An Analysis of Discrete Stated Responses to Parking Pricing Based Transportation Control Measures

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Abstract

The realization that one can no longer build out of congestion while preserving the urban environment has led to an increasing interest in the potential application of transportation control measures (TCMs) for curbing vehicular travel demand. Parking pricing, which is intended to encourage travelers to switch to alternate modes of transportation, is one such measure that has been receiving considerable attention around the world. This paper is aimed at examining the potential impacts of parking pricing on commuter behavior. A stated adaptation questionnaire consisting of hypothetical parking pricing scenarios was administered to a sample of 656 commuters in the Washington D.C. metropolitan area. Their stated adaptations indicating how they would respond in the event of parking pricing implementation were recorded. A descriptive multivariate statistical analysis was performed to identify factors that significantly influence commuter response to parking pricing. The exploratory analysis revealed that commuter response to parking pricing was dependent on several socio-demographic and travel variables such as type of residence, household size, income, car ownership, commute distance, availability of alternate modes, and level of parking tax. The exploratory analysis conducted in this paper provided key insights into commuter behavior that may be useful for subsequent modeling efforts.

Introduction

Urban areas around the world are having to deal with increasing levels of traffic congestion and vehicular emissions. Economic and environmental constraints associated with building new infrastructure have motivated transportation planners to embrace a series of strategies, termed transportation control measures (TCMs), aimed at curbing vehicular travel demand (*1*, *2*). One such TCM, commonly referred to as parking pricing, involves the levying of parking charges or taxes in an attempt to encourage travelers to use alternative modes of transportation (*3*, *4*).

Parking pricing may influence travel behavior in several ways. In order to avoid the parking surcharge, travelers may switch to an alternate mode of transportation that does not involve parking such as transit, bicycle, or walk. On the other hand, one may choose to car or van pool to share the parking costs among several passengers thereby reducing the financial impact of the parking pricing scheme. Alternatively, one may visit new destinations (where parking pricing is not prevalent) for pursuing non-work trip purposes even though these destinations are inferior to those visited previously. In addition, behavioral responses such as choosing to telecommute, changing work or home locations, and parking in alternate locations (resulting in longer walking distances) are also conceivable.

There is very little information about the potential impacts of parking pricing schemes on traveler behavior. Without sufficient data on potential traveler responses to parking pricing strategies, it is virtually impossible to quantitatively predict the impacts of various parking pricing measures on vehicular travel demand. This paper is aimed at filling this critical research need by providing an analysis of stated response data collected from a sample of commuters in the Washington, D.C. metropolitan area in 1994. The data collection effort involved the administration of an elaborate activity-based travel survey together with a TCM response questionnaire that collected information on how commuters might adapt in the event of a parking pricing implementation. Hypothetical parking pricing scenarios were presented to the survey respondents and their stated adaptations or responses were recorded.

This paper provides an exploratory analysis of commuter response to parking pricing that may guide subsequent efforts aimed at developing predictive models of behavior. The distributions of commuter responses cross-classified by selected socio-demographic and travel characteristics are examined to identify those variables that significantly influence commuter behavior in the event of parking pricing. This is followed by a multivariate discriminant analysis that provides a clearer understanding of the combinations of explanatory variables that best distinguish among various response groups.

This paper is organized as follows. Following this introductory section, a description of the data set and survey sample used in this study is provided. The third section provides results of a bivariate descriptive statistical analysis aimed at identifying socio-demographic and travel indicators that are significantly related to commuters' stated response to parking pricing. The fourth section provides results of the discriminant analysis that was conducted to explore relationships in a multivariate statistical framework. Based on the results of the exploratory analysis presented in this paper, conclusions are drawn and directions for further research are outlined in the last section.

