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

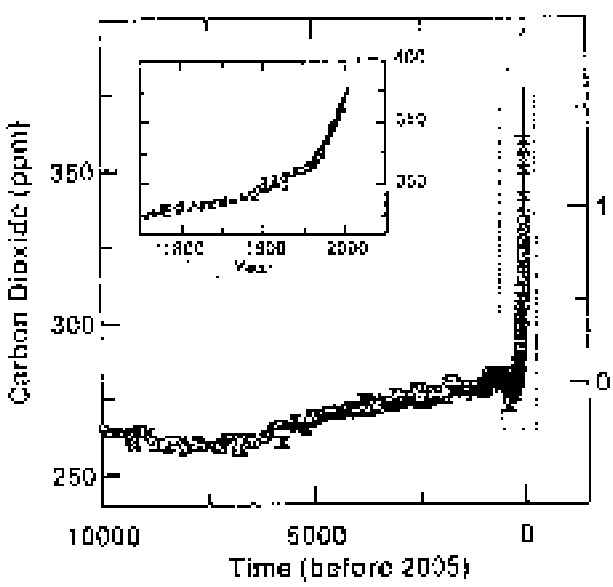
Chapter by chapter, this book addresses the impacts of the following:

- 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).[9]

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).[10] 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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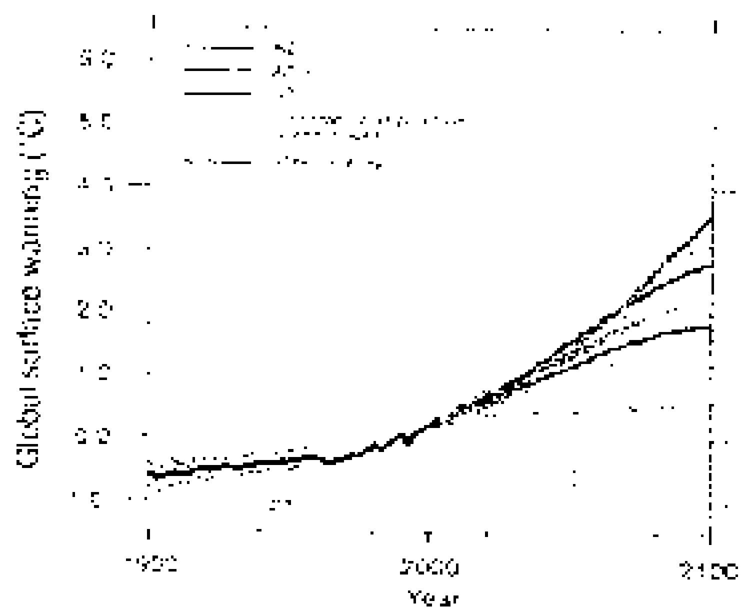
[9] Carbon dioxide equivalent (CO_2e) is an internationally accepted measure of the amount of global warming of greenhouse gases (GHGs) in terms of the amount of carbon dioxide (CO_2) that would have the same global warming potential.

[10] 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).

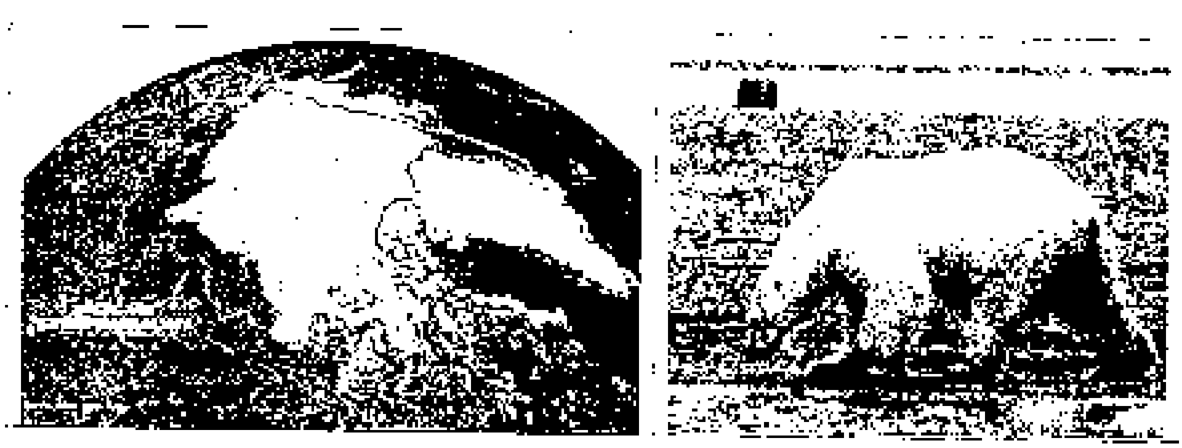
Figure 2-2 Global Average Surface Temperature Warming under Different Scenarios
Source: IPCC 2007a, p. 14.



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.

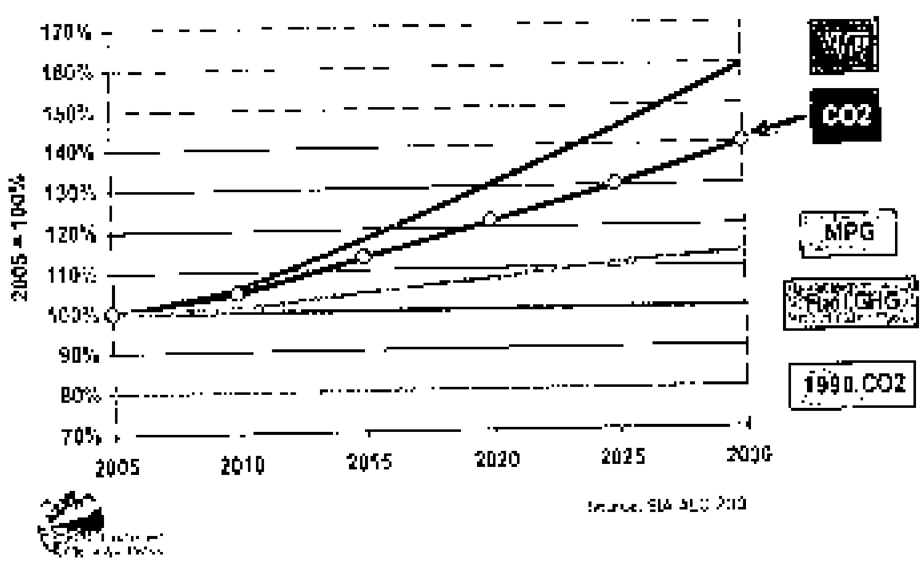
There is a popularly held expectation that electricity or hydrogen fuels will provide long-term solutions to energy security and transportation GHG concerns, essentially shifting transportation GHG emissions upstream to other sectors of the economy. Biofuels also could potentially play an important role, 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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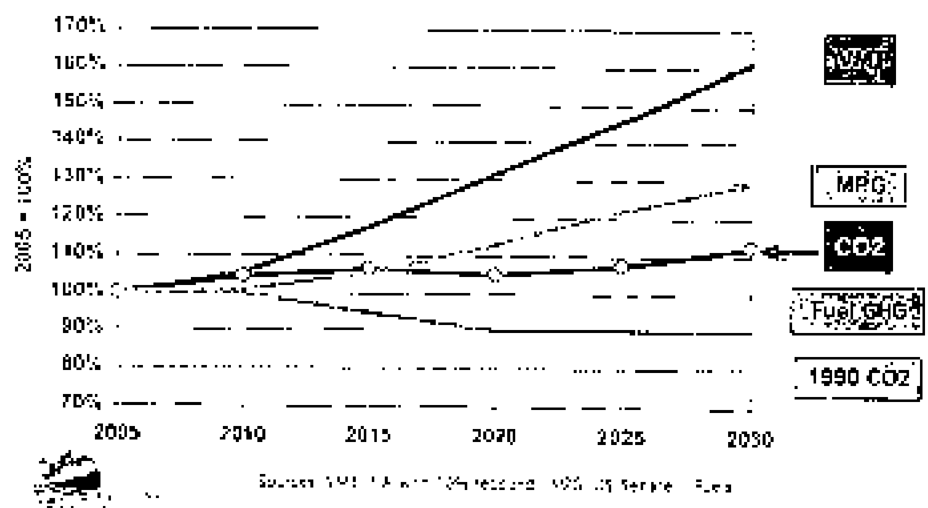
[14] 159% [vehicle miles traveled] / 1.133 [mpg] = 140% [CO_2] with constant fuel carbon content

[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's low carbon fuel standard of -10 percent in 2020, applied nationally. Assumes a ... percent reduction.

