Impacts of Land-Use Mix on Passenger Vehicle Use and Greenhouse Gas Emissions

Technical Background Document

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Study Selection

A thorough search of the academic literature was conducted regarding the impacts of land-use mix on vehicle use and greenhouse gas emissions in order to identify the appropriate studies for inclusion in this assessment. This brief draws heavily on studies cited in the reviews by Ewing and Cervero (2001, 2010), but has been updated to include three new studies published from 2011 to 2014 (Frank et al., 2011; Nasri and Zhang, 2012; and Zhang et al., 2012).

The review and meta-analysis conducted by Ewing and Cervero (2010) identifies a total of 17 studies that deal with the relationship between vehicle miles traveled (VMT) and land-use mix, and a subset of those studies was used as the primary evidence for this brief. The studies that were included in the analysis met two criteria. First, the effect on VMT must have been statistically significant at no less than a 90 percent level. Second, the study must have been conducted on an urban area that was similar to the California context. This left a total of five representative studies with a range of elasticities from -0.02 to -0.11. The primary studies cited by Ewing and Cervero (2010) were reviewed directly, and the results discussed in the brief are based on a review of those studies and the literature, not on the meta-analysis in Ewing and Cervero (2010).

Three studies published since the Ewing and Cervero publication in 2010 also meet the specified criteria and are included in this brief (Frank et al., 2011; Nasri and Zhang, 2012; and Zhang et al., 2012). The new studies represent a wider range of area types (including a smaller urban region in addition to major urban regions) and a broader range of elasticities (-0.01 to -0.17) than those reported in Ewing and Cervero (2010).

Effect Size, Methodology, and Applicability Issues

Several metrics have been used to quantify land use mix in the research literature. Among them are jobs-housing balance, land-use dissimilarity index, land-use entropy index, and mixed-use index. Though the effect sizes obtained from the various metrics are quite consistent, an understanding of the derivation of each of the measures is helpful in gauging their policy implications.

Bento et al. (2005) use jobs-housing imbalance to evaluate land use mixing. The imbalance measure was obtained by ordering zip code zones within each metropolitan area in the study from lowest to highest number of jobs. The cumulative percent of jobs was then plotted against the cumulative percent of population in each zip code to obtain what is known as a Lorenz curve. They then plotted the 45 degree line, which represents perfect jobs-housing balance. The area between the curve and the line indicates the degree of jobs-housing imbalance. This value is also known as the Gini coefficient. The larger the Gini coefficient, the greater, the spatial imbalance between jobs and housing.

The second measure, and perhaps most commonly used, is land-use entropy. Land-use entropy is a measure of the variety of land uses within a given radius of a land parcel or grid block. A radius of ½ mile is often used to compute neighborhood-level land-use mix (i.e. Cervero and Kockelman, 1997; Vance and Hedel, 2007). The equation for land-use entropy is:

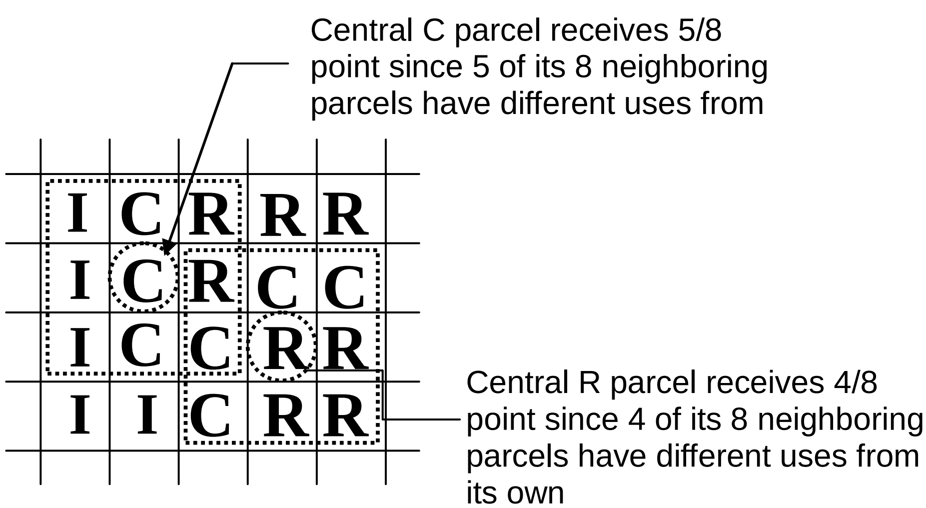
$$H = -\sum_{j}^{S} p_j \ln p_j$$

where H is the entropy value, S is the number of different types of land use in the region of interest, and p_j indicates the number of parcels or grids of j land use type. The entropy value ranges from zero (completely homogeneous land use) to one (perfectly balanced among all S uses). Two of the recent studies use this measure (Zhang et al., 2012; Nasri and Zhang, 2012).

