

## Measuring the impacts of local land-use policies on vehicle miles of travel: The case of the first big-box store in Davis, California

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### Abstract:

Concerns over climate change have brought new impetus to the goal of reducing vehicle travel through land-use policy. To determine the degree to which land-use policies are effective in reducing vehicle travel, studies are needed that measure and compare vehicle travel both before and after a land-use policy change. The opening of the first big-box retail store in Davis, California, represented a major change in the retail landscape and an unusual opportunity to study its effect on shopping travel. Surveys of residents' shopping behavior conducted before and after the opening of the store revealed a significant shift in where people shopped and a measurable reduction in overall vehicle miles traveled (VMT) for shopping. Although the observed change in VMT is specific to the Davis context, the findings support the general proposition that bringing retail destinations closer to residences could help reduce vehicle travel, particularly where the comparable alternatives for the newly introduced store are far away. The study also offers important insights into the challenges of conducting before-and-after studies of the impact of local land-use changes.

### 1 Introduction

Concerns over climate change have brought new impetus to the goal of reducing vehicle travel through land-use policy. In California, for example, Senate Bill 375 (2008) led to the establishment of regional targets for reducing greenhouse gas emissions from passenger vehicles and requirements that metropolitan planning organizations adopt land-use policies, among other strategies, that help meet these targets. While empirical evidence shows that residents drive less in communities with greater densities and mixes of land uses, local governments have little basis for knowing how much less their own residents will drive if they succeed in increasing densities or the land-use mix. At the local level, changes are usually incremental, occurring one project at a time within the context of the existing community, and neither one-size-fits-all elasticities based on cross-sectional studies (Ewing and Cervero, 2010) nor regional travel-demand models (Rodier, 2009) are likely to offer more than rough predictions of the potential reduction in driving.

To determine the degree to which land-use policies are effective in reducing vehicle travel, a National Academies report recently called for more before-and-after studies (National Research Council, 2009). Before-and-after studies, considered

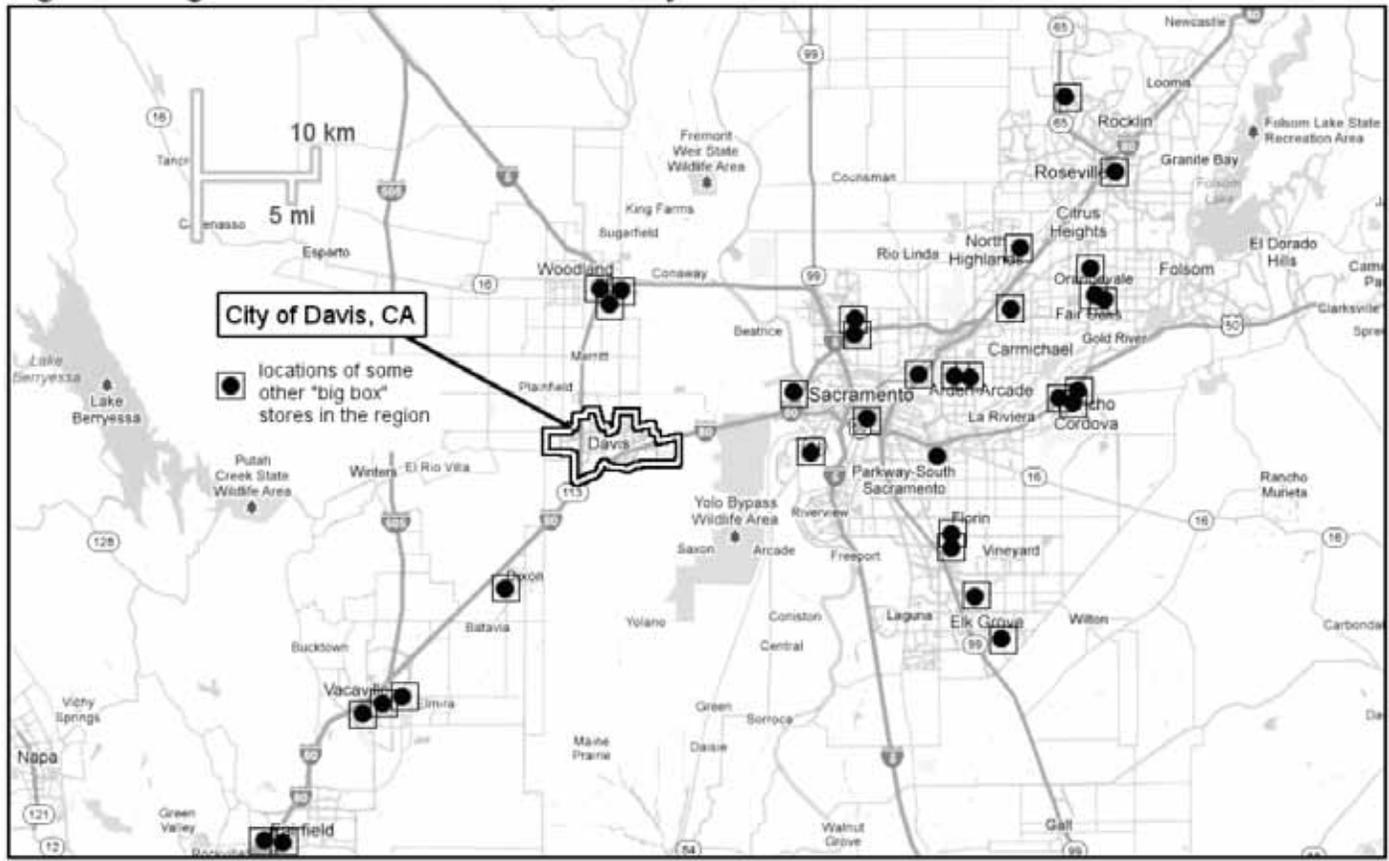
the “gold standard” for accurately measuring project impacts, are rare in the extensive literature on the links between land use and travel behavior. Rooted in program evaluation, these studies measure the behavior of interest before an intervention is implemented and compare it to behavior measured after the intervention. Such studies approximate true controlled experiments to the extent possible in the real world. A body of such studies would provide decision makers with more credible and reliable evidence on the effectiveness of alternative land-use policies in reducing driving than is available from cross-sectional studies or travel-demand models.