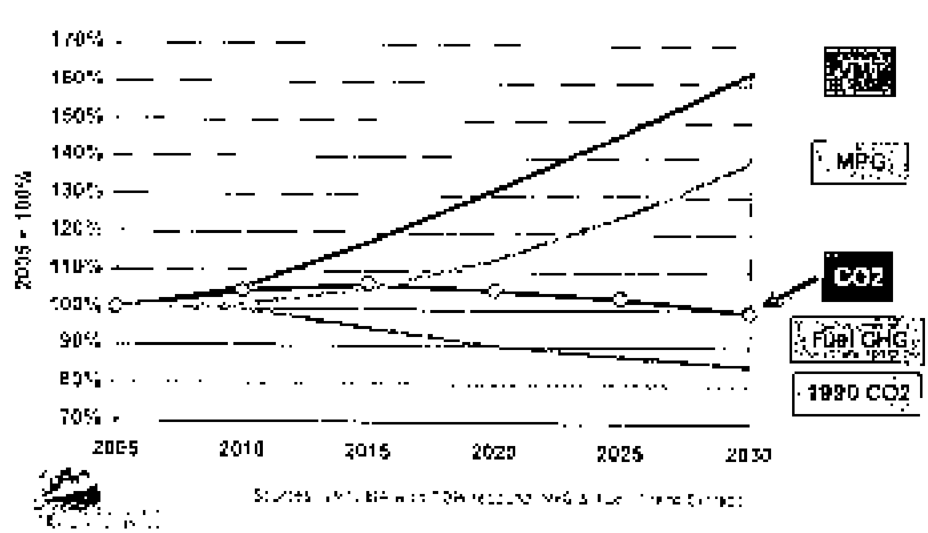


If the fuel economy and fuel carbon content trends represented in Figure 2-4 were extended through to 2030, so that new vehicle fuel economy would increase to 45 mpg and fuel carbon content would decrease to 15 percent below current levels, then 2030 CO_2 emissions would be reduced to 1 percent below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

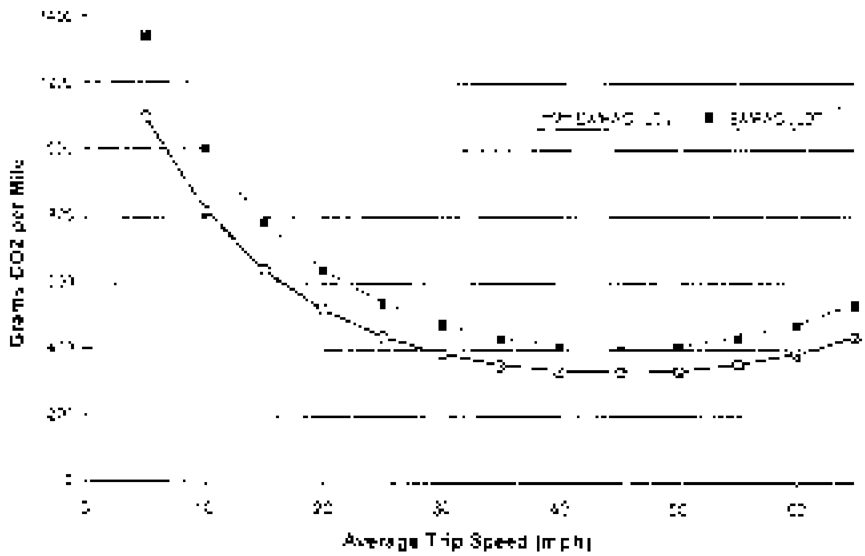
Still, any cold start penalty associated with compact development is likely to be small. From the EMFAC model, CO_2 emissions from *all* vehicle starts (cold, intermediate, and hot) account for just 3.3 percent of total annual passenger vehicle CO_2 emissions in California.[18] Moreover, while there 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.

[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 60°F and relative humidity of 60 percent.

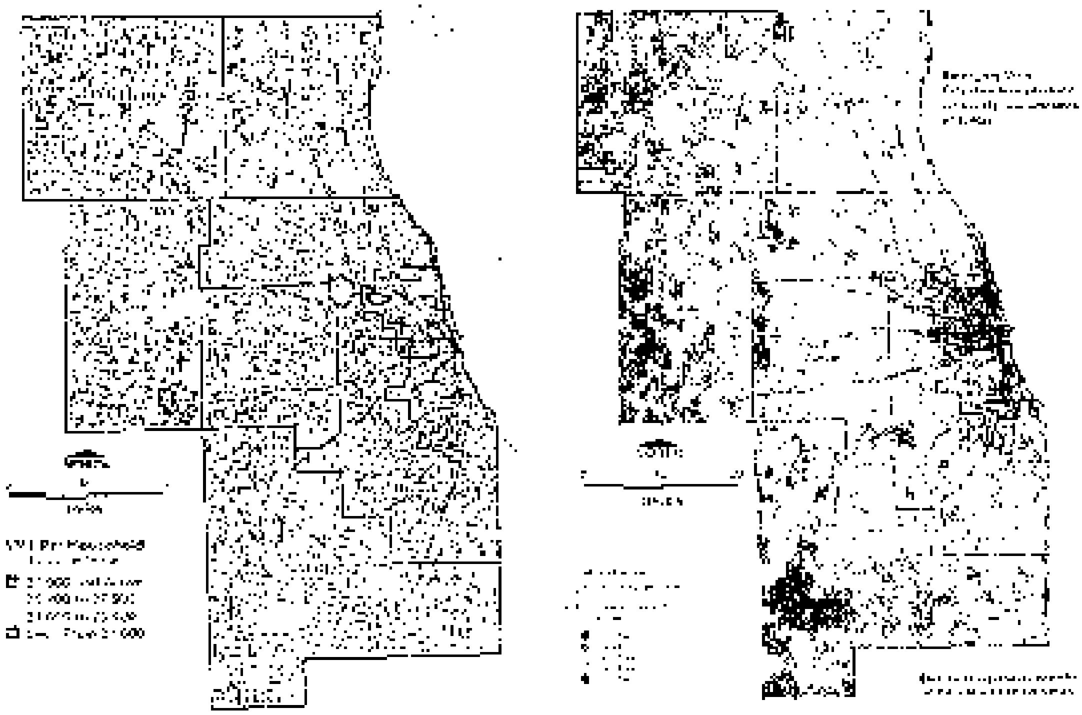
Can we therefore conclude that it would be most efficient to design cities and roadways to maximize vehicle operating efficiency? No, because the efficiency gained by designing roads for high average speeds would be negated by an increase in miles traveled. Development can and would become ever more 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).

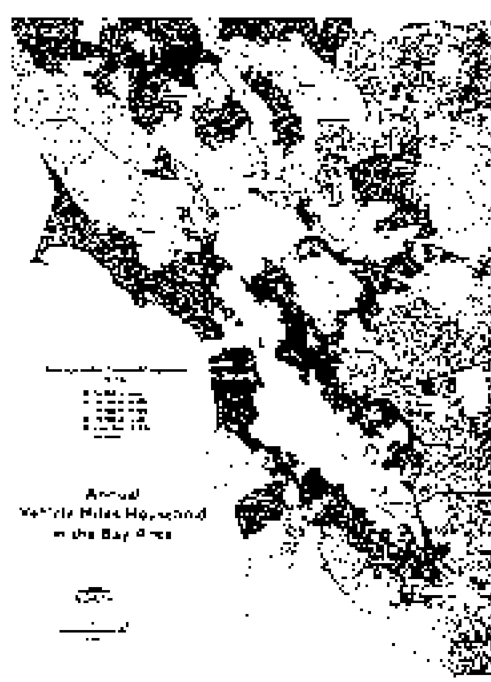


Figure 3-1 Vehicle Miles Traveled per Household for Neighborhoods in the San Francisco Metropolitan Area

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.

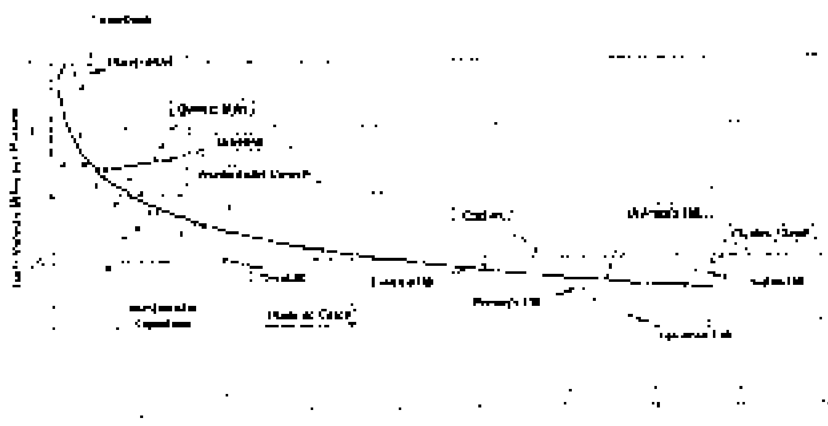
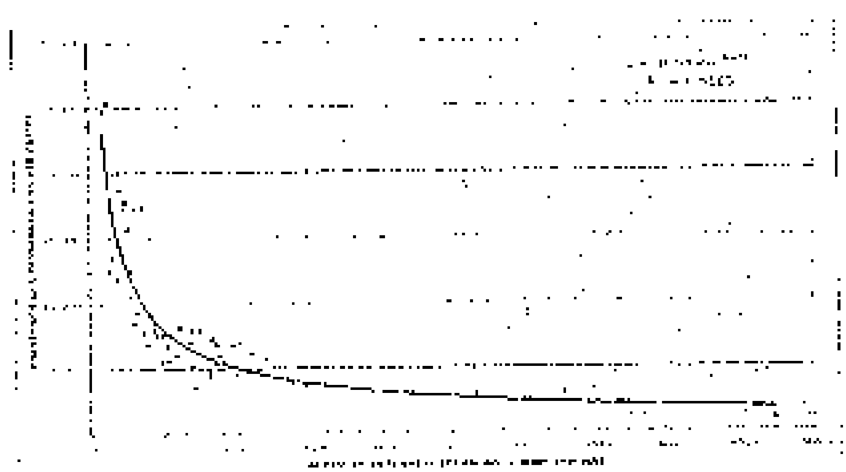