Description of Data Set and Survey Sample

The data set used for this study was derived from an elaborate activity-based travel survey that was administered to a random sample of 656 commuters in the Washington, D.C. metropolitan area in 1994 (*5*). In addition to gathering socio-demographic characteristics and revealed preference activity and travel data, the survey collected stated adaptation data on commuter responses to hypothetical scenarios of six transportation control measures. One of the six measures included in the survey was parking pricing. Respondents were presented with a scenario in which a daily parking surcharge would be levied at their regular workplace. The daily parking surcharge ranged between $1 and $3 per day for suburban work locations and between $3 and $8 per day for downtown and other central Washington, D.C. locations. One parking pricing scenario was presented to each respondent (based on their work location) in an open-ended question format. Their stated adaptation responses were recorded into one of eight possible categories:

- No change in behavior
- Switch to transit mode
- Switch to car/van pool mode
- Switch to bicycle

- Switch to walk
- Work at home
- Change departure time
- Other

The remainder of this section is intended to provide a brief overview of the characteristics of the survey sample. The average household size of the sample of 656 commuters is about 2.7 persons per household, while the average car ownership is about 2 cars per household. An interesting feature of the sample is that auto availability per commuter is quite high with 90 percent of the sample residing in households with one or more cars per commuter. The gender distribution of the sample indicates that 58 percent of the respondents are male. Virtually all of the respondents are licensed to drive. On average, the sample reported a commute (one-way, home-to-work distance) 15.2 miles long and 30 minutes in duration.

Table 1 shows the distribution of commute modes for the sample. The commute mode is assigned based on that used most frequently by a respondent on a weekly basis.

Table 1
Modal Split for Commute Trip
(N=656)

Commute Mode	Number of Persons	Percentage Share
Drive Alone	458	70%
Transit	66	10%
Car/Van Pool	105	16%
Bike/Walk	20	3%
Other	7	1%

About 70 percent of the respondents usually drive alone to work, 10 percent use bus, rail, or metro, and 16 percent use car or van pool. Only about 3 percent of the sample reported using non-motorized modes for commuting purposes.

Table 2 provides the univariate distribution of stated adaptation responses for the sample of respondents. About 70 percent of the respondents indicated that they would not change their behavior even after the introduction of parking pricing. It should be noted, however, that this includes those who currently use transit, car/van pool, and non-motorized modes of transportation. About one-quarter of the sample responded that they would switch to an alternate mode; as expected, virtually all of these respondents currently drive alone to work. As such, about 34.5 percent of those who usually drive alone to work indicated that they would switch to an alternate mode of transportation in the event of parking pricing implementation.

Table 2
Distribution of Stated Adaptation Responses to Parking Pricing TCM
(N=656)

Response Option	Number of Persons	Percentage Share
No Change	457	70%
Use Transit	72	11%
Use Car/Van Pool	66	10%
Use Bike/Walk	20	3%
Other*	41	6%

*Other includes work at home and change work/home location

Comparative Analysis of Stated Adaptation Response Distributions

This section provides a summary of a comparative analysis of different response groups in the survey sample. For purposes of the comparison, four response groups are used:

- No change in behavior
- Switch to transit
- Switch to car/van pool
- Switch to non-motorized modes (Bicycle and Walk)

As not much is known about the exact nature of the “Other” category, this response group is not included in the analysis.

Table 3 offers a statistical comparison of means of selected socio-demographic variables across response groups. The F-statistic can be used to test the null hypothesis that the means across response groups are equal. If the F-statistic is larger than the critical value at the desired significance level (usually, 0.05), then the means may be considered to be significantly different from one another (*6*).

It was found that the average number of commuters per household is virtually identical across all the TCM response groups. The F-statistic of 0.20 indicates that the null hypothesis of equality of means can not be rejected. With regard to the number of years that the respondent has resided at the current residence, it was found that the response groups indicating no change in behavior and a potential switch to transit exhibited the longest durations of stay at one location. It appears that a longer stay at one residential location contributes to two potential phenomena. The first one is where commuters are resistant to changing their behavior and will continue habitual behavior despite a change in the transportation environment. The second one is where commuters who have resided at the same location for a long time are more familiar with transit schedules and service reliability that they would feel comfortable shifting to public transportation.