In this paper, we present a before-and-after study of the impact of the opening of the first “big-box”<sup>1</sup> store in Davis, California, on vehicle-miles travelled (VMT) for shopping. We use a repeated cross-sectional design to capture residents' shopping travel before and after the store's opening, allowing us to more directly identify a possible causal relationship between a change in land use and VMT than is possible with studies that simply compare behavior across communities. Although the observed change in VMT is specific to the Davis context, the findings support the general proposition that bringing retail destinations closer to residences could help reduce vehicle travel, thus contributing one piece of evidence to the body of stud-

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<sup>1</sup>Big-box stores are generally defined as very large stores, sometimes as large as 200,000 square feet, usually part of a chain, selling either general merchandise or a particular line of goods.





**Figure 2:** Big-box stores in the Davis vicinity

be inherently incompatible with sustainability goals as well as Davis culture. In contrast, others argued that Davis residents already shopped at stores like Target in other cities, and that a Davis Target would fill a retail need, keep sales tax revenues within the city, and reduce driving. Narrowly approved by a 674-vote margin, the store opened on October 11, 2009.

The concerns about Target coming to Davis echoed criticisms frequently voiced about big-box stores in general in the United States and elsewhere. Studies show, for example, that Walmart's entry into a new market is associated with a decline in small retailers (Basker, 2005; Jia, 2005), while other studies have addressed the impact on wages and public subsidies (Boarnet et al., 2005; Dube and Jacobs, 2004). Although impacts on traffic in the surrounding area are usually studied as a part of the project approval process, little attention has been given to the potential of such stores to reshape travel behavior more generally. An understanding of such changes is important, given the fact that non-work travel accounted for most of the growth in average VMT and vehicle trips per household from 1983 to 2001 (Transportation Research Board, 2011); for shopping alone the average annual person miles traveled

per household grew 90 percent during this period, and shopping frequency, measured as the average annual person trips per household, grew nearly 50 percent (Hu and Reuscher, 2004). In light of California's climate-change policies, the question of the impact of Target on vehicle travel for Davis residents was especially important. Whether Target would increase or decrease driving depended on three components, as follows.

First, would trips to Target replace trips to stores outside of Davis or stores within Davis? The answer to this question would determine the change in average travel distance for each shopping trip. Theory posits that a retail center's ability to attract consumers depends on its attractiveness and proximity to customers relative to the attractiveness and proximity of competing venues (Lakshmanan and Hansen, 1965). Previous studies demonstrate how consumers balance attractiveness and distance, oftentimes opting for more distant destinations offering more desirable qualities. For example, a study in Singapore found that suburbanites made fewer shopping trips to nearby neighborhood shopping centers following the opening of an upscale suburban shopping mall, though they also made fewer trips to the more distant downtown (Lee and Yong, 1998). A

<sup>2</sup>The online community discussion is archived at [http://daviswiki.org/Target\\_Debate](http://daviswiki.org/Target_Debate).

Flemish study showed that residents in more urbanized areas were much more likely to travel farther than necessary for shopping, exercising greater choice among a wider variety of destinations, than rural residents who more often chose the closest destination (Boussaw et al., 2011). Indeed, a study in Finland concluded that new out-of-town retail locations mostly affected nearby residents and had little effect on trips to the central city and neighborhood stores (Marjanen, 1995), while a study in the Puget Sound region showed that urban residents made the overwhelming majority of their shopping trips outside the neighborhood rather than close to home (Krizek, 2003).

Second, it was possible that Target would lead to a shift in mode, particularly if driving trips to Target replaced walking or bicycling trips to downtown or neighborhood centers. Of course, it was also possible that walking, bicycling, or transit trips to the Davis Target would replace trips to other Target (or similar) stores outside of Davis. As studies in Texas and California show, walking to stores is primarily a function of distance, though other factors also come into play (Handy and Clifton, 2001; Handy et al., 2006). For example, another California study found that the environment surrounding a shopping center had a significant influence on mode share (JHK and Associates and K.T. Analytics, 1993). The importance of the surrounding environment is also highlighted by two studies from outside the United States. In Prague, new shopping malls in highway-adjacent locations on the urban fringe were associated with a decline in walking and an increase in driving for shopping trips (Newmark et al., 2004). Conversely, urban infill malls in Haifa, Israel, produced a decline in car trips, particularly among consumers who previously shopped at malls on the urban fringe (Shifan and Newmark, 2002).

Third, how would Target affect the frequency of shopping trips? It was possible that the new store would generate new shopping trips given that it meant a significantly shorter distance to the nearest Target for Davis residents. It was also possible that the new store would lead to fewer trips overall, given the increased potential for “one-stop shopping” that a store like Target offers, or that trips to Target would replace trips to other stores on a one-to-one basis. Many previous studies have found that trips to new shopping destinations are largely redistributed from existing locations, because, for example, they would otherwise have been made to other retail locations (Shifan and Newmark, 2002; Kamali and Crow, 1988; Kittelson and Lawton, 1987). Entirely new shopping trips, as documented in one study, were only about 5 percent of all shopping trips (Kittelson and Lawton, 1987). However, other evidence suggests that a greater variety of shopping destinations leads to greater frequency of shopping trips overall (Handy, 1996). In the Puget Sound region, residents of areas with access to more

retail and services made more frequent trips for shopping and other personal maintenance, though they made fewer stops on such trips (Krizek, 2003).

The answers to these three questions together determine the effect of the Target opening on shopping VMT in Davis. The three components of change could potentially offset each other, leading to little change in VMT, or work together to produce substantial changes in VMT. Previous studies exploring the complex interactions among the retail landscape, the urban context, and shopping behavior suggest that more proximate retail will not necessarily reduce shopping travel. For example, one study showed that although urban residents’ non-work trips were shorter than those of rural residents, urbanites make such trips more frequently, offsetting environmental benefits to some degree (Boussaw et al., 2011). In Prague, customers at new malls on the periphery shopped less frequently than they had before, offsetting at least in part the increased distance to the new malls, though the impacts on overall VMT were not assessed (Newmark et al., 2004). A study in the San Francisco Bay Area concluded that increasing density of retail opportunities within a four-mile radius of the home location can reduce VMT and vehicle hours traveled, though reductions are small relative to those from a better balance of jobs and housing (Cervero and Duncan, 2006). In Austin, Texas, a study found that walking to stores is more common in traditional neighborhoods but concluded that creating more local shopping opportunities, as might exist in a traditional community, would not significantly reduce shopping-related vehicle travel (Handy and Clifton, 2001). In light of such varied findings and their apparent dependence on the specific context, the effect of the Davis Target store—closer than other big-box stores but farther than downtown or neighborhood centers for most residents—was difficult to predict in advance.

