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### Publication Date

2008-07-01

# How do people respond to congestion mitigation policies? A multivariate probit model of the individual consideration of three travel-related strategy bundles

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Published online: 27 November 2007  
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**Abstract** This study explores the relationships between adoption and consideration of three travel-related strategy bundles (travel maintaining/increasing, travel reducing, and major location/lifestyle change), linking them to a variety of explanatory variables. The data for this study are the responses to a fourteen-page survey returned by nearly 1,300 commuting workers living in three distinct San Francisco Bay area neighborhoods in May 1998. We first identified patterns of adoption and consideration among the bundles, using pairwise correlation tests. The test results indicate that those who have adopted coping strategies continue to seek for improvements across the spectrum of generalized cost, but perhaps most often repeating the consideration of a previously-adopted bundle. Furthermore, we developed a multivariate probit model for individuals' simultaneous consideration of the three bundles. It is found that in addition to the previous adoption of the bundles, qualitative and quantitative Mobility-related variables, Travel Attitudes, Personality, Lifestyle, Travel Liking, and Sociodemographics significantly affect individual consideration of the strategy bundles. Overall, the results of this study give policy makers and planners insight into understanding the dynamic nature of individuals' responses to travel-related strategies, as well as differences between the responses to congestion that are assumed by policy makers and those that are actually adopted by individuals.

**Keywords** Multivariate probit · Congestion response · Travel behavior

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## Introduction

Today more than 200 million vehicles operate on highways in the U.S., producing more than 2.5 trillion annual vehicle-miles traveled (VMT). Traffic congestion is a common, and worsening, feature of everyday life in metropolitan areas, resulting in high social costs (Downs 2004; The Economist 1998): according to the annual Texas Transportation Institute congestion report, the average traveler in 85 urban areas of the U.S. wasted 47 h and 28 gallons of fuel in congestion delays in 2003, costing an estimated \$63 billion (Shrank and Lomax 2005). Recognizing these problems, in May 2006 the U.S. Department of Transportation launched its “*National Strategy to Reduce Congestion on America’s Transportation Network* (the Congestion Initiative), a bold and comprehensive national program to reduce congestion on the Nation’s roads, rails, runways, and waterways” (<http://www.its.dot.gov/press/itscongestion.htm>, accessed April 3, 2007). The program includes urban partnership agreements to pursue “four strategies with a combined track record of effectiveness in reducing traffic congestion” (*loc. cit.*). The strategies, known as the Four T’s, are Tolling, Transit, Telecommuting, and Technology & Operations. In addition, a recent report argues that (despite the conventional wisdom that “we can’t build our way out of the problem”) selected infrastructure capacity improvements (together with some or all of the Four T’s) can, in fact, substantially reduce congestion (Hartgen and Fields 2006).

These strategies are not new, of course. For at least the last three decades, policy makers and transportation planners have devised a series of policy instruments to tackle traffic congestion, starting with supply and demand controls. Transportation Systems Management (TSM) and Transportation Demand Management (TDM) programs are well-known classes of such policy strategies. A number of studies (e.g., Downs 2004; Giuliano and Small 1995; Rouwendal and Verhoef 2006) have also proposed market-based pricing policies such as congestion pricing, undergirded by the concept that users of a particular transportation facility should pay the costs they impose on others. In addition, promoting the use of information and communication technology (ICT) substitutes for travel, such as telecommuting, has been proposed as a strategy for reducing congestion (e.g., Niles 1994).

Although many of these strategies have been implemented, they in fact have failed to appreciably reduce traffic congestion to date (Colgan and Quinlin 1997). A number of reasons have been offered for this failure. Gärling et al. (2002) and Giuliano (1992) comment that TDM strategies are less likely to be effective without understanding individuals’ current travel behavior and preferences, from which derives the public or political acceptability of those strategies. Stopher (2004) argues that people become more tolerant of congestion as rising incomes increase their mobility expectations; Taylor (2002) points out that time in congested traffic may constitute only a minority of total travel time for many individuals (giving them little incentive to reduce it and diminishing the perceived impacts of policies that do). Ory et al. (2004), among others, note that people are adept at making adjustments that reduce the personal impact of congestion, while Levinson and Kumar (1994) explain how some of these adjustments can increase system congestion while leaving individuals better off (as when a person switches from a slower transit trip to a faster one by auto). The literature on induced demand (e.g., Noland 2001) argues that improved highway capacity can stimulate auto travel, resulting in the increase of travel demand. With respect to ICT applications, substitution of telecommunications for travel is the impact most desired from a public policy perspective, but ICT may also have a complementary relationship to travel—generating more, on net (Mokhtarian 2002). In particular, mobile phones and other ICTs may contribute to the problem by reducing the disutility of travel and thereby diminishing the incentive to curtail it (e.g., Niles 1994; Lyons and Urry 2005). Scott (2002,

p. 335) refers to second-order or indirect effects (such as trip generation effects of compressed work schedules, or shifting of trips to other household members), and to the questionable assumption that “drivers are cost minimizers when they are, in fact, utility maximizers”. These arguments suggest that there is a discrepancy, sometimes large, between the responses to congestion that are assumed by policy makers and those that are actually adopted by individuals (similarly, see Stead 2006 and references cited therein for studies showing discrepancies between the public and decision-makers in Europe with respect to the perceived effectiveness of, and support for, various policy measures). This mismatch in behavioral responses makes policies less effective, and needlessly consumes large amounts of time and money in their trial-and-error implementation.