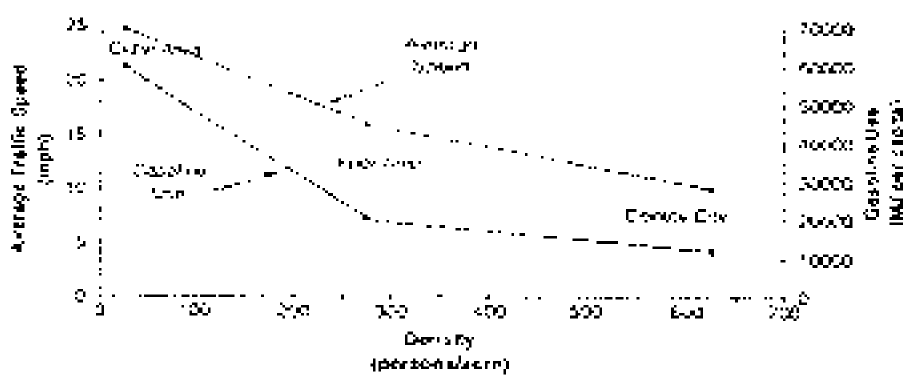
Figure 3-3 Vehicle Kilometers Traveled per Capita versus Activity Intensity for 58 Higher-Income Cities *Source: Newman and Kenworthy 2006.*



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.[13]

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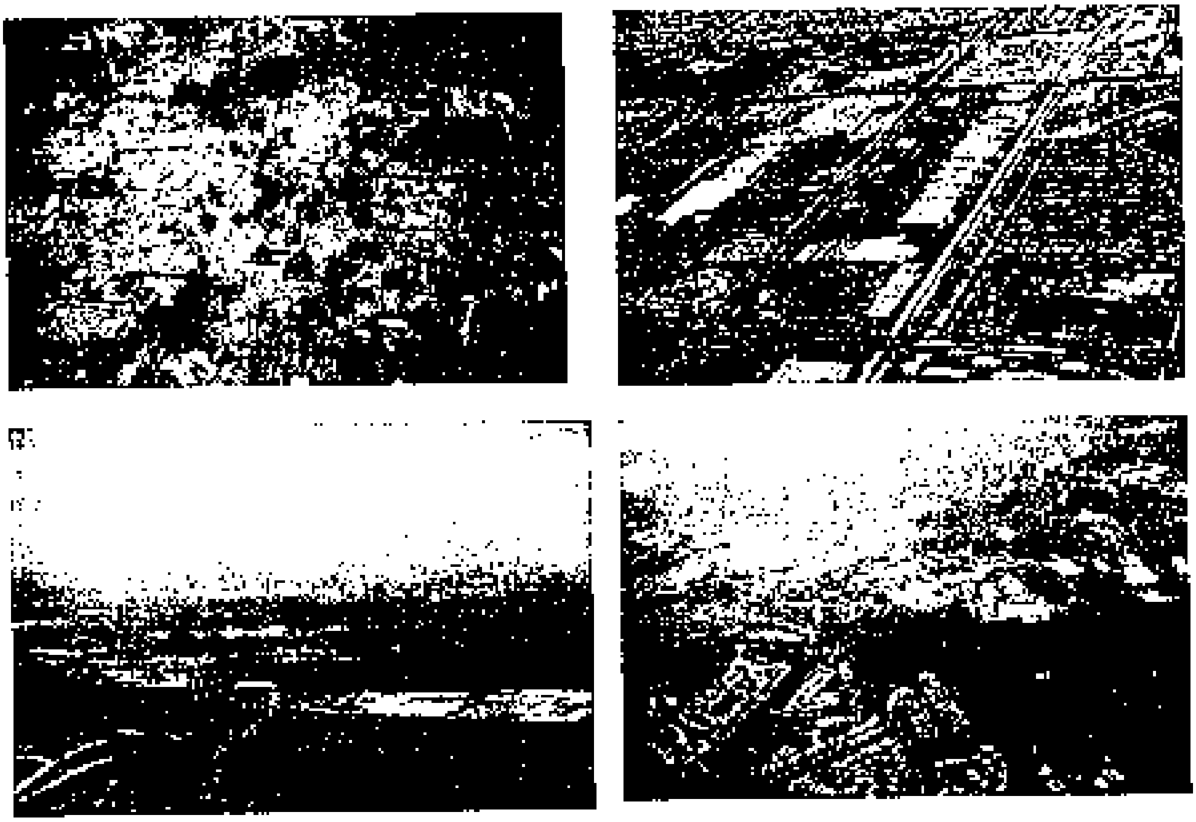
13 This is due to the so-called ecological fallacy. The ecological fallacy is a widely recognized error in the interpretation of statistical data, whereby inferences about individuals are based solely upon aggregate statistics for the group to which those individuals belong.

Sprawling development patterns include low-density and single-use development (top left), unscreened 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).

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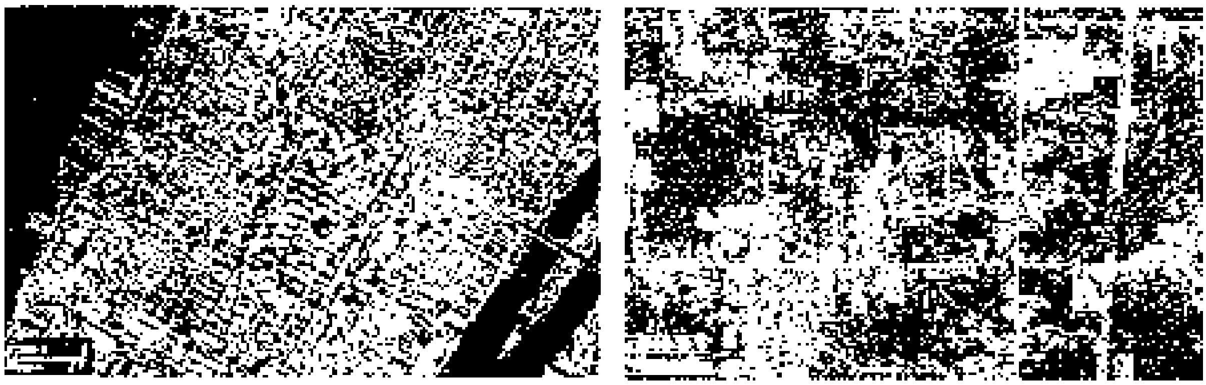
[21] "Residential density" was defined in terms of gross and net densities and proportions of the population living at different densities; seven variables made up the metropolitan density factor. "Land use mix" was defined in terms of the degree to which land uses are mixed and balanced within subareas 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.

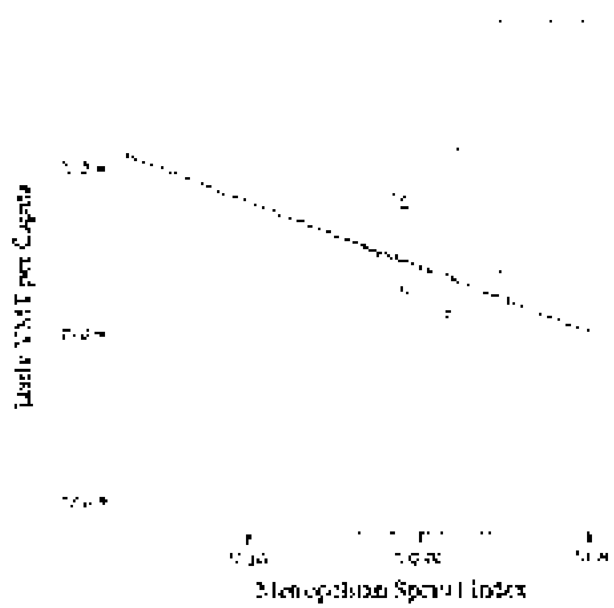
Obviously, these relationships are not independent of each other. The lower level of vehicle ownership in dense metropolitan areas contributes to higher mode shares for alternatives to the automobile. These, in turn, contribute to lower VMT, which contributes to lower traffic fatalities and ozone levels. 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 Work Trips*	*Walk Share of Work Trips*	*Mean Travel Time to Work*	*Annual Delay per Capita*	*VMT per Capita*	*Fatalities per 10,000 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.

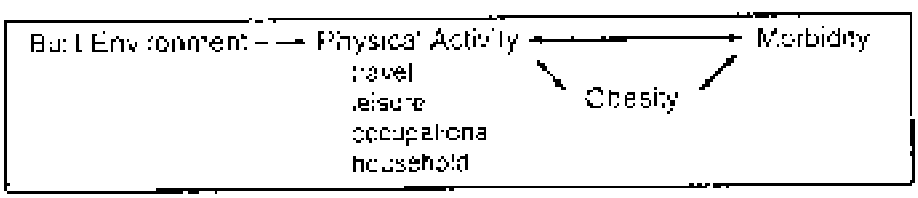
3.2 Disaggregate Travel Studies

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.