### 3 Methodology

We used an online survey to measure shopping-related VMT among Davis residents before and after the Target store opened. We considered but rejected other methods sometimes used to measure household VMT. We reasoned that travel diary surveys impose a significant respondent burden and because shopping trips occur on an irregular basis, a one-day diary can mischaracterize shopping travel, particularly more occasional, long-distance trips. Global Positioning Systems (GPS) and other in-vehicle devices can be used to track vehicle travel, but cannot easily isolate shopping trips or capture travel by other modes, and furthermore can be logistically complicated and expensive to deploy. Instead, we used a simple 20-minute survey relying on respondents’ recall of several different compo-

**Table 1:** Survey sample and city of Davis population characteristics

	Davis population <sup>a</sup>		Survey sample		
	Among individuals age 18+	Among individuals age 25+	Among individuals age 18+	Among individuals age 25+	Age 25+ and weighted by 5-year age group
Female	53.2%	52.7%	55.1%	54.6%	56.2%
Median age	32.0	46.0	52.0	52.0	46.0
Age 18-24	39.7%		2.9%		
Age 25-34	15.5%	25.8%	14.3%	14.7%	25.8%
Age 35-44	11.5%	19.0%	15.9%	16.3%	19.0%
Age 45-54	12.4%	20.6%	21.6%	22.2%	20.6%
Age 55-64	10.7%	17.8%	21.8%	22.4%	17.8%
Age 65-74	5.4%	8.9%	14.4%	14.8%	8.9%
Age 75+	4.8%	8.0%	9.2%	9.5%	8.0%
Currently in school <sup>b</sup>	40.8%	12.2%	9.7%	7.8%	12.7%
Bachelor's degree or more <sup>b</sup>	48.1%	68.4%	84.5%	85.4%	86.3%
Employed <sup>b</sup>	59.4% <sup>c</sup>	61.4%	61.8%	62.0%	66.6%
	Among all households				
Average household size	2.55		2.54	2.52	2.61
Person living alone	23.9%		19.8%	20.1%	18.1%
Lives with non-family roommates	28.1%		7.9%	6.6%	9.7%
Lives with family	47.9%		72.3%	73.3%	72.2%
Children present (<18 years)	19.70%		30.6%	31.3%	33.1%
Mean income <sup>b,d</sup>	\$81,863		\$90,322	\$91,997	\$87,350
Among families <sup>b</sup>	\$103,045		\$103,230	\$103,920	\$100,880
Among non-family households <sup>b,d</sup>	\$53,840		\$53,819	\$56,354	\$49,996
Median income <sup>b,d</sup>	\$80,487		\$80,487	\$82,912	\$79,115
Among families <sup>b</sup>	\$90,839		\$91,170	\$92,496	\$89,621
Among non-family households <sup>b,d</sup>	\$47,956		\$47,950	\$50,174	\$46,498
Household owns a vehicle <sup>b</sup>	93.2%		n/a	n/a	n/a
Level of vehicle access					
Never	n/a		1.4%	1.3%	1.5%
Sometimes	n/a		8.2%	7.6%	9.1%
Whenever I want	n/a		90.4%	91.1%	89.4%

<sup>a</sup> Source is 2010 U.S. Census except where noted.

<sup>b</sup> Source is 2010 American Community Survey 5-year estimates (2006-2010).

<sup>c</sup> For population age 16+ rather than 18+.

<sup>d</sup> Represents household income for all figures from the Census but individual income for those in non-family households in the survey sample. Survey sample income levels are based on the midpoint values of six categorical ranges.

nents of shopping travel—destinations, modes, and frequency.

### 3.1 Sampling and recruitment

We administered two online surveys, one in September 2009 shortly before the Target store opened on October 10, 2009, and a second one in October 2010. To simplify recruitment, we opted to conduct a repeated cross-sectional survey, with two separate sets of respondents for each year, rather than a panel survey, in which the same respondents from year one would need to be recontacted in year two. In each year, we purchased

from a private marketing firm the names and mailing addresses of 5,000 randomly selected Davis residents (excluding the University of California Davis campus, but not excluding any students or staff living off campus). Potential respondents were mailed a letter addressed “Dear Davis resident,” with individual names printed on the envelopes. The letter invited the recipient to visit a website to complete the online survey or to contact the researchers for a paper version if they preferred. As an incentive to participate, respondents were given the option of entering a drawing for five \$100 cash prizes. Reminder postcards were sent to all potential respondents a week later.

In total, 1018 and 1025 residents completed the survey in 2009 and 2010, respectively, including 103 who requested and completed the survey on paper. After accounting for letters returned by the postal service as undeliverable (about 600 each year), the response rates were 22.9 percent in 2009 and 23.1 percent in 2010.

The two separately drawn samples are consistent with one another in terms of respondents' demographic characteristics and general travel-related characteristics, such as possession of a driver's license, automobile access, and use of bicycles for transportation. However, the overall sample differs from the Davis population in several ways, notably with respect to age. Especially under-represented are residents aged 18-24, many of whom are likely to be University of California (UC) Davis students living off campus. Because the sampling frame from which we drew potential participants might be prone to miss this group, whose residences are more transitory, we decided to exclude them altogether, focusing on the population age 25 and older. Data on the characteristics of this population are not readily available, so it was not possible to assess how closely the remaining sample matches the population, but differences between our sample and the adult population as a whole are shown in Table 1. (The much lower share of individuals living with family in the population, in comparison to the sample, reflects the presence of students.) To correct for any remaining bias, we considered two different ways to weight the sample, by five-year age groups and by presence of children, since prior research has shown that households with children have different shopping patterns than those without (Srinivasan and

Ferreira, 2002; Gliebe and Koppelman, 2002). We found that the age-weighted, children-weighted, and un-weighted results were similar; we present the age-weighted results in this paper.

### 3.2 Survey instrument

The online surveys were programmed in LimeSurvey survey software and presented on a website hosted on UC Davis servers. In each year, the survey asked respondents about their most recent visit to downtown Davis and its purpose, as well as whether they had shopped for a list of specific types of items at any time in the last year in each of three different geographic areas: downtown Davis, in Davis but outside downtown (and not at Target in year two), anywhere beyond Davis, or online. (Shopping conducted via "mail-order" catalogs was not mentioned on the survey and therefore not measured unless respondents made a purchase from such a catalog online and decided to count it as a part of online shopping.) The survey defined downtown as bounded by particular streets and showed a map of the area. The year-two survey also asked about shopping at the Davis Target. The types of items included in the survey, shown in Table 2, were identified as the sort offered at Target; groceries were intentionally excluded. "Shopping" was defined to include not just purchasing but also browsing and gathering information about an item.