Pursuant to the aim of improving our understanding of individuals’ behavior and attitudes, Salomon and Mokhtarian (1997) developed a conceptual model of the behavioral response to congestion, that incorporates the dynamics of the decision process for individuals’ choices adjusted by costs and benefits from their previous experiences. In a subsequent empirical study, Mokhtarian et al. (1997) identified rank-based (travel maintaining, travel reducing, and major location/lifestyle change) and factor-based (auto improvement, departure time, work schedule change, remote work, relocation, and work/lifestyle change) tiers for a set of coping strategies ranging from lower-cost to higher-cost, and short-term to longer-term, using empirical rank ordering and factor analysis, respectively. This study used data collected from 621 employees of the City of San Diego, California in 1992. Later, Raney et al. (2000) estimated binary logit models for the consideration of each of 15 congestion-response strategies using the same data, and found that individuals are likely to change their responses to congestion from lower-cost, short-term strategies to higher-cost, long-term ones when dissatisfaction remains. They also pointed out that besides travel-related variables, various non-travel-related motivations and constraints affect individuals’ responses. In a separate study, Arentze et al. (2004) found that in response to congestion pricing, individuals are more likely to adopt lower-cost strategies (route changes and departure time adjustments) than higher-cost ones (changing to public transit and working at home), especially for the work activity.

As a sequel to the above research, a series of studies (Clay and Mokhtarian 2004; Cao and Mokhtarian 2005a, b) on a newer set of data explores relationships between adoption and consideration of 17 (prespecified) travel-related strategies, linking them to mobility-related variables, travel attitudes, personality, lifestyle, travel liking, sociodemographic traits, and other variables. However, investigating 17 strategies individually is not only analytically unwieldy but behaviorally unrealistic, since there are clearly relationships among the strategies by which groups of them may be considered together, either as substitutes or as complements. Similarly to Mokhtarian et al. (1997), we grouped these 17 sets of strategies into two sets of bundles or tiers: a three-bundle grouping based on generalized cost and lifestyle change involved, and an eight-bundle grouping based on empirical relationships revealed through a factor analysis. The eight-bundle grouping is analyzed in Choo and Mokhtarian (2004); the present paper focuses on the three-bundle grouping (described more fully in the next section).

In this study, we explore the relationships between the adoption and consideration of the three travel-related strategy bundles by identifying characteristics associated with patterns of adoption and consideration among bundles, and by developing a multivariate discrete choice (probit) model for individuals’ consideration of bundles. The multivariate formulation allows us to model the simultaneous but separate consideration of all three bundles and permits correlations among the unobserved portions of the utility for each bundle, in contrast to the independent binary choice models of individual strategies that were formulated in the previous work on this data.

The adoption and time since adoption for single or bundles of strategies are included as explanatory variables in the model. In particular, we focus on whether the adoption of lower-cost, short-term strategies statically and/or dynamically affects the consideration of higher-cost, longer-term ones. We also investigate whether individuals with a high liking for travel, indicative of a positive utility of travel, are resistant to higher-cost, longer-term travel-reduction strategies. This study will give policy makers and planners insight into the dynamic nature of individuals' responses to travel-related strategies, and potentially help them to improve on the currently available strategies.

This paper consists of five sections. The following section describes the data for this study, and explains the key types of variables measured by the survey and used in this study, the “[Descriptive relationships between adoption and consideration](#)” section presents the correlations between adoption and consideration of strategy bundles. The next section discusses the results of multivariate probit models of consideration of strategy bundles, focusing on the significant variables in the model. Finally, we summarize the results and suggest policy recommendations.

## Data description

### Data collection

The data analyzed in this study come from a fourteen-page self-administered survey mailed in May 1998 to 8,000 randomly selected households in three neighborhoods of the San Francisco Bay Area (despite the age of the data, for the most part they capture attitudes and behaviors that are still quite timely—the exception being that measures of the adoption of mobile phone service would be far higher today. As such, it is reasonable to believe that the findings of this analysis remain relevant). Half of the total surveys were sent to an urban neighborhood of North San Francisco and the other half were divided evenly between the suburban cities of Concord and Pleasant Hill. These areas were chosen to represent the diverse lifestyles, land use patterns, and mobility options in the Bay Area. Approximately 2,000 surveys were completed by a randomly selected adult member of the household and returned, for a 25% response rate. The subset of 1,283 cases used in this study constitutes those respondents identified as workers (either part-time or full-time) who commute at least once a month and have relatively complete responses to key questions. We restricted the study to commuting workers on the assumption (borne out by testing) that their travel behavior and attitudes (especially their exposure to congestion and hence motivation to seek travel solutions) would differ significantly from those of non-commuters. [Table 1](#) presents some key sociodemographic characteristics of the sample. The sample is relatively balanced in terms of representation by neighborhood and gender. Nearly 95% of respondents have one or more personal vehicles in their households. Higher incomes are overrepresented compared to Census data, as is typical for self-administered questionnaires.

### Travel-related strategy bundles

Part E of the survey consisted of two multi-part questions. The first question asked the respondent, with respect to a list of 17 travel-related strategies (see [Table 2](#)), to check off whether each strategy had been adopted or not, and if so, to write in how long ago (in

**Table 1** Sociodemographic characteristics of the sample used in this study

Category	Frequency	Percent
<i>Neighborhood (n = 1283)</i>		
Concord (suburban)	294	22.9
Pleasant Hill (suburban)	346	27.0
North San Francisco (urban)	643	50.1
<i>Gender (n = 1279)</i>		
Female	651	50.9
Male	628	49.1
<i>Employment status (n = 1283)</i>		
Full-time worker	1,080	84.2
Part-time worker	203	15.8
<i>Age (n = 1283)</i>		
18–23	42	3.3
24–40	563	43.9
41–64	640	49.9
>65	38	2.9
<i>Personal annual income (n = 1255)</i>		
<\$15,000	91	7.3
\$15,000–34,999	266	21.2
\$35,000–54,999	386	30.8
\$55,000–74,999	229	18.2
\$75,000–94,999	126	10.0
>\$95,000	157	12.5
<i>Family status (n = 1277)</i>		
Single	319	25.0
2 or more adults, no children	609	47.7
1 adult with children	28	2.2
2 or more adults with children	321	25.1
<i>Number of personal vehicles in HH (n = 1280)</i>		
0	69	5.4
1	432	33.8
2	505	39.5
3 or more	274	21.3

years) the most recent adoption occurred (and check off for what reason(s) among a list of five presented, though the reasons are not explored in depth here). The second question asked, with respect to the same list, to check off whether or not each strategy was being “seriously” considered (and if so, why, among the same five reasons). For further details on these questions, see Cao and Mokhtarian (2003).