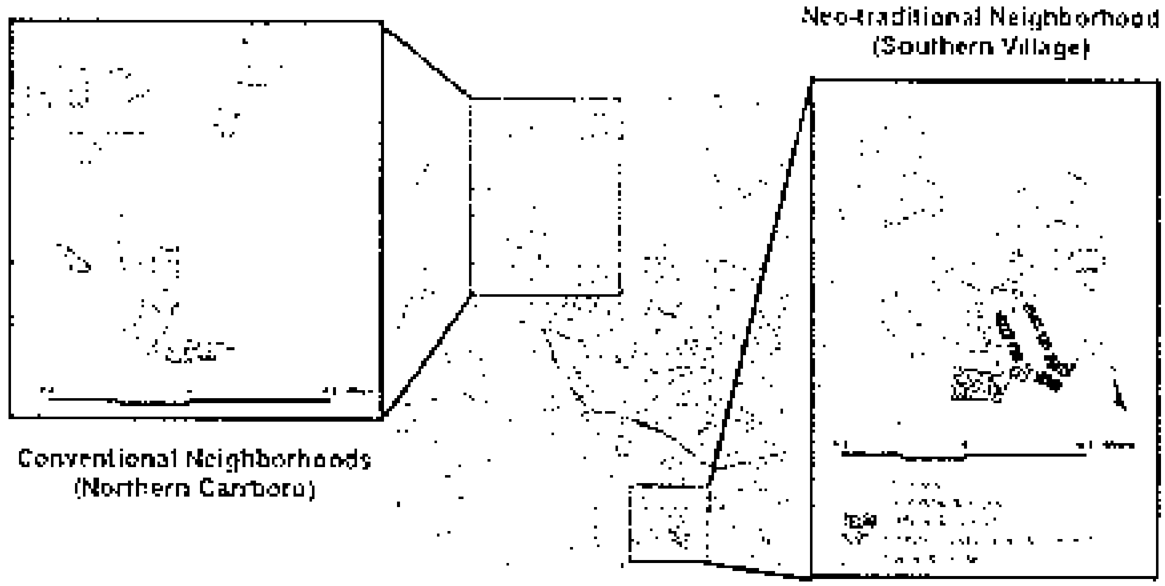
Figure 3-7 Causal Pathways Linking the Built Environment to Health
Source: Ewing et al. 2003.



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 Rodriguez 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.

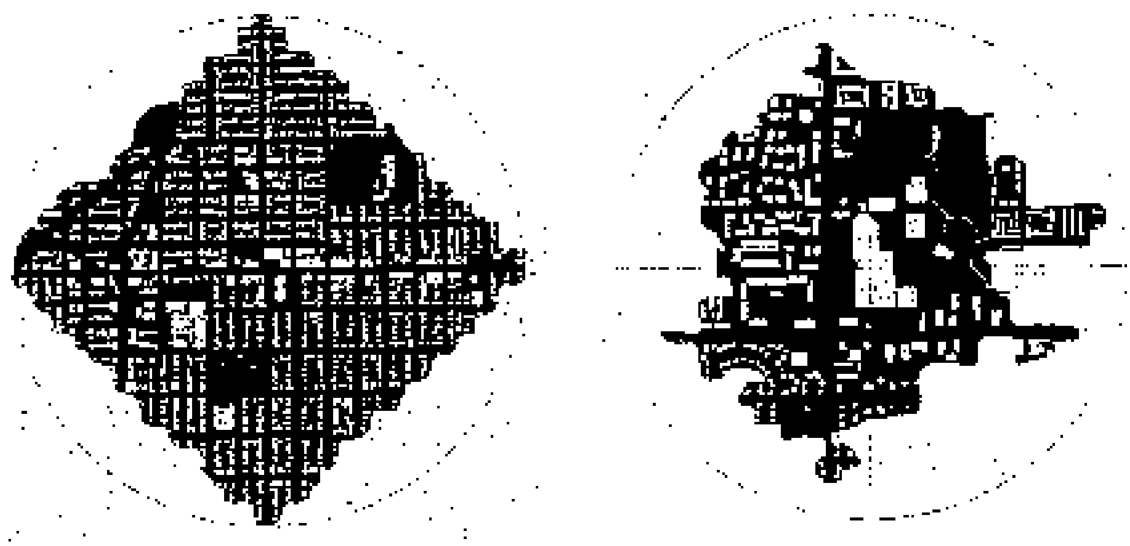
Trip chaining, or the linking of trips into tours, has been increasing over time (Levinson and Kumar 1995; McGuckin, Zmud, and Nakamoto 2005). Trips are more likely to be linked into long tours in areas of poor residential accessibility, simply because this is a way for households living in sprawl to 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.

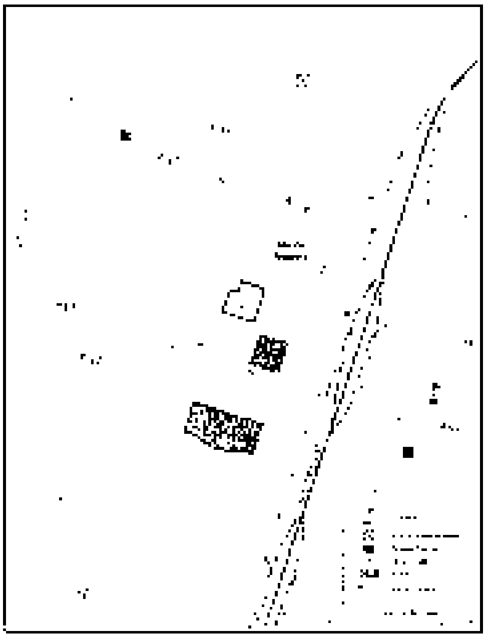


Figure 3-10 Built Environment and Mode Shares of Metro Square in Sacramento, California
Source: NRDC 2000.

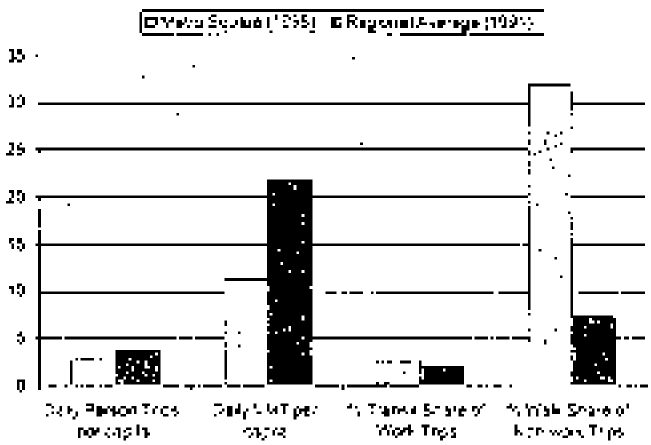
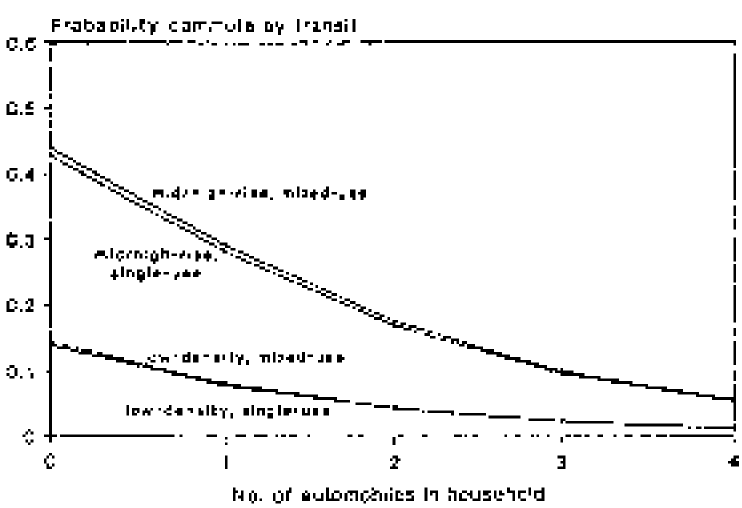


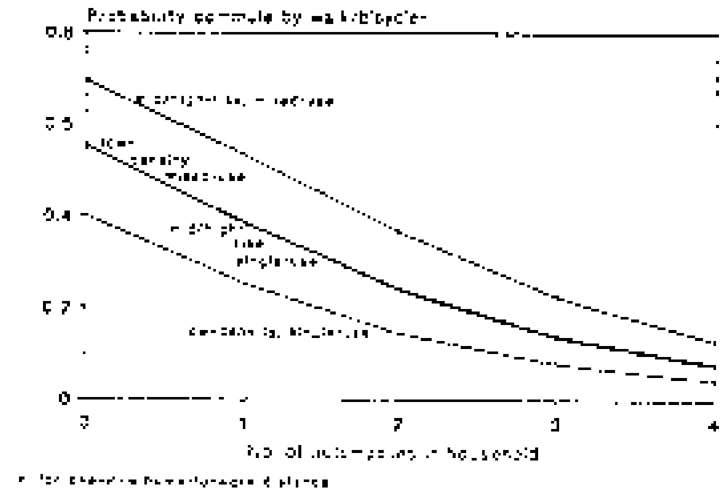
Figure 3-11 Effects of Density and Mixed Use on Choice of Transit for Commutes*
Source: Cervero 1996



*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 to neighborhoods was associated with several percentage point higher levels of transit commuting across 11 U.S. metropolitan areas.

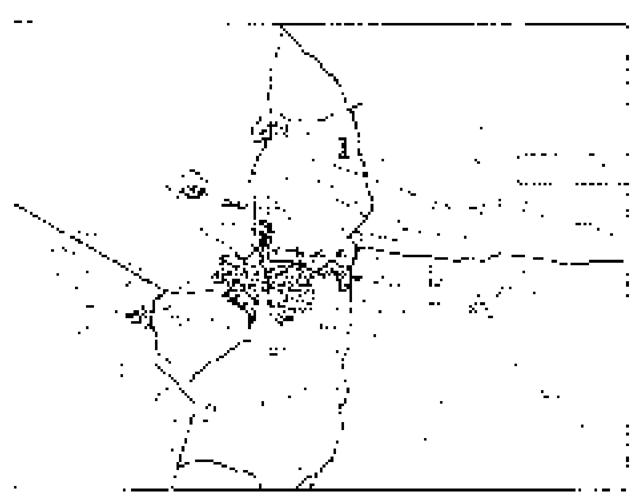
Figure 3-12 Effects of Density and Mixed Use on Choice of Walk/Bike for Commutes*
Source: Cervero 1996.