For each shopping location, we asked respondents about what types of items they had shopped for (in the last year) in that location, the typical frequency with which they shop in that location, and for the most recent occasion, a series of other

**Table 2:** Types of items included in the scope of shopping<sup>1</sup>

Bedding and bath items	Sheets, pillows, bedspreads, towels, shower curtains, soap dishes, etc.
Books or electronic media	Books, DVDs, mp3s, video games
Cleaning supplies	Mop, sponges, detergent, cleaner, etc.
Clothing for adults	Clothes, shoes, accessories for women and/or men
Clothing for children	Clothes, shoes, accessories for children and babies
Electronics	Phones, cameras, audio equipment, video game consoles, and related items
Furniture	Tables, chairs, sofas, bookcases, lamps, etc.
Garden supplies	Plants, pots, potting soil, plant food, etc.
Hardware	Hand tools, hooks, knobs and pulls, etc.
Home décor	Curtains, rugs, picture frames, vases, etc.
Office, school, or art supplies	Paper, notebooks, pens, wrapping paper, scrapbooking supplies, etc.
Patio items	Patio furniture, barbecues, umbrellas, etc.
Small appliances	Microwaves, blenders, irons, vacuum cleaners, etc.
Sporting goods	Sports equipment, fitness equipment, camping equipment, bicycles, etc.
Storage and organization	Storage boxes or baskets, closet systems, shelving, etc.
Toiletries or cosmetics	Shampoo, soap, toothpaste, make-up, etc.
Toys or games	Character toys, stuffed animals, board games, puzzles, playhouses, etc.

<sup>1</sup> Respondents were asked, "Have you shopped at a store in [location] for any of the following items within the last year? (Remember that we mean not just purchasing, but also browsing or gathering information about an item.)"

questions: how long ago the occasion was, what mode they had used to get there, the stores visited and their locations, whether the trip was on the way elsewhere and, if so, how far out of the way, the items purchased or browsed for, whether they purchased items, and, if so, how much they spent. For shopping at the Davis Target in year two, we also asked respondents where they would have shopped if the Davis Target had not been available and what mode of transportation they would have used to get to the alternative location(s).

Finally, the surveys also included questions to measure respondents' attitudes about shopping options in each location as well as their general attitudes about shopping, time use, transportation modes, and environmental issues. The surveys concluded with questions capturing socio-demographic characteristics of individuals and their households and the cross-streets near where they lived.

### 3.3 Calculation of vehicle miles generated by shopping

The calculation of average shopping VMT in each year consisted of several steps involving data from different questions from the survey and several critical assumptions. The first step was to estimate the distance from home to the store for each location category based on the respondent's most recent trip in each category. The second step was to convert this distance to vehicle miles traveled per trip, adjusting for whether the shopping trip was a stand-alone trip or a part of a trip chain and depending on whether the trip was made by car. The final step was to account for the average frequency of shopping in each location category. These steps yield the estimated shopping VMT per month for each location category for each respondent. The sum over all location categories represents the total shopping VMT per month for each respondent. The details of each step are as follows.

First, we geocoded the location of the intersection in Davis nearest to each respondent's home (which they reported on the survey) and the addresses of the stores they reported visiting, and then calculated the shortest-time network distance between the two using the Network Analyst tool in ArcGIS. When respondents reported visiting more than one destination in a location category (such as "downtown"), we used the distance of the farthest one as the destination of record for that location category; we did not calculate the total tour distances from home to all the destinations listed. For all destinations more than 50 miles away and for any destination outside of Davis where the exact store location could not be identified, we used distances from respondents' homes to a single centroid of the destination city rather than to addresses of specific stores, given that distances within the destination city are small rela-

tive to the distance from Davis to that city. Because the section on shopping beyond Davis asked respondents about whatever shopping outside of Davis was most recent, some destinations were quite far and almost certainly part of a trip made for other purposes, including 25 destinations outside California or the United States. For the purposes of this analysis, we decided to exclude the 59 cases for which the most recent shopping occasion beyond Davis was more than 75 miles away. For any respondents whose home locations were unknown (230 cases or 11 percent), we could not calculate exact distances to any shopping destinations, but we assumed a starting home location at a centroid near downtown for shopping destinations outside of Davis and left distances for destinations within Davis as missing. Ultimately, we successfully calculated valid shopping distances for about 90 percent of the respondents' shopping in each location within Davis and 99 percent for beyond Davis.

Based on these calculations, we estimated the overall VMT generated by the shopping itself as summarized below. First, we accounted for whether the most recent shopping occasion generated new travel or was conducted on the way somewhere else, for instance, as a part of a trip chain. The survey asked respondents, "Thinking about any other activities that you may have conducted during the same outing, how important was doing this shopping to that particular outing?" asking them to choose between "I wouldn't have made the trip otherwise," "I probably would have made the trip anyway, to do other things," and "I definitely would have made the trip anyway, to do other things." For any that probably or definitely would have made the trip otherwise, we asked whether they traveled out of their way to shop and, if so, "How far out of your way did you go?" We then gave them four choices of detour-distance categories: "less than 1 mile," "1–3 miles," "3–10 miles," or "more than 10 miles." For those who reported they would not have made the trip otherwise, we assumed the shopping was a single-purpose, home-based trip. Second, we counted travel miles as VMT if a respondent indicated having driven or ridden as a passenger in a private vehicle during his or her most recent trip in that location category. Trips by all other modes, including walking, biking, and riding transit, were not counted toward VMT. For each respondent, VMT per shopping trip in each location category was determined as follows:

Vehicle-miles traveled by each respondent (per occasion shopping in each location category) =	0, if they did not shop there at all
	0, if they used transit, walking, or biking to get there
	0, if they probably/definitely would have made this trip for other activities and the shopping was directly on the way
	If they probably/definitely would have made this trip for other activities but went out of their way to shop, then the miles generated by the shopping were set to equal the following values, for each of four detour-distance categories respondents could indicate:
	0.75 miles, if they went out of their way "less than 1 mile"
	2 miles, if "1-3 miles"
6.5 miles, if "3-10 miles"	
11 miles, if "more than 10 miles"	
If they would not have made the trip otherwise (i.e. shopping at that location was the only reason for the trip), then miles generated was calculated as two times the one-way distance from their home to the farthest destination visited within that location category.	

We note that the detour distances are necessarily coarse estimates, and that assuming just 11 miles for the "more than 10 miles" category is conservative, meaning that this formula may err on the side of overestimating the savings in travel resulting from trip-chaining, especially on longer trips outside of Davis. In addition, assuming that all other trips were home-based

(even if shopping at that location was the main purpose of the trip) might not be accurate, potentially affecting some location categories more than others.