As indicated earlier, the initial study in this series (Clay and Mokhtarian 2002) conceptually classified the 17 strategies into three bundles based on the generalized cost and the amount of lifestyle change for each. As shown in Table 2, Group 1 includes low (generalized) cost strategies such as getting a more comfortable car or purchasing a mobile

**Table 2** Travel-related strategy bundles

Group 1: Travel maintaining/increasing	Group 2: Travel reducing	Group 3: Major location/lifestyle change	
<ul style="list-style-type: none"> <li>• Buy a car stereo system</li> <li>• Get a mobile phone</li> <li>• Get a better car</li> <li>• Get a fuel efficient car</li> <li>• Change work trip departure time</li> <li>• Hire someone to do house or yard work</li> <li>• Adopt flextime</li> <li>• Change from another means of getting to work to driving alone</li> </ul>	<ul style="list-style-type: none"> <li>• Adopt compressed work week</li> <li>• Change from driving alone to work to some other means</li> <li>• Buy equipment/services to help you work from home</li> <li>• Telecommute (part- or full-time)</li> </ul>	<ul style="list-style-type: none"> <li>• Change jobs closer to home</li> <li>• Move your home closer to work</li> <li>• Work part-time instead of full-time</li> <li>• Start home-based business or put more effort into an existing one</li> <li>• Retire or stop working</li> </ul>	
Low			High
Short			Long

phone. In general, these are strategies that allow one to maintain travel more pleasantly or productively, or may even facilitate increasing one’s travel. Group 2 includes more costly (in the sense of involving lifestyle changes for the individual or the household) alternatives such as adopting a compressed workweek or telecommuting. These changes reduce one’s vehicular travel through reducing the frequency of commuting or changing to shared-ride commute modes. The third group consists of major location or lifestyle changes such as quitting work, working part-time instead of full-time and moving home or work closer to the other. These strategies reduce travel through more drastic means.

In this study we treat the consideration of strategy *bundles* as dependent variables in a multivariate probit model, and the prior adoption of strategy bundles (as well as individual strategies) and time since adoption of individual strategies as key explanatory variables. The bundle variables were defined as 1 if any strategy in the bundle had been checked off as adopted or seriously considered, respectively, and 0 otherwise. Not surprisingly, the lowest-cost travel maintaining/increasing bundle is the most popular one, adopted by 92% of the sample and considered by 72%. In contrast, the travel reducing and major location/lifestyle change bundles are adopted by 48 and 50%, and considered by 39 and 46%, respectively.

As suggested by Raney et al. (2000), the previous adoption of a bundle or single strategy could logically either positively or negatively affect the consideration of other (and the same) strategies. For example, the adoption of a higher-cost strategy could reduce the probability of considering a lower-cost strategy if the higher-cost strategy were

effective, but it could increase the probability of considering lower-cost strategies if the effectiveness of the higher-cost strategy had diminished over time or were not as great as expected. In general, we could hypothesize a progression from lower-cost to higher-cost strategies, but it is also natural to expect some respondents to cycle within a given strategy bundle (i.e., repeating strategies such as getting a better car or changing work trip departure time) or to cycle back to a lower-cost strategy after adopting a higher-cost one. Also, some strategies within a given bundle may be complements (so that recently adopting one strategy in the bundle increases the probability of considering another one in the same bundle—e.g., buying equipment to support working from home, and telecommuting), whereas others may be substitutes (so that recently adopting one strategy in the bundle decreases the probability of considering the same bundle—e.g., better car and fuel efficient car). With respect to the time-since-adoption variable, we might initially expect that people with a longer time since adoption of an individual strategy are more likely to consider the corresponding bundle strategy. However, again, to the extent that strategies in a given bundle are complements, the reverse may be true. Thus, for all these variables we are in the somewhat unaccustomed position of being able to justify virtually any relationship of prior adoption of one strategy to the consideration of the same or a different strategy. However, it would be of interest to identify which of the many *conceptually* possible relationships are *empirically* dominant for this dataset. We explore this descriptively in the “[Descriptive relationships between adoption and consideration](#)” section, and analytically through the model presented in the “[Modeling the individual consideration of strategy bundles](#)” section.

It should be emphasized that the individual travel-related strategies, as the basis of the strategy bundles, primarily focus on commute or work-related travel. However, discretionary travel such as recreation and entertainment travel can directly or indirectly affect the consideration of strategy bundles. For instance, people who desire to increase recreation travel may want to reduce their commute time, so that they can spend more time on the desired travel.

### Key explanatory variables

To conserve space, the key explanatory variables other than those based on the travel-related strategies are briefly summarized in Table 3. The three mobility categories (Objective, Subjective, and Relative Desired) and the Travel Liking category had similar structures. In each case, measures were obtained both overall and separately by purpose and mode, for short-distance and long-distance travel. Consistent with the American Travel Survey in use at the time, long-distance trips were defined as those longer than 100 miles, one way. The short-distance modes measured were: personal vehicle, bus, Bay Area Rapid Transit (heavy rail)/light rail/train, walking/jogging/cycling, and other. The short-distance purposes measured were: commuting to work or school, work/school-related, grocery shopping, eating a meal, and taking other people where they need to go. Long-distance measures were obtained for the personal vehicle and airplane modes, and for the work/school-related and entertainment/social/recreational purposes.

