Driving and the Built Environment

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

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Suburbanization is a longstanding trend reflecting the preference of many Americans for living in detached single-family homes. The automobile and an extensive highway network have provided the mobility to make this possible. Yet 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, TRB 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 assesses whether petroleum use—and by extension, emissions of the primary greenhouse gas, carbon dioxide (CO_2)—could be reduced by more compact, mixed-use development—that is, development at higher densities with a variety of land uses.

The committee that produced the report estimates that the reduction in vehicle miles traveled (VMT), energy use, and CO_2 emissions resulting from more compact, mixed-use development would range from less than 1 percent to 11 percent by 2050. All of the committee members did not agree, however, that the changes in development patterns and public policies necessary to achieve the high end of the estimates were plausible. The study committee was appointed by National Research Council of the National Academies under the auspices of TRB and the Board on Energy and Environmental Systems (see box, page 28).

PHOTO: ARLINGTON COUNTY, VIRGINIA

Findings

More compact development patterns are likely to reduce VMT.

Both logic and empirical evidence suggest that development at higher population and employment densities results in trip origins and destinations that are closer to each other, on average; therefore average trip lengths are shorter. Although theory suggests that reduced trip lengths can increase trip frequencies, empirical evidence indicates 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; in addition, higher densities are well-suited for 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 with other policy measures that make the alternatives to driving more convenient and affordable. Examples include a street network that provides good connectivity and accommodates nonvehicular travel; well-located transit stops; and good neighborhood design. Demand management measures, such as reducing the supply and increasing the cost of parking, also can complement efforts to reduce VMT.

The most reliable studies estimate that doubling residential density across a metropolitan area may 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.

Many of the studies reviewed by the committee failed to distinguish between different types of density changes—for example, decreasing lot size versus increasing multifamily housing—or to examine the location of these changes in a region. Relatively few accounted for self-selection—people's tendency 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 reduce energy consumption and CO_2 emissions 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, because the existing building stock is durable, limiting opportunities to build more compactly; new housing may be built to accommodate a growing population and to replace the small percentage of 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; from longer vehicle lifetimes, through less driving; from smaller homes and more multifamily units, which are more energy-efficient than the average single-family dwelling; and from 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 absolute savings in energy use and CO_2 emissions from developing more compactly will be reduced, all else being equal.

Exploring the Effects of Compact Development

Approximately 80 percent of the U.S. population lives in metropolitan areas, but population and employment continue to decentralize within regions, and population density continues to decline at the urban fringe.

The adverse effects of suburbanization and automobile dependence have long been evident but now are particular concerns 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 accounts for more than 28 percent of annual U.S. energy consumption; cars and light trucks, mostly used for personal transportation, represent approximately 17 percent of annual U.S. energy consumption, and the share is rising.

Second, concern about climate change has grown domestically and internationally, and transportation is a major contributor to the 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 and 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, saving energy and reducing CO_2 emissions.

A key question is to what extent developing more compactly would reduce vehicle miles traveled and make alternative modes of travel—such as transit and walking—more feasible. Special Report 298, *Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and CO_2 Emissions,* focuses on metropolitan areas and on personal travel, the primary vectors through which policy changes encouraging more compact development should have the greatest effect.

(*Photograph, facing page:*) High-density residential and business development—as along the Ballston–Rosslyn Metrorail corridor in Arlington County, Virginia—tends to result in shorter trip lengths, since origins and destinations are closer to each other and public transportation is readily accessible.

Traffic Congestion and Greenhouse Gases

MATTHEW BARTH AND KANOK BORIBOONSOMSIN

Fuel consumption and carbon dioxide (CO_2) emissions are sensitive to many factors, including individual driving behavior, vehicle and roadway types, and traffic conditions. Therefore estimating CO_2 emissions from a single variable, such as trip distance or average speed, cannot provide a reliable measure. A comprehensive methodology has been developed to take advantage of the latest vehicle activity measurements and detailed vehicle emission factors to create a more accurate emissions inventory for different types of vehicles and different levels of traffic congestion (*1, 2*). This methodology produces better estimates of CO_2 reductions from improvements in traffic operations, including

- Congestion mitigation strategies—such as ramp metering and incident management—that achieve higher average traffic speeds;
- Speed management techniques—such as better enforcement and active speed governors—that can reduce excessive speeds to more moderate speeds of approximately 55 miles per hour; and
- Traffic-flow smoothing techniques— such as variable speed limits and intelligent speed adaptation—that can suppress shock waves, reducing the number of acceleration and deceleration events.

PHOTO: ARIZONA DOT

Speed management techniques, such as this dynamic message sign in Phoenix, Arizona, can help reduce vehicle emissions.

Figure 1 (below) shows an example of a speed-based CO_2 emissions curve for a typical vehicle traveling on a highway section (solid line). The curve indicates how different traffic management techniques would affect CO_2 emissions:

- Congestion mitigation increases average traffic speeds from those under heavily congested conditions;
- Speed management reduces excessively high speeds to safer speeds; and
- Traffic smoothing reduces the number and intensity of accelerations and decelerations.

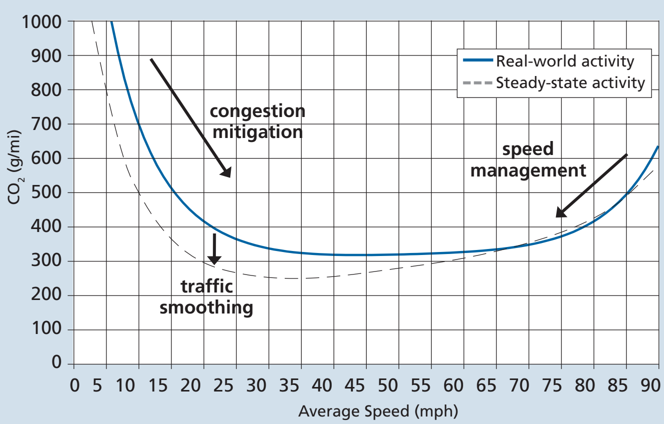

***FIGURE 1** Possible use of traffic operation strategies in reducing on-road CO_2 emissions.*

The dashed line in Figure 1 represents the approximate lower bound of CO_2 emissions for vehicles traveling at constant steady-state speeds.