*Rates of walk and bicycle trips (for a 3-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).

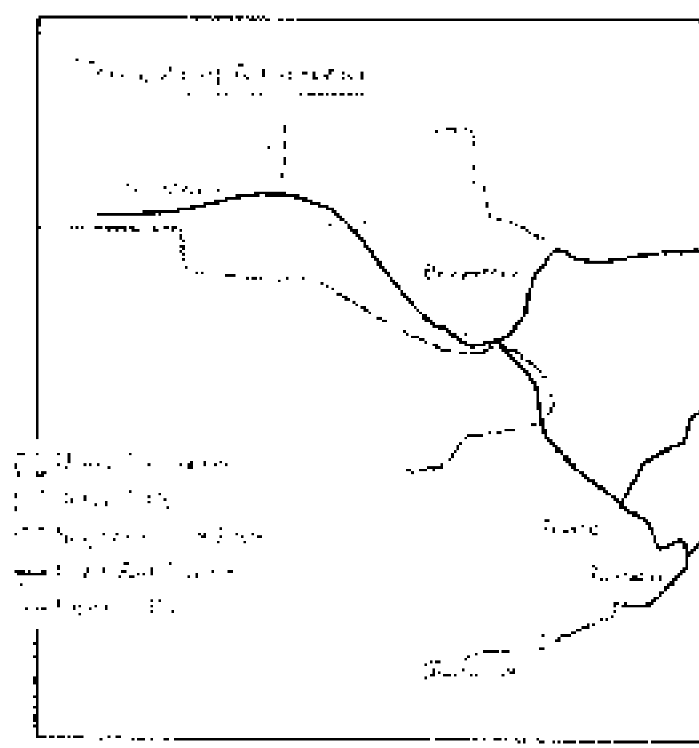
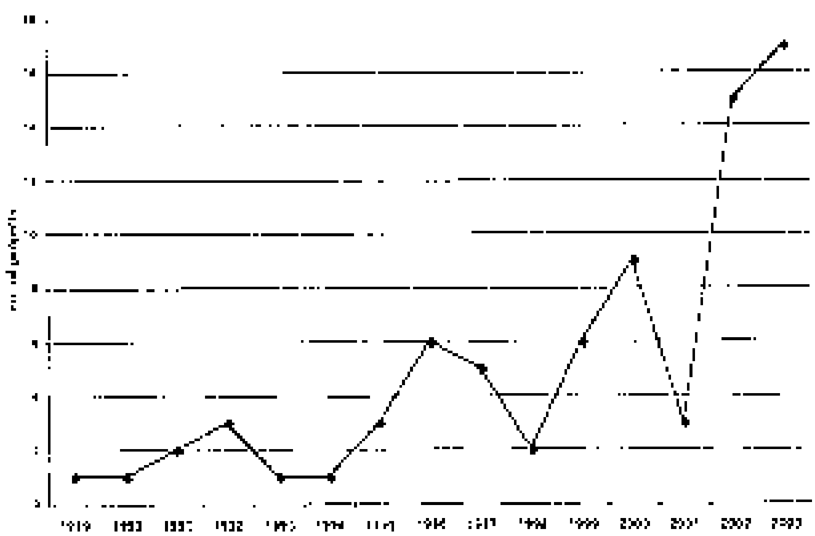


Figure 3-15 The LUTRAQ Plan for the Western Portland Metro
Source: 1000 Friends of Oregon 1997

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.

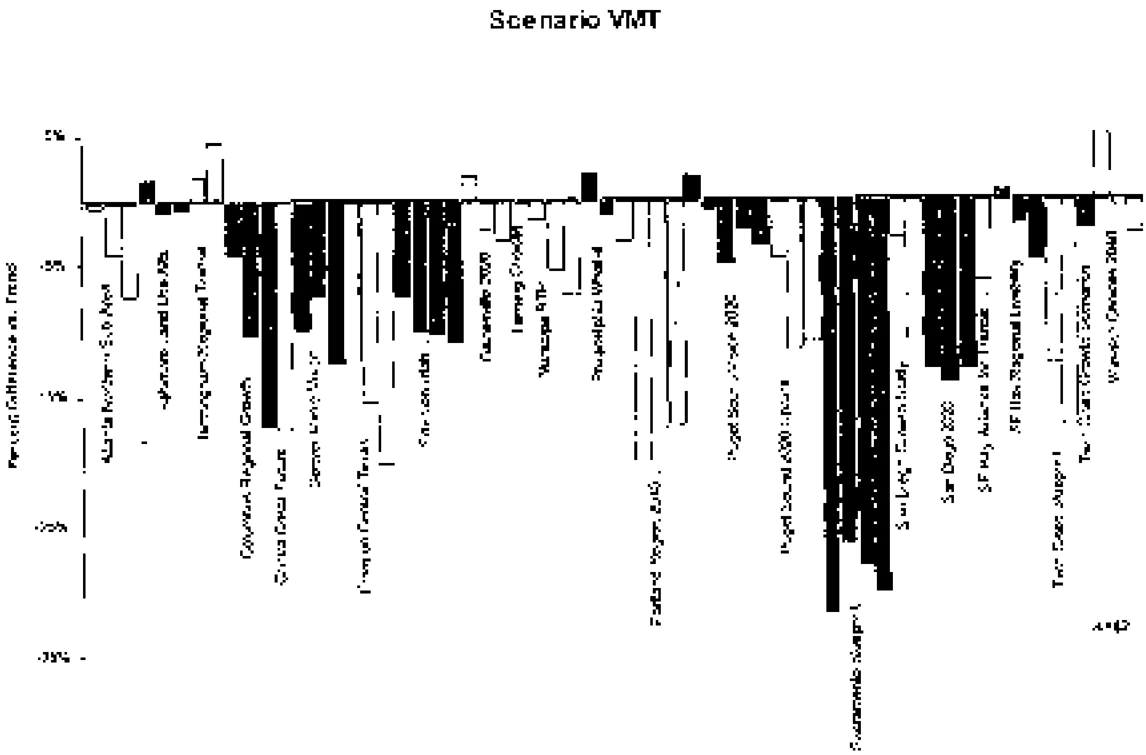
Why is there so much difference in VMT across scenarios? Bartholomew identifies many of the potential sources of variation that could be considered in a meta-analysis. These, with their presumed impact on VMT, include the following:

- 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.

