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The Intersection of Urban Form and Mileage Fees: Findings from the Oregon Road User Fee Pilot Program

MTI Report 10-04

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MTI REPORT 10-04

THE INTERSECTION OF URBAN FORM AND MILEAGE FEES: FINDINGS FROM THE OREGON ROAD USER FEE PILOT PROGRAM

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16. Abstract

This report analyzes data from the 2006-2007 Oregon Road User Fee Pilot Program to assess if and how urban form variables correlate with travel behavior changes that participants made in response to the mileage fee program. The study tested the impact of two fee structures, a variable charge and a flat rate, on seven types of vehicle miles traveled (VMT), and finds that charging a noticeably higher fee for driving in congested conditions can successfully motivate households to reduce their VMT in those times and places where congestion is most a problem. Households in both traditional (mixed use, dense, transit-accessible) and suburban (single-use, low density) neighborhoods will likely reduce their peak-hour and overall travel under a charging scheme that charges a high-rate for peak-hour travel, though households in the traditional neighborhoods will do so more.

It also finds that a mileage fee program that charges a high rate during the peak hour is likely to strengthen the underlying influence of urban form on travel behavior. In other words, land use probably will matter more to transportation planning if the nation shifts to a new paradigm of mileage-based financing and pricing system, especially one that charges higher rates during peak hours. This finding suggests that switching from fuel taxes to mileage taxes would strengthen the option to use land-use planning as a policy tool to shift some travel from solo driving trips to more sustainable modes. For policymakers designing a mileage fee, this finding about the link between land-use patterns and travel behavior in response to a mileage fee implies that program designers will need to carefully consider both current and future land-use patterns when estimating the likely revenues collected from mileage fees and also the impact the fees could have on congestion levels.

Finally, the research also reveals that decisions about when and how mileage fees are paid could significantly affect a household's response to a mileage fee program. In the Portland pilot program, where participants paid the fees out of a so-called "endowment account" established for them by the Oregon DOT rather than with their own money, household VMT actually increased when participants switched from paying the gas tax to paying the mileage fee. This result is the opposite of expectations. One possible explanation is that paying the mileage fees once a month, instead of paying the gas tax at each visit to the pump, may have encouraged households to drive more by reducing the gas price at the pump.

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EXECUTIVE SUMMARY

In 2006 and 2007 the state of Oregon conducted a groundbreaking mileage fee pilot program. The program responded to a national concern that fuel taxes will stop serving as a reliable revenue source as a large proportion of the vehicle fleet transitions to running on little or no petroleum-based fuel. To prepare Oregon for this future threat to its transportation revenues, the state legislature authorized a pilot program to test mileage fees as a replacement for the state fuel tax.

THE STUDY DESIGN

This study examines the interactions between urban form and drivers' responses to the Oregon mileage fee program, using data from 130 households participating in the program. The analysis compares the program's impact on vehicle miles traveled (VMT) in different locations and at different times for households charged with two different fee structures:

- Peak-Charged households, who paid a fee of 10 cents per mile during peak hours in the region's congested zone but a fee of only 0.43 cents per mile for all other mileage within Oregon.

- Flat-Rate households, who paid a flat fee of 1.2 cents per mile for all mileage within Oregon.

THE STUDY FINDINGS

The analysis focused on testing four hypotheses. These, along with the key results, are as follows:

Hypothesis 1: Peak-Charged households will reduce their VMT during high-cost times more than will Flat-Rate households.

> Peak-Charged households did, as expected, reduce their driving during high-cost times more than did the Flat-Rate households. Charging a noticeably higher fee for driving in congested conditions successfully achieved the goal of inducing households to reduce their VMT in those times and places where congestion is most a problem.

Hypothesis 2: Peak-Charged households will increase travel in the off-peak time period, and/or at all times outside the peak-charge zone, as compensation for reducing their travel during the peak hour within the peak-charge zone.

> Contrary to this hypothesis, there were no detected spillover effects to off-peak weekday hours or to areas in Oregon outside the peak-charge zone. The results about spillover effects to weekends and to areas outside the state of Oregon were inconclusive. The lack of evident spillover may result from conditions specific to the Portland region, including the urban growth boundary (UGB) in Portland, which limits the presence of travel destinations outside the urban area.

Hypothesis 3: Given a sufficient incentive to reduce driving, households in denser, mixed-use, and transit-accessible neighborhoods are more likely to reduce their VMT than would households in other types of neighborhoods.

The findings confirm this hypothesis for Peak-Charged households. Density and a mix of land uses were statistically significantly correlated with reduced VMT of several types, suggesting that when the travel cost increases in peak hours, households in denser and mixed-use neighborhoods are able to reduce their VMT more than those who do not live in these neighborhoods.

The models also suggest that the urban form effects on Flat-Rate households are quite different from the effects on Peak-Charged households. For a Flat-Rate household, density and mixed-use tended to encourage, not discourage, driving. A possible explanation for this surprising finding is presented in the main text of the report.

Hypothesis 4: Replacing the gas tax with a mileage fee reinforces the influence of urban form on households' travel patterns, perhaps because such a fee establishes a stronger and more prominent connection between travel cost and travel distance than does a gas tax.

The study results mostly confirm this hypothesis. The introduction of the peak charge enhanced the influence of urban form on several types of household VMT. Also, for all types of VMT the urban form variables had a greater influence on the Peak-Charged households than on the Flat-Rate households.

POLICY IMPLICATIONS

The study results suggest various implications for transportation policymakers, including the following five:

1. Charging a noticeably higher fee for driving in congested conditions can successfully motivate households to reduce their VMT in those times and places where congestion is most a problem.

2. Households in all types of neighborhoods studied will likely reduce their peak-hour and overall travel under a mileage fee program that charges a high-rate for peak-hour travel, though households in higher-density neighborhoods with a mix of land uses will likely make greater reductions in VMT.

3. A mileage fee program that charges a high rate during the peak hour will likely strengthen the underlying influence of urban form on travel behavior, as compared to the current gas tax system. In other words, urban form patterns will affect travel behavior more than they currently do if the nation shifts to a new system of mileage charges that vary by congestion levels. For planners, this finding suggests that switching from fuel taxes to mileage taxes would strengthen the power of land-use planning as a policy tool to shift some travel from solo driving trips to more sustainable modes. Also, this finding about the link between urban form and travel

behavior in response to a mileage fee implies that mileage-fee program designers will need to carefully consider both current and future urban form patterns when estimating the likely revenues collected from mileage fees and also the impact the fees could have on congestion levels.

4. The study findings suggest that residents in lower-density suburban areas, as well as residents in higher-density and more mixed-use neighborhoods, are able to reduce their driving in response to a mileage fee. Therefore, the results add new empirical evidence to the ongoing equity debate about whether mileage fees are unfair to households living in suburban communities, and suggest that this concern may not be warranted.

5. Although a peak-hour mileage charge could encourage drivers to think carefully about their travel decisions and they would probably reduce their VMT accordingly, the ultimate program outcomes will likely depend on the specific program design, especially when and how the mileage fee is paid. If the payment is made less frequently than the current system of gas taxes charged at the pump, such as through a monthly billing program, drivers might increase instead of decrease their VMT because they would be less aware of the cost of their travel.

INTRODUCTION

In 2006 and 2007 the state of Oregon conducted a groundbreaking mileage fee pilot program. The program responded to a national concern that fuel taxes will stop serving as a reliable revenue source as a large proportion of the vehicle fleet transitions to running on little or no petroleum-based fuel. To prepare Oregon for this future threat to its transportation revenues, the state legislature authorized a pilot program to test mileage fees that could potentially replace the state fuel tax. The pilot tested both a flat-rate fee that was the same for any mile driven, and also a variable fee structure that charged drivers a higher fee for miles driven during the rush hour.[1]

Since the pilot ended, researchers have examined many facets of the program's success, including the performance of the technology and ways that drivers changed their travel behavior once they were paying the flat-rate and variable mileage fees rather than the gas tax. One crucial aspect of the behavioral response that has not yet been well studied, however, is whether people's behavioral responses to the mileage fees are correlated with any elements of the urban form around their homes. The term urban form is defined broadly to include land use patterns, such as density and mixed use, urban form measures, such as location in a metropolitan region and street connectivity, and accessibility to public transit. This study addresses that research gap by exploring three specific research questions:

- Does urban form correlate with any of the travel behavior changes that participants made in response to the Oregon mileage fee pilot program?
- Which urban form factors are most significant in explaining travel behavior variations?
- Do the effects of urban form differ under the two fee structures tested: the flat-rate fee and the variable fee with a higher rate during the peak periods?

THE POLICY IMPLICATIONS OF THE STUDY

Both federal and state policymakers are currently studying mileage fees as a serious option for replacing or supplementing fuel taxes, and a growing number of transportation finance experts believe that mileage fees are the future of transportation financing and congestion pricing.[2] Internationally, mileage fee programs have already been established for trucks in Austria, Switzerland, the Czech Republic, and Germany, and the Netherlands was, until recently, planning to implement the first ever nationwide mileage fee system for all vehicle types. Within the United States, numerous other states, including Hawaii, Ohio, Pennsylvania, Colorado, Florida, Rhode Island, Minnesota, and Texas, have also expressed an interest in phasing out fuel taxes in favor of charging motorists for how much they drive.

Given this intense interest in mileage fees, and the likelihood that a number of such programs will be tested and perhaps established in the upcoming decade, the need for a better understanding of behavioral responses is important. This study's results join the small but rapidly expanding body of empirical studies that seek to understand the benefits, potentials, and concerns of a mileage fee program. In particular, the study complements the existing research by using empirical analysis to explore a question previously almost untested: the link between urban form and behavioral responses to mileage fees.

Investigating whether urban form influences behavioral responses to the mileage fees has various important research and policy implications. Most important, urban form patterns might prove the key to better explaining the observed behavioral responses to the mileage fee program. We hypothesized that urban form, which has been mostly overlooked by prior studies, could significantly affect a household's response to a mileage fee program and should be taken into account in program design and evaluation.

Understanding the relationship between mileage fees and urban form will help researchers and policymakers more accurately predict outcomes, including the effect of a mileage fee on VMT and revenue in different locations. Such analysis can also inform the equity discussions that arise whenever mileage fee programs are proposed. A common concern is that switching from fuel taxes to a mileage fee program will penalize residents in low-density communities, since they have fewer transit options and nearby destinations than residents of more urban communities and thus might have a more difficult time reducing VMT. Looking at the Oregon data allows us to add real-world evidence to a debate that has, so far, largely been conducted without any particular empirical evidence.

EXISTING RESEARCH ON MILEAGE FEE PROGRAMS

Despite worldwide interest in mileage fees as a possible replacement for fuel taxes, very little research has been done to understand how applying a mileage fee to all travel might influence travel behavior. In the United States, there have been just a handful of pilot mileage fee programs that provided usable data for analysis. Along with the Oregon project that is the focus of this report, the Minnesota Department of Transportation and Puget Sound Regional Council (PSRC) tested experimental mileage-fee programs in 2006 and 2007, and the Netherlands ran a road pricing experiment for six months in the city of Eindhoven. (The University of Iowa is also currently conducting a national field test and evaluation of a mileage fee program.) Given the scarcity of data on how users have responded to real-world mileage fee programs, a few researchers have also developed models using survey data or travel diary data to predict how people might respond to mileage fees charged on all their travel.[3]

Previous empirical studies confirmed a great variation in behavioral responses in both Oregon[4] and Minnesota,[5] but they have failed to explain most of the variation. For example, only 6% of the VMT changes in the Oregon pilot were explained by household characteristics, access to transit, and personal attitudes. We hypothesize that urban form such as density, land use diversity, and proximity to different types of transportation facilities, which have been overlooked in most previous research, could significantly affect a household's response to a mileage fee program and should be taken into account in future program design and evaluation.

To date, research has looked at only two different connections between urban form and behavioral responses to mileage fee programs. First, Rufolo and Kimpel analyzed the

Oregon pilot program data and found that close proximity to a transit stop was correlated with greater reductions in VMT with the mileage fee.[6]

A second connection that has been explored involves differences between urban and rural areas. This connection responds to equity concerns, raised because rural residents usually have to travel farther for work and personal needs and have fewer transit and nonmotorized transportation options than residents in more urban communities.[7] One group of authors has written two papers using modeling of 2001 NHTS data to estimate the cost to drivers of a mileage tax versus a fuel tax that would both raise the same total revenues for Oregon.[8] The authors conclude that a shift to a VMT fee yields the opposite result for rural residents from what conventional wisdom suggests. With a revenue-neutral VMT fee, a rural household on average would pay less than under a traditional gas tax, mostly because of the lower average fuel efficiency in most rural vehicles, as compared to the urban fleet.

