.
TDM marketing (information and encouragement)	Generally positive, since better information tends to increase efficiency.	Generally positive, although overly aggressive campaigns can be annoying.	Generally positive.
No-drive days	Generally negative.	Generally negative.	Mixed. May be more equitable than pricing.
Improved Options			
Transit improvements	Mixed. Is cost effective on major urban corridors.	Generally positive, provided it meets user demands.	Generally positive. Provides basic mobility.
Walking and cycling improvements	Improvements justified to meet growing demand.	Generally very positive.	Generally positive. Provides basic mobility.
Rideshare programs	Mixed. Is cost effective on major urban corridors.	Generally positive, provided it meets user demands.	Generally positive.
Telework and flextime	Generally cost effective and beneficial.	Generally very positive as a user option.	Generally positive.
Carsharing	Generally cost effective and beneficial.	Generally very positive as a user option.	Generally positive.
Land use Policies			
More flexible zoning (more density, mix, housing types, etc.)	Generally reflects market principles and increases efficiency.	Mixed. Benefits some consumers but disadvantages others.	Generally achieves equity objectives
Location-efficient development.	Generally reflects market principles and reduces public service costs.	Mixed. Benefits some consumers but disadvantages others.	Generally achieves equity objectives.
Urban growth boundaries.	Mixed. Restricts development but increases efficiency.	Mixed. Benefits some consumers but disadvantages others.	Mixed.

This table summarizes efficiency, consumer and equity impacts of mobility management strategies.

Legitimate Criticisms of VMT Reduction Targets

This section discusses legitimate criticisms of VMT reduction targets and mobility management strategies and how they can be addressed.

Some mobility management strategies can be inefficient and unfair. For example, it would be inappropriate to arbitrarily forbid driving at certain times or locations if no suitable alternatives are available. Some strategies, such as "no drive days," are blunt, they fail to give consumers maximum flexibility so they can reduce their least-valued vehicle travel while retaining higher-value trips. As much as possible, mobility management strategies should reflect market principles, including consumer sovereignty, efficient pricing, and neutral planning.

Mobility management programs can be uncoordinated. For example, it would be inequitable to increase user fees if alternatives (good walking and cycling conditions, convenient ridesharing and public transit service, telework options, affordable housing in accessible communities, etc.) are unavailable. Similarly, it would be inefficient to spend a lot of money on alternative modes (walking and cycling facilities, public transit service improvements, etc.) without sufficient incentives to encourage their use.

Vehicle travel reduction targets are somewhat arbitrary, not based on detailed benefit-cost analysis. However, there are currently many market distortions that favor automobile travel, including underpriced roads and parking facilities, and automobile-oriented planning which underinvests in other modes, resulting in economically excessive vehicle travel (Litman 2014a). Vehicle travel reduction targets can be considered an appropriate way to focus policy and planning decisions to correct these distortions (Thorwaldson 2020).

Mobility management requires public support. For example, it would be inappropriate to tell people that they must reduce their automobile travel without communicating why and how. It will be important to show consumer benefits.

VMT reduction targets may be nothing more than words. For example, a community may establish long-term VMT reduction targets while continuing existing transportation and land use planning practices that stimulate automobile dependency and sprawl. It is important that VMT reduction targets actually lead to positive and rational change.

Two Narratives

This debate reflects two conflicting narratives. Reader must decide which to believe:

1. VTM reduction critics claim that virtually everybody wants to lead high-mileage lifestyles and live in automobile-oriented communities, so vehicle travel reduction policies are futile and harmful.
2. VMT reduction supporters believe that high levels of vehicle travel are an anomaly resulting from a combination of automobile-oriented planning, sprawled development and cheap fuel that result in economically excessive vehicle travel – and given better options and more efficient incentives, many people would drive less, rely more on non-auto modes, live in more compact, multimodal neighborhoods, spend less time and money driving, and be better off overall as a result.

Conclusions

There are many reasons to reform current transportation policies. The last century was the period of automobile ascendency during which it made sense to invest significant resources to build roads and parking facilities, and in other ways accommodate increased motor vehicle travel. The next century requires very different policies. Demographic and economic trends are reducing vehicle travel demand increasing demand for alternative modes. Economic competitiveness will require more efficient transportation systems. To meet these needs, transport policies must place more emphasis on efficient management. No single strategy will suffice: a variety of integrated transport and land use policy reforms are needed to prepare for the future.

To facilitate these changes policy makers can establish mobility management objectives to reduce vehicle travel and increased use of alternative modes. Such objectives help coordinate individual planning decisions to create a more diverse and efficient transportation system.

Mobility management criticism tends to reflect an older planning paradigm which assumes that *transportation* means driving, and transport agencies have limited responsibilities and solutions. Critics tend to ignore many costs of automobile travel and many benefits of alternatives. The new paradigm applies *systems analysis* which considers a variety of objectives, impacts and options.

Critics argue that mobility management and smart growth harm consumers and the economy, but such criticisms are often inaccurate and do not apply to appropriate, integrated mobility management programs which reduce vehicle travel in ways that reflect efficient market principles (consumer options, cost-based pricing, neutral policies). Until efficient road, parking, insurance and fuel pricing are fully implemented, and planning practices are more neutral, blunter strategies (such as regulations and subsidies) may be justified to reduce economically excessive automobile travel.

Many VMT reduction critics actually support certain mobility management strategies, such as efficient road and parking pricing, more flexible zoning codes, and ridesharing incentives. Mobility management tends to be most effective if implemented as an integrated program, so some criticism are really justifications for additional strategies, such as investments to improve public transit in conjunction with road pricing. In a more diverse and efficient transportation system, consumers will choose to drive less, rely more on alternative modes, and be better off overall as a result. Automobile travel will not disappear, but it will decrease compared with current planning practices.

Mobility management policies help create a transportation system that meets future needs. VMT reduction targets are the first step in implementing such policies.

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