### Descriptive relationships between adoption and consideration

This section explores the descriptive relationships between previous adoption and current consideration of strategy bundles, without considering the other variables. It is of interest



**Table 3** Summary of potential explanatory variables

Variable category	Description
Objective Mobility	<ul style="list-style-type: none"> <li>• Questions about short-distance and long-distance travel by a variety of modes for a variety of purposes;</li> <li>• Short-distance questions asked respondents to indicate frequency of travel (six ordinal choices) and distance traveled (write-in response);</li> <li>• Long-distance questions required respondents to indicate the number of trips made to each of nine regions of the world in the past year, by purpose and mode (distance estimates were created by measuring approximate distances from a central position in the Bay Area).</li> </ul>
Subjective Mobility	<ul style="list-style-type: none"> <li>• Respondents' perceptions of their amount of travel, by mode and purpose;</li> <li>• Rated on a five-point ordinal scale anchored by "none" and "a lot".</li> </ul>
Relative Desired Mobility	<ul style="list-style-type: none"> <li>• How much respondents want to travel compared to what they are doing now, by mode and purpose;</li> <li>• Rated on a five-point scale ranging from "much less" to "much more".</li> </ul>
Travel Liking	<ul style="list-style-type: none"> <li>• Operationalization of one's affinity for travel, in the same categories as the Mobility questions;</li> <li>• Rated on a five-point scale from "strongly dislike" to "strongly like".</li> </ul>
Attitudes	<ul style="list-style-type: none"> <li>• Thirty-two statements regarding travel, land use, and the environment;</li> <li>• Respondents agreed or disagreed with the statements using a five-point Likert-type scale;</li> <li>• Factor analyses (see Mokhtarian, et al., 2001) revealed six dimensions: travel dislike, pro-environmental solutions, commute benefit, travel freedom, travel stress, pro-high density.</li> </ul>
Personality	<ul style="list-style-type: none"> <li>• Seventeen traits expected to relate to travel;</li> <li>• Respondents indicated how well the attributes described them on a five-point scale ("hardly at all" to "almost completely");</li> <li>• Factor analyses (Mokhtarian, et al., 2001) revealed four dimensions: adventure-seeker, organizer, loner, calm.</li> </ul>
Lifestyle	<ul style="list-style-type: none"> <li>• Eighteen statements related to work, family, money, status, and the value of time;</li> <li>• Respondents agreed or disagreed with the statements using a five-point Likert-type scale;</li> <li>• Factor analyses (Mokhtarian, et al., 2001) revealed four factors: status seeker, workaholic, family/community, frustrated.</li> </ul>
Mobility Constraints	<ul style="list-style-type: none"> <li>• Seven statements regarding physical conditions or anxieties preventing various types of travel;</li> <li>• Respondents indicated the degree of the mobility constraint ("No limitation", "Limits how often or how long", "Absolutely prevents");</li> <li>• Examples include: "driving on the freeway", "driving at night", "walking", "flying in an airplane";</li> <li>• The percentage of time an automobile is available to the participant is also considered a constraint, oriented in the reverse direction.</li> </ul>
Sociodemographics	<ul style="list-style-type: none"> <li>• Twenty questions at the end of the survey, measuring age, income, household size, employment type, number of household workers, education level, gender, and make/model of the automobile driven most often;</li> <li>• Data allows for comparison of our sample with more general populations.</li> </ul>

to explore whether the previous adoption of a strategy bundle is directly associated with the current consideration of the corresponding or other strategy bundles. We first discuss the distribution of previous adoption and current consideration for strategy bundles, and then examine their correlations.

Table 4 presents the cross-tabulation of previous adoption against current consideration of combinations of the strategy bundles. Focusing first on the rows of Table 4, among the 48 non-adopters (adoption segment 1), more than half of the respondents are considering one or more strategy bundles, especially the travel maintaining/increasing strategy bundle. These people have likely been mostly satisfied with their current travel conditions or are just starting to feel some dissatisfaction, so they are more likely to consider a lower-cost strategy such as those in the travel maintaining/increasing bundle. In addition, for every adoption segment except segment 7 (adoption of Groups 2 & 3), the diagonal elements have the highest or second-highest proportion of consideration for that category. That is, as could be expected, those who previously adopted single or combined strategy bundles are more likely to consider the same strategy category than to extend their consideration to other categories. For example, those who previously adopted a single strategy in a bundle tend to consider adding another strategy in the same bundle (or re-adopting the same strategy), more often than changing to another bundle. Interestingly, as shown by the cross-hatched cells in Table 4, in contrast to the single-bundle adopter segments 2, 3, and 4, those who adopted two strategy bundles (segments 5, 6, and 7) tend to consider adding another strategy bundle (i.e., to consider all strategy bundles, as for segments 5 and 7), dropping the higher-cost one (as for segment 6), or dropping both (as for segment 7). (By “dropping” here we mean from consideration, not necessarily from adoption). It may well be that people dissatisfied with their previously adopted strategies tend to consider adding another strategy bundle, whereas people who are satisfied with their previously adopted strategies tend to contemplate fewer or no new strategies.

Looking at the columns of Table 4,  $209 - 20 = 189$  (14.7%) respondents in the sample are not considering any strategy bundle, despite having previously adopted one or more bundles. As discussed before, such non-considerers might think that they have gained few (current) benefits from the strategy bundles they have adopted, even the higher-cost ones. Or, these people are satisfied with their current travel conditions due to previous adoptions, so they are not motivated to consider any strategy bundle at this time. Additionally, the bold numbers of Table 4 also show that previous adopters of a particular combination of bundles are generally more likely than adopters of other combinations to consider the same combination. For the absolute frequencies in the final row and column, it is reasonable that either or both of the travel reducing and major location/lifestyle change bundles are least likely to have been adopted or to be considered because of their higher costs, compared to the other (separate or combined) groups.