We estimated the shopping frequency for each respondent based on a combination of his or her answers to two different survey questions. Respondents were first asked to indicate how often they shopped in each location in the last year, from among four answer categories. However, because the answer categories covered such a broad range of frequency levels (especially at the more-frequent end of the spectrum), we assigned specific monthly values from within these ranges based on respondents' answers to another question: how recent the last occasion was, from among seven answer categories. We used these recentness responses to assign values at the minimum, maximum, or middle of the annual frequency range (divided by 12 to reflect a monthly average), as shown in Table 3. VMT per month was then calculated as this frequency multiplied by the VMT generated on the most recent trip for each location.

Overall shopping VMT per month was the sum over the location categories, as follows:

$$\text{for year one} = \text{downtown Davis} + \text{in Davis but outside downtown} + \text{beyond Davis}$$

$$\text{for year two} = \text{downtown Davis} + \text{in Davis but outside downtown (and not Target)} + \text{at the Davis Target store} + \text{beyond Davis}$$

**Table 3:** Assumed number of shopping occasions per month, for each combination of frequency and recentness responses

		Response to "How often did you shop there in the last year?"				
		"Once a week or more" (4.33 – 30.42 per month)	"1 – 3 times a month"	"5 – 11 times this last year" (0.42–0.92 per month)	"1 – 4 times this last year" (0.08 – 0.33 per month)	Did not shop there
Response to "When was the most recent occasion?"	"0 – 2 days" (1 day ago = 3.5/week, 15.21/month, or 182.50/year)	15.21	3.00	0.92	0.33	0.00
	"3 – 6 days" (4.5 days ago = 1.28/week, 5.53/month, or 66.36/year)	5.530				
	"1 – 2 weeks" (10.5 days ago = 2.64/month or 31.74/year)	4.33	2.65			
	"3 – 4 weeks" (24.5 days ago = 1.19/month or 14.31/year)		1.19			
	"1 – 2 months" (45 days ago = 0.66/month or 7.93/year)	1.00	0.66			
	"3 – 6 months" (135 days ago = 0.22/month or 2.68/year)		0.42	0.22		
	"7 – 12 months" (287.5 days ago = 0.11/month or 1.27/year)			0.11		

We note that this method of summing across location categories could be somewhat prone to capture more travel in year two than year one, and therefore biased to show an overall increase in shopping travel. In particular, because respondents might be more likely to report behavior if queried about it, the fact that we had one more section querying them about their behavior in year two (for Target shopping) might lead respondents to record more trips in year two, even if they did not in fact make more trips. Further, because we segmented the survey questions into discrete sections addressing recent shopping in each of four shopping locations, there was potential for double counting of trips that spanned more than one of the geographic areas (e.g., visiting stores both within and outside our “downtown” boundary area in the same trip). While we tried to eliminate these biases, there was some possibility of more double counting in year two given the greater number of location categories in that year’s survey. This potential bias toward higher VMT in year two could lead to an inflated estimate of the impact of Target if the results show an increase in VMT but an under-estimate of the impact in the case of a decrease.

Because of the repeated cross-sectional design of the study, to evaluate the change in shopping VMT between year one and year two, we calculated the difference between the average across all respondents in each year. In contrast, a panel survey would have enabled a calculation of the change in shopping VMT for each respondent, as well as an analysis of the factors associated with changes in shopping VMT at the individual level.

## 4 Results

Our objective was to determine the change in shopping VMT resulting from the opening of the Target store. Because changes in VMT may come from changes in distances, chaining, modes, and/or frequencies for the different shopping destinations, we first present the results on changes in each of these components.

### 4.1 Distance, chaining, and mode

The four shopping locations differed in their average distance from respondents’ homes, the extent to which respondents tended to shop there on the way to somewhere else, and the modes of transportation they used when visiting these locations. Within each location category, however, there were no significant differences in year one versus year two in these components, and results are presented for both years combined. The average one-way distance from respondents’ homes to the store in both years was shortest for destinations outside downtown (excluding Target), at 2.0 miles, and slightly farther to downtown destinations, at 2.2 miles, and to the Davis Target, at 3.5 miles away, on average. Destinations beyond Davis were all more than 7 miles and averaged 17.7 miles from home (see Table 4).

In addition to requiring longer travel distances from respondents’ homes, shopping at Target and at destinations outside of Davis was less likely to be conducted on the way

**Table 4:** Distances and mode used by shopping location category

	One-way distance (miles) <sup>a</sup>	Mode of transportation used on most recent trip								Weighted N <sup>b</sup>
		Any driving			Any non-driving					
		Total	Driver	Passenger	Total	Transit	Bicycle	Walk	Other	
Downtown	2.17	81.1%	74.7%	6.3%	18.9%	0.8%	13.2%	4.9%	0.1%	1570.6
Outside downtown										
Not at Target	2.02	80.1%	75.9%	4.1%	19.9%	0.8%	12.4%	6.5%	0.2%	1380.2
Target	3.54	92.8%	84.9%	7.9%	7.2%	0.6%	5.3%	1.3%	0.1%	713.5
Beyond Davis	17.73	98.3%	87.0%	11.3%	1.7%	1.3%	0.1%	0.3%	0.0%	1521.0

Comparisons across locations	Average distance (miles)		Percent driving	
	Difference	p-value <sup>c</sup>	Difference	p-value <sup>d</sup>
Downtown vs. outside downtown (not at Target)	+ 0.15	0.000	+ 1.0%	0.483
Downtown vs. Target in Davis	- 1.38	0.000	- 11.7%	0.000
Target in Davis vs. other outside downtown	+ 1.52	0.000	+ 12.7%	0.000

<sup>a</sup> Total distance from respondent’s home to the shopping destination. Any shopping at destinations greater than 75 miles from home are excluded from the analysis.

<sup>b</sup> Respondents are weighted by five-year age groups so that the age distribution of the sample matches that of the population, among those age 25 and older.

<sup>c</sup> Significance level for t-test of difference of means (across locations).

