Compact Development Reduces VMT: Evidence and Application for Planners

Arthur C. Nelson, FAICP
Professor of Planning and Real Estate Development, University of Arizona
Presidential Professor Emeritus, University of Utah

In recent years there have been numerous scholarly articles assessing the relationship between urban form and personal travel (Stevens 2017). Most studies show small to modest effects of changes in factors that influence travel behavior considering five "D" variables. These articles apply sophisticated statistical analysis to datasets that assess effects of several or all five of the following D-variables on travel:

- *Density* is the number of people, households, or jobs per unit of land area—typically square mile. Higher densities may reduce trips and trip lengths by making destinations closer together.
- *Diversity* measures the mix of land uses in a given area—often square mile, census tract, or transportation analysis zones—with lower values indicating lack of diversity (such as mostly single-family detached homes) and higher values indicating multiple land uses. Diversity can include jobs-people/housing balance usually measured as the ratio of jobs to people (JPH) or households (JHB). Assuming there are 0.6 jobs per person in the region, a JPH of 1.0 means the local area is at balance with the region. Higher measures of diversity are thought to reduce driving and encourage walking/biking.
- *Design* measures the extent to which the street network includes a large number of intersections—especially 4-way intersections— in the analysis area. This may reduce

driving by reducing the network distance route to destinations while also making walking and biking more convenient.

- *Destination accessibility* measures the distance from a home to key central locations such as downtown, or the number of jobs accessible by car or by transit within a certain time frame. More accessible destinations may reduce trips or encourage the use of other than cars to access them.
- *Distance to transit* measures the distance from a home to the nearest transit stop—either all options such as conventional bus and rail or just rail—using the shortest street route. Homes nearer to transit may reduce driving by making transit more convenient.

Statistical analysis applied to the D-variables estimates the extent to which aspects of compact development reduce trips, trip lengths, and per capita vehicle miles traveled (VMT), all things considered. In this issue of the *Journal of the American Planning Association*, Mark R. Stevens (2017) asks: “Does compact development make people drive less, and if so, how much less?” (Stevens: ___) He addresses the question by applying meta-regression analysis to 37 studies reported between 1996 and 2015 assessing the relationship between several or sometimes all five D-variables to travel behavior. He finds that compact development does make people drive less but the impact is fairly small in that “compact development features don’t appear to have much influence on driving” (Stevens: ___). He further cautions that “driving is not very sensitive to changes in D-variables. This suggests that compact development has limited potential for making people drive less” (Stevens 2017: ___). In his zeal for caution, Stevens misses an opportunity to show planners how compact development can make a difference in reducing per capita VMT in future plans and development approvals. I do so here. I make my case as follows:

- The Aggregate D-variable Effects on VMT are Important;
- The Market Demand for More Compact Development is Considerable and the Potential for VMT Reduction is Substantial;
- Application to a Not So Hypothetical Example; and
- Summary and Next Steps.

The Aggregate D-variable Effects on VMT are Important

Stevens derives elasticities from a meta-regression analysis of those 37 studies, which are summarized in Table 1. I report only those elasticities for studies that controlled for residential self-selection ("Stevens' Corrected Elasticities").

Table 1
D-Variable Elasticities

D-variable measure	**Stevens' Corrected Elasticities**
Distance to downtown	-0.63
Household/population density	-0.22
Job accessibility by auto*	-0.20
Intersection/street density*	-0.14
Land use mix	0.11
Job density	-0.07
% 4-way intersections*	-0.06
Distance to nearest transit stop*	-0.05
Job accessibility by transit*	0.00
Jobs-housing balance*	0.00

Source: Stevens (2017), adapted from his Table 2, reporting outcomes that control for self-selection.
*Stevens had no need to correct these elasticities to control for self-selection.

Elasticity measures can help planners understand the potential outcome to planning and development decisions. Elasticities estimate the percent change in a planning objective—such as reducing per capita VMT—associated with a one percent change in a planning action such as achieving more compact development. While many of the elasticities Stevens reports are quite small, three stand out because they are not: (1) household/population density; (2) job accessibility by auto; and (3) intersection/street density. For example, from a planning perspective, the elasticity for density can be interpreted as follows:

> Increasing density of households/population by 25 percent will decrease per capita VMT by 5.5 percent (0.22 elasticity times 0.25). If density is 2,000 persons or 800 homes per square mile and VMT is 10,000[1] miles annually per capita, increasing density by 25 percent to 2,500 persons or 1,000 homes per square mile –just 200 more residential units in a square mile—will reduce annual VMT by 550 miles for each of the 2,500 residents.