Correlation tests were conducted to identify significant pairwise correlations between previous adoption and current consideration. Table 5 presents the results of the tests for the strategy bundles. Interestingly, except for Group 1 adoption and Group 3 consideration, previous adoption of any bundle is significantly, positively correlated with current consideration of each of the strategy bundles. The implication is that those who have any experience in adopting a travel-related strategy bundle are more likely to consider another or the same bundle than are non-adopters. The highest correlations are between adoption and consideration of the *same* bundle (the major diagonal elements), indicating that the same or similar strategies are likely to be considered/adopted repeatedly throughout an individual’s life. The adoption of the two higher-cost strategy bundles tends to be somewhat more strongly associated with the consideration of all three strategy bundles,

**Table 4** Adoption and consideration of combinations of travel-related strategy bundles ( $n = 1283$ )

Adoption segment	Consideration segment										Total
	None	Group 1 only	Group 2 only	Group 3 only	Groups 1 & 2	Groups 1 & 3	Groups 2 & 3	Groups 1 & 2 & 3	Groups 1 & 2 & 3	Groups 1 & 2 & 3	
1. Non-adoption	30 (41.7)	12 (25.0)	0 (0.0)	1 (2.1)	2 (4.2)	7 (14.6)	3 (6.3)	3 (6.3)	3 (6.3)	48 (100.0)	
2. Group 1 only: Travel maintaining/increasing	68 (20.9)	107 (32.8)	6 (1.8)	26 (8.0)	28 (8.6)	57 (17.5)	5 (1.5)	29 (8.9)	29 (8.9)	326 (100.0)	
3. Group 2 only: Travel reducing	2 (16.7)	1 (8.3)	2 (16.7)	0 (0.0)	1 (8.3)	3 (25.0)	1 (8.3)	2 (16.7)	2 (16.7)	12 (100.0)	
4. Group 3 only: Major location/lifestyle change	5 (18.5)	3 (11.1)	0 (0.0)	7 (25.9)	4 (14.8)	5 (18.5)	2 (7.4)	1 (3.7)	1 (3.7)	27 (100.0)	
5. Groups 1 & 2	37 (14.4)	45 (17.5)	9 (3.5)	13 (5.1)	48 (18.7)	27 (10.5)	9 (3.5)	69 (26.8)	69 (26.8)	257 (100.0)	
6. Groups 1 & 3	41 (15.6)	72 (27.4)	1 (0.4)	21 (8.0)	23 (8.7)	57 (21.7)	4 (1.5)	44 (16.7)	44 (16.7)	263 (100.0)	
7. Groups 2 & 3	3 (25.0)	2 (16.7)	1 (8.3)	0 (0.0)	2 (16.7)	1 (8.3)	0 (0.0)	3 (25.0)	3 (25.0)	12 (100.0)	
8. Groups 1 & 2 & 3	33 (9.8)	59 (17.5)	8 (2.4)	13 (3.8)	50 (14.8)	32 (9.5)	16 (4.7)	127 (37.6)	127 (37.6)	338 (100.0)	
Total	209 (16.3)	301 (23.5)	27 (2.1)	81 (6.3)	158 (12.3)	189 (14.7)	40 (3.1)	278 (21.7)	278 (21.7)	1283 (100.0)	

*Notes:* The numbers in parentheses are the percents of the corresponding row category; the table focuses on the percentage of people that have previously adopted a particular combination of bundles, who are considering each possible combination of bundles. Bold numbers indicate the highest row percentage for that column, that is, the adoption group having proportionately the highest rate of consideration of that combination of strategies. Cross-hatched cells indicate the highest row percentage for that row, that is, the combination of bundles most often considered by a given adoption segment. Shaded cells simply highlight the main diagonal, i.e., the consideration of a given combination by those who have adopted the same combination

**Table 5** Correlation between adoption and consideration of travel-related strategy bundles ( $n = 1283$ )

Adoption	Consideration		
	Group 1	Group 2	Group 3
Group 1: Travel maintaining/increasing	0.127 <sup>++</sup>	0.071 <sup>+</sup>	
Group 2: Travel reducing	0.088 <sup>++</sup>	0.336 <sup>++</sup>	0.101 <sup>++</sup>
Group 3: Major location/lifestyle change	0.080 <sup>++</sup>	0.112 <sup>++</sup>	0.124 <sup>++</sup>

Notes: <sup>+</sup>positive correlation with  $0.01 < p\text{-value} \leq 0.05$ , <sup>++</sup>positive correlation with  $p\text{-value} \leq 0.01$ , insignificant correlation omitted for simplicity

compared to the adoption of the travel maintaining/increasing bundle. In particular, higher-cost bundle adopters are more inclined to consider lower-cost bundles than lower-cost bundle adopters are to consider higher-cost ones.

### Modeling the individual consideration of strategy bundles

#### Model specification

In the previous section, we discussed the descriptive relationships between previous adoption and current consideration without involving other variables, and the results show that adoption and consideration are significantly related in both directions, from lower-cost strategy bundles to higher-cost ones, and conversely. In this section, we develop a model for consideration of strategy bundles, as a function not only of adoption and time since adoption, but potentially also of the explanatory variables described in the “Descriptive relationships between adoption and consideration” section. We model only consideration and not adoption, because the respondents’ adoption takes place at various points in the past while the explanatory variables available in our cross-sectional data set represent measures in the present. To model past adoption as a function of present attitudes, say, would run the risk of reversing cause and effect: the present attitude is likely to be a consequence of, rather than a cause of, the prior adoption (Clay and Mokhtarian 2004).