OVERVIEW OF THE REPORT

The remaining sections of this report cover three main topics:

The section titled “Study Methodology” describes the operational details of the 2006-2007 Oregon Road User Fee Pilot that are relevant to the data analysis presented here, and discusses the methodology and data used for the analysis.

The section titled “Analysis and Findings” presents the analysis conducted for this study. The chapter begins by presenting a series of four hypotheses and the analyses completed to test each one. The discussion ends with additional modeling work conducted to explore some puzzling results.

Finally, the section titled “Conclusion” summarizes the key findings from the data analysis and suggests some policy implications, as well offering suggestions for future research into the interaction between mileage fee programs and urban form.

STUDY METHODOLOGY

THE OREGON MILEAGE FEE PILOT PROGRAM

In 2006 and 2007 the state of Oregon conducted a groundbreaking mileage fee pilot program in response to a concern that fuel taxes would eventually cease to provide sufficient transportation revenues as an increasing percentage of the vehicle fleet began to run on little or no petroleum-based fuel. This section of the report discusses the design of the Oregon program, the socioeconomic characteristics of the participants, and the survey and vehicle-miles-traveled (VMT) data collected.

The Program Design

Oregon's Mileage Fee Pilot Program tested two types of experimental fees: a flat-rate VMT fee that approximated the price of the state gas tax, and a fee whose rate varied by the time of day and location. The latter system imposed a high peak-hour fee for driving in the Portland metropolitan area during specific times of the day, paired with a low fee for all miles driven outside the metropolitan area and/or outside the peak hours. The primary goal of the pilot program was to test whether the technology to track vehicle mileage and charge the appropriate fees to drivers would work, but the program also collected mileage and survey data that have made it possible to investigate how the program affected household driving behavior.

Oregon DOT recruited participants in the spring of 2006 through press releases, an informational website, and radio and print advertising. Volunteers were initially screened by telephone and then asked to attend an evening sign-up meeting.[9] In the end, 168 households with 207 vehicles were enlisted to participate in the program, which ran for a ten-month period from 2006-2007.[10]

All vehicles in participating households were outfitted with Global Positioning System (GPS) devices designed to record the participants' driving behavior. The participants also agreed to purchase gasoline at two specific service stations at regular intervals, and the mileage data was transferred from the vehicles to the program managers each time gas was purchased from these two stations. A third requirement for participants was that they complete a survey on three separate occasions: before the program (June 2006), midway through the program (October-November 2006), and at the end of the program (March-April 2007). The surveys gathered information on household characteristics and travel decisions made during the program.

Most of the participating households were located in the eastern portion of the metropolitan region, likely because that's where the two gasoline stations participating in the study were located (Figure 1). Large portions of the suburbs east of downtown Portland were developed prior to World War II, resulting in neighborhoods today that have a greater mix of land uses, a finer-grained grid street network, and higher densities with better transit service. However, neighborhoods farther from downtown, including those close to the participating gas stations, do not exhibit many of these traditional urban form characteristics. As a result, there is significant variation among the participating households with respect to urban form characteristics that might influence travel behavior.

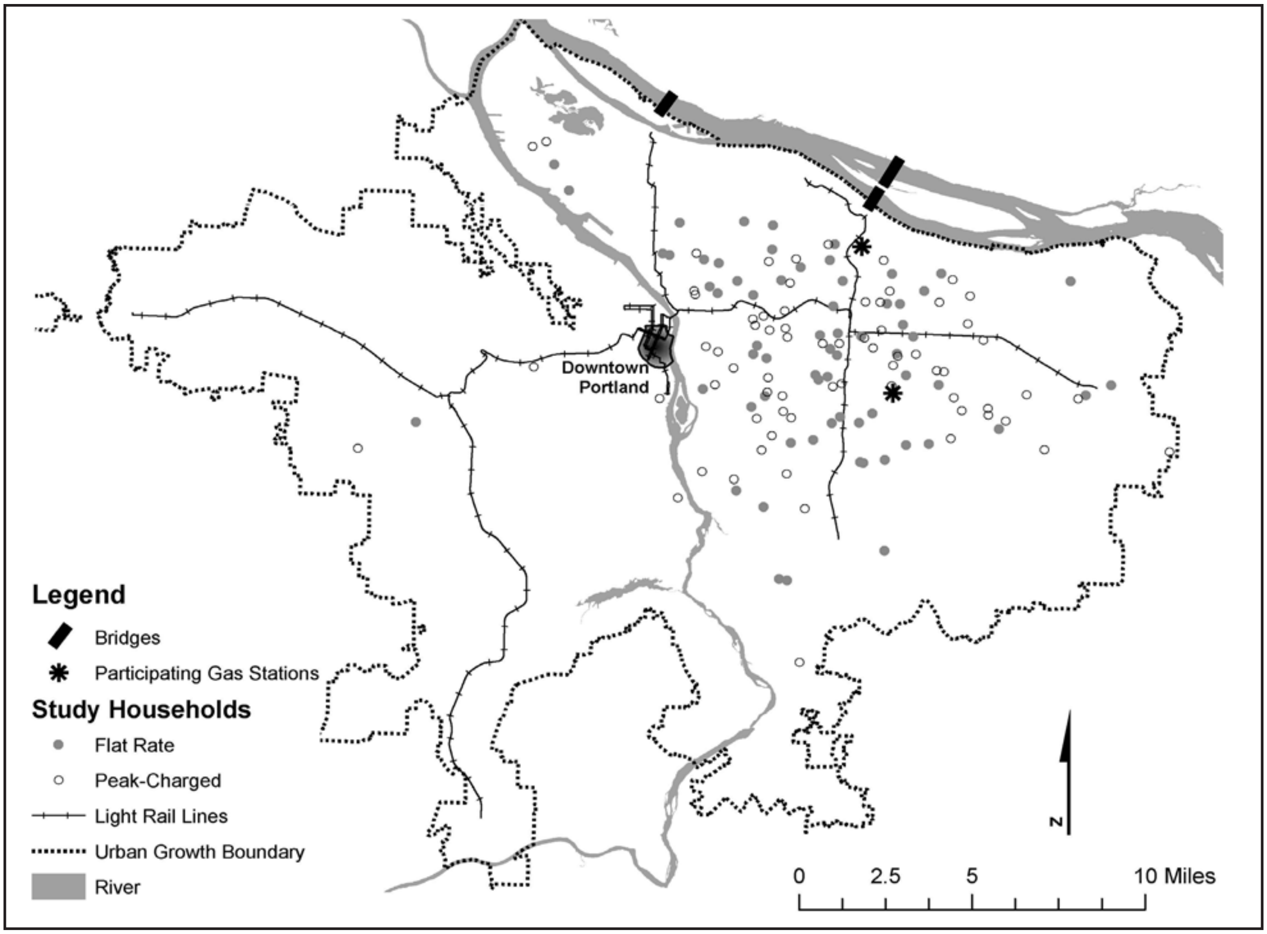

Figure 1. Residential Locations of the 130 Study Participants Used in the MTI Analysis

Source: Map prepared by Melissa Reese using data from the Oregon Department of Transportation and Metro's Regional Land Information System (RLIS).

The program was broken into two phases. In Phase 1, a 4.5-month control phase, the households paid the regular state gas tax, so there was no program-based incentive for them to change their regular driving behavior. The VMT was recorded for all the participating vehicles to establish baseline driving behavior for that vehicle. In Phase 2, which lasted for 5.5 months, participants were broken into three groups, each of which paid a different type of tax or fee on gasoline purchases:

Control group: Members of the small Control group (approximately 10% of the participating households) continued to pay the regular state gas tax, though the data from their miles driven was recorded when they fueled up at the participating gas stations.

Flat-Rate group: Members of the Flat-Rate group did not pay the state gas tax, but were instead charged a VMT fee of 1.2 cents per mile for all miles driven within Oregon. This rate was chosen to approximate the 24-cent-per-gallon state gas tax. In other words, the rate was set so that participants would pay about the same amount in VMT fees that they would otherwise pay in state gasoline taxes. Participants did not pay the mileage fee for travel outside of Oregon, nor did they receive refunds on taxes paid on gas purchased outside of the state.

Peak-Charged group: Members of the Peak-Charged group paid a higher VMT fee of 10 cents per mile for all driving inside the Portland urban growth boundary (UGB) during the peak periods (7 to 9 AM and 4 to 6 PM, Monday through Friday, excluding holidays).[11] For other travel within Oregon during the peak hour, as well as for travel within the UGB at off-peak times, they paid only 0.43 cents per mile. As with the Flat-Rate group, these households did not pay a mileage fee for travel outside of Oregon, nor did they receive refunds on taxes paid on gas purchased outside of the state.

Households were not randomly assigned among the three groups. Instead, the program managers assigned participants to a group using a designated set of rules. First, if the household owned one or more ineligible vehicles (i.e., diesel vehicles or cars bought before 1996), then it was assigned to the Control group. Households that failed to regularly purchase their gas at one of the two designated service stations during Phase 1 were also placed in the Control group. The remaining vehicles were divided between the Flat-Rate and Peak-Charged groups according to how many miles they drove within the UGB during peak hours. For households that regularly traveled in the UGB during peak hours, three were placed into the Peak-Charged group for every one placed in the Flat-Rate group.[12] As a result, only one-third of the Flat-Rate households typically traveled within the UGB during peak hours, while the number of Peak-Charged group participants who didn't use the congestion zones in their daily travel was kept to a minimum.[13]

Households received special receipts each time they purchased gas at one of the two participating service stations (see Figure 2). These receipts showed participants the money they "saved" by not paying the gas tax, how much money they were charged in mileage fees, and how many miles they had driven in four different categories since last refueling at one of the participating service stations: miles charged the peak rate, other miles in Oregon, miles driven outside Oregon, and miles for which the GPS device did not record a location. The participants in the two experimental groups were also able to submit receipts in January and March of 2007 and receive refunds on the gas tax for gasoline purchased at non-participating service stations within Oregon.

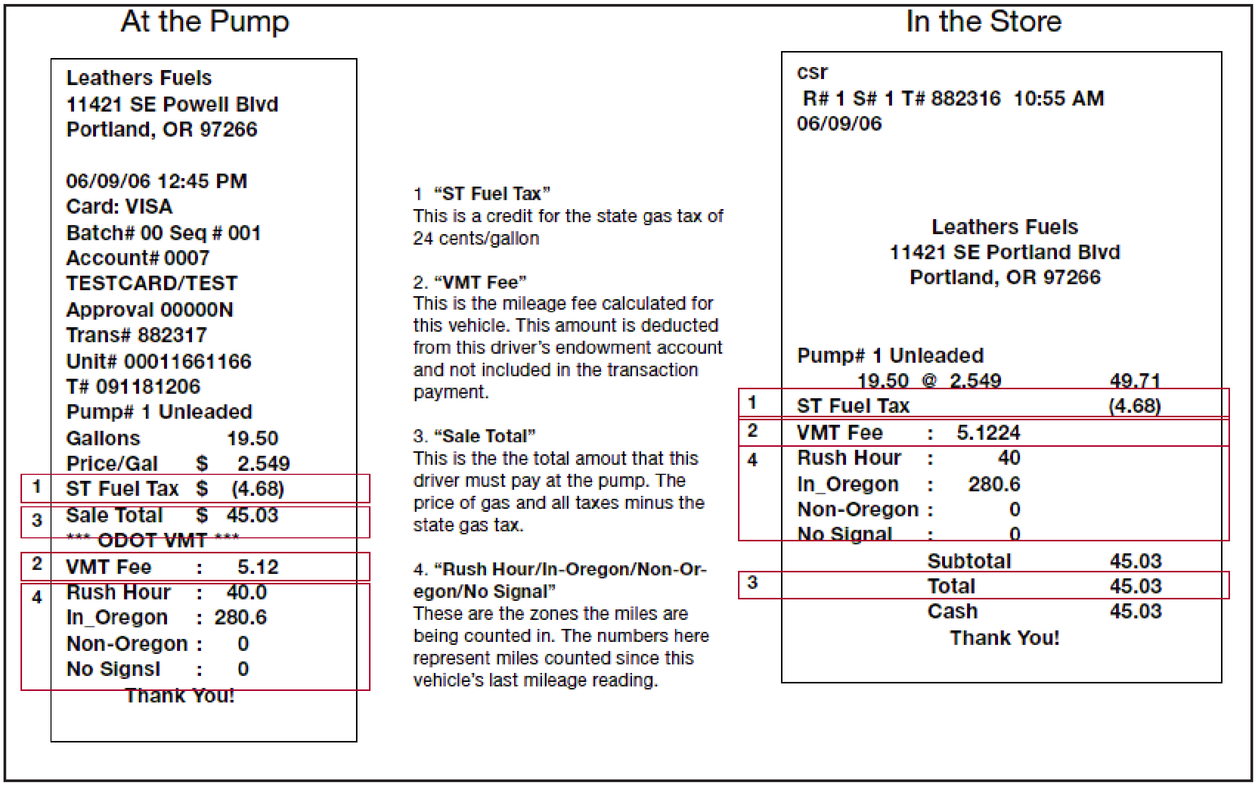

Figure 2. Sample Mileage Fee Receipts

Source: James M. Whitty, Oregon's Mileage Fee Concept and Road User Fee Pilot Program: Final Report (Oregon Department of Transportation, November 2007), p. 20.