Table 3
Comparison of Means Across Response Groups

Variable	TCM Response Group				F-stat
	No Change	Switch to Transit	Switch to Car/Van Pool	Switch to Non-Motorized	
No. of commuters	1.7	1.6	1.7	1.6	0.20
Years in current residence*	11.6	10.0	7.8	7.9	2.72
No. of vehicles*	2.0	1.7	2.0	1.9	1.95
No. of bicycles*	1.5	1.0	1.54	1.0	2.28
Current parking charge* (Dollars per month)	$9.40	$18.01	$9.42	$1.05	2.25
Commute time** (min)	32.5	32.5	29.0	20.6	1.76
No. of days stopped on home-to-work trip*	1.29	0.39	1.20	1.25	2.90

*significant at 0.05 level
**significant at 0.10 level

The response group indicating a potential switch to transit exhibited the lowest average vehicle ownership rate. Presumably, these may also be the lower income households who would be most affected, from a financial standpoint, by the imposition of parking pricing. It is interesting to note that this same group also pays, on average, the highest parking charges at their current workplace. As such, this group would be adversely affected by the imposition of an additional parking surcharge over and above what they currently pay.

As expected, it is found that the response group indicating a switch to non-motorized modes of transportation has the lowest average commute time among all groups. Clearly, shorter commute distances are more conducive to the use of such modes. While the groups indicating "no change" and "switch to transit" exhibit identical average commute times at 32.5 minutes, the group that would switch to car/van pool has a slightly lower commute time of about 29 minutes. Interestingly, it is found that the number of bicycles owned by a household does not play a significant role in encouraging a switch to non-motorized modes of transportation. One may conjecture that, while the availability of bicycles is important, it is the commute distance or time that ultimately determines whether a switch to the bicycle mode will be made.

Trip chaining is now widely recognized as an extremely important aspect of travel behavior that has important implications for mode choice, destination choice, and departure time choice for trip making. In order to assess the effect of trip chaining on commuter response to parking pricing, the respondents were asked several questions regarding their usual trip chaining patterns on the way to and from work. In Table 3, the average number of days per week that a commuter stops on the way from home to work (for any trip purpose) is compared across response groups. The most noteworthy finding is that those who indicate a potential switch to transit are those who are the least prone to chain trips to the work trip. While all other groups indicate that they stop on the way from home to work about 1.2 days per week, the group switching to transit exhibits an average of only about 0.4. Trip chaining appears to deter a switch to the transit mode, but does not appear to deter a switch to car/van pool or non-motorized modes of transportation. It is possible that informal car/van pools among household members, co-workers, or neighbors will still allow trip chaining. With regard to those switching to bicycle and walk, it is possible that those trips previously chained to the work trip will now be undertaken in separate trip chains (possibly using the automobile) or made by other household members.

The comparative analysis was further extended to include those socio-demographic and travel indicators that are categorical in nature and for which sample means can not be easily interpreted. Bivariate cross-classification techniques were used to analyze the effects of these variables on parking pricing response distributions. Figures 1 through 8 constitute a set of notable and statistically significant cross-classifications that describe variations in response distributions by different socio-demographic and transportation variables. While there are several other cross-classifications that are also noteworthy and statistically significant, they are not included here for the sake of brevity. The multivariate discriminant analysis presented in the next section sheds light on other socio-demographic and transportation indicators that significantly influence commuter responses to parking pricing.

Figure 1 shows the response distributions by level of parking pricing scenario. As mentioned earlier, the parking pricing scenarios ranged from $1 per day to $8 per day. As expected, it is found that commuters who were presented with low parking pricing scenarios indicated a greater propensity to continue their current behavior. At higher parking pricing levels ($5 and greater), respondents showed a greater propensity to shift to transit. The potential shift to transit is greater than that to car/van pool presumably because those switching to car/van pool would still have to share the parking costs. From the indications provided by this figure, it appears that the stated response questionnaire provided plausible and useful data suitable for TCM analysis.

Figure 2 examines response distributions by age category. This figure indicates that the percentage of respondents who would not change their behavior is virtually identical across all age groups. However, among those who indicated a propensity to switch modes, it is found that commuters of older age groups (50 years and greater) are more prone to switch to transit while those in lower age groups are more prone to switch to car/van pool. This finding has important implications for transit planners as it appears that there are clear differences in potential transit usage across different market segments.