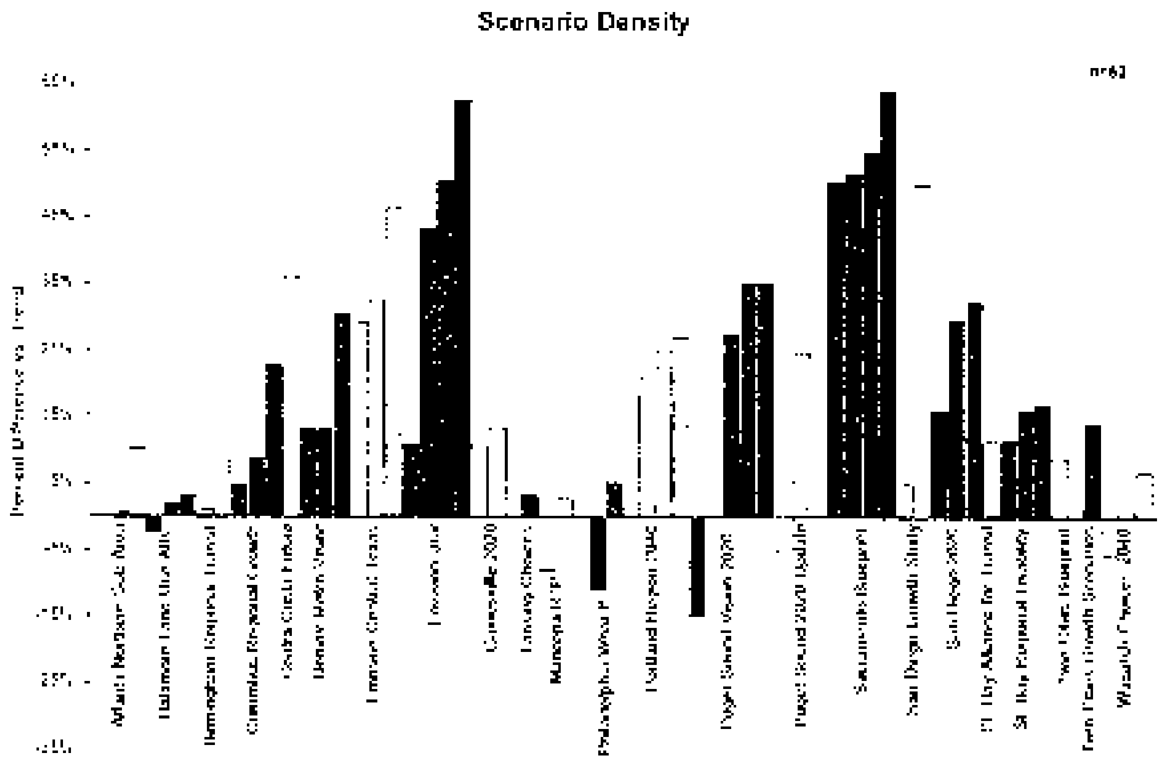
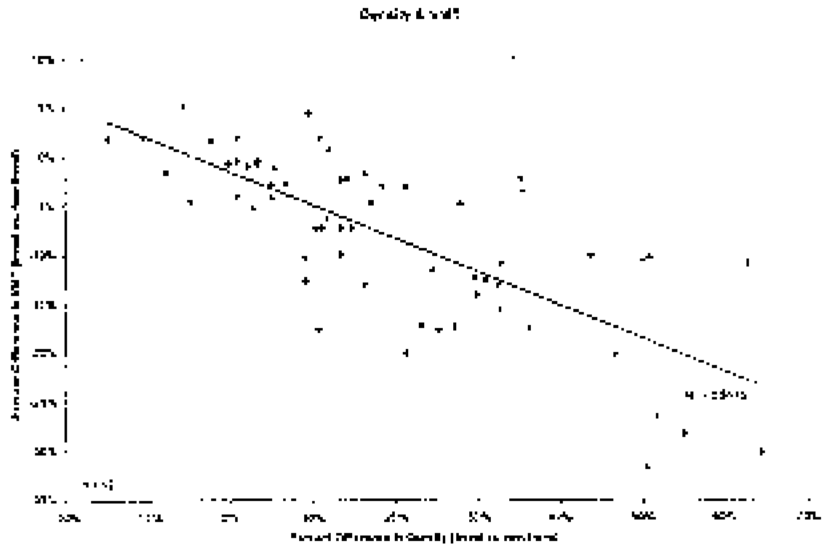
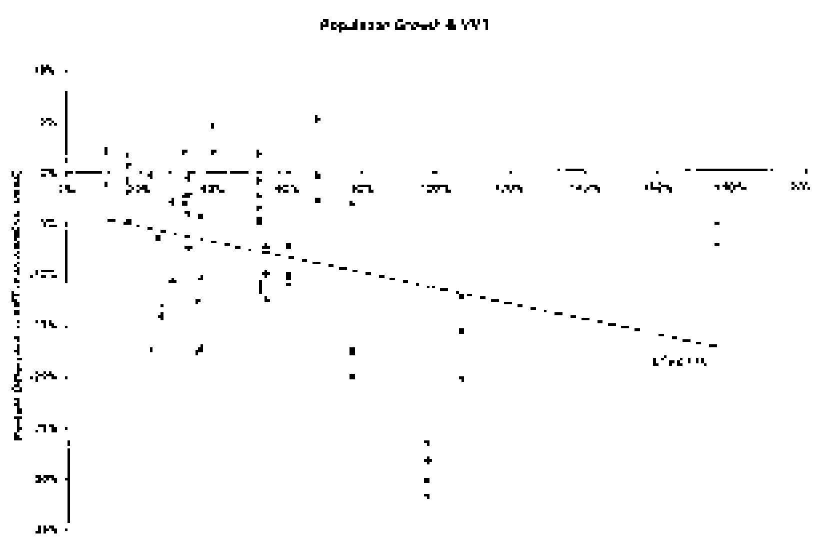


Figure 3-21 VMT versus Density for 62 Planning Scenarios Relative to the Trend
Source: Bartholomew 2005.



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]

[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	1.56	−2.13	0.037
Land uses mixed	−3.64	−2.15	0.036
Population growth increment (% over base)	−0.068	−2.02	0.059
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

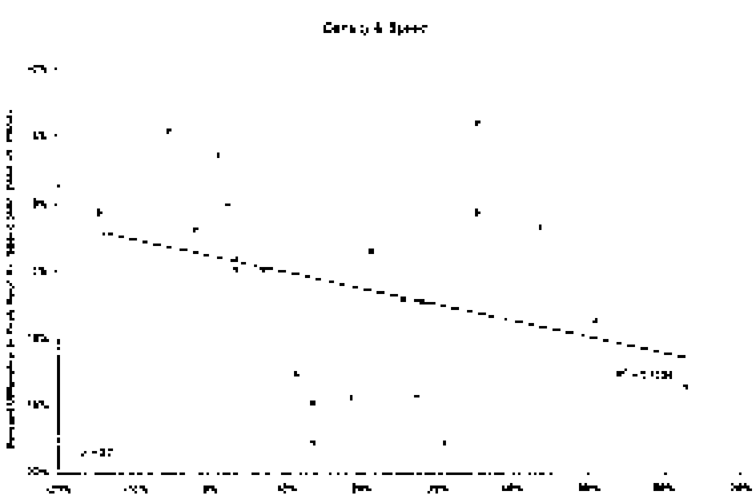


Figure 3-25. Percent Difference in NOx Emissions versus Percent Difference in Density for Planning Scenarios Relative to the Trend

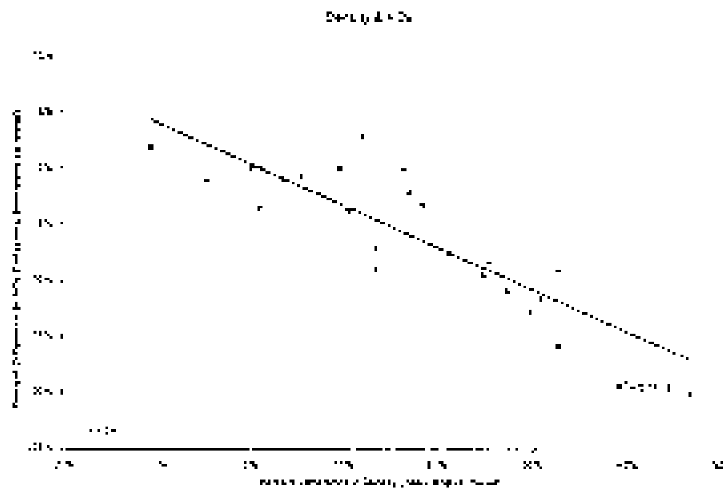
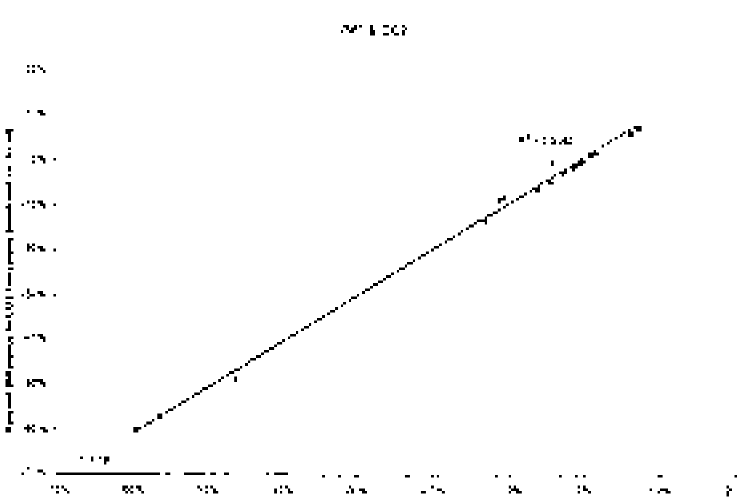


Figure 3-25 plots nitrogen oxide (NOx) emissions versus density differences for 24 planning scenarios. The scatter plot shows a strong association between the two variables. The strength of the association appears equivalent to that between VMT and density. Because most or all of these studies use vehicle 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.

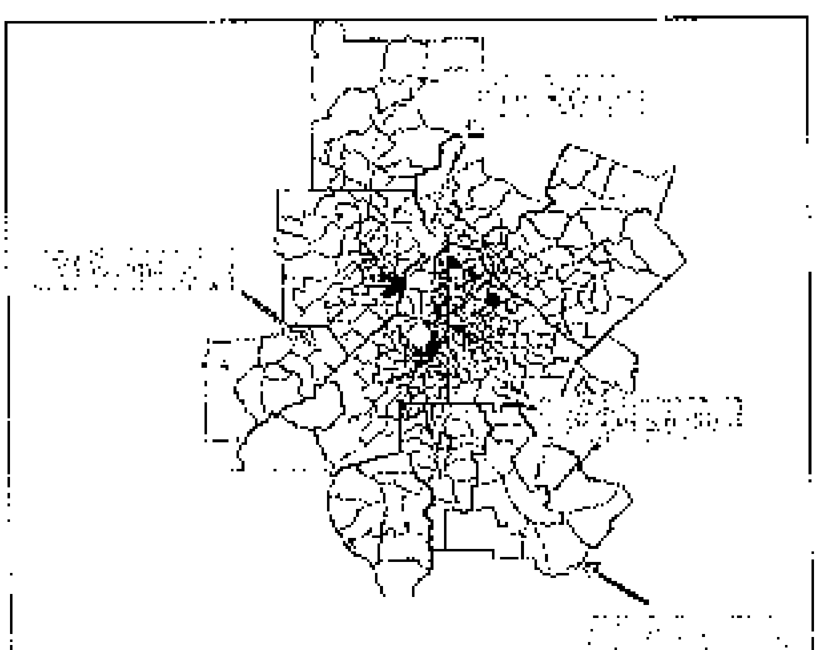
Under a program called Project XL (excellence and leadership), the EPA has the power to waive environmental regulations when a superior environmental outcome may be achieved by some otherwise prohibited action. Based on an analysis showing that redevelopment of the Atlantic Steel site would produce less 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.

