11.3 Cross Section Testing of Land Use/Transportation Factors

11.3.1 Background and Definition

"Land use/transportation" factors (also known as "the Ds") combine an area's land use and transportation characteristics to explain variation in travel behavior of its residents. LU/T factors are very well-studied in research literature, using household travel surveys and disaggregated land use data as the basis of analysis. For evaluating SACSIM19, our primary reference was a 2010 meta-analysis (a review and compilation of studies) by Ewing and Cervero[30]. Although several years old, a more recent (July 2017) article by Litman[31] summarizing research done on the land use-transportation relationship indicated that the 2010 Ewing-Cervero meta-analysis is the most recent of its kind, therefore we consider it reasonable to continue using its findings in our evaluation of SACSIM19. The meta-analysis examined the following land use/transportation factors, with results summarized in Table 11-8:

- **Regional accessibility**, which quantifies how connected a given area is to existing development, and is usually stated as the number of jobs within an average auto commute time. Regional accessibility is usually higher in areas within the existing urbanized area, and tends to be lower in outlying areas or areas on the urban edge. This factor has the strongest potential effect on VMT—a 10 percent increase in an area's accessibility results in a roughly two percent decrease in VMT for residents of that area.
- **Street pattern/urban design**, or how walkable a given area is based on characteristics of its street pattern and is usually measured as intersection density. A higher intersection density typically means smaller blocks and more potential walking connections there are in that area. Although other factors affect walkability and walk mode share (e.g., presence/absence of sidewalks, pedestrian amenities on the street, traffic volumes on streets, presence/absence of crosswalks, treatment of pedestrians at signalized intersections), intersection density has been used in research as a proxy for walkability, in part because it is relatively easy to assemble data. In terms of VMT reduction, street pattern is the second strongest factor with a 10 percent increase in intersection density resulting in a roughly one percent decrease in VMT.
- **Mix of use** refers to the inclusion in an area of a range of complementary land uses, which allows for more activities (i.e., working, shopping, school) to be contained within that area. Good land use mix allows for reductions in VMT through shortening of vehicle trips or shifting to other non-vehicle modes of travel such as walking. The most common measures of mix of use combine the relative proportions of residential, overall jobs, retail and other residential-supporting land uses into an "entropy" formula, which translates the balance of land use mix into a 0 to 100 scale[32].

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[30] Ewing, R. and Cervero, R., "Travel and the Built Environment: A Meta-Analysis," *Journal of the American Planning Association*, Vol. 76, No. 3, Summer 2010.
[31] Litman T., "Land Use Impacts on Transport: How Land Use Factors Affect Travel Behavior" Victoria Transport Policy Institute, July 2017
[32] Hossack, Gary, "Measuring and Visualizing the Diversity of Land Use and Its Relationship with Travel Behavior", TRB 2008 Annual Meeting, Paper #08-2742, Session 337.

- **Proximity to transit** refers to the distance from a residence to the nearest transit station or stop, with VMT declining, and both walking and transit use increasing, as distance to the nearest transit decreases.
- Residential density refers to the number of persons or dwellings within a given area. Conceptually, density is quite easy to understand—the number of persons or housing units within a given area. However, different definitions of area (e.g., net acreage, gross acreage, total area) and the fact that higher densities often co-exist with other land use/transportation factors such as high regional accessibility, walkable street patterns, and more transit service, the effects of density are often over- or under-stated. The Ewing/Cervero meta-analysis controlled for differences in definition of density across the studies they reviewed.

Table 11-8 provides a summary of the results of the Ewing/Cervero meta-analysis of LU/T factors and travel outcomes, stated as an elasticity of the travel outcomes for each land use/transportation factor. These elasticities will be used as a basis for evaluating whether SACSIM19's sensitivity to LU/T factors is reasonable.