Figure 3 shows that households residing in single family detached homes are least likely to change commuting behavior. Households in single family detached homes live in suburbs (where transit service is poor), have longer commutes, are of larger household sizes, and belong to higher income categories. As such, their resistance to change is explicable. Figure 4 further confirms that higher income groups are less likely to change behavior. Lower income groups for whom the financial impact of a parking pricing scheme is substantial indicate a greater propensity to switch to transit and non-motorized modes of transportation. Middle income groups are found to choose the car/van pool mode, possibly because they can afford to share parking costs.

Figure 1
Distribution by Level of Parking Tax

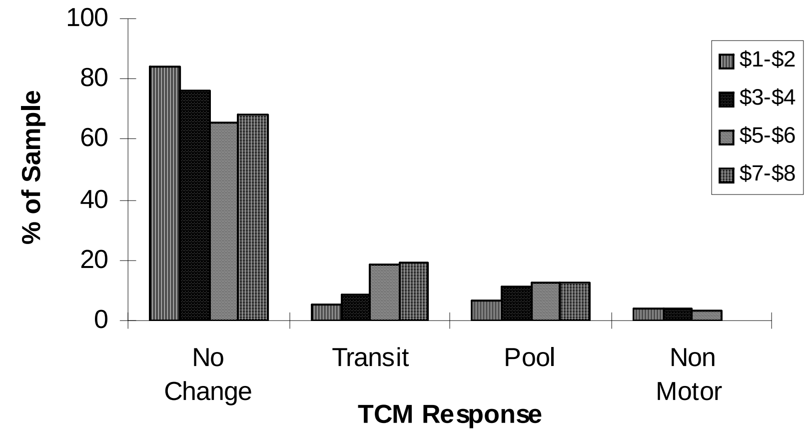


Figure 2
Distribution by Age Category

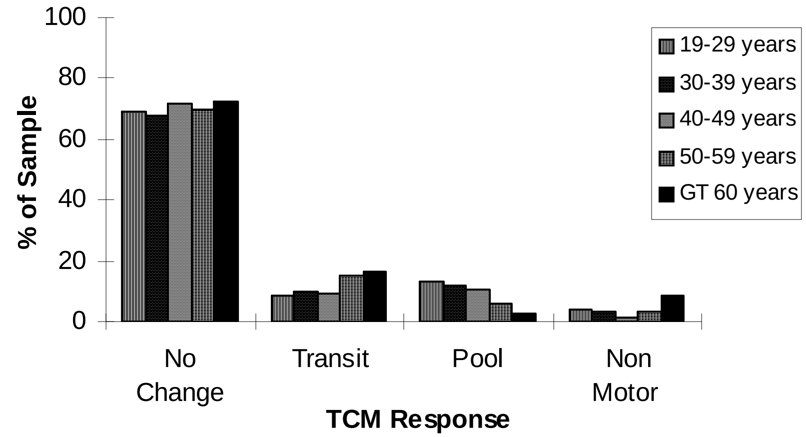


Figure 3
Distribution by Residence Type

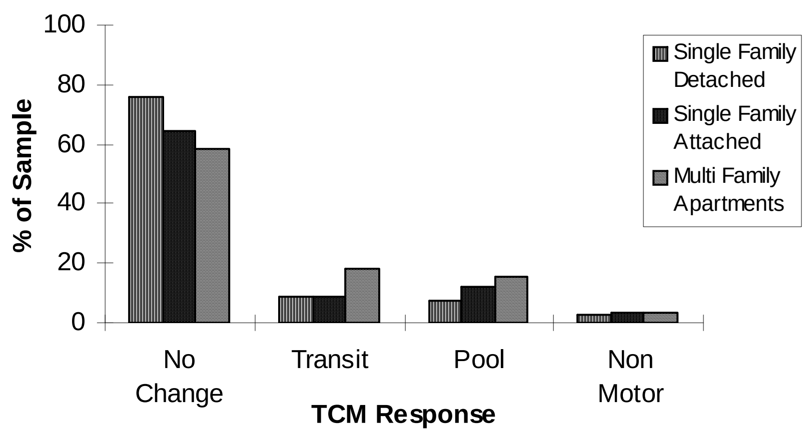


Figure 4
Distribution by Income Group

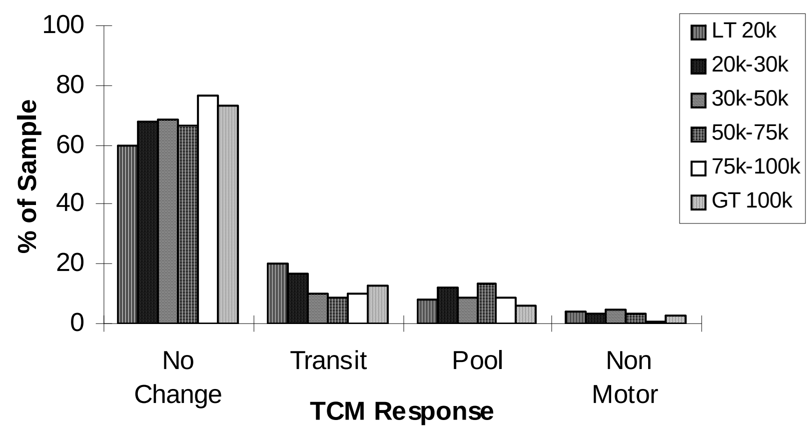


Figure 5
Distribution by Availability of Transit

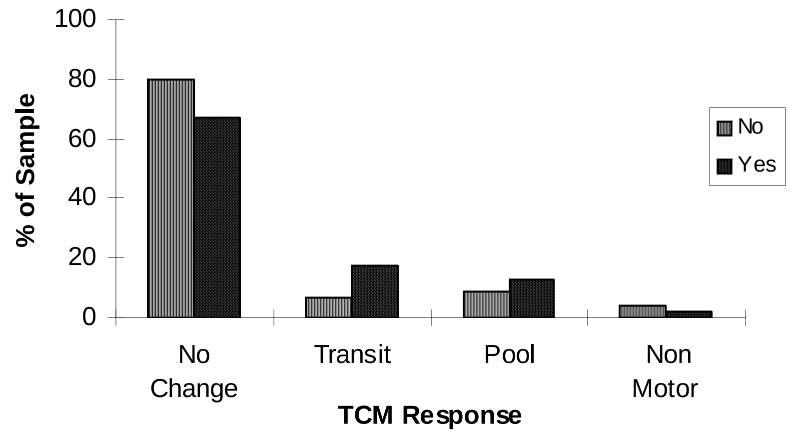


Figure 6