This improvement is not trivial. For instance, in this scenario, a doubling of density can reduce VMT by 2,200 miles annually per person, reducing it from 10,000 miles to 7,800 miles per capita for everyone.

Moreover, with caution, elasticities may be combined to create even larger effects. For instance, adding elasticities for household/population density, job accessibility by auto, and intersection/street density is an elasticity of 0.56. If through good planning and urban design all three of these variables increased by 25 percent nationally between now and midcentury, VMT per capita would fall by 14 percent (0.56 elasticity times 25 percent increase) or 1,400 miles, and mean VMT per capita would fall to 8,600 miles. As the US will add about 100 million people between now and midcentury, total VMT will be much larger then than now but neither would the reduction be trivial.

Applying measures of elasticity can be tricky for two main reasons. The first is that often elasticity estimates are based on small datasets and/or small ranges between high and low data points. Fortunately for purposes of this commentary, nearly 90 percent of the studies assessed by Stevens use more than one thousand cases and about a third include more than 10,000 cases. As large sample sizes improve veracity of statistical analysis this concern seems obviated. Moreover, the ranges used in Stevens' studies are likely quite large. For instance, population, household and job densities range more than ten times from the smallest to the largest data point. Intersection densities likely range well over ten-fold from smallest to largest. The distance of homes to downtown, the nearest transit station, and job accessibility by auto or transit can range at least ten-fold and perhaps more than one hundred-fold (depending on the specific study design).[2] It is unlikely that there are narrow ranges between highest and lowest data points when considering the totality of the studies so this concern is also obviated. In effect, extrapolating elasticities to estimate effects of a doubling of density, for instance, should not cause much interpretive alarm. This is important for reasons that will be apparent later.

Second, when aggregated, elasticities of two or more variables can over- or under-estimate actual effects. Over-estimation can occur when the sum of two or more elasticities exceeds the real effect. This happens when they are highly or reasonably highly correlated; the correction could be an index that appropriately weights all variables in the same composite variable. Underestimation can occur when the sum of two or more elasticities is less than the real effect. For instance, in the absence of transit options the combination of density and transit accessibility elasticities may be less than if there were transit options. Indexing could again be a solution though with respect to transit the mode, frequency, quality of stops, and other factors can also affect transit accessibility elasticities. Yet, researchers strive to control for these effects to generate estimates with reasonable fidelity, allowing many to be cumulated where appropriate.

By not cumulating appropriate elasticities where reasonable in the context of planning, Stevens' contribution to planning may be understated. From a planning perspective, it may be reasonable to aggregate selected elasticities reported in Table 1 in the manner shown in Table 2. After all, good planning and urban design maximizes benefits by choreographing numerous efforts individually having small or modest impacts because taken as a whole they can have large impacts. Excluding the variable for distance to downtown, a one percent increase in each of the D-variables listed in Table 2 may be associated with a 0.63 percent decrease in per capita VMT. One variable stands out for suggesting that an increase in land use mix could increase VMT. While counter-intuitive, it could be the case that more land uses close-by but without convenient walking/biking/transit access could induce more traffic between them. Put differently, doubling measures of each variable may have a cumulative effect of reducing per capita VMT by 63 percent. This is an important contribution to planning for reasons shown next.

Table 2
Selected D-Variables for Interpretation

D-Variable	**Stevens' Corrected Elasticity**
Household/population density	-0.22
Job accessibility by auto*	-0.20
Intersection/street density*	-0.14
Land use mix	0.11
Job density	-0.07
% 4-way intersections*	-0.06
Distance to nearest transit stop*	-0.05
Total	-0.63

Source: Adapted from Stevens (2017).
*Stevens had no need to correct these elasticities to control for self-selection.
Note: Job accessibility by transit and Jobs-housing balance are removed because of their negligible effects based on Stevens' analysis.

The Market Demand for More Compact Development is Considerable and the Potential for VMT Reduction is Substantial

Planning for more compact development means increasing household/population density, expanding land-use mix and connectivity thereby improving job accessibility by auto, increasing intersection/street density, and reducing the distance between people and jobs and transit opportunities, among other factors. But these efforts will be successful only if the market wants it. Fortunately, this seems to be the case. Consider two indicators: demand for traditionally-designed communities[3] and walkable communities.

Based on a survey of more than 10,000 respondents in 2003 and 2005, Handy et al. (2008) found that in 2003, more than 40 percent expressed support for supporting or living in a traditionally-designed community that included such features as walkable destinations, housing and land use mix, and smaller lots. This support rose to nearly 60 percent by 2005. Taken together, my interpretation of Handy et al.'s work is that about half of Americans would both support and choose to live in a traditionally-designed community. Those communities are typically designed for at least 10,000 persons per square mile and a sizeable employment base though typically not one achieving jobs-person or jobs-housing balance (Nelson 2013). Handy et al. observe that the supply of traditionally designed communities does not meet demand.