Another piece of the charging structure in Phase 2 was that members of both experimental groups received so-called "endowment accounts" with which to pay their mileage fees. These accounts were given to the participating households at the beginning of Phase 2, and all mileage fees charged to them were deducted from these accounts.

Each household's endowment account was set at a level that was estimated to be slightly higher than would be needed to cover the mileage fees the household would pay if it continued to drive in its Phase 1 patterns.[14] Therefore, if a household's driving pattern remained the same in both phases, its endowment account would almost balance out to zero at the end of the experiment. The average amount of money placed in the endowment accounts was $51.50 for a Flat-Rate household and $123.20 for a Peak-Charged household.

Participants were told the amount of their endowment account at the beginning of Phase 2 of the experiment, but were not informed of how it was calculated. They received notice from ODOT about the balance in their account every few weeks but could not track the balance in real time. Households were told that if there was any balance left in their account at the end of the program, they could keep that money.[15] This element of the program was designed to create an incentive for households to reduce their VMT. Finally, ODOT did not hold households responsible for paying the mileage fees if they ran out of money in the endowment account, though households were not told this.[16]

THE PARTICIPANTS

A total of 183 households participated in the pilot program. For the analysis conducted in this report, however, that group was reduced for the reasons detailed in Table 1. After all these exclusions, the end result was a sample of 130 households, with 62 in the Flat-Rate group and 68 in the Peak-Charged group.

Table 1. Households Excluded from the Analysis in the MTI Study

Reason for exclusion	Number excluded
Valid VMT data was not captured	15
Home address could not be geocoded in GIS	17
Household was located outside the urban growth boundary	2
Household bought or sold a vehicle during the program	12
Household had at least one car not enrolled in program	19
Household had highly unusual VMT patterns: i.e., had an unusually high average daily VMT per vehicle in Phase 1 (more than 100 miles a day[a]) or had a change of 40 miles or more in average daily VMT per vehicle from Phase 1 to Phase 2	7
Control Group households that did not pay any form of mileage fee in Phase 2	8

Note: Some households were excluded for multiple reasons.

[a] We suspect that such households may have done long-distance driving atypical of their daily routines, such as cross-country travel, and therefore should be excluded from this analysis.

Table 2. Socio-Demographic and Structural Characteristics of the Participant Households

	All households in the ODOT pilot (n=183)	All households in the MTI analysis (n=130)	Households in MTI analysis, by group	
			Peak-Charged households (n=68)	Flat-Rate households (n=62)
Drivers in HH				
1	62%	61%	59%	63%
2	37	38	40	37
3	1	1	1	0
Vehicles in HH				
1	68	70	69	71
2	29	26	29	23
3	3	4	1	6
4	1	0	0	0
Adults in HH (16+ years)				
1	46	47	46	48
2	46	45	46	45
3	6	5	6	5
4	1	2	3	0
5	1	1	0	2
Child in HH (≥1)	28	28	32	24
Employment in HH				
Full-time employee ≥1)	71	68	78	58
Only part-time employees	10	10	6	15
Only unemployed	16	20	15	26
Only full-time students	2	2	1	2
HH Income				
< $40K	33	37	29	45
$40-60K	36	37	40	34
> $60K	27	26	31	21

Note: Percentages within each category may not sum to 100 due to rounding.

THE DATA: SURVEY DATA, TRAVEL DATA, AND URBAN FORM MEASURES

- Mileage within Portland UGB during the AM peak, PM peak, and non-peak on each of the five weekdays (5 x 3 = 15 types)
- Mileage within Oregon but outside the Portland UGB in the peak and off-peak hours on each of the five weekdays (5 x 2 = 10 types)
- Mileage on Saturday and Sunday inside Portland UGB, plus weekend mileage outside Portland UGB but inside Oregon (2 x 2 = 4 types)
- Mileage outside Oregon for all days (1 type)
- Mileage driven where the GPS signal could not be read (1 type)

After the full set of 96 variables had been defined, two processes were followed to refine this large set into a small number of the most appropriate variables for use in the models. First, for all variables looking at the same factor at different scales, simple regression models were estimated to select the most appropriate spatial scale. Only the scale that yielded the highest adjusted R^2 value was included in the final model specification. Adjusted R^2 indicates the goodness-of-fit of the model, the higher the better. Second, correlations among variables were tested, and when variables were correlated only the one that achieved the highest R^2 value was retained.

Completing these two steps resulted in nine urban form measures: five measured accessibility, one measured density, one measured land-use mix, and the final two measured street pattern and cycling infrastructure. Table 3 describes how each of the variables was defined and the sources of data used to construct them.

In addition to testing the urban form variables, we also included in the model one program variable related to the pilot study design: the network distance to the two designated refill gas stations. This variable was included in the models to check whether the location of these two gas stations could have affected participants' behavioral response to the program, especially for those who lived farther away from the stations. Since participants had to use the stations periodically during the study, living far away from the stations might have influenced their driving patterns.

Household-level demographic variables were created using the survey data. These variables included the number of drivers, the number of vehicles, the number of adults, the presence of children, employment status, and income. In addition, each household's "Phase 1 base VMT," or the household's average daily VMT per vehicle during Phase 1, is also included in the analysis.

Table 3. Urban Form Variables Used in the Study Modeling

Category	Definition	Description/operation	Data source
Access	Network distance to frequent bus stop (dummy variable; 0.25-mile buffer)	• 0 = no stops within 0.25 miles, by network distance • 1 = network distance to stop is less than 0.25 miles • Frequent bus = with a headway less than 15 minutes • (Method follows Rufulo and Kimpel.[a])	RLIS Bus Stops shapefile
	Network distance to light rail stop (dummy variable; 0.5-mile buffer)	• 0 = no light rail stops within 0.5 miles, by network distance • 1 = network distance is less than 0.5 miles	RLIS Light Rail Stops shapefile (minus the light rail stops added in 2009 after the study, which took place from Oct. 2007 to Sept 2008)
	Network distance to downtown (miles)	• Defined downtown as a single downtown point, Pioneer Courthouse Square. • Calculated the network distance using ESRI's network analyst closest facility operation.	Geocoded one point for downtown based on the location of Pioneer Courthouse Square
	Network distance to Portland's UGB (miles)	• Created points for all places where the UGB intersects a major arterial road. • Found the network distance to closest point using ESRI's network analyst closest facility operation.	RLIS UGB shapefile
	Network distance to closest freeway exit (miles)	• Exported the freeway ramps from the major arterial shapefile. • Converted the ramps that were lines into points representing the point of entry on the highway. • Used the network analyst tool to find the minimum network distance between each household and the closest freeway entry ramp.	RLIS Major Arterial Streets shapefile
Density	Density of residential units within 0.5-mile buffer (residential units per acre)	• Calculated the land area within a 0.5-mile buffer of each study household, then subtracted the area of all bodies of water in the buffer zone. • For all block groups within 0.5 mile of a study household, calculated the percentage of each block group's land area that lies within the buffer. • Allocated the corresponding percent of the block groups' residential units to each buffer and found the sum of the estimated residential units within the 0.5-mile buffer, based on the percentage of each block group in the study area. • Found the density of residential units within each buffer based on the estimated number of units and the calculated land area within the 0.5-mile buffer zone around each study household. • (Method follows Forsyth, Section 3.6.[b])	U.S. Census 2000
Mixed use	Entropy Index (captures 7 land-use types)	• The Entropy Index is a measure of land use homogeneity. The formula is: $Entropy\ \{-\sum_k[(p_i)(\ln p_i)]\}/(\ln k)$ where k= number of land use categories and p_i = Proportions of each of the six land-use types. • Seven land-use categories were used: single family residential, multi-family residential, commercial, vacant, public, other, and industrial. • The study area was a 0.5-mile buffer around each household. • (Method follows Forsyth, Section 5.9.[c])	RLIS tax lot shapefile (Scale 0 to 1: value of 0 indicates homogeneity, wherein all land uses are of one type; a value of 1 indicates complete heterogeneity, wherein all land-use categories are evenly distributed)
Street connectivity	4-way intersection density within 0.5-mile buffer (intersections per acre)	• Created intersections for all streets within a 0.5-mile buffer of each study household. • Selected only the intersections within the 0.5-mile buffer of each household, to eliminate the false intersections created at the edge of the 0.5 mile buffer. • Found all intersections that represented points where 3 or more street-line segments converge (vs. cul-de-sac end points and points where streets bend). • Calculated the number of intersections divided by the area of each 0.5-mile buffer around the study households (area excluding water). • (Method follows Forsyth, Section 6.6[d])	RLIS streets shapefile
	Bike lane length within 3-mile buffer (feet)	• Calculated the total length of bike routes and multi-use paths within a 3-mile buffer of each household.	RLIS bike routes shapefile

[a] Anthony M. Rufolo and Thomas J. Kimpel, "Responses to Oregon's Experiment in Road Pricing," Transportation Research Record 2079 (2008): 1-7.
[b] Ann Forsyth, ed, Environment and Physical Activity: GIS Protocols (Minneapolis, MN: Design Center, 2007), Version 3.6, Section 6.6, http://www.designforhealth.net/resources/gis_protocols.html.
[c] Ann Forsyth, ed, Environment and Physical Activity: GIS Protocols, (Minneapolis, MN: Design Center, 2007), Version 5.9, Section 6.6, http://www.designforhealth.net/resources/gis_protocols.html.
[d] Ann Forsyth, ed, Environment and Physical Activity: GIS Protocols, (Minneapolis, MN: Design Center, 2007), Version 6.6, Section 6.6, http://www.designforhealth.net/resources/gis_protocols.html.

ANALYSIS AND FINDINGS

We tested four hypotheses to understand the effect of the pilot program on VMT changes, as well as the interaction between urban form and the mileage fees. The first two hypotheses look at how each household's daily VMT may have varied between Phase 1 and Phase 2:

> Hypothesis 1: Peak-Charged households will reduce their VMT during high-cost times more than will Flat-Rate households.
>
> Hypothesis 2: Peak-Charged households will increase travel in the off-peak time period, and/or at all times outside the peak-charge zone, as compensation for reducing their travel during the peak hour within the UGB (the peak-charge zone).

The next two hypotheses assess the interaction between urban form and the mileage fee program:

> Hypothesis 3: Given a sufficient incentive to reduce driving, households in denser, mixed-use, and transit-accessible neighborhoods are more likely to reduce their VMT than would households in other types of neighborhoods.
>
> Hypothesis 4: Replacing the gas tax with a mileage fee reinforces the influence of urban form on households' travel patterns because such a fee establishes a stronger and more prominent connection between travel cost and travel distance than does a gas tax.

After presenting the findings for each hypothesis, this chapter ends with a discussion of how the program design, especially the endowment accounts, may have affected participants' response to the program.

EXPLORING THE VARIATION IN VMT BETWEEN PHASE 1 AND PHASE 2

To investigate the nuances of how VMT varied between the two phases of the pilot program, as well as between the Flat-Rate households and Peak-Charged households, we looked at seven different measures of VMT, consolidated from the 31 types available in the original data set. The unit for all seven measures is the average daily VMT per household vehicle in a participating household.

1. **Portland Weekday Peak:** The average daily VMT per household vehicle inside the Portland urban growth boundary (UGB) during peak hours (7 to 9 AM and 4 to 6 PM).

2. **Portland Weekday Off-Peak:** The average daily VMT per household vehicle inside the Portland urban growth boundary (UGB) but in the off-peak hours (before 7 AM, between 9 AM and 4 PM, and after 6 PM).

3. **Oregon Low-Fee Weekday:** The sum of Portland Off-Peak VMT and the VMT outside the UGB but still inside Oregon.