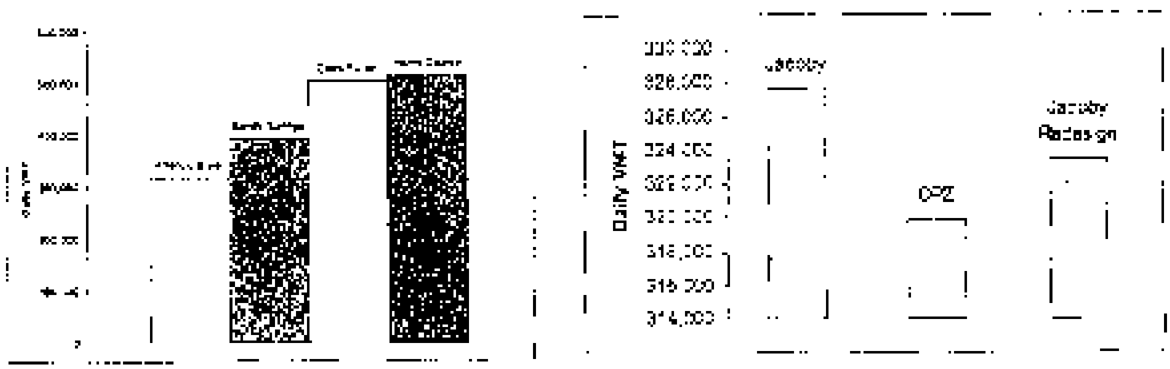
Jacoby's final site plan is a compromise between the two earlier plans. The land use mix is more fine-grained than the original plan's but not as fine-grained as the DPZ redesign. The street network is more fine-meshed than the original plan's but less so than the redesign. Other concepts from the DPZ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

Alternative site plans evaluated
Based on EPA (1999)

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).

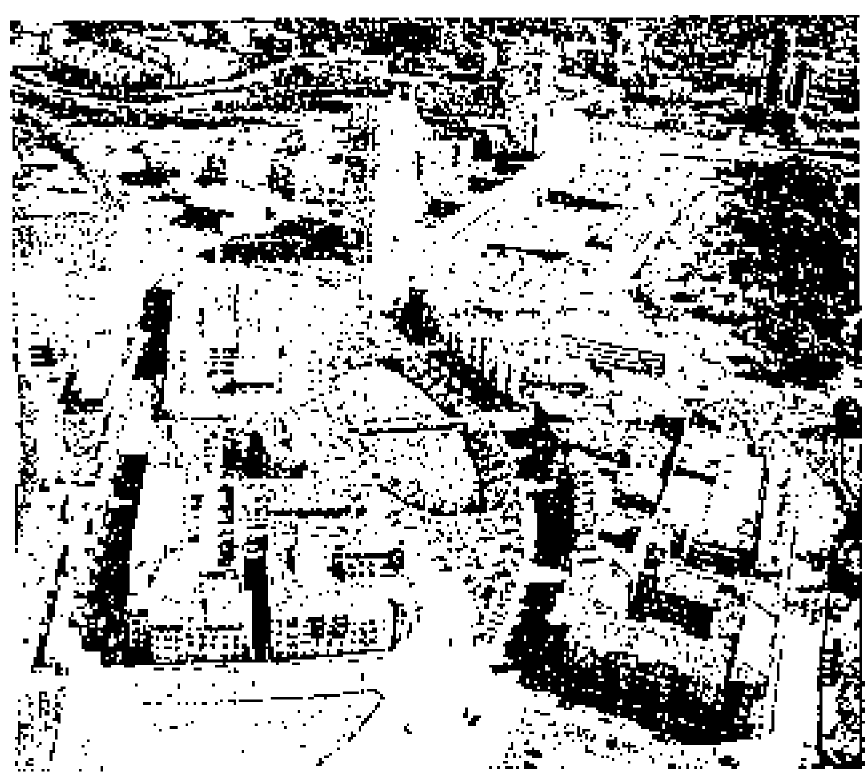
Model results demonstrated that VMT and emissions would be about 30 percent lower at the Atlantic Steel infill site than at the remote greenfield locations, and an additional 5 percent lower with the revised site plan (see Figure 3-28). As a result, for the first time, the EPA designated a land development 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.

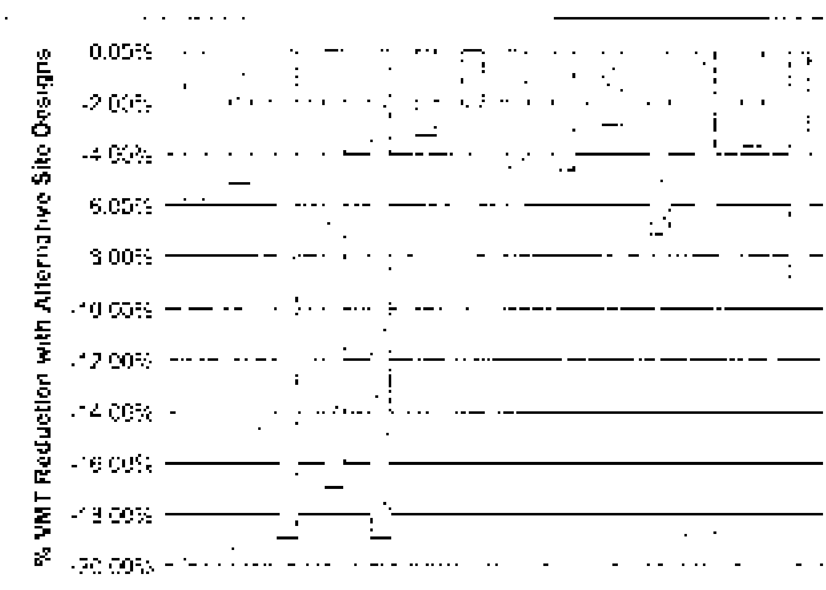
Source: Jacoby Development Company



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

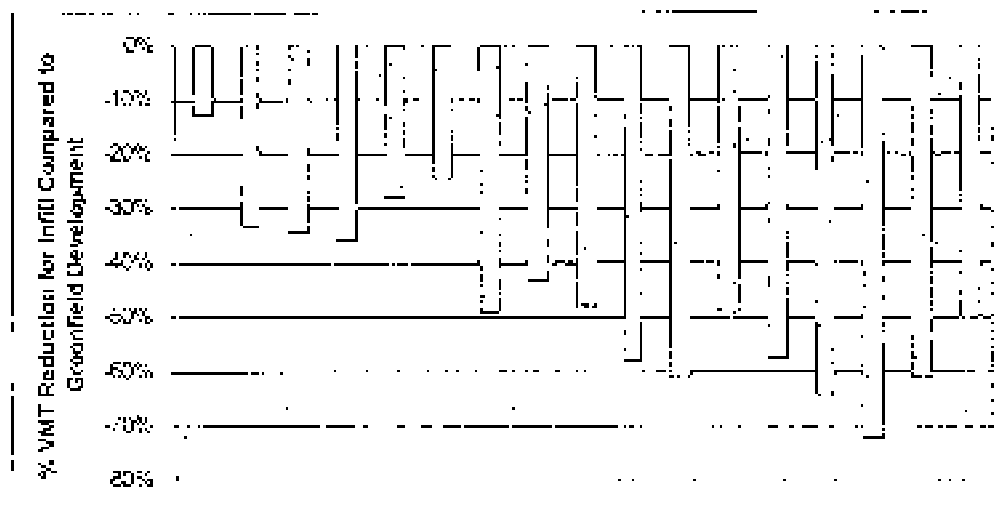


Results suggest that VMT and CO_2 per capita decline as site density increases and the mix of jobs, housing, and retail uses becomes more balanced. However, the limited number of studies, differences in assumptions and methodologies from study to study, and the variability of results make it difficult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

3.4.3 Regional Location Influences on VMT

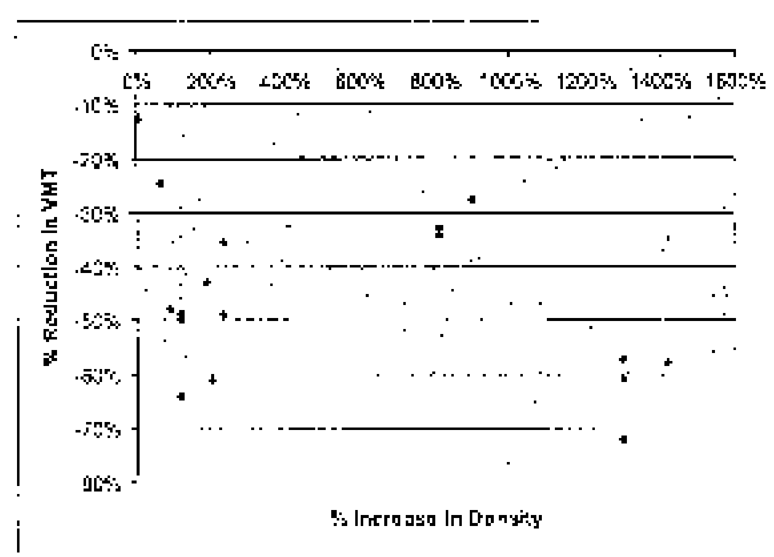
Approximately ten studies have considered the effects of regional location on travel and emissions generated by individual developments (EPA 1999, 2001a, 2001b, 2006, Hagler Bailly 1998, Hagler Bailly and Criterion Planners/Engineers 1999; IBI Group 2000; Allen and Benfield 2003; U.S. Conference of Mayors 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 [illegible] 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