Table 11-8 Land Use/Transportation Factors and Travel Outcomes

	Travel Outcome		
Land Use /Transportation Factor	*VMT**	Walk	Transit
Reported Elasticities[33,34,35]			
Regional Accessibility	-0.20 [*-0.13 to -0.25*]	+0.15	n/a
Street Pattern/Urban Design	-0.12 [*-0.03 to -0.19*]	+0.39	+0.23
Mix of Use	-0.09 [*-0.02 to -0.11*]	+0.15	+0.12
Proximity to Transit	-0.05 [*uncertain*]	+0.15	+0.29
Residential Density	-0.04[*-0.04 to -0.19*]	+0.07	+0.07

*Ranges were reported for VMT but not for other travel outcomes because the amount of research done on the land use/transportation effects on VMT is more robust.

11.3.2 Challenges of Testing Land Use-Transportation Sensitivities

Although it is tempting to assume that the relationships shown in Table 11-8 are discrete dials that can be adjusted to achieve pre-defined results, there are many factors that confound attempts to isolate individual effects. Self-selection bias is a major confounding factor, which is poorly accounted for in most of the research. Self-selection bias refers to fact that personal preference affects where someone chooses to live and the travel choices they make. E.g., people who like walking may

[33] Elasticities are stated as the proportional change in the travel outcome with respect to a change in the land use/transportation factor.

[34] Unbracketed elasticities from Ewing, R. and Cervero, R., "Travel and the Built Environment: A Meta-Analysis," *Journal of the American Planning Association*, Vol. 76, No. 3, Summer 2010.

[35] Bracketed elasticities are the range of elasticities reported by in research syntheses by, as well as by Boarnet, M. and Handy, S. and posted on the CARB website: http://arb.ca.gov/cc/sb375/policies/policies.htm

gravitate to walkable environments in their place of residence or place of work, and some of the land use-transportation relationships which are shown in research based on travel surveys may simply be measuring personal preferences rather than the environment's effects on behavior. Replicating in new areas the high walk share observed in existing well-mixed, walkable neighborhoods may be impossible, simply because the existing areas may have attracted a unique population of individuals who prefer walking.

Further, interactions among the land use-transportation factors themselves are difficult to control, and many factors are highly correlated. For example, many areas with denser street patterns (i.e., more intersections per unit of area) also have higher development densities, simply because their block and lot sizes are also smaller. Research has also recognized that the combined effects of many factors is not always equal to adding up the individual effects of each factor—there may be ceilings on some of the combined results. On the other side, some of the combined effects may be greater than the sum of the individual effects. For example, evidence from transit-oriented developments suggests that the combined effects of density, proximity to transit, and street pattern around rail stations with frequent service may far exceed the reductions in VMT and increases in walking and transit travel suggested by Table 11-8.[36] Although some factors are known to have greater potential influence (e.g., regional accessibility), significantly changing those factors may be difficult.

11.3.3 Land Use-Transportation Sensitivity Testing with SACSIM

The approach used to evaluate the sensitivity of SACSIM to LU/T factors focused on the household-generated travel and DAYSIM submodel outputs. SACSIM has several advantages in doing this sort of evaluation:

- Land use data in SACSIM is maintained at parcel/point level (see Chapter 1), which allows for much more nuanced and accurate representations of the land use context for a given area. Land use context is defined at parcel/point level, with surrounding land uses based on one-quarter and one-half mile "buffers" around each parcel/point. This provides more accurate land use context than the zone or fixed subarea systems typically used in travel demand modeling. SACSIM19's buffering system further increases the accuracy by basing its buffers on a "circuity factor," which instead of assuming a circle-shaped, or radial buffer, modifies the buffer's shape to consider street network characteristics that affect what is actually within a quarter or half mile. For example, two destinations may be 500 feet apart "as the crow flies", but due to some obstacle like a freeway or river would require a much longer trip to travel between using the street network.
- Demographics is a disaggregate, representative population file rather than a zone-aggregated summary or cross-classification of households. The population file includes characteristics such as an individual's age , worker or student status, and income of the household he/she lives in. The file also includes variables related to household structure (e.g., presence/absence of school age children) which are highly influential in determining travel behavior. Realistically zeroing in on the LU/T effects *requires controlling for key*

[36] Arrington, G.B., and Cervero, Robert, "Effects of TOD on Housing, Parking, and Travel", Transit Cooperative Research Program No. 128, Transportation Reseach Board, 2008.

demographic factors. Often these controls are not implemented, and LU/T factors are consequently over-attributed with effects on travel behavior.