More recently, the National Association of Realtors (NAR) and Portland State University (2015) reported findings of their survey of 3,000 respondents living in the 50 largest metropolitan areas. As a stated-preference survey, it forces respondents to choose between choices. One of the stated-preference/forced-choice survey questions was this:

> *Imagine for a moment that you are moving to another community. These questions are about the kind of community where you would like to live. Please select the community where you would prefer to live.*

The choices and responses were:

> *(COMMUNITY A) Houses with large yards and you have to drive to the places where you need to go.* **45 percent**
>
> *(COMMUNITY B) Houses with small yards, and it is easy to walk to the places you need to go.* **48 percent**

and

(COMMUNITY A) Own or rent an apartment or townhouse, and you have an easy walk to shops and restaurants and have a shorter commute to work. **45 percent**

(COMMUNITY B) Own or rent a detached, single-family house, and you have to drive to shops and restaurants and have a longer commute to work **48 percent**

In the choice among strictly detached residential neighborhood options, slightly more respondents would choose smaller yards (48 percent) if they could have an easy walk to places compared to those who would prefer larger lots and have to drive places (45 percent). Designed right, smaller-lot developments with walkable destinations can enjoy many features of compact development, especially if attached housing options are also available (Parolek 2008).

In choosing between even more stark options, slightly more respondents would choose the "sprawl" option where they need to drive to places and have a longer commute to work (48 percent) than the compact development option that includes owner or renter attached residential options with an easy walk to places and a shorter commute to work (45 percent). I am impressed with such a small difference in selections between the attached and detached residential options.[4]

Why is this important? According to the 2013 American Housing Survey (AHS), only 26 percent of Americans lived in homes where they could walk to places.[5] Put differently, of the roughly 120 million occupied housing units in 2015, the demand for living in walkable neighborhoods—arguably a form of compact development[6]—is for nearly 60 million homes but the supply is about 30 million. As the U.S. adds about one million occupied homes annually, even if all homes built between 2015 to the end of the 21st century were in walkable neighborhoods the demand may still not be met. Perhaps current neighborhoods that are not walkable or compact will become such through infill and redevelopment. We would not need to wait to the end of the century to meet the market demand for these residential options.

Suppose through planning and urban design that by midcentury half of the roughly 160 million homes in the U.S. then were in more compact communities, an increase of 50 million above my estimate of 30 million in 2015.[7] How would this effect VMT? In 2011, the nation's mean per capita VMT was 9,560 miles.[8] Despite projected increases, let us assume this does not change to midcentury.[9] If 50 million homes comprising roughly 125 million Americans lived in areas where the mean of the selected D-variables were double then than what they are now—through planning and urban design, VMT per capita would be reduced by more than 6,000 miles or about 700 billion total miles. While total VMT would increase considerably, it would do so at a rate substantially lower than current levels. This is not trivial.

What does doubling the selected D-variables mean? In 2010, the urbanized land areas of the U.S. averaged about 2,500 persons per square mile or roughly the density of the Kansas City and Orlando urbanized areas. Double this density would be roughly half the minimum density of modern low-rise new urbanism communities[10] that tend to command a market premium (Song and Knaap 2003) because (a) benefits such as lower VMT are capitalized into higher values and (b) demand exceeds supply among other factors.

But density of development serving new population might nearly double anyway. Consider that in the early 1990s, the average lot size of a new detached home was 0.60 acres but it fell steadily to 0.30 acres in the early 2010s.[11] Further, while the total number of detached homes increased about 30 percent, the number of homes on small lots (less than one-eighth acre) doubled to nearly 14 million units. During the same period, attached residential units accounted for about 9 million units of the total change of 27 million units or one-third. In other words, trends of the past two decades suggest that housing is becoming somewhat more compact, perhaps consistent with emerging market demand. Planning can help accelerate the pace by facilitating more efficient urban forms.

Application to a Not So Hypothetical Example

There would seem to be substantial market demand for land use patterns that inherently reduce per capita VMT. Stevens' analysis indicates that per capita VMT can be reduced by choreographing changes to the built environment, perhaps consistent with existing and emerging market conditions. Let us consider the hypothetical example of metropolitan Tucson, Arizona. In 2011, its population was 988,000 and is projected to reach 1.5 million by 2050, an increase of about 52 percent.

