TRANSPORTATION RESEARCH BOARD

TRB REPORT IN BRIEF

August 2009

Driving and the Built Environment

The Effects of Compact Development on Motorized Travel, Energy Use, and CO_2 Emissions

Suburbanization is a long-standing trend reflecting the preference of many Americans for living in detached single-family homes and made possible through the mobility provided by the automobile and an extensive highway network. Yet these dispersed, automobile-dependent development patterns have come at a cost, consuming vast quantities of undeveloped land; increasing the nation's dependence on imported petroleum; and increasing greenhouse gas emissions that contribute to global warming.

STUDY CHARGE AND OVERVIEW

Requested by Congress and funded by the U.S. Department of Energy, *Special Report 298: Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and CO_2 Emissions* examines the relationship between land development patterns, often referred to as the built environment, and motor vehicle travel in the United States. The study, which was conducted jointly by the Transportation Research Board and by the Board on Energy and Environmental Systems of the Division on Engineering and Physical Sciences, assesses whether petroleum use, and by extension carbon dioxide (CO_2) emissions, could be reduced by more compact, mixed-use development, the term used in the report to describe development at higher densities with mixing of land uses. The committee that produced the report estimated that the reduction in vehicle miles traveled (VMT), energy use, and CO_2 emissions resulting from more compact, mixed-use development would be in the range of less than 1 percent to 11 percent by 2050, although committee members disagreed about whether the changes in development patterns and public policies necessary to achieve the high end of these estimates are plausible.

FINDINGS

More compact development patterns are likely to reduce VMT.

Both logic and empirical evidence suggest that developing at higher population and employment densities results in trip origins and destinations that are closer to each other, on average, and thus in shorter trip lengths, on average. Theory suggests that reduced trip lengths can increase trip frequencies, but empirical evidence suggests that the increase is not enough to offset the reduction in VMT that comes from reduced trip length alone. Shorter trips also may reduce VMT by making walking and bicycling more competitive alternatives to the automobile, while higher densities make it easier to support public transit. Mixing land uses to bring housing closer to jobs and shopping can reduce trip lengths as well.

The effects of compact, mixed-use development on VMT can be enhanced when it is combined with other policy measures that make alternatives to driving relatively more convenient and affordable. Examples include a street network that provides good connectivity between locations and accommodates nonvehicular travel, well-located transit stops, and good neighborhood design. Demand management

Impetus for Study

The vast majority of the U.S. population, some 80 percent, now live in metropolitan areas, but population and employment continue to decentralize within regions, and density levels continue to decline at the urban fringe.

The adverse effects of suburbanization and automobile dependence have long been evident but are currently of particular concern for several reasons. First, after decades of low energy prices, the cost of oil rose to record highs in 2008, reflecting the growth of China and India and the instability of many key suppliers in the Middle East and other oil-producing areas, and underscoring U.S. dependence on imported fuels. The transportation sector as a whole accounts for more than 28 percent of annual U.S. energy consumption. Cars and light trucks, most of which are used for personal transportation, represent about 17 percent of that total, and this share has been rising. Second, concern about climate change continues to grow both domestically and internationally, and transportation is a major and increasing contributor to that problem. Gasoline consumption, largely by personal vehicles, accounts for about 20 percent of annual U.S. CO_2 emissions.

At the same time, changing demographics—an aging population, continued immigration—and the possibility of sustained higher energy prices could lead to more opportunities for the kinds of development patterns that could reduce vehicular travel, thereby saving energy and reducing CO_2 emissions.

A key question of interest is to what extent developing more compactly would reduce VMT and make alternative modes of travel (e.g., transit, walking) more feasible. The study is focused on metropolitan areas and on personal travel, the primary vectors through which policy changes that encourage more compact development should have the greatest effect.

measures, such as reducing the supply and increasing the cost of parking, can also complement efforts to reduce VMT.

The most reliable studies estimate that doubling residential density across a metropolitan area might lower household VMT by 5 to 12 percent, and perhaps by as much as 25 percent, if coupled with higher employment concentrations, significant public transit improvements, mixed uses, and other supportive demand management measures.