As discussed before, more than half of the respondents consider more than one strategy bundle simultaneously. This indicates that a simultaneous model for consideration of the three bundles would be more realistic than individual models. Thus, considering that the dependent variables are binary—1 if the respondent seriously considered any individual strategy in the bundle and 0 otherwise—and related to each other, a multivariate probit model was selected for this study.

The general specification (with the person subscript suppressed for simplicity) for a multivariate probit model with three dependent variables (as we have) is

$$Y_i^* = \beta_i' \mathbf{X}_i + \varepsilon_i, \quad i = 1, 2, 3,$$

where  $Y_i^*$  is an unobserved variable representing the latent utility or propensity of considering bundle  $i$ ,  $\mathbf{X}_i$  is a vector of observed characteristics believed to be relevant to the consideration of bundle  $i$ ,  $\beta_i$  is a vector of unknown coefficients to be estimated,  $\varepsilon_i$  is normally distributed with mean 0 and variance 1, and the variance-covariance matrix of the error terms is

$$\Sigma = \begin{bmatrix} 1 & \rho_{12} & \rho_{13} \\ & 1 & \rho_{23} \\ & & 1 \end{bmatrix}.$$

Here, the observed binary consideration variable  $Y_i = 1$  if  $Y_i^* > 0$ , 0 otherwise. Thus, the probability that  $Y_i = y_i$ , conditioned on parameters  $\beta$ ,  $\Sigma$ , and a set of explanatory variables  $X$ , can be written as

$$\Pr[Y_i = y_i, i = 1, 2, 3 | \beta, \Sigma] = \int_{A_1} \int_{A_2} \int_{A_3} \phi(z_1, z_2, z_3, \rho_{12}, \rho_{13}, \rho_{23}) dz_3 dz_2 dz_1,$$

where  $\phi$  is the density function of a multivariate normal distribution with mean vector 0 and the variance-covariance matrix (correlation matrix)  $\Sigma$ , and  $A_i$  is the interval  $(-\infty, \beta'_i X_i)$  if  $y_i = 1$  and  $(\beta'_i X_i, \infty)$  if  $y_i = 0$  (Chib and Greenberg 1998). Then, using the maximum likelihood method, the parameters  $\beta_i$  and the three correlations of the error terms can be estimated. The LIMDEP software package (Greene 2002; see Section E17.7) was used for this estimation. All explanatory variables in the final model were conceptually interpretable and statistically significant at the 0.05 level or better, except for four significant at 0.1 which were retained for their conceptual relevance.

## Model results

Table 6 summarizes the results of the multivariate probit model. Although there is no universally-reported measure of goodness of fit for such a system of equations, McFadden's  $R^2$  can be used for the goodness of fit of a multivariate probit model (Lansink et al. 2003).<sup>1</sup> The McFadden's  $R^2$  of the final model is 0.108. The  $\chi^2$  test shows that the final model is significantly better than the corresponding market share model at  $p \ll 0.001$ . Additionally, all correlation coefficients are positive and statistically significant at  $p \ll 0.001$ . This implies that unobserved variables involved in the consideration of each bundle are significantly positively related, and confirms that it is more efficient to model the consideration of all three bundles jointly rather than separately. Correlations of unobserved variables in the utilities of adjacent bundles ( $\rho_{12}$  and  $\rho_{23}$ ) are higher than that of the non-adjacent bundle pair ( $\rho_{13}$ ).

Turning to the explanatory variables, all Objective Mobility variables have positive signs in the model. It is clear that the greater the amount of travel the individual does, the more likely she is to consider the travel reducing or major location/lifestyle change strategy. Interestingly, the amount of travel for eating out positively affects consideration of the travel maintaining/increasing strategy as well as the travel reducing strategy. Similarly, Choo et al. (2005) found that the frequency of traveling to eat a meal is positively related to the Relative Desired Mobility for overall short-distance travel. They suggested that for some people, a higher amount of this travel indicates a substitute fulfillment of the desire to undertake more recreational/social travel under the current

<sup>1</sup> McFadden's  $R^2$  is calculated by  $1 - \log[L(\beta)]/\log[L(\text{MS})]$ , where  $\log[L(\beta)]$  and  $\log[L(\text{MS})]$  are the values of the log-likelihood function evaluated at the estimated parameters of the final model and at constant terms only (the market share model), respectively.

**Table 6** Multivariate probit model of consideration of travel-related strategy bundles

Variable	Travel maintaining/ increasing	Travel reducing	Major location/ lifestyle change
Constant	−1.326	−2.010	−0.0492
<i>Objective Mobility</i>			
Frequency of commuting (SD)		0.0793**	
Weekly miles to eat a meal (SD)	0.00925**	0.00605*	
Weekly miles by walking/jogging/bicycling (SD)			0.00951**
Total trips (LD)		0.00511**	
<i>Subjective Mobility</i>			
Taking others where they need to go (SD)	0.152**		
Travel by personal vehicle (SD)	0.101**	0.0811**	
<i>Relative Desired Mobility</i>			
Travel by walking/jogging/bicycling (SD)			−0.324**
Travel by air (LD)			0.0891**
<i>Travel Liking</i>			
Travel by personal vehicle (LD)	0.142**		
<i>Attitudes</i>			
Pro-environmental solutions factor score		0.235**	
<i>Personality</i>			
Adventure seeker factor score		0.122**	
<i>Lifestyle</i>			
Frustrated factor score			0.0824*
Family & community-oriented factor score			0.192**
<i>Mobility Constraints</i>			
Limitations on driving during the day	0.826**	0.916**	
<i>Sociodemographics</i>			
Years lived in the U.S.	−0.0103*	−0.0126**	
Manager/administrator occupation	0.310**		
Household income category		−0.0913**	
Number of people ages under 6 in HH			0.152*
Number of people ages 65–74 in HH			0.434**
<i>Strategy Adoption</i>			
Buy a mobile phone	−0.165**		
Time since getting a fuel efficient car	0.0272**		
Change work trip departure time	0.167**	0.215**	
Time since changing work trip departure time			0.0333**
Hire somebody to do house or yard work	0.377**		
Time since hiring domestic help	−0.0371**		
Adopt compressed work week		0.435**	
Change from another means to driving alone		0.369**	
Buy equipment to help work from home		0.815**	0.188**