<sup>d</sup> Significance level for a  $\chi^2$ -test of independence in percent driving (across locations).

to other activities, with about 70 percent reporting that they “wouldn’t have made the trip otherwise,” compared with 60 percent of those shopping at other destinations within Davis, both downtown and outside downtown (see Table 5). When on the way to other activities, Target and destinations outside of Davis were more likely to be farther out of the way. Outside of Davis, about 13 percent of those shopping on their way to somewhere else reported traveling more than 10 miles out of their way. Shopping downtown was associated with the smallest detour distances, followed by shopping outside downtown at stores other than Target, and then Target. However, it is notable that of those shopping at destinations outside of Davis on their way to somewhere else, over two-thirds reported traveling less than 3 miles out of their way, showing that on many occasions, shopping outside of Davis might contribute fewer overall travel miles than a shopping-only, round trip within Davis. In all shopping locations, over 80 percent of respondents reported having traveled by car, and almost all of those shopping outside of Davis reported doing so (see Table 4). Within Davis, nearly 20 percent reported using non-driving modes for shopping trips, both for destinations within and outside downtown other than Target. However, a much smaller share, about 7 percent, used non-driving modes when shopping at the Davis Target.

**4.2 Shopping frequency and items shopped for**

In contrast, how frequently people shopped and at what locations changed markedly between year one and year two. The average number of shopping trips, for those who shopped at least once in the last year, declined between year one and year

two, with the largest decline at destinations beyond Davis, followed by Davis stores outside downtown other than Target, followed by stores in downtown (see Table 6). In year two, trips to Target averaged about two per month. These results suggest that new trips to Target roughly offset reductions elsewhere, and that respondents substituted trips to Target for trips outside of Davis and outside of downtown to a greater degree than they did for downtown trips. The proportion of respondents who reported having shopped at least once at any store in Davis (for at least one of the listed items) increased while the portion having done so at stores outside of Davis decreased. Within Davis, the portion having shopped at stores outside of downtown other than Target decreased by a substantial 11 percentage points, while the portion shopping at stores downtown did not change. Another indicator of changes in shopping patterns was changes in how many types of specific items people reported having shopped for in each location. The percent of people shopping at destinations outside downtown declined in year two for 10 of the 17 item categories, and for 14 of the 17 item categories at destinations beyond Davis (Table 7). By contrast, the percent shopping downtown declined slightly for only one of the item categories (“bedding and bath items”) and for none of the online shopping. The percent of people shopping at any store outside downtown, including Target in year two, increased significantly in almost all item categories, suggesting that while Target might have drawn some business away from other Davis stores outside of downtown, it probably also replaced some shopping beyond Davis and could have generated altogether more shopping for these types of items.

**Table 5:** Extent that shopping was on the way to other activities, by location category

Shopping location	This shopping was the main purpose	This shopping was done on the way to somewhere else						Mean detour distance <sup>a</sup>	Total shoppers (weighted <i>N</i> <sup>b</sup> )
		It was directly on the way	Had to detour						
			Any distance	Less than a mile	1-3 miles	3-10 miles	More than 10 miles		
Downtown	57.4%	29.9%	12.7%	9.2%	3.0%	0.6%	0.0%	0.38	1568.4
Outside downtown									
Not at Target	60.1%	29.62%	10.2%	3.7%	5.0%	1.2%	0.4%	0.59	1406.3
Target	69.8%	17.52%	12.7%	2.6%	7.4%	2.7%	0.0%	1.13	691.1
Beyond Davis	68.5%	18.38%	13.1%	1.0%	2.1%	6.0%	4.0%	2.76	1568.4
Comparisons across locations				Percent for whom shopping was the main purpose		When not the main purpose, percent who had to detour			
				Difference	p-value <sup>c</sup>	Difference	p-value <sup>c</sup>		
Downtown vs. outside downtown (not at Target)				- 2.7%	0.130	- 4.1%	0.116		
Downtown vs. Target in Davis				- 12.4%	0.000	+ 12.2%	0.001		
Target in Davis vs. other outside downtown				+ 9.7%	0.000	- 16.3%	0.000		

<sup>a</sup> Calculated by assuming the values of 0 (when directly on the way) and 0.75, 2, 6.5, and 11 miles, for each of the distance categories, respectively.

<sup>b</sup> Respondents are weighted by five-year age group so that the age distribution of the sample matches that of the population, among those age 25 and older.

<sup>c</sup> Significance level for a  $\chi^2$ -test of independence in percent (across locations).

**Table 6:** Shopping frequency by location category and year

	Year 1	Year 2	Change across years			<i>p</i> -value <sup>b</sup>
			Average	Lower bound <sup>a</sup>	Upper bound <sup>a</sup>	
Percent who shopped (at least once in the last year):						
Within Davis (any location)	99.1%	99.9%	+ 0.8%	+ 0.1%	+ 1.5%	0.025
Downtown	96.6%	97.0%	+ 0.4%	- 1.3%	+ 2.1%	0.642
Outside downtown (any location)	92.5%	97.9%	+ 5.4%	+ 3.4%	+ 7.4%	0.000
Not at Target	92.5%	81.5%	- 11.0%	- 14.3%	- 7.7%	0.000
At Target	n/a	90.7%	n/a	n/a	n/a	n/a
Beyond Davis	97.1%	93.3%	- 3.8%	- 5.9%	- 1.8%	0.000
Online	85.6%	86.6%	+ 0.9%	- 2.4%	+ 4.3%	0.580
Among those who shopped, average number of shopping occasions per month:						
Downtown	3.3	3.0	- 0.3	- 0.7	+ 0.05	0.084
Outside downtown						
Not at Target	4.3	3.4	- 0.9	- 1.4	- 0.4	0.000
At Target	n/a	2.1	n/a	n/a	n/a	n/a
Beyond Davis	3.5	2.5	- 1.1	- 1.4	- 0.7	0.000
Online	3.4	3.6	+ 0.2	- 0.3	+ 0.7	0.359
All locations, summed	13.2	12.6	- 0.6	- 1.5	+ 0.4	0.227
All physical locations, summed	10.3	9.5	- 0.8	- 1.6	- 0.04	0.040
Weighted <i>N</i> <sup>c</sup>	745.3 to 887.4	615.5 to 793.5				

<sup>a</sup> For 95% confidence interval.

<sup>b</sup> Significance level for a  $\chi^2$ -test of independence in percent shopping (across years) and for a t-test of difference of mean number of locations and mean number of trips (across years).

<sup>c</sup> Respondents are weighted by five-year age group so that the age distribution of the sample matches that of the population, among those age 25 and older.

### 4.3 Overall change in vehicle miles traveled

The average VMT generated by shopping in each location on any given trip is calculated by combining the results for distance, chaining, and mode (Table 8). The average per-trip VMT associated with shopping at destinations in Davis other than Target was about the same whether in downtown or beyond downtown at about 2.3 vehicle miles per trip. Given a greater average distance and a higher share of trips by car, shopping at Target generated significantly greater VMT per trip, at about 4.8 vehicle miles per trip on average (Table 8). As expected, shopping at destinations beyond Davis generated the most VMT per trip, at about 24.3 vehicle miles on average. Within location categories, there were no significant changes in the average VMT per trip across years.