Suppose metropolitan area planners consider two scenarios. In the "sprawl" scenario, 20 percent of all future development occurs in existing developed areas as infill and redevelopment, and the rest (80 percent) occurs with roughly the same parameters as existed in 2011. This is roughly how the metropolitan area is trending to grow anyway. The mean distance of a person to downtown increases by 10 percent, through anticipated transit expansions there will be a 25 percent decrease in the mean distance to transit, and there will be a 10 percent increase in household/population density, job accessibility by auto, intersection/street density, land use mix, job density, and %4-way intersections. (As the variables for job accessibility to transit and jobs-housing balance are zero they are excluded here.) Analysis summarized in Table 3 shows that between 2011 and 2050, VMT per capital is estimated to fall by 0.75 percent, the mean VMT/capita falls from 8,627 miles to 8,562 miles, and total VMT increases from 8.5 billion miles in 2011 to 12.8 billion miles in 2050, or 51 percent, roughly comparable to population growth.

In the "infill-redevelopment" scenario, all (100 percent) future development occurs in existing developed areas as infill and redevelopment. This is easily imagined given very low development intensities, vast amounts of undeveloped land surrounded by development, and moderately assertive efforts to use public resources to leverage private "smart growth" investment and development. The mean distance of a person to downtown decreases by 20 percent, anticipated transit expansions will cut the mean distance to transit by half (meaning a 50 percent reduction in the mean distance to transit), because new growth is about 50 percent of existing and occurs within the urbanized area there will be a 50 percent increase in household/population density, job accessibility by auto, and land use mix, job density along with a 25 percent increase in intersection/street density and %4-way intersections. Between 2011 and 2050, VMT per capita is estimated to fall by 42.6 percent, the mean VMT/capita falls from 8,627 miles to 4,952 miles, and total VMT falls from 8.5 billion miles in 2011 to 7.4 billion miles in 2050, or 13 percent. Although metropolitan Tucson grows by 52 percent, its VMT in 2050 is actually less than in

2011. The weighted population density[12] increases from 3,200 to 4,800 persons per square mile or roughly what metropolitan Denver was in 2010.

Limitations and extensions of this application of Stevens' insights are summarized next.

Table 3
VMT Change Scenario, Metropolitan Tucson, AZ

D-Variable	Baseline and Projection	Stevens' Corrected Elasticity	Tucson Mero Sprawl Scenario	Tucson Metro @ 20% Infill, Development	Tucson Metro Infill-Redevelopment Scenario	Tucson Metro @ 100% Infill, Development
Distance to downtown		-0.63	10% increase*	+6.30%	20% decrease	-12.60%
Household/population density		-0.22	10% increase	-2.20%	50% increase	-11.00%
Job accessibility by auto		-0.20	10% increase	-2.00%	50% increase	-10.00%
Intersection/street density		-0.14	10% increase	-1.40%	25% increase	-7.00%
Land use mix		+0.11	10% increase	+1.10%	50% increase	5.50%
Job density		-0.07	10% increase	-0.70%	50% increase	-3.50%
% 4-way intersections		-0.06	10% increase	-0.60%	25% increase	-1.50%
Distance to nearest transit stop		-0.05	25% decrease	-1.25%	50% decrease	-2.50%
Total Change				-0.75%		-42.60%
Population 2011	988,000					
VMT 2011, millions	8,524					
VMT per Capita, 2011	8,627			8,562		4,952
Projected Population, 2050	1,500,000					
VMT Reduction, millions				97		3,675
Total VMT, millions				12,844		7,428
Change	52%			51%		-13%

Source: Elasticities from Stevens (2017)
*Technically an increase in mean distance from downtown means higher VMT.
Note: Job accessibility by transit and Jobs-housing balance are removed because of their negligible effects based on Stevens’ analysis.

Summary and Next Steps

It is possible that planners usually do not know how to apply insights of statistical analysis such as those referenced and synthesized by Stevens. My aim was to provide a straightforward way in which to estimate effects in Table 3, and interpret them for policy.

In the hypothetical example, the infill-redevelopment scenario could be considered aspirational yet within reach over the next several decades. It of course represents a "best case" scenario assuming that the effect of D-variables on VMT can be maximized. As alluded to earlier, it also assumes that the D-variables are independent and that their individual effects can be summed. The total effect could be smaller—perhaps likely, but also larger if there are synergistic effects. This would be the next logical area of research. The point is, VMT reduction would be real and likely substantial.