- The activity/tour based modeling approach used for household-generated travel allows for a more complete accounting of travel by residents of the region. Tours are series of trips made from home to an activity (e.g., work), and back home. All trips on the tour are counted and "tracked" by DAYSIM as part of a given person's travel. This allows for all travel to be attributed to a given person or household, and be correlated with the LU/T characteristics of that person's place of residence or work. This contrasts with a traditional, trip-based travel demand model in which approximately one-third of all trips are "non-home-based" and the characteristics of the traveler and the traveler's place of residence or place of work are unknown and unaccounted for.

Given the disaggregate nature of the DAYSIM travel outputs, the units of analysis for LU/T sensitivity testing are individual people. For this test, all VMT and person trips by mode of travel are tallied by person and attributed to the person's place of residence. LU/T characteristics of the place of residence are tallied for each person in the population (2.2 million in this case). Key demographic characteristics (e.g., age, income, worker status, student status) as well as household structure characteristics (e.g., household size) are used as continuous (in the case of income or age) or categorical (in the case of worker or student status) variables.

The analysis performed is *cross-sectional*—that is, it examines a single set of data for one point in time, and evaluates variations in independent (in this case, a combination of demographic and LU/T factors) and dependent (household-generated VMT per person, transit trips per person, and walk trips per person) variables across the dataset, then evaluates the correlations between these variables. This is distinct from the experimental approach, which tests variables through direct manipulation of independent or input variables, and measures variations in output variables. Because LU/T factors by definition combine several different factors, this sort of experimental approach is difficult or impossible. For example, varying density means, of course, adding population or jobs to a given area—but that variation also affects mix of use and regional accessibility. The cross-sectional approach relies on statistical analysis to sort out and quantify the major LU/T effects.

Table 11-9 provides a comparison of the LU/T effects, converted from regression coefficients to elasticities, to the elasticities reported in the Ewing/Cervero meta-analysis[30] referred to above. Two values for SACSIM-estimated elasticities are provided; one is an "all variables" value, in which the elasticity was drawn from regression coefficients from a regression with all LU/T factors and all demographic factors in the model. The second is a "single variable" elasticity, in which the elasticity was drawn from regression coefficient from a regression with only a single LU/T variable and all demographic factors.

We determined how reasonable SACSIM's sensitivity to Land Use factors was by comparing its land use-transportation elasticities to those in Ewing and Cervero meta-analysis[30]. If the elasticity found in the meta-analysis fell within SACSIM's all-variable and single-variable elasticities, the LU/T factor is considered to be reasonably sensitive. This general test of reasonable sensitivity is not a "hard and fast" rule, nor do Ewing and Cervero recommend rigidly applying the values published in the meta-analysis.

In part, this flexible approach to comparing to the meta-analysis elasticities is consistent with the level of certainty around the research and limitations of "borrowing" research results from a range of geographic areas and a range of studies. The flexibility recognizes that many of the studies combined in the meta-analysis include some, but not all, of the LU/T factors, and some, but not all, of the demographic control variables.

Many of the LU/T variables themselves correlate with one another. An example is residential density and street pattern, which in the SACOG region show partial correlation of 0.52. Other LU/T factors which are highly correlated area residential density and transit accessibility to jobs (0.40), and street pattern and level of land use mix (0.36). By combining all variables within one statistical regression, some of the strength of variables may be shared, which may in turn account for the "all variables" elasticities falling somewhat below the published meta-analysis elasticities.

Finally, some of the research studies in the Ewing/Cervero meta-analysis[30] treated households as units of analysis while some treated persons as units of analysis. The effects of differences in units of analysis were not controlled in the meta-analysis[37]. Because households in areas with higher density and access to good transit service (i.e., areas which have "good" LU/T context) also tend to be smaller in size, results of person-level analysis, which was used for the SACSIM testing, may result in slightly lower LU/T elasticity effects.