4. **Oregon Weekday:** The average daily VMT per household vehicle for all weekday travel within Oregon.

5. **Oregon Weekend:** The average daily VMT per household vehicle on weekends and holidays everywhere in Oregon, including within the Portland UGB.

6. **Outside Oregon All Days:** The average daily VMT per household vehicle outside Oregon on all days of the week (weekdays, weekends, and holidays).

7. **Overall:** The average daily VMT per household vehicle inside and outside Oregon on all days of the week (weekdays, weekends, and holidays).

Table 4 and Table 5 summarize the descriptive statistics of the seven types of VMT, in Phase 1 and Phase 2, for both Flat-Rate and Peak-Charged households. Peak-Charged households drove more than Flat-Rate households in Phase 1, a distinction caused by the selection process described in the previous section. Most types of VMT decreased from Phase 1 to Phase 2 except the Portland Weekday Peak for Flat-Rate households, which, surprisingly, increased by 18%. This increase might be caused by the pilot program design, especially the endowment account that essentially exempted participants from paying the gas tax or the mileage fee. This issue will be discussed again at the end of the chapter.

Note that the Oregon Weekend and Overall VMT decreased dramatically from Phase 1 to Phase 2 for both household groups, with the two groups showing similar percentage changes. This similarity in behavior between the two groups indicates that the reduction might not be caused by the pilot program. We suspect that the reduction resulted from a seasonal change in travel patterns. It is well documented that total monthly VMT in the U.S. tends to be higher in the summer than in the winter.[19] Also, data from nine traffic monitoring stations[20] on the main highway intersections in the Portland metropolitan indicated that for the five-month period from November to March 2007 (roughly the months of Phase 2), average monthly VMT is 7% lower than for the months from June to October in 2006 (roughly the months of Phase 1). Later in the chapter we use the difference-in-difference method to control for this seasonal change.

Table 4. Average Daily VMT per Household Vehicle for the Flat-Rate Households, for Different Categories of Travel, by Phase (n=62 HHs)

	Average			Median			
	Miles	%	Standard Deviation	Miles	%	Minimum (miles)	Maximum (miles)
Portland Weekday Peak							
Phase 1 (P1)	4.6		3.7	3.3		0.7	19.2
Phase 2 (P2)	5.3		4.3	3.9		0.9	18.7
Difference (P2 – P1)	0.6	18	2.2	0.3	12	-5.1	8.3
Portland Weekday Off-Peak							
Phase 1	14.2		6.2	13.9		4.3	36.7
Phase 2	14.2		6.6	12.8		3.5	36.1
Difference (P2 – P1)	0.01	3	4.0	-0.2	-1	-12.1	10.9
Oregon Low-Fee Weekday							
Phase 1	18.0		8.1	16.8		6.6	41.8
Phase 2	16.8		8.6	16.1		3.5	40.6
Difference (P2 – P1)	-1.2	-4	5.4	-1.9	-13	-12.1	16.5
Oregon Weekday							
Phase 1	22.6		9.8	20.7		8.8	52.6
Phase 2	22.2		10.8	21.2		4.4	53.6
Difference (P2 – P1)	-0.5	-1.0	6.6	-2.2	-10	-11.7	21.2
Oregon Weekend							
Phase 1	35.5		14.4	37.9		8.9	77.0
Phase 2	26.4		15.1	22.4		7.2	59.4
Difference (P2 – P1)	-10.8	-27	10.9	-10.0	-31	-33.5	23.9
Outside Oregon All Days							
Phase 1	2.8		4.1	1.3		0.0	21.8
Phase 2	1.7		4.8	0.2		0.0	36.1
Difference (P2 - P1)	-1.1	-28	5.0	-0.4	-68	-21.8	24.9
Overall							
Phase 1	28.1		12.3	26.8		9.0	58.7
Phase 2	24.4		12.7	22.5		7.4	80.6
Difference (P2 – P1)	-3.7	-12	8.2	-3.9	-18	-27.3	23.3

Table 5. Average Daily VMT per Household Vehicle for the Peak-Charged Households, for Different Categories of Travel, by Phase (n=68)

	Average			Median			
	Miles	%	Standard Deviation	Miles	%	Minimum (miles)	Maximum (miles)
Portland Weekday Peak							
Phase 1	8.7		5.7	6.7		3.2	36.3
Phase 2	7.7		6.1	6.6		0.0	32.3
Difference (P2 - P1)	-1.1	-13	3.0	-0.4	-7	-10.7	9.4
Portland Weekday Off-Peak							
Phase 1	17.1		7.4	15.6		5.3	39.5
Phase 2	16.7		8.9	15.7		3.1	48.4
Difference (P2 - P1)	-0.3	-2	4.7	-0.3	-2	-12.1	16.2
Oregon Low-Fee Weekday							
Phase 1	21.5		9.8	21.0		5.3	53.5
Phase 2	18.9		9.2	19.9		3.1	48.9
Difference (P2 - P1)	-2.6	-10	6.1	-3.3	-18	-24.5	13.1
Oregon Weekday							
Phase 1	30.0		11.9	28.2		8.9	67.5
Phase 2	26.6		11.5	25.2		6.4	56.6
Difference (P2 - P1)	-3.6	-11	6.8	-3.5	-12	-26.7	7.4
Oregon Weekend							
Phase 1	49.2		22.8	46.9		9.2	80.1
Phase 2	33.2		16.4	31.6		1.2	74.6
Difference (P2 - P1)	-16.0	-28	17.0	-13.8	-28	-77.5	8.8
Outside Oregon All Days							
Phase 1	3.5		4.1	1.8		0.0	19.8
Phase 2	2.7		4.9	0.6		0.0	22.5
Difference (P2 - P1)	-0.8	-56	4.7	-0.5	-57	-13.3	18.7
Overall							
Phase 1	37.7		14.3	35.2		13.3	74.9
Phase 2	31.3		11.8	30.5		9.1	56.3
Difference (P2 - P1)	-6.4	-15	9.0	-6.5	-18	-34.4	10.1

THE EFFECT OF THE MILEAGE FEE ON VMT CHANGES

Hypothesis 1

Hypothesis 1: Peak-Charged households will reduce their VMT during high-cost times more than will Flat-Rate households.

To test the effect of the peak charge on household VMT within the UGB during the peak hour, a difference-in-difference method[21] was used. The basic premise of this method is to examine the effect of a treatment by comparing the treatment group after treatment both to the treatment group before treatment and to some other control group. Because many factors may impact the participants during the treatment period, this method uses a control group to eliminate the influence of the non-treatment factors, assuming that these other factors were the same for the treatment and control groups.

The difference-in-difference method was used to control for any potential travel changes between Phase 1 and Phase 2 caused by seasonal travel patterns. First, the changes between Phase 1 and Phase 2 VMT were calculated for both the Flat-Rate and Peak-Charged households. Second, the VMT change for both household types was compared using the paired-difference method.

This analysis found that Peak-Charged households reduced their Portland Weekday Peak VMT by an average of 1.46 miles more than did the Flat-Rate households (see the first data row in Table 6). However, we wondered if this difference between the two groups might be explained not by the different fee structures, but rather by the fact that the Peak-Charged households had a higher average VMT in Phase 1. (Households were not randomly assigned to the two groups, as explained in the previous chapter.) To control for this effect, the sixth data column of Table 6 shows the percentage changes in VMT. Looking at the change in miles driven as a percentage, rather than as an absolute number, shows that the Peak-Charged households reduced their Portland Weekday Peak driving by 30 percentage points more than did the Flat-Rate households.

In summary, the difference-in-difference analysis confirms Hypothesis 1. It shows that the Peak-Charged households did, as expected, reduce their Portland Weekday Peak driving more than did the Flat-Rate households. The reduction was 30 percentage points more for Portland Weekday Peak miles, 9 percentage points more for Oregon Weekday miles, and 3 percentage points more for Overall miles. Charging a noticeably higher fee for driving in congested conditions successfully achieved the goal of inducing households to reduce their VMT in those times and places where congestion is most a problem.

Table 6. Change in Average Household Daily VMT per Vehicle, from Phase 1 to Phase 2, Comparing Peak-Charged and Flat-Rate Households

	Mean difference[a] in change in average daily VMT			Mean % difference in average daily VMT		
	Peak-Charged[b] (miles)	Flat-Rate[c] (miles)	Peak-Charged – Flat-Rate[d] (miles / p-value)	Peak-Charged (miles)	Flat-Rate (miles)	Peak-Charged – Flat-Rate[d] (percentage points/p-value)
Portland Weekday Peak	-1.1	0.7	**-1.46 (0.00)**	**-13%**	**18%**	**-30 (0.00)**
Portland Weekday Off-Peak	-0.3	0.01	-0.34 (-0.61)	-2%	3%	-5 (0.28)
Oregon Low-Fee Weekday	-2.6	-1.2	-1.34 (-0.16)	-10%	-4%	-5 (0.39)
Oregon Weekday	-3.6	-0.5	**-2.79 (-0.01)**	**-11%**	**-1%**	**-9 (0.05)**
Oregon Weekend	-16.9	-10.8	**-5.18 (-0.04)**	-28%	-27%	-1 (0.80)
Outside Oregon All Days	-0.8	-1.1	-0.28 (-0.77)	56%	-28%	99 (0.30)
Overall	-6.4	-3.7	**-3.03 (-0.05)**	-15%	-12%	-3 (0.46)

Notes:
- Bold font indicates the difference is significant at the 5% level.
- The Peak-Charged households group has 68 observations, and the Flat-Rate households group has 62 observations
- See Table 4 and Table 5 for the VMT data used to create this table.

[a] The difference is calculated first, and then the mean is derived.
[b] Peak-Charged households, N=68. Difference calculated as Phase 2 – Phase 1.
[c] Flat-Rate households, N=62.Difference calculated as Phase 2 – Phase 1.
[d] This is the difference-in-difference calculated using the paired difference function in SPSS (the numbers are not the direct difference between the first two columns in this table).

Hypothesis 2

Hypothesis 2: Peak-Charged households will increase travel in the off-peak time period, and/or at all times outside the peak-charge zone, as compensation for reducing their travel during the peak hour within the UGB (the peak-charge zone).

It is possible that the Peak-Charged households might compensate for reducing their Portland Weekday Peak travel by increasing travel at other times. For example, households might shift shopping trips from weekdays to weekends as a way to reduce mileage during the peak hours. To test Hypothesis 2, four such possible spillover effects were checked: increases in Portland Weekday Off-Peak, Oregon Low-Fee Weekday, Oregon Weekend, and Outside Oregon All Days VMT.

First, a check of Table 6 shows that there was no statistically significant increase in Portland Weekday Off-Peak VMT or Oregon Low-Fee Weekday VMT. To confirm this finding, we also compared (1) the expected reduction of Oregon Weekday VMT caused by the reduction of the Portland Weekday Peak VMT with (2) the actual reduction of Oregon Weekday VMT. The VMT data in Table 5 indicate that, for the Peak-Charged households, the average Portland Weekday Peak VMT is 29% of the Oregon Weekday VMT in Phase 1 (8.6 miles / 30.0 miles). A 30% reduction in Portland Weekday Peak VMT equals an 8.7% reduction in Oregon Weekday VMT (30% x 29%), which is the exact same reduction that Table 6 shows for the change in Oregon Weekday VMT. It is thus reasonable to conclude that the drop in observed Oregon Weekday VMT is caused entirely by the reduction of Portland Weekday Peak VMT. Therefore, there are no spillover effects to off-peak hours on Portland weekdays and to areas outside the Portland UGB.

The same process was used to check if there was spillover to the Oregon Weekend, and Outside Oregon All Days VMT. The Oregon Weekday VMT accounts for about 65% of the Overall VMT for the Peak-Charged households (Table 5). A 9% reduction would result in a 5.8% reduction (65% x 9%) in Overall VMT. However, the actual Overall VMT change is only a 3% reduction (and the change is statistically insignificant), suggesting that the Oregon Weekday VMT reduction may be offset by increases in other VMT types. For example, there is a large increase in Outside Oregon All Days VMT, though the change is statistically insignificant and, so, inconclusive. One possible explanation for the inconsistency is that Outside Oregon VMT has a large standard error in the change in miles (2.4 miles) and Oregon Weekend VMT has a large standard error in the percentage change (94%). Therefore, there might be a spillover effect for VMT on the weekends and outside Oregon, but our data are unable to confirm this due to the small sample size and a large variation in the data.