Another measure of land-use mix used in the cited studies is the dissimilarity index. Cervero and Kockelman (1997) define this as the fraction of abutting parcels or grids that have different land uses from the parcel or grid of interest. Figure 1 graphically illustrates the calculation of the dissimilarity index for an urban area divided into one-hectare grids. As with the jobs-housing and entropy measures, the possible values of the dissimilarity index range from zero (all abutting uses the same as the central area) to one (all abutting uses different from the central area).

Cervero and Kockelman (1997) state that the advantage of the dissimilarity index over an entropy index is its usefulness in studying finely grained use mixing – down to the parcel level. In fact, the three measures, as used in the cited studies, represent land-use mixing at three different scales: jobs-housing balance at the metropolitan to district level, entropy at the neighborhood level, and dissimilarity at the neighborhood to parcel level.

Figure 1: Dissimilarity index calculation. Source: Cervero and Kockelmann, 1997, p 207



Finally, Frank, et al. (2011) use a mixed-use index that is based on building square footage of various land use types within a 1 kilometer buffer of the home location of each household in the study. The formula for the mixed-use index is as follows:

Land-Use Mix = -1*A/(ln(n))

where A=(b1/a)*ln(b1/a) + (b2/a)*ln(b2/a) +…+ (bn/a)*ln(bn/a)
a = total square feet of land for all five land uses
b1= square ft. of building floor area in land use type b1
b2= square ft. of building floor area in land use type b2
bn= square ft. of building floor area in land use type n

A value of zero indicates dominance by a single land use; a value of one indicates equal distribution of square footage across all the land-use categories. Residential land use was excluded from the index.

Each of the indices presented here has limitations, either due to the scale of measurement or due to the difficulty in assessing the attractiveness of various destination types. Some land use types, such as convenience and food stores, are more likely to attract local trips than others, such as warehouse spaces. The specific mix of uses also will likely matter in the context of VMT reduction. In addition, the elasticities given in these studies are averages over the ranges of index values for each study. Neighborhoods with land-use mix that fall at extreme ends of the scale may exhibit VMT elasticities that vary from the average.

As was noted in the brief, none of the cited studies controlled for residential self-selection. In fact, none of the studies included in the land-use mix portion of the Ewing and Cervero (2010) meta-analysis included such a control. Because of this, the effect of self-selection on the VMT effect size for land-use mix is unknown. However, recent studies such as Cao, Mokhtarian and Handy (2009) indicate that built environment effects on travel behavior are generally not negated by self-selection. Of the 38 empirical studies they reviewed, virtually all exhibited significant built environment impacts even after controlling for self-selection.

However, it seems likely that if residential self-selection was accounted for, the effect sizes stated in the brief would be lower. Cao, Mokhtarian and Handy (2009) found significant variation in the relative strength of self-selection versus built environment impacts on travel behavior across studies. This introduces additional uncertainty into how much of the reported effects from previous studies can be attributed to the land-use mix alone.

The methodologies used in the individual studies cited in this brief are similar to each other and typical of those used to examine the relationship between land use and VMT. Kockelman (1997) used linear regression models to examine the effects of demographic and land-use variables on VMT. Independent variables related to land-use mix that were used in the study included entropy of all land uses, entropy of non-work land uses, and dissimilarity index. Both Chapman and Frank (2004), and Frank et al. (2005) developed linear regression models of VMT, vehicle hours traveled (VHT), and pollutant emissions. Independent variables in their studies included demographic and attitudinal variables collected in regional travel surveys as well as land-use variables developed from parcel-level data in the Atlanta and Seattle metropolitan regions.

Bento et al. (2005) used data on household travel from the 1990 Nationwide Personal Transportation Survey and estimated a multinomial logit model for household vehicle ownership and then ran a regression for miles driven per vehicle, conditional on vehicle ownership. Because unobservable factors might affect the error term in both a vehicle ownership and miles-driven regression equation, they allowed correlation between the error terms in both equations and econometrically corrected for that correlation in error terms.

Unlike the individual primary studies cited in the brief, Ewing and Cervero (2010) used meta-analysis techniques to calculate average elasticities of VMT with respect to land-use mix. They used elasticities derived from 12 primary studies to compute weighted-average elasticities for land-use entropy and jobs-housing balance. Weighting in their meta-analysis was based on sample size of the primary study.

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Acknowledgments

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