Distribution by Availability of Car/Van Pool

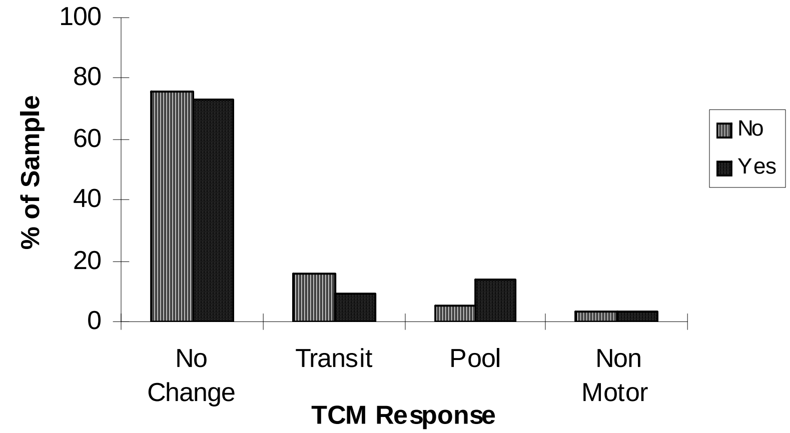


Figure 7
Distribution by Presence of Sidewalk

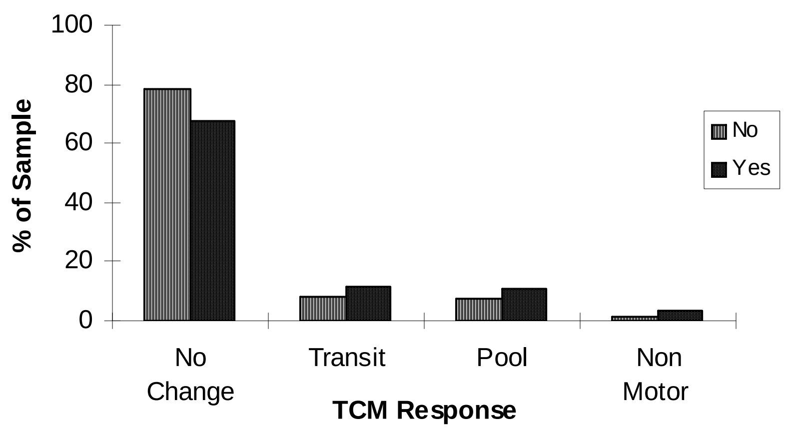
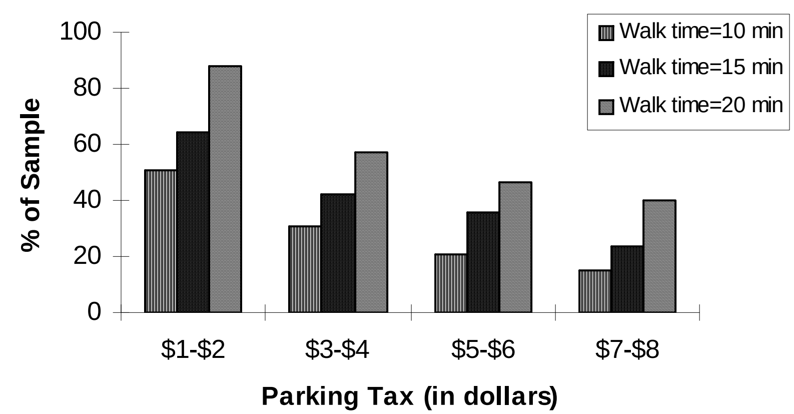


Figure 8
Distribution of Willingness to Pay by Walk Time



Figures 5 and 6 clearly show that alternate modes need to be perceived to be available for people to consider changing behavior. Similarly, the presence of a sidewalk appears to encourage a shift to transit, car/van pool and non-motorized modes (Figure 7). The provision of pedestrian facilities would allow commuters to walk to bus stops, transit stations, car/van pool pick-up locations, and to work, thus making the use of alternate modes more user-friendly.

Finally, Figure 8 shows how commuters trade-off parking costs against walking time. In order to achieve this, two alternatives were presented to survey respondents. First, commuters would pay a parking charge and walk one minute to their final destination or, second, commuters would pay no parking charge and walk 10, 15, or 20 minutes to the final destination. The results yielded very plausible indications. It was found that, as the parking price increases, willingness to pay decreases. Also, within each price category, as walk time increases, willingness to pay increases.

The analysis presented in this section clearly showed that there are several socio-demographic and transportation indicators that are significantly related to commuter responses to parking pricing strategies. Also, the analysis provided very plausible results indicating that the stated response data collected in the survey may be used for further analysis and modeling efforts.

Results of Multivariate Analysis

The analysis presented in the previous section considered the effects of socio-demographic and travel variables on response distributions one at a time. However, for modeling purposes, it is necessary to consider combinations of socio-demographic and travel variables that may explain commuter response to parking pricing. Multivariate discriminant analysis is a statistical procedure that is particularly suited for conducting exploratory investigations prior to undertaking predictive modeling efforts. Discriminant analysis is particularly suited to the analysis of discrete choice variables such as that considered in this study, namely, commuter response to parking pricing scenarios (*7*).