To conclude, the results do not confirm Hypothesis 2. There are no detected spillover effects to off-peak hours or to areas outside the peak-charge zone. There could be spillover effects to weekends and to areas outside the state of Oregon, but the result is not conclusive. The lack of evident spillover to areas outside Oregon where no mileage fee was applied, including just over the Columbia River to the state of Washington, makes sense given the economics of the region. First, most of the region's jobs are located within the Oregon part of the region. Second, and perhaps more important in explaining off-peak and weekend travel, the State of Oregon does not have a sales tax, while the State of Washington does. Therefore, people living in Oregon have an economic disincentive to shop in Washington.

THE INTERACTION BETWEEN URBAN FORM AND THE MILEAGE FEE

Hypothesis 3

Hypothesis 3: Given a sufficient incentive to reduce driving, households in dense, mixed-use, and transit-accessible neighborhoods are more likely to reduce their VMT than would households in other types of neighborhoods.

In order to capture the interaction between the urban form and the mileage fee, we ran regression models for each of the seven types of VMT. For each model, the dependent variable is the *change* between Phase 1 and Phase 2 in average daily VMT per household vehicle. The models incorporate several types of likely causal factors as independent variables: household attributes, measures of the urban form around a household's residential location, and the household's average daily VMT per vehicle in Phase 1 for each of the 7 VMT types (the "base" household VMT for each of the 7 types). The household attributes include the number of vehicles owned, household size, employment status, and income level. The urban form measures include the spatial location of the household residence in the Portland metropolitan region (e.g., distance to downtown and distance to the UGB), accessibility to public transit, and development density and land-use mix in the neighborhood. The model on Outside Oregon All Days has one extra variable: the network distance to the two bridges on the Columbia River that lead to the city of Vancouver in the State of Washington. (Table 3 lists all the independent variables used.)

Table 7 presents the results of the 14 models: one model for each VMT type was run for each of the two household types (the Flat-Rate and Peak-Charged households). All models are the best specifications with the highest adjusted R^2. Four urban form variables were statistically insignificant and thus were excluded from all the results shown. These final models were selected using a backward-delete process: the least significant variable was excluded with each successive application of the model, until the adjusted R^2 became the highest. Comparing these results with the initial models that included all the variables shows that the results are almost identical for both approaches to the modeling. Therefore, only the reduced models in Table 7 are analyzed in the following discussion.

The overall explanatory power of the models ranges from an adjusted R^2 of 0.039 to 0.561, indicating that the included independent variables explain 4% to 56% of the variation in the dependent variable (the change in VMT). The models were least successful at explaining changes in weekday peak VMT within the Portland UGB.

Table 7. A Comparison of the Effect of Urban Form Factors on the *Changes* from Phase 1 to Phase 2 of the Average Daily VMT per Household Vehicle (values shown are the coefficients from the final model specifications)

	Change in Portland Weekday Peak VMT		Change in Portland Weekday Off-Peak VMT		Change in Oregon Low-Fee Weekday VMT		Change in Oregon Weekday VMT		Change in Oregon Weekend VMT		Change in Outside Oregon VMT		Overall Change in VMT	
Independent Variables	PC[a]	FR[b]	PC	FR	PC	FR	PC	FR	PC	FR	PC	FR	PC	FR
Constant	1.39	0.003	5.13	-2.75	**9.22**	2.04	**17.3**	3.41	**37.4**	0.59	1.08	-2.86	**19.5**	-3.47
# of drivers	0.96	**-1.74**		*-2.85*	2.92	**-4.27**	*4.24*	**-6.56**	4.99	*-5.97*			**-4.13**	**-6.65**
# of vehicles		0.60	*-2.18*	*1.89*	*-3.99*		**-4.97**	1.98	*-8.56*	3.12				2.37
# of adults			1.06			**2.0**		1.45	**-5.92**	3.00	*-1.35*	**2.84**		*3.20*
Full-time (yes/no)		0.84		**3.76**		**3.81**		**5.53**		3.31				**4.75**
Part-time only				1.69	3.33							-2.05		
Children (yes/no)		0.91		**3.24**		**3.21**		**4.09**	**9.22**		**2.71**		**5.81**	*4.20*
Income [$40k–$60k]			1.21		2.04							**-1.99**		
Income ≥$60k		*1.17*		-1.52						*-5.46*	**-2.02**		-2.42	
Light rail (≤.5 mile)		*1.97*												
Downtown (miles)	-0.15			0.23						-0.48	*0.32*	*-0.46*		
Miles to UGB		0.22		0.36			-0.65					-0.39		
Gas station (miles)									-0.57			-0.24		
Housing unit density			-0.21	*0.18*	**-0.33**		*-0.33*		**-1.08**			-0.22	**-0.62**	
Entropy index	**-9.08**		*-12.5*		*-16.2*		**-27.4**		-29.0	*19.4*	*10.9*	9.92	-11.6	13.9
Phase 1 VMT				**-0.23**	**-0.40**	**-0.20**	**-0.24**	**-0.18**	**-0.54**	**-0.44**	**-0.40**	**-0.57**	**-0.40**	**-0.26**
Adjusted R^2	0.076	0.101	0.039	0.269	0.220	0.242	0.197	0.242	0.561	0.442	0.263	0.333	0.441	0.224

Note:

- The dependent variable is the change between Phase 1 and Phase 2 in average daily VMT per household vehicle
- *Italics with underlining* indicates that the coefficient is significant at the 10% level. **Bold** indicates that the coefficient is significant at the 5% level. The other variables are insignificant but had a t-statistic greater than 1.0 (in absolute value). Empty cells indicate the variable was included in the initial model but dropped out because its t-statistic had an absolute value of less than 1.0. In other words, these variables were deleted from the final model because doing so produced a model with a higher adjusted R^2 value.

[a] Peak-Charged households, n = 68.

[b] Flat-Rate households, n = 62.

Portland Weekday Peak models

For the Peak-Charged households, the only urban form variable significant at the 5% level is the Entropy Index, which measures land-use diversity. The negative sign indicates that for these households, a mix of land uses helps to further reduce their VMT in peak hours in Portland. (Note that the dependent variable here is the VMT *change* from Phase 1 to Phase 2.) By contrast, the only significant variable for the Flat-Rate households is accessibility to a light rail station, and this is only significant at the 10% level. Surprisingly, the coefficient for this variable has a positive sign. In other words, the closer a Flat-Rate household is situated to a light rail station, the more it will drive—the opposite of our expectation.

Portland Weekday Off-Peak models

For the Peak-Charged households, the only significant urban form variable (at the 10% level) is still the Entropy Index with a negative sign, the same pattern as in the Peak Portland model. None of the urban form variables are significant for the Flat-Rate households. One other variation between the two household types is that the density variable has opposite signs for the Flat-Rate and Peak-Charged households, though neither one is significant at the 10% level.

Oregon Low-Fee Weekday models

For the Peak-Charged households, two urban form variables are significant: housing unit density (at the 5% level) and the Entropy Index (at the 10% level), both with a negative sign. This suggests that density and mixed use could help households reduce VMT under a mileage fee with a higher peak charge. For the Flat-Rate households, no urban form variables were statistically significant in the final model specification.

Oregon Weekday models

For the Peak-Charged households, two variables are significant: density (at the 10% level) and mixed use (at the 5% level). The coefficients for both have the expected signs. For Flat-Rate households, no variables are significant; in fact, none even remain in the final model.

Oregon Weekend models

For Peak-Charged households, density is significant at the 5% level with the expected sign—households facing a penalty on driving will reduce VMT more if they live in a denser neighborhood (the dependent variable is the VMT *change* from Phase 1 to Phase 2). For Flat-Rate households, only the Entropy Index remains significant at the 10% level. The coefficient has a positive sign, indicating that Flat-Rate households in areas with a higher mix of land uses increase VMT more than Flat-Rate households living in neighborhoods with less variation in land use. Note that the Entropy Index has opposite signs for Flat-Rate and Peak-Charged households, though the latter is insignificant at the 10% level.

Outside Oregon models

For the Peak-Charged households, the network distance to downtown is significant at the 5% level with a positive sign. This suggests that, with a penalty for driving more, households living farther away from the Portland downtown are more likely to drive across the state border to avoid the penalty. The Entropy Index is significant at the 10% level with a positive sign, suggesting that Flat-Rate households living in mixed-use neighborhoods tend to increase their Outside Oregon All Days VMT more than other Flat-Rate households. Note that the network distance to downtown again has opposite signs between Flat-Rate and Peak-Charged households, though neither variable is significant.

Overall VMT models

For the Peak-Charged households, density is significant at the 5% level with an expected sign; dense developments help households to further reduce their overall VMT when a penalty is charged in peak hours in Portland. The Entropy Index coefficients have opposite signs for the Flat-Rate and Peak-Charged households, though both of them are insignificant at the 10% level.

Summary

In summary, the results confirm Hypothesis 3. They reveal that density and mixed-use are often statistically significant, with a negative sign for Peak-Charged households. This suggests that when the travel cost increases in peak hours in Portland, households living in denser and mixed-use neighborhoods are able to reduce their VMT more than those not living in these neighborhoods, possibly due to the alternative destinations available nearby and the availability of alternative modes of travel.

However, the models also suggest that the urban form effects on Flat-Rate households are totally different from those on Peak-Charged households. For a Flat-Rate household, density and mixed-use tend to encourage, not discourage driving. A possible explanation for this surprising finding—which contradicts the expectation that participants would reduce VMT to save money on fees—is proposed at the end of the chapter.

Hypothesis 4

Hypothesis 4: Replacing the gas tax with a mileage fee reinforces the influence of urban form on households' travel patterns, perhaps because such a fee establishes a stronger and more prominent connection between travel cost and travel distance than does a gas tax.

To test this hypothesis, two types of models were developed: one with and one without the urban form variables. The difference between the adjusted R2 values for each model indicates how much the urban form variables contribute to explaining the variation in the average daily VMT per household vehicle, among all households within that household group. The two models are applied to all seven types of VMT for both types of households (Flat-Rate and Peak-Charged) and for both time periods (Phase 1 and Phase 2).[22] For comparison, the Phase 1 and Phase 2 models have the same structure. The VMT base variable is not included in either model. Table 8 presents both the absolute contribution made by the urban form variables (the difference in the adjusted R^2 values), and also the share (percent) of the contribution by the urban form variables (the difference between the two adjusted R2 values divided by the adjusted R^2 value for the model containing all variables).

Table 8 summarizes the 56 values (2 households x 7 VMT types x 2 phases x 2 adjusted R^2 values = 56). For example, in Phase 2, adding the urban form variables adds a value of 4 percentage points to the adjusted R^2 for the model for Overall VMT for the Flat-Rate households, and these percentage points account for 22% of the overall variation explained by the model with the urban form variables. The same values for the Peak-Charged households are 14 percentage points and 49%, respectively.

Overall, adding the urban form variables improves the adjusted R^2 values by 3 to 15 percentage points for the Flat-Rate households and generally a bit more (4 to 22 percentage points) for the Peak-Charged households. (Note that the change in the adjusted R2 values is higher for the Peak-Charged households in all but one of the 14 models.)

The difference-in-difference method is used to test the degree to which the urban form variables explain the difference from Phase 1 to Phase 2 in average daily VMT per household vehicle for the Peak-Charged versus the Flat-Rate households. The percentage point difference in the adjusted R^2 values between Phase 1 and 2 for the Flat-Rate households is compared to the same values for the Peak-Charged households. Table 9 presents these 14 values. For example, for Overall VMT, the contribution that the urban form variables make to explaining household VMT is 8.9 percentage points higher for the Peak-Charged households than for the Flat-Rate households, while the share of the urban form contribution (compared to the model with just the demographic and base VMT variables) increases by 38.8 percentage points.

In summary, the findings mostly confirm Hypothesis 4. Table 9 suggests that the peak charge enhances the influence of urban form on four of the seven types of household VMT and reduces the influence of urban form on the other three, which are Portland Weekday Off-Peak VMT, Oregon Low-Fee Weekday VMT, and Outside Oregon All Days VMT. However, even for these three types of VMT, the influence of the urban form variables is higher for the Peak-Charged households than for the Flat-Rate households.