**Table 6** continued

Variable	Travel maintaining/ increasing	Travel reducing	Major location/ lifestyle change
Work part- instead of full-time			<i>0.444**</i>
Start home-based business		0.395**	<i>0.439**</i>
Retire or stop working			<i>0.502**</i>
Major location/lifestyle change	0.171**		
<i>Correlation</i>			
$\rho_{12}$		0.396**	
$\rho_{13}$		0.202**	
$\rho_{23}$		0.356**	
Number of observations		1215	
Log likelihood ( $\beta$ )		-2038.4	
Log likelihood (MS)		-2286.2	
$\chi^2 = -2(\log[L(\text{MS})] - \log[L(\beta)])$		495.6	
McFadden's $R^2 = 1 - \log[L(\beta)]/\log[L(\text{MS})]$		0.108	

Notes: SD = Short Distance, LD = Long Distance. \*0.05 <  $p$ -value < 0.1, \*\* $p$ -value  $\leq$  0.05

Italicized cells denote significant relationships between consideration of one bundle and prior adoption of strategies in the same bundle

constraints. So, it is plausible that this group of people is more likely to consider the travel maintaining/increasing strategy bundle.

Similar to Objective Mobility, all Subjective Mobility variables also have positive signs. It is intriguing that two of them, travel for taking others where they need to go and by personal vehicle, are significant in the consideration of the travel maintaining/increasing strategy bundle. The former probably indicates travel that is considered essential in some respects, so the individual is more likely to maintain such travel rather than to eliminate it. The latter may initially seem counter-intuitive. But, similar to the chauffeuring variable, if the personal vehicle travel is considered *necessary*, those who must do it a lot are more likely to try and improve their current travel conditions by making driving more comfortable, or to reschedule their travel by changing trip departure time (Clay and Mokhtarian 2004). On the other hand, where *possible*, those who currently travel a lot by personal vehicle will look for ways to curtail their travel, as shown by the presence of the same variable in the equation for consideration of the travel reducing bundle.

Not surprisingly, the liking for long-distance personal vehicle travel has a positive effect on the consideration of the travel maintaining/increasing strategy bundle. Choo et al. (2005) found that this variable positively influenced the desire for more travel in the same category; the current result adds the (not surprising) information that individuals who like such travel make active plans to support it through the consideration (and adoption) of strategies that facilitate it (primarily buying a better car; see Clay and Mokhtarian 2002). Also, two Relative Desired Mobility variables specific to mode are significant in the consideration of the major location/lifestyle change strategy bundle, with opposite signs. The signs are reasonable in each case. In our sample, higher levels of walking/jogging/bicycling are associated with lower incomes, suggesting that such travel is done out of necessity rather than by choice. Therefore, it is natural that those who want to decrease their walking/jogging/bicycling would be more likely to consider the major location/

lifestyle change bundle that would reduce such travel, at least for commuting. On the other hand, the desire for long-distance travel by air is strongly correlated with that for long-distance travel for entertainment or recreation ( $r = 0.517$ ). Thus, the individual with a higher desire for air travel may consider the major location/lifestyle change bundle in order to save work travel time and expense (as well as work time itself, in the case of the part time work and retirement strategies) and then reallocate the saved resources to recreational travel.

Some Attitudes/Personality/Lifestyle variables are positively associated with higher-cost strategies. As expected, pro-environmentalists are more likely to consider the travel reducing strategy bundle. Adventure seekers want to do outdoor activities more, perhaps often putting a higher value on recreation or entertainment travel than on work. Consequently, they too are more likely to consider the travel reducing strategy bundle. Frustrated people may seek a better lifestyle or environment because they are currently unsatisfied with their lives and feel they have little control over them. Thus, those respondents are more likely to consider the major location/lifestyle strategy bundle. Not surprisingly, those who are family/community-oriented are more likely to consider the major location/lifestyle strategy bundle, so that they can spend more time on their family or community and less on commuting and/or work.

Similar to the Subjective Mobility variable for short-distance personal vehicle travel, a Mobility Constraint variable is positively associated with both the travel maintaining and travel reducing strategy bundles. Those who have limitations on driving during the day are more likely to consider ways to make their necessary driving more comfortable, and ways to reduce their unnecessary driving, so as to lessen their physical or psychological travel burdens.

Sociodemographic variables involving household, income, and occupation are significantly related to various strategy bundles. The number of years lived in the U.S., as a proxy for age, is also related to both the travel maintaining and travel reducing strategy bundles, in this case negatively. That is, younger people are more likely than older ones to consider the lower-cost strategies against congestion, either maintaining more comfortably (if necessary) or reducing (if possible) their travel. On the other hand, people in a high-income household are less likely to consider the travel reducing strategy bundle, perhaps because they can more easily afford the monetary costs associated with adopting strategies in the other two bundles. Similarly, managers or administrators, typically higher-income jobs, are positively inclined to consider the travel maintaining/increasing strategy bundle, perhaps in view of a relative inability to reduce the amount they must travel. People living with children under 6 years old or with people ages 65–74 are more likely to consider the major location/lifestyle change strategy bundle, presumably in order to free more time to take care of their dependents.