Shifts in how often people shopped in each location category thus drove changes in monthly VMT per capita associated with shopping in each location and overall (Table 9). Monthly VMT associated with shopping at destinations beyond Davis and at non-downtown destinations other than Target both decreased by about a quarter (about 23.4 and 3.1 vehicle-miles per person per month, respectively, on average; see Table 9). These declines more than offset the increase in VMT associated with shopping at Target in year two, estimated to be about 8.4 vehicle miles per person per month. As a result, overall shop-

ping VMT at all locations decreased significantly in year two, by about 18.9 vehicle miles per person per month, or by about 19 percent.

The fact that the decline in VMT is primarily driven by shifts in where respondents shopped, rather than a decline in the frequency of shopping trips, lends support to the conclusion that the decline is attributable to Target rather than to the economic downturn. Trends in taxable sales apparently bolster this conclusion: Taxable sales in retail and food service declined from 2008 to 2009 in the state, the region, and Davis but increased from 2009 to 2010, though at a slower rate in Davis than in the region and the state.<sup>3</sup> The slight decline in overall shopping frequency noted earlier might reflect an increase in the efficiency of shopping trips within Davis following the opening of Target rather than a decline in buying in that Target enables shoppers to buy a wider variety of items in one place.

### 4.4 Comparison of real travel to Target versus hypothetical alternative destinations

As another test of the impact of Target on shopping travel, the year-two survey asked respondents what they would have done "on this occasion, if [they] hadn't been able to shop at the Davis Target," an approach used in prior studies to measure trip substitution (Handy and Clifton, 2001). As shown in Table 6,

**Table 7:** Change in the types of items shopped for, by shopping location

	Percent of people shopping for each category, averaged across all 17 categories <sup>a</sup>		Among item categories with a change <sup>c</sup>				
			Number with a decrease	Number with an increase	Percentage point change		
	Year 1	Year 2			Average	Smallest	Largest
Downtown	32%	31%	1	0	-4%	-4%	-4%
Outside downtown							
Not at Target	24%	18%	10	0	-9%	-3%	-16%
Any store <sup>b</sup>	24%	43%	0	16	+19%	+5%	+35%
Beyond Davis	49%	41%	14	0	-8%	-5%	-15%
Online	20%	22%	0	16	+20%	+36%	+6%

<sup>a</sup> The 17 item-type categories are shown in Table 2.

<sup>b</sup> Shopping anywhere within Davis but outside downtown (both years) and/or at the Davis Target (in year two).

<sup>c</sup> A  $\chi^2$ -test of the independence in the portion shopping for each item category (across years) is statistically significant at  $p < 0.05$ .

about 91 percent of the year-two respondents reported having shopped at Target. Among these, about 90 percent indicated that they would have shopped elsewhere for the items, while about 7 percent indicated that they “wouldn’t have shopped for these items at all,” and 3 percent reported that they would have shopped online only instead. Three-quarters of the alternative destinations reported were beyond Davis, making the average distance to the hypothetical destinations substantially greater than to Target, at 10.4 versus 3.5 miles (see Table 10). Respondents were equally likely to drive to the Davis Target as to their hypothetical alternative destinations. But because those alternatives tended to be farther away, we estimate that the number of vehicle miles generated when shoppers traveled from their homes to Target (without taking into account whether it was

on the way to other activities or how frequently it might have been done) was as little as a third of what it would have been had they shopped at the identified alternatives, suggesting a 67 percent savings in VMT as a result of the opening of the Davis Target. The extent to which shoppers might visit farther destinations less often than they do Target, or visit them on their way to other activities in their vicinity, would lessen the net reduction in VMT attributable to Target, bringing it more in line with the estimates shown in Table 9.

## 5 Discussion and conclusion

Our results show how the effects of a change in land use—in this case the opening of a major big-box chain store in a com-

**Table 8:** Average shopping VMT per trip, by location category and year

Location category	Vehicle miles per trip			Change across years			
	Both years	Year 1	Year 2	Average	Lower bound <sup>a</sup>	Upper bound <sup>a</sup>	<i>p</i> -value <sup>b</sup>
Downtown	2.30	2.35	2.24	-0.11	-0.35	+0.14	0.383
Outside downtown							
Not at Target	2.29	2.38	2.18	-0.20	-0.49	+0.10	0.189
At Target (Year 2)	4.79	n/a	4.79	n/a	n/a	n/a	n/a
Beyond Davis	24.27	23.81	24.82	+1.01	-1.11	+3.13	0.350
All locations (average)	8.35	9.15	7.45	-1.70	-2.57	-0.83	0.000
Weighted <i>N</i> <sup>c</sup>	671.5 to 1678.5	770.3 to 886.1	562.8 to 792.4				
					Difference across locations (both years combined)		
Comparison across locations				Average	Lower bound <sup>a</sup>	Upper bound <sup>a</sup>	<i>p</i> -value <sup>d</sup>
Downtown vs. outside downtown (not at Target)				+0.01	-0.2	+0.20	0.922
Downtown vs. Target in Davis				-2.5	-2.8	-2.1	0.000
Outside downtown (not at Target) vs. at Target in Davis				-2.5	-2.9	-2.1	0.000
Beyond Davis vs. Target in Davis				+19.48	+18.37	+20.59	0.000

<sup>a</sup> For 95% confidence interval.

<sup>b</sup> Significance level for a t-test of difference of means across years.

<sup>c</sup> Respondents are weighted by five-year age group so that the age distribution of the sample matches that of the population, among those age 25 and older.

<sup>d</sup> Significance level for a t-test of difference of means across locations.

munity where there previously was none—can be measured using a relatively simple before-and-after survey. We document a shift in where, how often, and for what products people shopped at other locations, as well as a reduction in VMT to shop for the types of items carried by Target. This result may at first glance be surprising: A single store’s existence could alter behavior enough that our survey methodology could detect it and that the effect was a reduction rather than an increase in travel. As such, our findings demonstrate the importance of the particular context at hand, especially the existing alternatives and the sorts of trips that are most likely to be displaced as a result of a proposed land-use change.