The benefits to metropolitan Tucson can be considerable. For instance, under the sprawl scenario, the demands of roughly four billion more vehicle miles traveled in metropolitan Tucson will need to be met. This is roughly equivalent to 1,500 lane miles of new roads[13]. At roughly $2 million per land mile, this comes to about $3 billion. Under the infill-redevelopment scenario, metropolitan Tucson could save $3 billion which could be used to improve existing roads, enhance pedestrian and bicycle ways, expand transit, and make other strategic investments that improve quality of life.

There are other tangible benefits from reduced VMT per capita. A few of them include reduced greenhouse gases with associated environmental improvements (Ewing et al. 2008), improved physical activity (Ewing et al. 2013), improved public health and traffic safety (Ewing and Hamidi 2014), and improved economic productivity and resilience (Nelson 2013). Future work can estimate VMT-related elasticities with respect to these and other benefits so planners can estimate benefits of reducing VMT per capita.

It is past time for the insights of researchers such as those referenced by Stevens and Stevens himself to be made accessible to planners. I trust my commentary helps meet this need.

References

Ewing, Reid and Shima Hamidi (2014). *Measuring Urban Sprawl and Validating Sprawl Measures*. Washington, DC: National Cancer Institute, National Institutes of Health.

Ewing, Reid, Keith Bartholomew, Steve Winkelman, Jerry Walters, and Donald Chen (2008). *Growing cooler: The evidence on urban development and climate change*. Washington D.C.: The Urban Land Institute.

Ewing, Reid, Gail Meakins, Shima Hamidi and Arthur C. Nelson (2013). Relationship between urban sprawl and physical activity, obesity, and morbidity - update and refinement**.** *Health & Place* 26:118-26 doi: 10.1016

Handy, Susan, James Sallis, Deanne Weber, Ed Maibach, and Marla Hollander (2008). Is Support for Traditionally Designed Communities Growing? Evidence from Two National Surveys. *Journal of the American Planning Association* 74 (2): 209-221.

National Association of Realtors and Portland State University (2015). *Community & Transportation Preferences Survey: U.S. Metro Areas, 2015*. Washington, DC: National Association of Realtors.

Nelson, Arthur C. (2013). *Reshaping Metropolitan America*. Washington, DC: Island Press.

Parolek, Daniel (2008). *Form Based Codes: A Guide for Planners, Urban Designers, Municipalities, and Developers*. New York: Wiley.

Office of Highway Policy Information (2016). *FHWA Forecasts of Vehicle Miles Traveled (VMT): Spring 2016*. Washington, DC: Federal Highway Administration, US Department of Transportation.

Song, Yan and Gerrit-Jan Knaap (2003). New Urbanism and Housing Values: A Disaggregate Assessment. *Journal of Urban Economics* 54(2):218-238.

Stevens, Mark R. (2017). Does Compact Development Make People Drive Less? *Journal of the American Planning Association*. 83(1):

Endnotes

---

[1] In 2005, the national average VMT was 10,083. See https://www.brookings.edu/wp-content/uploads/2016/06/vehicle_miles_traveled_report.pdf.

[2] I am indebted to Reid Ewing and Shima Hamidi for access to their sprawl index data (Ewing and Hamidi 2014) to make these points.

[3] For a review of traditional neighborhood design features, see http://www.sustainablecitiesinstitute.org/topics/land-use-and-planning/traditional-neighborhood-development-(tnd).

[4] The NAR's 2011 and 2013 national surveys included similar questions. In those, roughly 60 percent of respondents to the large or small lot detached homes options chose the small-lot one while about 40 percent of respondents to the attached/walkable or detached/drive-only options chose the attached one. But when respondents were filtered to include only those living in the 50 largest metropolitan areas, results from the 2013 survey were reasonably comparable to the 2015 survey.

[5] This is based on my analysis of the AHS Public Use File.

[6] See http://business.gwu.edu/about-us/research/center-for-real-estate-urban-analysis/research/walkable-urban-places-research/.

[7] All new homes would be built in compact, walkable communities plus about 15 million or a sixth of all current residential units would become part of a compact/walkable community by midcentury owing to infill, redevelopment, and expansion of alternative transportation modes.

[8] See http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/state_transportation_statistics/state_transportation_statistics_2011/html/table_05_03.html).

[9] According to the Office of Highway Policy Information (2016), VMT is actually projected to increase more than one-half percent per year, compounded.

[10] See https://www.cnu.org/.

[11] See *American Housing Survey for the United States* for1991 and 2013.

[12] See http://www.census.gov/population/metro/data/pop_pro.html.

[13] Calculated as [4.2 billion new annual VMT / 365 days per year / 7,500 VMT per lane mile based on the local level of service standard].