Table 8. Contribution of Urban Form Variables to the Explained Variation in Average Daily Household VMT per Vehicle

	Portland Weekday Peak		Portland Weekday Off-Peak		Oregon Low-Fee Weekday		Oregon Weekday		Oregon Weekend		Outside Oregon		Overall	
	P1[a]	P2[b]	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
Flat-Rate HHs														
Absolute[c]	10	3	5	3	9	4	11	5	5	3	8	15	12	4
Shared (%)	30	10	51	10	82	27	55	20	19	14	100	61	58	22
Peak-Charged HHs														
Absolute	16	14	9	6	18	11	22	20	4	7	22	12	12	14
Share (%)	53	59	71	50	91	84	77	74	22	37	68	93	47	49

[a] Phase 1: Mid-June to mid-November, 2006.
[b] Phase 2: Mid-November 2006 to mid-March 2007.
[c] The absolute difference between the two adjusted R^2 values – i.e., the R^2 value of the first model minus the R^2 value of the second model.
[d] The difference between the two adjusted R^2 values, divided by the adjusted R^2 value for the model containing all variables.

Table 9. Effect of the Peak-Charge Fee Design on the Urban Form Contribution to Household VMT (in Percentage Points)[a]

	Portland Weekday Peak	Portland Weekday Off-Peak	Oregon Low-Fee Weekday	Oregon Weekday	Oregon Weekend	Outside Oregon	Overall
Change of contribution	4.1	-0.3	-1.1	3.7	5.1	-16.1	8.9
Change of share of contribution	26.1	20.4	48.1	32.3	19.4	64.1	38.8

[a] The values expressed are the adjusted R^2 values for the Peak-Charged households (Phase 1 - Phase 2) minus Flat-Rate households (Phase 1 - Phase 2).

RETHINKING THE PROGRAM: THE INTERACTION BETWEEN THE MILEAGE FEE PROGRAM'S COST STRUCTURE FOR PARTICIPANTS AND THE URBAN FORM EFFECT

One key feature of the Portland pilot program was the establishment of an endowment account for each enrolled vehicle, a common practice of pilot programs such as this. As described earlier, the amount of money in the account was calculated by ODOT using a formula based on the household's VMT in Phase 1 and the fee structure in Phase 2. For a Flat-Rate household, the account value was set as its total Oregon mileage in Phase 1 multiplied by 1.2 cents per mile. For a Peak-Charged household, the account value was set as the sum of (1) the Portland Weekday Peak mileage in Phase 1 multiplied by 10 cents per mile and (2) all other miles driven in Oregon in Phase 1 multiplied by 0.43 cents per mile. Therefore, if a household's driving pattern remained the same in Phase 2 as in Phase 1, the endowment account balance would approximately equal zero at the end of Phase 2.[23] The average amount of money deposited in the endowment accounts was $51.50 for a Flat-Rate household and $123.20 for a Peak-Charged household.[24]

The program designers included the endowment account for two reasons. First, the accounts provided a logistically simple way for participating households to pay the mileage fee in Phase 2. Also, this element of the program design helped recruit participants by ensuring that their participation wouldn't cost them money out-of-pocket. Second, the endowment accounts created an incentive for households to reduce their VMT in Phase 2. If a household reduced VMT in Phase 2, any endowment balance remaining at the end was granted to the household. Building such a financial incentive into the program was important, since in Phase 2 the households were paying neither the mileage fee nor the gas tax with their own money. During the program, ODOT notified participants of their endowment balances every few weeks, giving them information that could help them modify their driving habits in order to reduce the mileage fee charged to their account balance and maximize their reward at the completion of the pilot program.[25] However, if a household drove more in Phase 2 than in Phase 1 and used up all the endowment account money, it was not required to pay off this "debt."[26]

Although the initial purpose of the endowment accounts was to provide a real-life incentive for households to save money by driving a bit less, evaluations of the mileage fee program have not tested whether households actually reacted as expected. Given the complex cost structure of the Portland program, we suspected that this signal might be too weak or ambiguous to effectively encourage households to reduce VMT.

Therefore, we decided to test the endowment-account effect by including the starting value of each household's endowment account as a variable in the seven VMT models for both Flat-Rate and Peak-Charged households and comparing the result with the original models run without this variable. We found that the cost structure of the Portland program, especially the endowment account feature, sent multiple signals to participating households that, on balance, actually encouraged Flat-Rate households to increase their average daily VMT per household vehicle in Phase 2, as compared to Phase 1, but had little effect on Peak-Charged households.

Evaluating the Effect of the Endowment Account

To test this hypothesis, four types of variables were tested in the seven VMT models: household attributes, urban form measures, the household's Phase 1 base VMT (average daily VMT per household vehicle), and the value of the household's endowment account at the beginning of Phase 2. Model 1 includes the first three types of variables and Model 2 adds the endowment account variable. The regression results are summarized in Table 10 for Flat-Rate households and in Table 11 for Peak-Charged households. Only the estimations of the base VMT in Phase 1 and the endowment account variables are presented in the tables.

Before analyzing the result, the relationship between the Phase 1 base VMT and the endowment account should be clarified. First, including the base VMT is necessary to control for the fact that the households were not randomly assigned to the Flat-Rate and Peak-Charged groups; their assignment was based partly on their Phase 1 base VMT. Second, we tested and confirmed that the base VMT and the endowment account are not highly correlated. (There was no correlation because the mileage used to calculate the endowment account money is not one of the seven types of mileage used for this study.[27])

As Table 10 and Table 11 show, the endowment account proves insignificant in all the models for the Peak-Charged Households. By contrast, for the Flat-Rate households the endowment account variable is significant in the models for four types of VMT. In each case the coefficient is positive, indicating that the endowment account money is associated with driving more, not less, in Phase 2. For example, one extra dollar in the endowment account is associated with an increase of 0.235 Overall VMT miles from Phase 1 to Phase 2 (Table 10, last column).

Another interesting observation about the Flat-Rate households is that when the endowment account variable is included, the coefficient for the base VMT variable increases in absolute value. This further proves that the base VMT and endowment account have opposite effects on the dependent variable. The estimations of the base VMT in Model 2 capture the real effect of seasonal VMT change while those in the Model 1, without the endowment account, underestimate that effect. For example, for Overall VMT, Model 1 shows that a Flat-Rate household normally would reduce average daily VMT by 0.256 miles in Phase 2 for each mile driven in Phase 1. However, Model 2 shows that this 0.256-mile drop is actually caused by a reduction of 0.628 miles from each Phase 1 Base VMT mile (due to the seasonal change), combined with an increase of 0.235 miles per dollar in the starting value of the endowment account.

For a typical Flat-Rate household with the median overall daily VMT in Phase 1 (26.8 miles) and the median endowment account value ($45.2), about 63%[28] of the seasonal reduction in VMT that would otherwise be expected is offset by the growth in VMT induced by the endowment account. In other words, a household's Phase 2 VMT reduction would be 63% greater if the endowment account were completely removed.

Further inspection of Table 10 shows that the effect of the endowment account varies among the 7 different VMT models. Note that the endowment account variable is insignificant in two of the different VMT models (the Portland Weekday Peak and Portland Weekday Off-Peak models), and only significant at the 10% level in the Oregon Weekday model. This result suggests that the endowment account affects primarily non-commuting travel—i.e., travel *outside* Portland during the peak times, travel on weekends, and travel outside Oregon. Such a finding makes intuitive sense; households most likely are traveling for non-work purposes in these conditions, and trips for which the members likely have more flexible travel schedules.

Finally, note that for Flat-Rate households, when the endowment account is significant, the goodness-of-fit (adjusted R^2) of the model improves dramatically—by an average of 30% compared to the models without the endowment account.

Behavioral Explanation

In order to understand the different behavioral responses from Flat-Rate and Peak-Charged households, it is useful to look at how the money in their endowment accounts was finally distributed between mileage fee payments and cash rewards to participants. This analysis suggests how the participating households used the endowment money (e.g., as a potential cash reward vs. as a fund for payment for VMT fee).

For the Flat-Rate households, the endowment account money was spent in two ways: part of the money covered all the mileage fee charges the household accrued in Phase 2, and the remainder was granted to the household at the end of Phase 2 as a cash reward (Figure 3a). On average, 64% of the endowment account money was spent on the VMT fee charges, and 36% went to the household as a cash reward.[29]

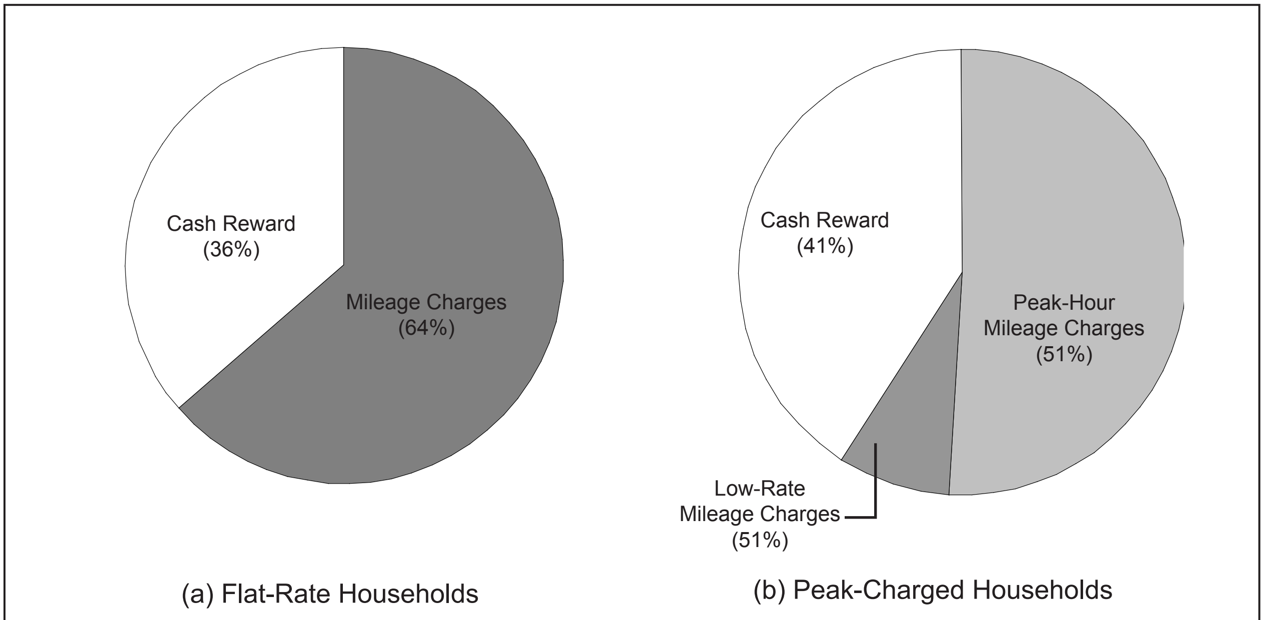

Figure 3. Average Distribution of Funds in the Endowment Accounts for Flat-Rate and Peak-Charged Households

Source: Calculated by the authors using the mileage data provided by ODOT.

For the Peak-Charged households, the endowment account money was divided among three expenditures: the 10-cents-per-mile fee applied to all Portland Weekday Peak mileage, the reduced mileage fee for all other Oregon mileage, and the cash reward to participants (Figure 3b). The money was, on average, divided as follows: 51% covered the peak-hour mileage charges, 8% covered the low-rate mileage charges, and 41% was given to the household as a cash reward.

The average values for all households presented mask the fairly significant variation in how the endowment account money was spent among households. Figure 4 shows the distribution of the percent of endowment money spent paying mileage fee charges for both Flat-Rate and Peak-Charged households. In both groups, the majority of households spent 50% to 80% of the money to pay mileage fee charges, but a few households spent only 10% to 20%, and there were five households in each group that actually overspent their endowment money (on average, 119% for the five Flat-Rate households and 113% for the five Peak-Charged households). The great variation indicates that the assumption that all households will treat the endowment account uniformly as an incentive to reduce driving does not hold.