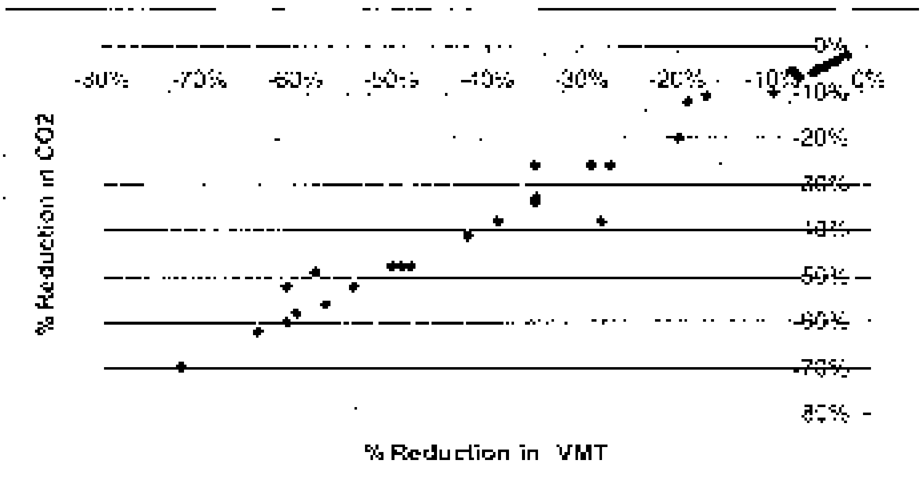


The data from project-level simulations are too limited to conduct a true meta-analysis of the variance in VMT per capita. However, the data clearly suggest that development that combines an infill location with higher density and good urban design can produce dramatic VMT reductions compared to typical 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 0.90. 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, 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.

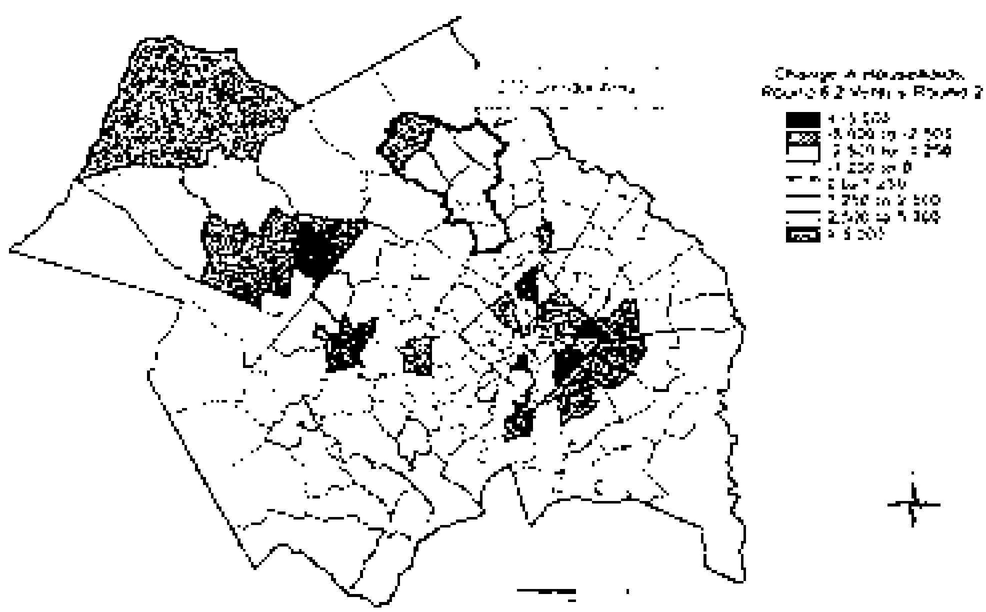
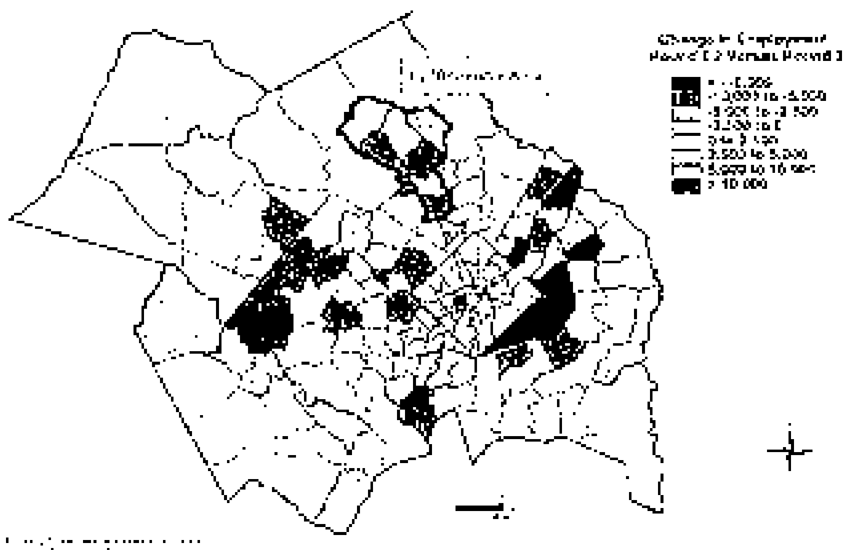


Figure 5-2 Difference between Actual and Forecasted Employment by Subarea (2000)
Source: NCRTPB/MWCOG 2001.



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).

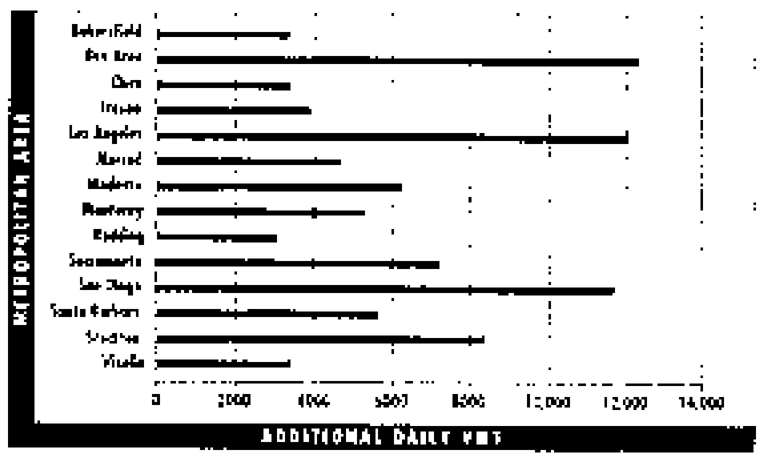


Figure 5-4 Estimated Additional VMT from an Additional Lane-Mile, California *Metropolitan Areas Source: Hansen and Huang 1997*

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.

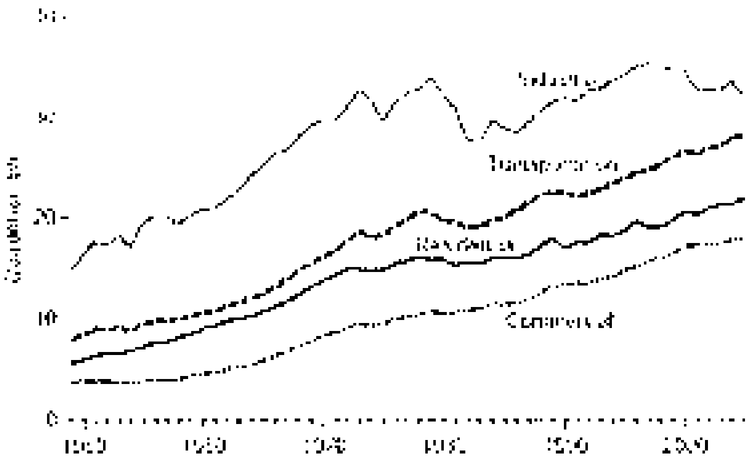
5.5 What Is Known about Induced Development

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.

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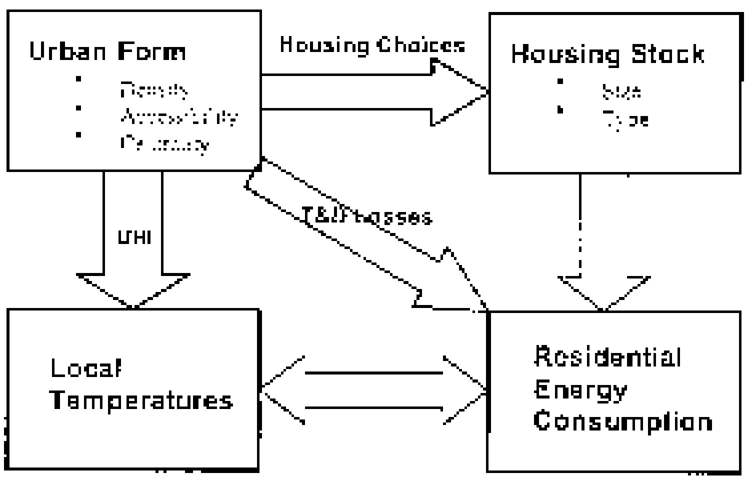
[27] Primary energy is energy contained in raw fuels, which is transformed in energy conversion processes to more convenient forms of energy, such as electrical energy and cleaner fuels. In energy statistics, these more convenient forms are called secondary energy.

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/d06572.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[11] 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.

[11] 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).

[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 2003 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, [illegible]

[36] For example, see California Market Advisory Committee, [illegible]

[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.