Most of the studies reviewed by the committee are subject to a number of shortcomings. For example, many fail to distinguish among different types of density changes (e.g., decreasing lot size versus increasing multifamily housing) or the location of these changes in a region. Relatively few attempt to account for self-selection—the tendency of people to locate in areas consistent with their housing and travel preferences. Finally, most studies are cross-sectional, that is, they find an association between higher density and lower VMT at a single point in time but cannot be used to infer cause and effect.

More compact, mixed-use development can produce reductions in energy consumption and CO_2 emissions both directly and indirectly.

To the extent that more compact development reduces VMT, it will directly reduce fuel use and CO_2 emissions. The VMT savings will be slow to develop, however, if only because the existing building stock is highly durable; therefore, opportunities to build more compactly are limited largely to new housing as it is built to accommodate a growing population and to replace the small percentage of existing units that are scrapped each year. Additional indirect savings in energy consumption and CO_2 emissions from more compact, mixed-use development can accrue from higher ownership of smaller, more fuel-efficient vehicles; longer vehicle lifetimes due to driving less; smaller homes and more multifamily units, which are more energy efficient than the average single-family dwelling unit; and more efficient urban truck travel and delivery patterns. To the extent that higher energy prices or other public policies and regulations increase vehicle fuel efficiency or the energy efficiency of residential heating and cooling, however, the savings in energy use and CO_2 emissions from developing more compactly will be reduced, all else being equal.

Significant increases in more compact, mixed-use development result in only modest short-term reductions in energy consumption and CO_2 emissions, but these reductions will grow over time.

The committee developed illustrative scenarios on the basis of housing forecasts prepared especially for the study and estimates of VMT reduction from the literature to quantify the potential effects of developing more compactly, looking forward to 2030 and to 2050. The scenarios assume that compact development is focused on new and replacement housing because of the difficulty of converting any significant fraction of existing housing to higher densities. As many as 57 million new housing units will be needed to accommodate population growth and as replacement housing by 2030, growing to between 62 million and 105 million units by 2050—a substantial net addition to the housing stock of 105.2 million in 2000. In the scenarios, developing more compactly is defined as doubling the current density of new residential development, mainly

at the urban fringe where most new development is taking place, but also through some strategic infill. The results depend importantly on assumptions about what percentage of new housing developments will be built compactly and how much less residents of these new, more compact developments will drive. The base case assumes continued low-density development, and all scenarios project that household VMT remains constant, an assumption tested in sensitivity analyses.

In an upper-bound scenario that represents a significant departure from current conditions, the committee estimates that, if 75 percent of new and replacement housing units are steered into more compact development and residents of compact communities drive 25 percent less, VMT and associated fuel use and CO_2 emissions of new and existing households would be reduced by 7 to 8 percent relative to base case conditions by 2030, with the reduction widening to between 8 and 11 percent by 2050.

A more moderate scenario, which assumes that 25 percent of new and replacement housing units will be built in more compact development and that residents of those developments will drive 12 percent less, would result in reductions in fuel use and CO_2 emissions of about 1 percent relative to base case conditions in 2030, growing to between 1.3 and 1.7 percent below the base case in 2050. If the residents of compact developments drive only 5 percent less—the lower bound of available estimates—the savings in fuel use and CO_2 emissions would be less than 1 percent compared with the base case, even in 2050.

The committee disagreed about the feasibility of achieving the target density in the upper-bound scenario—doubling the density of 75 percent of new development—even by 2050. Those members who believe it possible question whether densities will continue to decline. In their judgment, macroeconomic trends—likely higher energy prices and carbon taxes—in combination with growing public support for strategic infill, investments in transit, and higher densities along rail corridors could result in considerably higher densities by 2050. Other members believe that the curbing of large-lot development at the urban fringe and the substantial infill entailed in the upper-bound scenario require such a significant departure from current housing trends, land use policies of jurisdictions on the urban fringe, and public preferences that those measures are unrealistic absent a strong state or regional role in growth management.

Promoting more compact, mixed-use development on a large scale will require overcoming numerous obstacles.