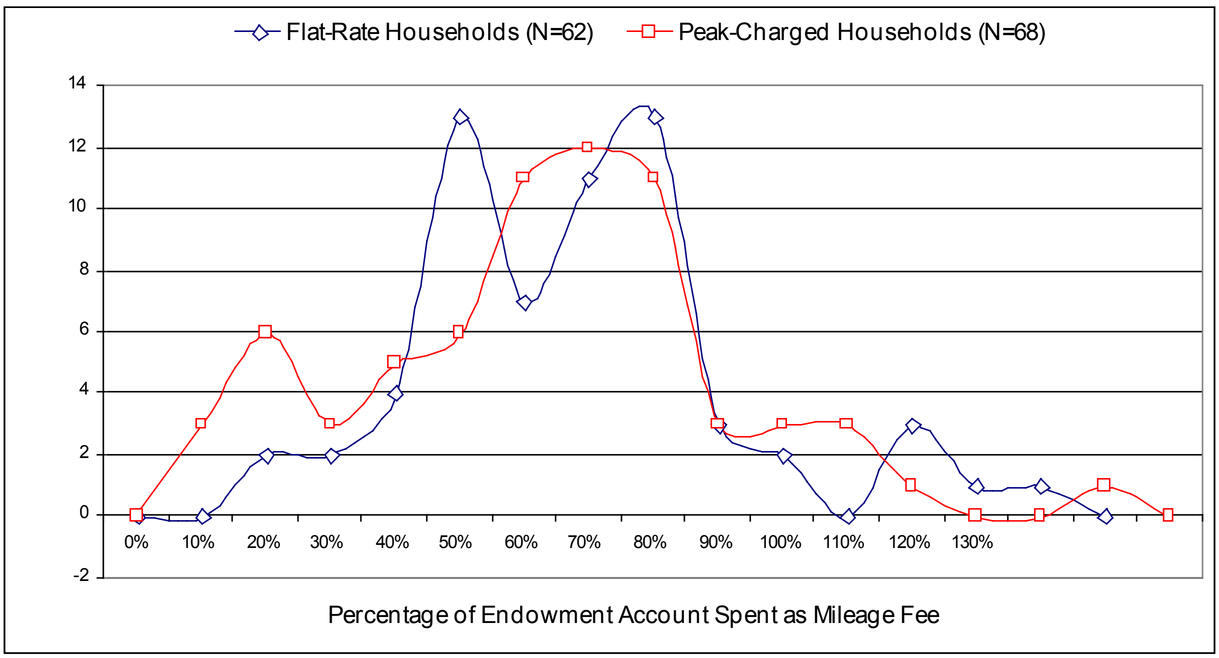

Figure 4. The Distribution of the Share of Endowment Account Spent to Pay the Mileage Fee for Flat-Rate and Peak-Charged Households

Given this vast difference in the usage of the endowment money, we assume that participating households may not all view the money the same way. For example, for a household that used only 10% of the money, this endowment account is more like a cash reward for its VMT reduction. For a household that used 90% of the money to cover mileage fees, the endowment account is more like a subsidy from the government to cover gas tax costs. Although each household falls in a different place along this reward-

Table 10. Effect of the Endowment Account on the Change in Average Daily Household VMT from Phase 1 to Phase 2, for Flat-Rate Households (n=62)

	Portland Weekday Peak		Portland Weekday Off-Peak		Oregon Low-Fee Weekday		Oregon Weekday		Oregon Weekend		Outside Oregon		Overall	
Model	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Adj. R^2	0.138	0.085	0.269	0.269	0.248	0.304	0.240	0.275	0.475	0.553	0.382	0.484	0.224	0.350
Base VMT Phase 1	[a]		**-0.21** **(-2.8[b])**	-0.25 (-3.0)	-0.17 (-2.1)	-0.32 (-3.2)	-0.17 (-2.2)	-0.33 (-2.9)	-0.45 (-5.6)	-0.64 (-6.8)	-0.64 (-5.1)	-0.79 (-6.4)	-0.26 (-3.1)	-0.63 (-4.7)
$ Endow[c]		-0.003 (-0.03)		0.02 (1.0)		0.08 (2.3)		0.09 (1.9)		0.18 (3.2)		0.08 (3.3)		0.24 (3.4)

Note: Model 1 and Model 2 differ only in that Model 2 includes the amount of the household's endowment account at the beginning of Phase 2. Both models include household demographic variables, the base (average daily) VMT from Phase 2, and urban form variables. Numbers in bold indicate the variable was significant at the 0.05 level.

[a] Indicates the variable has a t-statistic smaller than 1, and so was not included in the final model specification.

[b] Numbers in parentheses are the t-statistics.

[c] Value of the endowment account at the beginning of Phase 2.

Table 11. Effect of the Endowment Account on the Change in Average Daily Household VMT from Phase 1 to Phase 2, for Peak-Charged Households (n=68)

	Portland Weekday Peak		Portland Weekday Off-Peak		Oregon Low-Fee Weekday		Oregon Weekday		Oregon Weekend		Outside Oregon		Overall	
Model	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Adj. R^2									0.589	0.597			0.446	0.447
Base VMT Phase 1	[a]								**-0.54** **(-8.8[b])**	-0.51 (-8.0)			**-0.40** **(-6.5)**	**-0.41** **(-5.7)**
$ Endow[c]										-0.04 (-1.6)				0.02 (1.2)

Note: Model 1 and Model 2 differ only in that Model 2 includes the amount of the household's endowment account at the beginning of Phase 2. Both models include household demographic variables, the base (average daily) VMT from Phase 2, and urban form variables. Numbers in bold indicate that the variable was significant at the 0.05 level.

[a] Indicates that the variable has a t-statistic smaller than 1. and so was not included in the final model specification.

[b] Numbers in parentheses are t–statistics.

[c] Value of the endowment account at the beginning of Phase 2.

to-subsidy spectrum, there is a clear difference between the Flat-Rate and Peak-Charged households.

For the Flat-Rate households, the majority of the endowment account money (64%) was used to pay a mileage fee, a replacement for the gas tax. All participating households were informed that the fee was set up as equivalent to the gas tax—they would not pay more money under the new fee scheme. This payment was provided by the government at no cost to the participating households, effectively lowering the price of gas for them.

It is likely that the lowered gas prices proved a more salient financial incentive for participants than did the potential to keep unspent money from the endowment account. When households do not need to pay the gas tax at the pump, this provides a direct and immediate savings. And this price reduction was not minor. In Oregon, the state gas tax is 24 cents per gallon, while the average gas price in the West Coast in Phase 2 was $2.51 per gallon[30]. Therefore, all Flat-Rate participants enjoyed a 9.6% reduction in the price they paid at the pump during Phase 2. At the same time, the potential “cash reward” from the endowment account was likely much less salient and visible to the participants. Participants could not check the account balance by themselves, and the “reward” money they received if they reduced their VMT was available only at some unknown (to them) future date, after the program ended. Finally, even if households thought directly about the cost of the mileage fee when making travel decisions, the rate of 1.2 cents per mile most likely sounded too trivial to provide a clear incentive to reduce VMT.

The salience of price on consumer behavior has been well documented in the behavioral economics literature. For example, Chetty et al. found that consumption decreases substantially when sales tax is included in the displayed price, even though consumers would pay the same total price either way. The authors ran an experiment using 750 distinct products at a supermarket in Northern California over a three-week period, with a state sales tax of 7.375%. Consumers spent 8% less when the price tags showed the final price, including sales tax.[31]

The findings from the modeling appear to contradict the assumption by the program designers that the endowment account should not have impacted household VMT at all. As the modeling indicates, the endowment accounts did influence behavior, although the direction of the effect is counterintuitive (the larger the endowment account and potential cash reward, the greater the household’s VMT). This apparent contradiction between the modeling results and the assumption can be explained by reexamining what the endowment account variable actually represents. We suspect the endowment account variable was significant because it served as a proxy for the household’s savings in expenditures on gasoline during Phase 2, not because households were influenced by the prospect of receiving money left in the endowment account itself. In other words, the variable probably should be relabeled along the lines of “Potential Savings in Gasoline Expenditures.”

This reasoning, which could explain the behavior of the flat rate households, does not work for the Peak-Charged households. The modeling results show the latter to be uninfluenced by the endowment account variable (or its counterpart, the savings in gas expenditures). Why might this be? First, about half (51%) of the endowment money was spent on a congestion charge, a price nine times higher than the gas tax in Phase 1. This congestion charge also accounts for 86% (51% / 59% = 0.86) of all endowment money spent on mileage fee charges. While Peak-Charged households still paid no gas tax at the pump, it was probably hard for them to view the endowment money spent on the mileage fee as a replacement for the gas tax. Instead, they probably perceived the endowment account money spent on peak-charged VMT as a penalty on driving, an incentive which might be as salient as the direct savings at the pump. This reasoning may explain why the endowment account variable is insignificant for Peak-Charged households in Table 10. Most models (five out of seven) do not even have the variable in the final specification, and when they do, the coefficients show opposite signs, indicating that the endowment account had no apparent influence on driving behavior.

In summary, by artificially lowering the cost of gas, the cost structure of the Portland program may have encouraged Flat-Rate households to increase their VMT in Phase 2. This suggests that the program results underestimated the effect of a flat-rate mileage fee on VMT reduction. Based on our analysis, the reduction could have been 63% greater for Flat-Rate households if the mileage fees had been incorporated into the price of gasoline paid at the pump.[32] The same underestimation may have occurred with Peak-Charged households, but we are unable to detect it due to the mixed effects of the reduced gas price at the pump and the high congestion charge.

This result also sheds light on the likely effects that could be expected from an actual statewide or national mileage fee. First, because households would pay the mileage fee with their own money, a real program should lead to a larger VMT reduction than that observed in the Portland program, under either a flat-rate or variable-charged rate scheme. Second, if the mileage fee is not paid at the pump and is paid only infrequently—for example, once per month—the mileage-fee program may inadvertently encourage people to drive more, since the gas price reduction at the pump may prove a stronger incentive than the charges paid a month later with a credit card. The timing of payment is thus a key issue in determining the how a mileage fee program will impact overall VMT.

CONCLUSION

SUMMARY AND DISCUSSION OF FINDINGS

A key finding is that the mileage fee program led some households to reduce their overall VMT. The results showed significant VMT reductions in Portland Weekday Peak and Oregon Weekday VMT. There appears to have been no corresponding spillover effects to Portland Weekday Off-Peak or Oregon Low-Fee Weekday VMT. The lack of compensating spillover travel may be explained by multiple factors. For example, the UGB in Portland has prevented most development from occurring outside the congestion charge zone, so there are few substitutive destinations outside the UGB, at least within Oregon. Without the UGB, the likelihood of a spillover effect might have been greater. A second possibility is that people's travel schedules are less flexible on weekdays, making it impractical for them to increase weekday off-peak travel to compensate for reduced peak-hour travel. Finally, the analysis was unable to draw any conclusions about whether there were any spillover increases in Oregon Weekend and Outside Oregon VMT.

Second, the analysis also provides evidence that a mileage fee with a variable rate could potentially strengthen the interaction between urban form and travel decisions. The urban form measures were more influential in explaining household VMT for the households charged a variable mileage-fee than for households charged a flat-rate fee. This finding about the impact of the urban form variables held for the results measured both in absolute miles and percentage terms. Those Peak-Charged households located in denser neighborhoods with a mix of land uses reduced VMT more than Peak-Charged households located in other types of neighborhoods. For the Flat-Rate households, however, the opposite occurred: those households in higher density, mixed-use neighborhoods actually increased their VMT after the mileage fee was introduced.

A last significant finding is that the program design seems to have sent conflicting incentives to the participating households in terms of whether they should increase or reduce VMT in Phase 2. We suspect that the elimination of gas taxes from the price of gas encouraged Flat-Rate households to drive more instead of less because gas essentially become cheaper. Such an effect disappears for Peak-Charged households, however, perhaps because the high rate of the peak-hour mileage charge proved such a strong stimulus to reduce driving that it outweighed the incentive provided by the lower gas prices to drive more. The effect of the program design might help explain the unexpected findings that density and mixed uses were associated with increased VMT for the Flat-Rate households.

The findings presented in this report are somewhat, but not entirely, consistent with those of Rufolo and Kimpel's analyses of the Oregon Mileage Fee program,[33] though it is not possible to make a direct comparison because of differences in research design. First, Rufolo and Kimpel also did not find any spillover (increase) of VMT to off-peak hours. Rather, they actually found a further decrease of VMT in off-peak hours. Second, they found that access to public transit as measured by the network distance to frequently served bus stops affected VMT changes, which complements our findings about the influence of urban form variables.[34] While we did not find any significant associations between transit proximity and reduced VMT, we did see a relationship with density and mixed land uses.

Transit service is generally higher in areas of higher density, which makes the finding consistent with Rufolo and Kimpel.

LIMITATIONS TO THE STUDY

When considering the findings from the study, it is important to keep in mind the limitations of the data. The participants were not randomly selected, and the sample size was relatively small. However, we believe these limitations are likely irrelevant to our analysis for several reasons. First, we compared two groups of households within the sample, rather than comparing the sample with the general population. Second, we see no compelling theoretical argument for why the urban form effect should be correlated to people's decision to participate in the program. Only a few people mentioned environmental concerns as the reason they participated in the program, while most listed money, curiosity, and the dislike of gas taxes as main reasons to participate. Third, there is no obvious reason why the general population would respond differently to the financial incentives set up in the pilot program through the endowment account and the elimination of the gas tax. In sum, the study findings seem likely to hold for the general population, though that conclusion would need to be confirmed with additional research, particularly with data from a program that overcomes some of these limitations.