As shown in Table 11-9, all but two SACSIM LU/T elasticities bound the meta-analysis elasticities (i.e., the meta-analysis elasticity fell within the range bound by the all-variable and single-variable SACSIM elasticities). The exceptions were:

- SACSIM's range of elasticity of VMT with respect to mix of use is somewhat higher than the meta-analysis elasticity, indicating that SACSIM is slightly more sensitive to mix of use than the literature suggests.
- SACSIM's range of elasticity of transit trips with respect to residential density is significantly higher than the meta-analysis elasticity, indicating that SACSIM is more sensitive to residential density than the literature suggests.

Because the elasticities computed from the regression results matched the published Ewing/Cervero elasticities as to sign, and closely matched the elasticities as to magnitude of effect, SACSIM is reasonably sensitive to land use/transportation factors.

[37] Personal communication from Reid Ewing, December 2011.

Table 11-9 Land Use/Transportation Elasticity Comparison

Land Use/Transportation Factor	Variable	Elasticities From Literature[38]	Estimated From SACSIM19 (all variables)	Estimated From SACSIM19 (single variable)
VMT Per Person				
Regl Auto Accessibility	Jobs w/in 30-Min Drive†	-0.2	-0.217	-0.38
Regl Transit Accessibility	Jobs w/in 30-Min Transit Trip*	-0.05	-0.006	-0.04
Mix of Use	SACOG Mix Index (0-1 scale)†	-0.09	-0.167	-0.31
Street Pattern	3- and 4-way Intersections within 0.25mi of residence	-0.12	-0.093	-0.31
Proximity to Transit	Distance to Nearest Transit Stop (miles)**	-0.05	-0.001	-0.32
Residential Density	Households within 0.25 miles of residence†	-0.04	-0.100	-0.27
Transit Trips Per Person				
Regl Transit Accessibility	Jobs w/in 30-Min Transit Trip	na	0.128	0.22
Mix of Use	SACOG Mix Index (0-1 scale)†	0.12	0.235	0.57
Street Pattern	3- and 4-way Intersections within 0.25mi of residence	0.23	-0.164††	0.66
Proximity to Transit	Distance to Nearest Transit Stop (miles)**	0.29	0.000	0.39
Residential Density	Households within 0.25 miles of residence†	0.39	0.520	0.87
Walk Trips Per Person				
Destination Accessibility	Jobs within 0.25mi of parcel*	0.15	0.030	0.09
Mix of Use	SACOG Mix Index (0-1 scale)†	0.15	0.253	0.41
Street Pattern	3- and 4-way Intersections within 0.25mi of residence	0.39	0.172	0.54
Proximity to Transit	Distance to Nearest Transit Stop (miles)**	0.15	0.001	0.23
Residential Density	Households within 0.25 miles of residence†	0.07	0.307	0.53

* Range of SACSIM elasticity magnitudes below meta-analysis elasticity magnitude.

† Range of SACSIM elasticity magnitudes greater than meta-analysis elasticity magnitude.

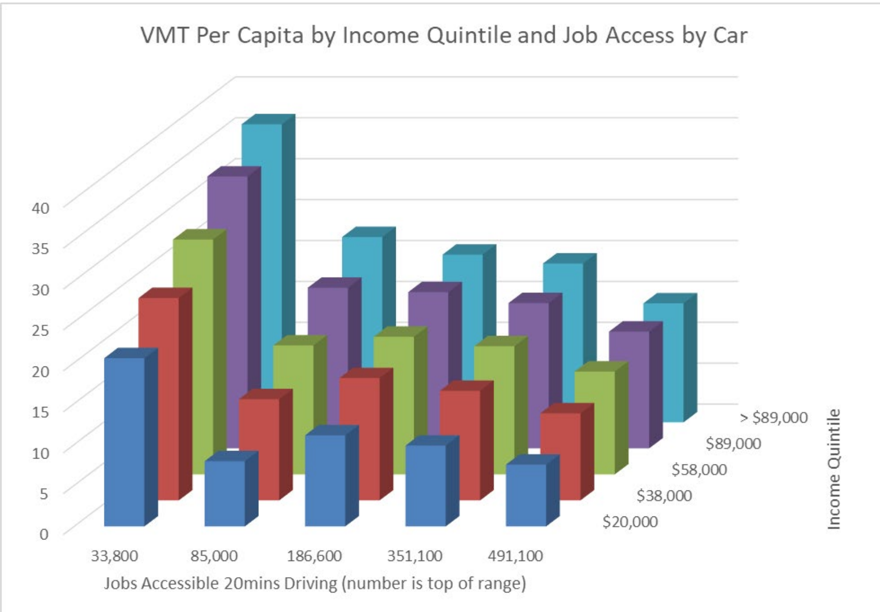
** Persons living more than 30 miles from a transit stop in the model were tagged as having a distance of 999 miles to transit. We included these cases for the all-variables regressions, but excluded them from the single-variable regressions for distance to nearest transit stop due to the skewing effect of having most cases being between 0-30 miles from transit, then have all other cases be “999” miles from transit.