Discriminant analysis involves the identification of linear combinations of variables that best explain the group membership of sample units. In other words, linear functions of explanatory variables that best distinguish among different response groups are estimated. While the explanatory variables included in the classification functions of different groups are identical, the coefficients associated with these variables may differ. These classification functions can be used to classify new cases whose group membership is not known. Each case is assigned to the response group offering the highest classification function score. Alternatively, classification scores can be used to compute the probability that a case belongs to a certain group using a logit type formulation (*6*):

$$P_{ij} = \frac{\exp(s_{ij})}{\sum_{k=1}^{g} \exp(s_{ik})}$$

where

g = Number of groups

s_{ij} = Classification score of case i for group j

P_{ij} = Posterior probability that case i belongs to group j

A stepwise discriminant analysis procedure was performed to allow explanatory variables to enter into the discriminant classification functions according to their statistical discriminatory power. The results of the stepwise discriminant analysis corroborated results from the comparative and bivariate analyses presented in the previous section. The variables that were entered into the classification functions include:

- Level of parking tax
- Type of housing unit
- Number of years in current residence
- Gender of respondent
- Age category of respondent
- Availability of car/van pool mode
- Availability of transit service
- Presence of bicycle path
- Number of days per week stopped (for any trip purpose) on way from home-to-work
- Number of days per week stopped (for any trip purpose) on way from work-to-home
- Home-to-work commute time
- Parking charges currently paid by respondent
- Flexibility to leave work early

The results indicated that the level of parking tax imposed is one of the strongest determinants of commuter response to parking pricing. The type of housing unit and the number of years of stay at the same residential location were also significant in explaining group membership. These findings are very consistent with those documented in the previous section. Among socio-demographic variables, the gender and age category of the respondent were found to be significant. In general, females were found to be more resistant to changing their behavior than males, possibly due to reasons dealing with household task allocation and safety. Variables representing the availability of alternative modes were important predictors of group membership. Trip chaining, as evidenced by the number of days that commuters stopped on the way to or from work, was found to deter shifts to alternate modes. As smaller commute times are more conducive to the use of alternative modes, the home-to-work travel time entered into the classification function. Similar to the result reported in the previous section, the parking charges currently paid by the respondent significantly differed across response groups. Finally, it was interesting to note that the flexibility to leave work early was also an important consideration in commuter response to parking pricing. As switching to an alternative mode such as transit or car/van pool may require commuters to leave work early (say, to catch a bus or car pool), it is conceivable that flexible work hours are more conducive to mode switching.

For the sake of brevity, coefficients associated with the discriminatory variables for each response group have not been reported in this paper. The analysis reported here was intended to provide an understanding of the factors influencing commuter response to parking pricing that may help guide future modeling efforts. However, it is to be noted that the discriminant functions may be used in practice within the context of the probability formulation presented earlier to predict traveler response to parking pricing.

Conclusions

This paper reported on the analysis of stated adaptation data to better understand the factors that affect commuter response to parking pricing based transportation control measures. Data from a 1994 activity-based travel survey conducted in the Washington D.C. metropolitan area was used for analysis purposes. A sample of 656 commuters provided stated adaptation information on how they might respond under a hypothetical parking pricing scenario. In general, it was found that about 70 percent of the respondents would not change their behavior, while about 25 percent of the respondents would switch to an alternative mode.

A comparative bivariate analysis and a multivariate discriminant analysis showed that several socio-demographic and travel variables are significantly related to commuter responses to parking pricing. The level of parking pricing, type of household, gender and age of the commuter, availability of alternative modes, trip chaining patterns of the individual, income of the household, and availability of flexible work hours were found to be important predictors of commuter response to parking pricing. In addition, it was found that commuters trade-off walking time against the amount they are willing to pay for parking. Commuters were willing to walk longer distances (park in distant off-site locations) if it would entail lower parking charges.

Ongoing research efforts include the development of discrete choice models of traveler response to parking pricing, examination of secondary and tertiary changes in travel patterns that would result from a mode switch, analysis of the impacts of an employer-paid transportation subsidy, and the estimation of joint revealed preference-stated preference models to better account for the relationships between revealed travel patterns and stated adaptation responses.

Acknowledgment

The authors are grateful to Resource Decision Consultants, Inc., San Francisco, for providing the data set used in this study.

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