POLICY IMPLICATIONS

The study results suggest several implications for transportation policymakers. First and foremost, charging a noticeably higher fee for driving in congested conditions can successfully motivate households to reduce their VMT in those times and places where congestion is most a problem.

Second, the spillover effect of a variable charge might be less than expected. The study found no evident spillover of VMT to off-peak hours on a weekday, perhaps indicating that households are relatively unwilling to change their weekday travel patterns . The study also found no spillover of VMT to the areas outside the peak-charged zone, though this finding might be unique to the Portland metropolitan area because its UGB has kept most development out of the land surrounding the metro region. Without such a boundary, spillover to outside areas might be more likely to occur.

Third, in terms of the connection between urban form, the mileage fee, and travel behavior, households in all types of neighborhoods will likely reduce their peak-hour and overall travel under a charging scheme that charges a high-rate for peak-hour travel, though households in higher-density neighborhoods with a mix of land uses will likely make greater reductions in VMT.

Fourth, the study findings suggest that a mileage fee program that charges a high rate during the peak hour will likely strengthen the underlying influence of urban form on travel behavior as compared to the current gas tax system. In other words, urban form patterns will affect travel behavior more than they currently do if the nation shifts to a new system of mileage charges that vary by congestion levels. For planners, this finding suggests that switching from fuel taxes to mileage taxes would strengthen the power of land-use planning as a policy tool to shift some travel from solo driving trips to more sustainable modes. Also, this finding about the link between urban form and travel behavior in response to a mileage fee implies that mileage-fee program designers will need to carefully consider both current and future urban form patterns when estimating the likely revenues collected from mileage fees and also the potential impact of the fees on congestion levels.

Fifth, the study findings suggest that residents in lower-density suburban areas, as well as residents in higher-density and more mixed-use neighborhoods, are able to reduce their driving in response to a mileage fee. Therefore, the results add new empirical evidence to the ongoing equity debate about whether mileage fees are unfair to households living in suburban communities and suggests that this concern may not be warranted. However, none of the study's households lived in rural areas, and Portland's UGB may result in higher suburban densities than those found in other metropolitan regions. Therefore, the applicability of the findings with respect to geographical equity is somewhat limited.

Sixth, although a peak-hour mileage charge could encourage drivers to think carefully about their travel decisions and they would probably reduce their VMT accordingly, the ultimate program impacts on VMT will likely depend on the specific program design, especially the timing of the mileage fee payment. If drivers pay mileage fees less frequently than they currently pay gas taxes at the pump—e.g., if they're billed monthly—they may increase instead of decrease their VMT. Policymakers will want to pay attention to the psychological aspects of the program design in order to best achieve their policy goals.

Seventh, these findings about the program design suggest that the results of the Portland pilot program may have underestimated the effect of a mileage fee on VMT reduction. If the mileage fee had been added to the price of the gas at the pump rather than billed later, participants might have reduced their VMT more.

Finally, the analysis of the program design's incentives may explain the apparently "inconsistent" impact of the urban form variables on the behavior of the Flat-Rate and Peak-Charged households in Hypothesis 3. This analysis found that some of the urban form variables (density, transit access, and mixed land use) had an unexpected positive coefficient for Flat-Rate households, though the positive coefficients are insignificant at the 10% level in all models except for the Oregon Weekend one. Although the evidence is not strong, these results suggest that with the incentive to drive more provided by a drop in gas prices, households in denser, mixed-use, and transit-accessible neighborhoods might increase their VMT more than would households in other types of neighborhoods. Theoretically, this argument is actually consistent with Hypothesis 3: if households in dense and transit-accessible areas are more elastic to travel cost than those who live in lower-density neighborhoods without good transit service, then the former households should reduce VMT more when travel cost increases and also increase VMT more when travel cost decreases. Further analysis is necessary to test this hypothesis.

RECOMMENDATIONS FOR FUTURE RESEARCH

In terms of future research, two issues need to be analyzed to better understand the effectiveness of a mileage-base fee program. The first is the behavioral analysis related to the endowment account. Such an analysis should cover both objective usage and subjective perception of the endowment money. The Oregon pilot program dataset is unable to support such analysis. A second issue for further research is the potential for spillover VMT on weekends and/or outside the zone where the mileage fee is charged. This research could neither prove nor disprove spillover in these latter cases due to limitation of the data—the sample size is too small. However, this issue is critical to understanding the overall effect on VMT that could be expected from a mileage fee program that was applied at any geographical scale other than nationwide. Finally, testing a mileage fee in other geographic areas, including rural ones, would help further address questions about equity impacts.

ENDNOTES

1. James M. Whitty, *Oregon's Mileage Fee Concept and Road User Fee Pilot Program: Final Report* (Oregon Department of Transportation, November 2007).

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7. See, for example: James M. Whitty and J. R. Svadlenak, "Discerning the Pathway to Implementation of a National Mileage-Based Charging System" (paper presented at the annual meeting of the Transportation Research Board, Washington, D.C., January 11-15, 2009).

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9. James M. Whitty, *Oregon's Mileage Fee Concept and Road User Fee Pilot Program: Final Report* (Oregon Department of Transportation, November 2007): 22.

10. Anthony M. Rufolo and Thomas J. Kimpel, "Responses to Oregon's Experiment in Road Pricing," *Transportation Research Record* 2079 (2008): 1.

11. James M. Whitty, *Oregon's Mileage Fee Concept and Road User Fee Pilot Program: Final Report* (Oregon Department of Transportation, November 2007): 24.

12. The remaining households were ranked by peak-hour-miles per vehicle. Going down the list, three households were assigned to the Peak-Charged group and one to the Flat-Rate group until the Peak-Charged group was approximately half of the non-control vehicles. The remainder were then assigned to the Flat-Rate group, so the total number of vehicles in each group was approximately equal. Source: Anthony Rufolo, email message to authors, April 6, 2010.

13. Anthony M. Rufolo and Thomas J. Kimpel, "Responses to Oregon's Experiment in Road Pricing," *Transportation Research Record* 2079 (2008): 2.

14. For a Flat-Rate household, the value of the endowment account was calculated as the total Oregon mileage in Phase 1 multiplied by the VMT fee of 1.2 cents per mile. For a Peak-Charged household, the account was calculated as the sum of the mileage in the peak period that was driven within the Portland UGB, plus the non-peak Oregon mileage in Phase 1, each multiplied by their respective VMT fees. Source: Anthony M. Rufolo and Thomas J. Kimpel. "Responses to Oregon's Experiment in Road Pricing," *Transportation Research Record* 2079 (2008): 1-7; James M. Whitty, *Oregon's Mileage Fee Concept and Road User Fee Pilot Program: Final Report* (Oregon Department of Transportation, November 2007): 25.

15. James M. Whitty, *Oregon's Mileage Fee Concept and Road User Fee Pilot Program: Final Report* (Oregon Department of Transportation, November 2007): 25.

16. Anthony Rufolo, email message to authors, April 6, 2010.

17. Anthony M. Rufolo and Thomas J. Kimpel, "Responses to Oregon's Experiment in Road Pricing," *Transportation Research Record* 2079 (2008): 2.

18. See, for example: Robert Cervero and Kara Kockelman, "Travel Demand and the 3Ds: Density, Diversity, and Design," *Transportation Research D* 2, no. 3 (1997): 199–219; Reid Ewing and Robert Cervero, "Travel and the Built Environment: A Synthesis," *Transportation Research Record* 1780 (2001): 87-114; Yan Song and Gerrit J. Knaap, "Measuring the Effects of Mixed Land Uses on Housing Values," *Regional Science and Urban Economics* 34, no. 6 (2004): 663-680; Susan Handy, Xinyu Cao, and Patricia Mokhtarian, "Correlation or Causality between the Built Environment and Travel Behavior? Evidence from Northern California," *Transportation Research Part D* 10, no. 6 (2005): 427–444; Daniel A. Rodríguez, Asad J. Khattak, and Kelly R. Evenson, "Can New Urbanism Encourage Physical Activity? Comparing a New

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19. Scott M. Festin, *Summary of National and Regional Travel Trends: 1970-1995* (Washington, D.C.: Federal Highway Administration, May 1996), http://www.fhwa.dot.gov/ohim/bluebook.pdf (accessed September 10, 2010).

20. Oregon Department of Transportation Automatic Traffic Recorders Database. Emailed via Don R. Crownover, ODOT Traffic Monitoring Unit, April 2, 2010. ATR #: 26-004, 26-002, 26-014, 26-015, 26-016, 26-018, 26-022, 26-024, 26-027.

21. Bruce Meyer, "Natural and Quasi-Natural Experiments in Economics," *Journal of Business and Economic Statistics* 13, no. 2 (1995): 151-161.

22. The only difference between the models for Phase 1 and Phase 2 is that the Phase 1 models do not include the "Phase 1 base VMT" variable.

23. As mentioned in the previous section, ODOT actually set the endowment amount to be a little bit higher than this formula out of concern that when the money in the endowment account was used up, the participating household might quit the program. Participants were not informed how the initial value of the endowment account was determined. (Source: Anthony Rufulo, e-mail message to authors, April 8, 2010.)

24. Although the starting value of the accounts does not seem large, we do not know how it was perceived by the participants. About 70% of participants listed money as one of the reasons they chose to participate in the program. In addition to receiving the remaining value of the endowment account at the end of Phase 2, participants received two other monetary incentives: $300 per vehicle to install a GPS device and a $40 gasoline voucher.

25. James M. Whitty, *Oregon's Mileage Fee Concept and Road User Fee Pilot Program: Final Report* (Oregon Department of Transportation, November 2007): 25.

26. Source: Anthony Rufulo, email message to authors, April 6, 2010.

27. The starting value of the endowment account was calculated based on the VMT inside Oregon for both weekdays and weekends in Phase 1. This particular type of VMT is not highly correlated with the seven types of VMT used in this research. For all the models in Table 10 and Table 11 for which the endowment account variable remains significant, the Pearson's correlation value ranges from 0.25 to 0.62 for the Flat-Rate households and 0.11 to 0.45 for the Peak-Charge households.

28. $$\frac{0.235 \text{ mile/\$} \times \$45.2}{0.628 \text{ mile/Phase 1 miles} \times 26.8 \text{ Phase 1 miles}} = \frac{10.62 \text{ miles}}{16.83 \text{ miles}} = 0.63$$

29. Source: Calculated by the authors based on the household VMT data collected by ODOT.

30. Energy Information Administration (EIA). Retail Gasoline Historical Price. Available at http://www.eia.doe.gov/oil_gas/petroleum/data_publications/wrgp/mogas_history.html

31. Raj Chetty, Adam Looney, and Kory Kroft, "Salience and Taxation: Theory and Evidence," *American Economic Review* 99, no. 4 (2009): 1145-1177.

32. This value is significantly higher than the typical gas price elasticity found in other studies, though this value is not exactly elasticity. For example, Hughes et al. found that gas price elasticity ranged from -0.034 to -0.077 during 2001 and 2006. We suggest two possible explanations. First, the participants in this program may not be representative of the general population. Monetary compensation was mentioned as one of the major reasons why they participated in this pilot study. They might be more sensitive to price. Second, we suspect that perhaps the elimination of gas tax posed an additional incentive beyond the mere price reduction, though we do not have evidence to support the argument.

33. Anthony M. Rufolo and Thomas J. Kimpel, "Responses to Oregon's Experiment in Road Pricing," *Transportation Research Record* 2079 (2008), 159-166; Anthony M. Rufolo and Thomas J. Kimpel, "Transit's Effect on Mileage Responses to Oregon's Experiment in Road Pricing," *Transportation Research Record* 2115 (2009): 60-65.

34. There are three key differences in research design. First, for this report the unit of analysis is the average VMT per vehicle for each household, whereas Rufolo and Kimpel's studies looked at average VMT per individual vehicle. Second, this study analyzed the Flat-Rate and Peak-Charged households in separate models, while Rufolo and Kimpel combined them together with dummy variables of groups. Third, Rufolo and Kimpel compared Phase 1 and Phase 2 to identify the program effect, while this study compared the difference between Flat-Rate and Peak-Charged household to identify the effect of peak charge.

ABBREVIATIONS AND ACRONYMS

DOE	Department of Energy
FR	Flat-Rate
GPS	Global Positioning System
HH	Household
ODOT	Oregon Department of Transportation
P1	Phase 1
P2	Phase 2
PC	Peak-Charged
RLIS	Regional Land Information System
UGB	Urban Growth Boundary
VMT	Vehicle Miles Traveled

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