As hypothesized, the previous adoption of any individual strategies in a bundle generally positively affects the consideration of the same bundle. The interpretation is that the individual who previously adopted a given strategy is more likely than others to seek either the same or another strategy in the same bundle. On the other hand, the previous adoption of lower-cost individual strategies also positively affects the consideration of the higher-cost strategy bundles, and the previous adoption of higher-cost individual strategies positively affects the consideration of lower-cost strategy bundles. In addition, three time-since-adoption variables are found in two strategy bundle equations. Our general hypothesis on time-since-adoption variables is that the longer ago the individual has adopted a strategy, the more likely she is to consider the same strategy bundle or higher-cost ones. Two of the significant variables are consistent with the hypothesis: the longer



ago the individual adopted getting a fuel efficient car (or changing trip departure time), the more likely she is to consider the travel maintaining/increasing bundle (or the major location/lifestyle change bundle, respectively, as a higher-cost one). In contrast, the time since adoption of “hiring domestic help” has a negative effect on the consideration of the travel maintaining/increasing strategy bundle. It is plausible that the more recently the individual hired someone to help with house or yard work, the more likely she is to consider the travel maintaining/increasing strategy bundle because the time she is saving by hiring help can be spent on other activities outside the home.

## Discussion and conclusions

Focusing on the travel-related strategy bundles (travel maintaining/increasing, travel reducing, and major location/lifestyle change), as one of a series of studies, this study explored the relationships between adoption and consideration of the bundles, linking them to Mobility-related, Travel Attitude, Personality, Lifestyle, Travel Liking, Sociodemographic, and other variables. The data for this study were collected from a fourteen-page survey returned by about 2,000 adult residents of three distinct San Francisco Bay area neighborhoods in May 1998. The current study is based on a subset of nearly 1,300 commuting workers.

We first identified patterns of adoption and consideration among bundles, using pairwise correlation tests. Specifically, we examined whether previous adoption is significantly related to current consideration. The test results show that previous adoption of a given bundle is strongly (generally positively) associated with current consideration of the same bundle. Where previous adoption is significantly correlated with consideration of other bundles, the association is always positive. Both higher-cost and lower-cost bundles are considered, with no clear dominance between the two groups. Taken together, these results indicate that those who have adopted coping strategies continue to seek for improvements across the spectrum of generalized cost, but perhaps most often repeating the consideration of a previously-adopted bundle.

Furthermore, we developed a multivariate probit model for individuals’ consideration of the travel-related strategy bundles. The McFadden’s  $R^2$  goodness-of-fit measure for the final model is 0.108. All correlation coefficients are positive and statistically significant at  $p \ll 0.001$ , indicating that unobserved variables involved in the consideration of each bundle are significantly positively related, and confirming that it is more efficient to model the consideration of all three bundles jointly rather than separately.

In the final model, we found significant a number of diverse variables (such as qualitative and quantitative Mobility-related variables, Travel Attitudes, Personality, Lifestyle, and Travel Liking), most of which have been little considered in establishing transportation policy strategies to reduce traffic congestion. For example, individuals’ subjective assessments of the amounts of their travel, and desires for more or less travel, play key roles in considering which types of strategies can satisfy their travel needs. Travel Liking, representing a positive utility of travel, can motivate individuals to consider strategies that support maintaining or increasing their current travel. Lastly, individuals’ Travel Attitudes, Personality, and Lifestyle also affect their consideration of travel-related strategies, either positively or negatively, in logical ways. Interestingly, several variables were significant (with the same signs) to the consideration of both travel-maintaining and travel-reducing strategies. For example, those who travel a lot by personal vehicle were more inclined to consider both types of strategies. We interpret this as distinguishing as many as three types

of travel: that which is possible to reduce (and desired to do so), that which cannot be reduced (and thus is desired to be made more pleasant), and that which is desired to be maintained or even increased (while being made yet more pleasant). Clearly, it is important to better understand the differences among these three types of travel, and the extent to which each is experienced (sometimes by the same person).

In addition, a couple of relationships between previous adoption and consideration of travel-related strategy bundles can be identified in the model. The previous adoption of any individual strategies in a bundle strongly positively affects the consideration of the same bundle, showing an *inertial* or *repetitive* response toward travel-related strategies. On the other hand, the previous adoption of any individual strategies in a bundle can significantly increase the consideration of either lower- or higher-cost strategy bundles, showing an *unstable* or *cycling* response toward travel-related strategies. It is natural that individuals keep seeking a better strategy at a different time or cost level to improve their current travel conditions, although this relationship is less often found in our model than the former (reconsideration of the same bundle). Further, time-since-adoption variables can partially explain the dynamic nature of individuals' responses to travel-related strategy bundles. That is, depending on the type of travel-related strategy in a bundle, an individual who adopted it longer ago is more (or less) likely to consider the same bundle or another bundle. As a general comment, it should be kept in mind that Clay and Mokhtarian (2004) found that the respondents adopted or are considering individual strategies for a variety of reasons including but not limited to travel. However the strategies all have travel implications, and therefore we interpret the relationships between adoption and consideration from a transportation perspective.

Overall, the results of this study give policy makers and planners insight into understanding the dynamic nature of individuals' responses to travel-related strategies, as well as differences between the responses to congestion that are assumed by policy makers and those that are actually adopted by individuals. One possible insight is that it could be productive to segment travelers based on whether their previous response behavior was closer to an inertial pattern or a cycling one. The former group is more likely to accept previously implemented travel strategies, whereas the latter group is more likely to adopt new ones. Our study, however, focused on individuals' responses to the travel-related strategy bundles (i.e., disaggregate behaviors, not aggregate). It would be very useful to develop aggregate approaches to explaining the Travel Attitudes, Personality, Lifestyle, and qualitative Mobility variables that are significant in this study, to support the development and evaluation of more effective transportation policies for reducing traffic congestion and/or improving mobility.

**Acknowledgements** This research was funded by the University of California Transportation Center. The study has benefited from discussions with Xinyu Cao, Gustavo O. Collantes, Michael J. Clay, Tim Schwanen, and Arno Hendricks. Suggestions by David Hartgen and anonymous referees improved the paper.

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