The context in this case is Davis, a city of 65,000 people where the only big-box options had previously been 10 to 15 miles away. Our results show that trips to the new Target mostly displaced vehicle trips to stores either outside of downtown or outside of Davis, rather than walking and biking trips to downtown, leading to a significant and sizable reduction in VMT: 18.9 miles per month per adult age 25 or older, totaling over

7.5 million miles of VMT per year, resulting in a reduction of over 2800 metric tons of carbon dioxide emissions.<sup>4</sup> While not every new big-box store will result in VMT reductions, our results offer support for the general policy of bringing shopping opportunities closer to residents, particularly when the comparable alternatives to the newly introduced store are far away.

Our results also provide evidence that some of the feared outcomes expressed prior to the public vote in 2006 did not come to pass. In particular, while much of the debate focused on the impact on downtown businesses, our findings suggest that downtown stores were the least affected, with a small reduction in shopping frequency and little change in the types of items shopped for, at least among the types of items included in the scope of the study. By contrast, Davis stores outside of downtown—many of which are national chain stores—seemed to take a bigger hit, with significant reductions in the frequency of shopping there and a reduction in the types of items for which people shopped. However, some downtown stores may have been especially affected. In January 2012, a

**Table 9:** Monthly shopping VMT per capita by location category and year

Location category	Monthly vehicle miles per capita		Change across years			
	Year 1	Year 2	Average	Lower bound <sup>a</sup>	Upper bound <sup>a</sup>	p-value <sup>b</sup>
Downtown	6.84	6.01	- 0.84	- 2.19	+ 0.52	0.225
Outside downtown						
Not at Target	8.66	5.54	- 3.12	- 4.79	- 1.45	0.000
At Target (Year 2)	n/a	8.43	n/a	n/a	n/a	n/a
Beyond Davis	82.87	59.49	- 23.38	- 37.72	- 9.04	0.001
All locations (sum)	98.38	79.47	- 18.91	- 33.98	- 3.83	0.014
Weighted N <sup>c</sup>	835.3 to 853.3	671.5 to 737.7				

<sup>a</sup> For 95% confidence interval; the estimated standard deviation used for the “all locations” sum takes into account the covariance among location categories.

<sup>b</sup> Significance level for t-test of difference of means (across years).

<sup>c</sup> Respondents are weighted by five-year age group so that the age distribution of the sample matches that of the population, among those age 25 and older.

**Table 10:** Miles to Target versus hypothetical alternative destinations

	Average among Year 2 Target shoppers		Difference in shopping somewhere other than Target				N <sup>e</sup> for paired sample
	Actual (at Target)	Hypothetical (at alternative)	Average	Lower bound <sup>a</sup>	Upper bound <sup>a</sup>	p-value <sup>b</sup>	
One-way distance shopper would travel to shop	3.54	10.44	+ 6.93	+ 6.40	+ 7.46	0.000	629.4
Percent that would make a physical trip to shop	100.0%	89.7%	- 10.3%	- 12.5%	- 8.1%	0.000	712.9
Percent of these that would drive to shop	92.8%	94.6%	+ 1.4%	- 0.6%	+ 3.4%	0.175	635.0
Vehicle miles generated by a round trip from home to this destination <sup>d</sup>	6.73	20.33	+ 13.72	+ 12.65	+ 14.78	0.000	626.0

<sup>a</sup> For 95% confidence interval.

<sup>b</sup> For paired-sample t-test of difference of means for the real versus hypothetical answers.

<sup>c</sup> Respondents are weighted by five-year age group so that the age distribution of the sample matches that of the population, among those age 25 and older.

<sup>d</sup> Calculated as simply the doubled one-way distance and, unlike the results in Table 9, is not adjusted for how often respondents might make the trip or whether it might be on the way to other activities.

locally owned toy store in downtown closed after 18 years, citing both the economic downturn and the opening of Target as causes (Hudson, 2012). While the question of economic impacts is beyond the scope of this paper, our survey collected information about purchases that could prove useful in future analyses on this question. It is interesting to note that while just over 50 percent of voters supported the Target store, nearly 90 percent of respondents reported having shopped there. In addition, agreement that “It was a good decision to allow a Target store in Davis” increased significantly from 59.9 percent to 67.8 percent of respondents in year two (with  $p=0.001$ ).

With respect to the environmental impact, it is important to note that the change in VMT evaluated here is just one element of Target’s overall impact on emissions and on environmental quality more broadly. First, our focus was limited to shopping for select types of items, notably excluding groceries. Furthermore, we neither considered the store’s effect on shoppers who do not live in Davis nor on the emissions associated with the production and movement of Target inventory—which depend on where and how items are produced and warehoused, how far they are shipped, by what mode, and how frequently—nor other impacts of the store’s physical presence. Finally, our methodology includes a number of limitations, described earlier, that should be kept in mind when interpreting our results.

We embarked on this before-and-after evaluation as a step toward improving the quality of the evidence on the effectiveness of land-use policies in reducing vehicle travel and associated greenhouse gas emissions. While this study illustrates some of the challenges inherent in measuring VMT, particularly the challenge of measuring respondents’ shopping travel through user-friendly instruments, it provides specific evidence of the impact of a change in the shopping environment on shopping-related travel in the particular context of the Target store in Davis. Further studies are needed to better understand how other land-use changes might impact travel in other geographic contexts. Such studies also offer an opportunity to develop a consensus methodology for measuring VMT that local governments can use in establishing baseline levels, a critical step toward understanding whether local land-use policies are making a difference for climate policy.

## Acknowledgements

This study was funded by grants from the UC Davis Sustainable Transportation Center, supported by the U.S. Department

of Transportation and the California Department of Transportation (Caltrans) through the University Transportation Centers program; the Sustainable Transport Program funded by UC Multicampus Research Programs and Initiatives; and the Hewlett Foundation. Thanks to Josh Miller, Calvin Thigpen, Sam Halstead, and Andrew Holguin for their contributions to the project.

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<sup>3</sup>Data are from the California State Board of Equalization (<http://www.boe.ca.gov/news/tsalescont10.htm>); 2009 and 2010 totals are based on first three quarters of the fiscal year only.

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<sup>4</sup>Based on an estimate of 33,069 adults (age 25 and older) from the 2006-10 American Community Survey, average fuel economy of 23.8 miles per gallon in 2009 as reported by the Bureau of Transportation Statistics ([http://www.bts.gov/publications/national\\_transportation\\_statistics/html/table\\_04\\_23.html](http://www.bts.gov/publications/national_transportation_statistics/html/table_04_23.html)) and 8.887 kg of CO<sub>2</sub> per gallon, as reported by the U.S. EPA (<http://www.epa.gov/otaq/climate/documents/420f11041.pdf>).