Local zoning regulations—particularly suburban zoning that restricts density levels and the mixing of land uses—represent one of the most significant barriers to more compact development. Highly regulated land use markets also limit the supply of compact developments, despite evidence of increased interest in such communities. Land use control is, and has remained, largely a local government function and thus sensitive to legitimate local concerns (e.g., about congestion, local taxes, or home values), which are sometimes at odds with other regional or national concerns, such as housing affordability or climate change. Thus, land use policies aimed at achieving sweeping changes in current development patterns are likely to be impeded by political resistance from existing homeowners and local governments that reflect their interests, which may help explain why metropolitanwide or state policies aimed at controlling land use and steering development and infrastructure investments are not widespread.

In the near term, the biggest opportunities for more compact, mixed-use development are likely to lie in new housing construction and replacement units in areas already experiencing density increases, such as the inner suburbs and developments near transit stops and along major highway corridors or interchanges. Coordinated public infrastructure investments and development incentives can be used to encourage more compact development in these locations, and zoning regulations can be relaxed to steer this development to areas that can support transit and nonmotorized travel modes. Market-based strategies, such as congestion pricing and market-based parking fees, along with zoning requirements for maximum rather than minimum parking, can complement higher-density development patterns that encourage transit use and pedestrian travel.

In the longer term, if housing preferences and travel patterns change and compact, mixed-use developments become more commonplace, a greater political consensus may emerge in support of stronger state and regional measures to control land use. Policy instruments might include setting urban growth or greenbelt boundaries to steer growth to areas already developed.

Changes in development patterns entail other benefits and costs that have not been quantified in this study.

On the benefit side, more compact, mixed-use development should reduce some infrastructure costs, increase the feasibility and cost-effectiveness of public transit, and expand housing choices where compact developments are undersupplied. Other benefits include less conversion of agricultural and other environmentally fragile areas and greater opportunities for physical activity by facilitating the use of nonmotorized modes of travel, such as walking and bicycling.

On the cost side, the savings in highway infrastructure will be offset, at least in part, by increased expenditures for public transit, particularly rail transit, to support high-density development. Moreover, many Americans appear to prefer detached single-family homes in low-density suburbs that are often associated with more privacy, greater access to open space and recreation, and less noise than characterize many urban neighborhoods. Of course, housing preferences may change in the future with changes in the demographic and socioeconomic characteristics of the population.

RECOMMENDATIONS

Policies that support more compact, mixed-use development and reinforce its ability to reduce VMT, energy use, and CO_2 emissions should be encouraged.

The committee recognizes that it does not have as much verifiable scientific evidence to support this recommendation as it would like. The committee's own scenarios suggest that the compact, mixed-use development will generate only modest reductions in energy use and carbon emissions in the near term. Moreover, the committee has not examined the other benefits and costs of compact, mixed-use development. Nevertheless, climate change is a problem likely to be more easily dealt with sooner rather than later, and more energy-efficient patterns may have to be part of the strategy if the nation sets ambitious goals to move toward greater energy efficiency and reduced production of greenhouse gases. Compact development also may, if implemented carefully, reduce housing costs while increasing housing choices. Given that the full energy and emissions benefits of land use changes take decades to realize and current development patterns take years to reverse, it is important to start implementing these policies soon. In view of the uncertainties, however, it would be wise to proceed carefully, monitoring the results and improving the understanding of the benefits and costs of different compact, mixed-use development policies.

More carefully designed studies of the effects of land use patterns and the form and location of more compact, mixed-use development on VMT, energy use, and CO_2 emissions are needed to implement compact development more effectively.

In particular, the committee identified five areas in which more research would be productive: (*a*) federally funded longitudinal studies based on panel data to help isolate the effects of different types of development patterns on travel behavior; (*b*) studies of changes in metropolitan areas at finer levels of spatial detail to help inform the needs and opportunities for policy intervention; (*c*) careful before-and-after studies of policy interventions to promote more compact, mixed-used development to help determine what works and what does not; (*d*) studies of threshold population and employment densities to support rail and bus transit and walking and bicycling, which would update old references and help guide infrastructure investments as well as zoning and land use plans; and (*e*) studies of changing housing preferences and travel patterns of an aging population, new immigrant groups, and young adults to help determine whether future trends will differ from those of the past.

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