Under typical traffic conditions in Southern California, each of these methods could lower CO_2 emissions by an estimated 7 percent to 12 percent as long as travel demand does not increase because of the improved traffic flow. Although the individual effects of single methods may not be that large, combining methods could have a synergistic effect, adding up to a greater amount. Because of the potential demand for additional driving in heavily congested areas such as Southern California, other demand management techniques also could be employed to realize these synergistic effects.

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References

1. Barth, M., and K. Boriboonsomsin. Real-World Carbon Dioxide Impacts of Traffic Congestion. In *Transportation Research Record: Journal of the Transportation Research Board, No. 2058,* Transportation Research Board of the National Academies, Washington, D.C., 2008, pp. 163–171.
2. Barth, M., and K. Boriboonsomsin. Traffic Congestion and Greenhouse Gases. *ACCESS Magazine,* University of California Transportation Center, Fall 2009. www.uctc.net.

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 deepen.

The committee assembled illustrative scenarios with housing forecasts prepared especially for the study and with 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 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 density of new residential development, mainly at the urban fringe, where most new development takes place, but also through some strategic infill.

The results depend on assumptions about the percentage of new housing developments to be built compactly and on how much less the residents of these more compact developments will drive. The base case assumes continued low-density development and that household VMT remains constant, an assumption tested in sensitivity analyses.

In an upper-bound scenario—a significant departure from current conditions—the committee estimates that 75 percent of new and replacement housing units are located in more compact developments, and that residents of compact communities would drive 25 percent less. The VMT and associated fuel use and CO_2 emissions of households would decrease by 7 to 8 percent by 2030, compared with base case conditions, and would widen to between 8 and 11 percent by 2050.

A more moderate scenario assumes that 25 percent of new and replacement housing units will be built in more compact development and that residents will drive 12 percent less. This would reduce fuel use and CO_2 emissions by approximately 1 percent in 2030, compared with base case conditions, and would grow 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. The members who believed the scenario is feasible questioned whether densities on the urban fringe will continue to decline and noted that macroeconomic trends—the likelihood of 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 produce considerably higher densities by 2050.

Other members pointed out that the upper-bound scenario required too significant a departure from current housing trends, land use policies of jurisdictions at the urban fringe, and public preferences. They maintained that curbing large-lot development and achieving substantial infill would be unrealistic unless states or regions took a strong role in growth management.

Promoting more compact, mixed-use development on a large scale will require overcoming many 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 largely a local government function and is sensitive to legitimate local concerns—for example, congestion, local taxes, and home values—which are sometimes at odds with other regional or national concerns, such as housing affordability or climate change. Land use policies aimed at achieving sweeping changes in development patterns therefore are likely to meet political resistance from homeowners and local governments. This may explain in part 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 arise in new housing construction and replacement units in areas already experiencing increases in density—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 encourage more compact development in these locations, and zoning regulations can be relaxed to steer 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 parking, can complement higher-density development pat-

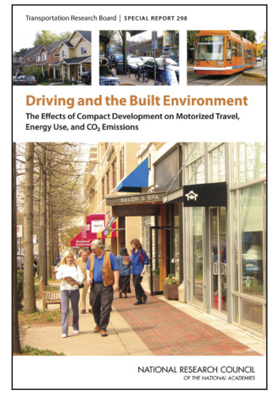

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Photo: Metro

Compact, high-density development in Portland, Oregon.

terns 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 may 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.

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 nonmotorized modes, 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 for rail transit—to support high-density development. Moreover, many Americans apparently prefer detached single-family homes in low-density suburbs offering more privacy, greater access to open space and recreation, and less noise than many urban neighborhoods. Nonetheless, housing preferences may change with changes in the demographic and socioeconomic characteristics of the population.

Committee for the Study on the Relationships Among Development Patterns, Vehicle Miles Traveled, and Energy Consumption

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Recommendations

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

The committee recognizes the lack of verifiable scientific evidence to support this recommendation. The committee's scenarios suggest that compact, mixed-use development will generate only modest reductions in energy use and carbon emissions in the near term. Moreover, the committee did not examine the other benefits and costs of compact, mixed-use development.

Nevertheless, climate change is a problem more easily dealt with sooner than later, and more energy-efficient land use patterns may become part of the strategy if the nation sets ambitious goals for energy efficiency and the reduction of greenhouse gas emissions. Implemented carefully, compact development also may reduce housing costs while increasing housing choices. Because the full energy and emissions benefits of changes in land use may take decades to realize, and development patterns take years to reverse, implementation of these policies should start soon.

Given the incomplete understanding of the benefits and costs of different policies for compact, mixed-use development, however, these policies should be implemented carefully and the effects monitored.

More carefully designed studies examining 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.

The committee identified five areas for more research:

- Federally funded longitudinal studies based on panel data to help isolate the effects of different types of development patterns on travel behavior;
- Studies of changes in metropolitan areas at finer levels of spatial detail to help inform the needs and opportunities for policy intervention;
- Careful before-and-after studies of policy interventions to promote more compact, mixed-used development to help determine what works;
- Studies of threshold population and employment densities to support rail and bus transit, walking, and bicycling, which would bring old references up to date and help guide infrastructure investments, as well as zoning and land use plans; and
- Studies of the 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.