†† Street pattern has high collinearity with housing density (0.52), job driving access (0.39), job transit access (0.39), and mix index (0.39), which likely explains the unexpected negative relationship between street pattern density and transit trips per person when all other land use factors are considered. As a single-variable regression, however, street pattern density shows an expected strong positive relationship with transit trips.

[38] Ewing, R. and Cervero, R., "Travel and the Built Environment: A Meta-Analysis", Journal of the American Planning Association, Vol. 76, No. 3, Summer 2010.

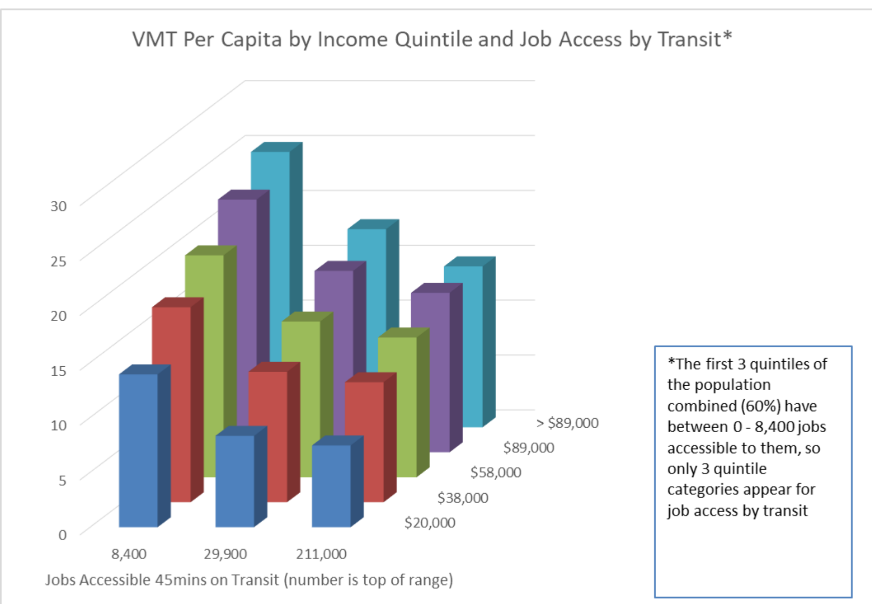
The charts in Figure 11-2 through Figure 11-5Figure 11-2 help illustrate the relationships between demographic factors, LU/T factors, and VMT per capita:

Figure 11-2 Modeled VMT Per Capita by Income and Job Accessibility by Car



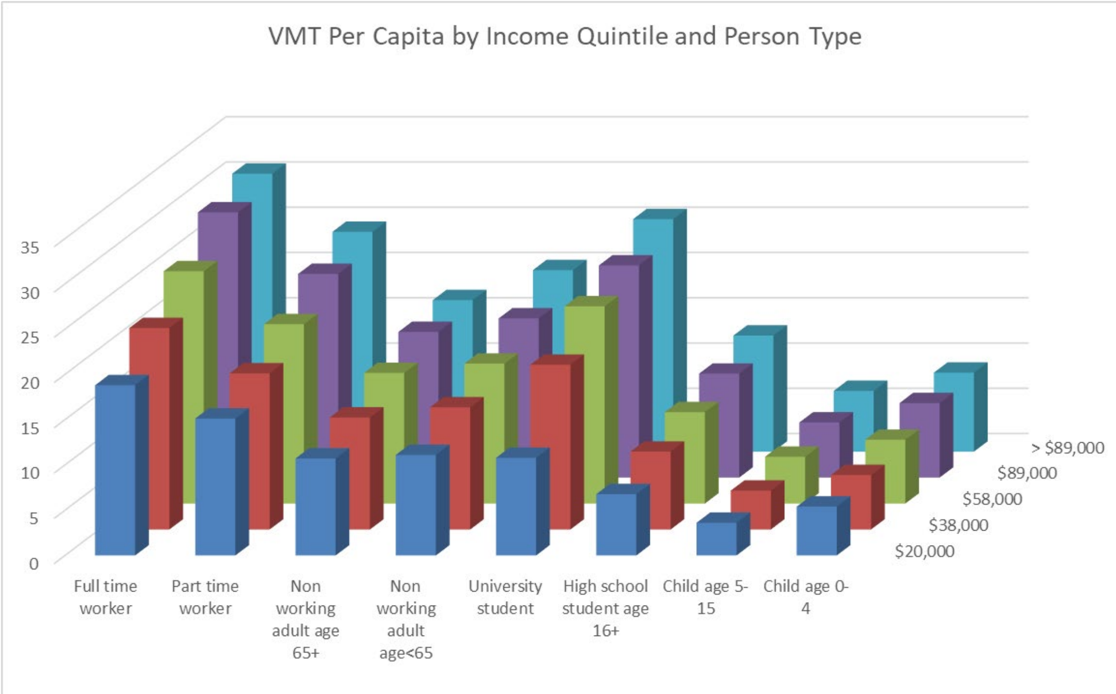
Source: SACOG 2020.

Figure 11-3 Modeled VMT Per Capita by Income and Job Accessibility by Transit



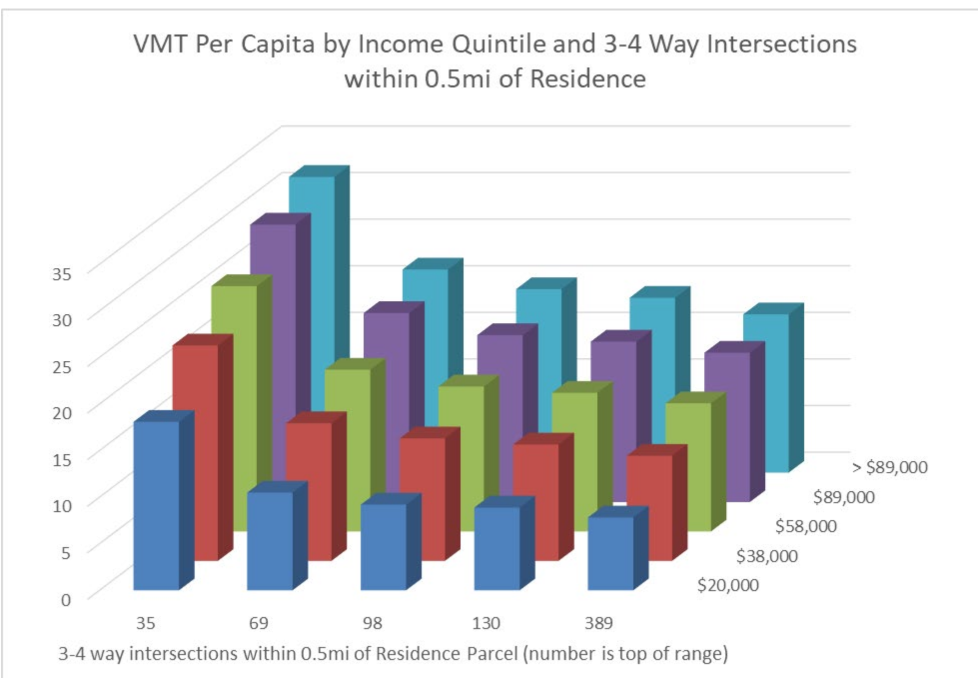
Source: SACOG 2020.

Figure 11-4 Modeled VMT Per Capita by Income and Person Type



Source: SACOG 2020.

Figure 11-5 Modeled VMT Per Capita by Income and Street Intersection Density Near Residence



Source: SACOG 2020.