An Examination of Houston's QuickRide Participants by Frequency of QuickRide Usage

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ABSTRACT

QuickRide is an innovative project designed to more effectively utilize the capacity of the high-occupancy vehicle (HOV) lanes on the Katy (I-10) and Northwest (US 290) freeways in Houston. Under this project, two-person carpools can pay $2.00 to use the HOV lanes during the peak period, even though the lanes were normally restricted to vehicles with three or more occupants. This form of HOV lane is typically termed a high-occupancy / toll (HOT) lane and can be an effective travel demand management and congestion mitigation tool. However, relatively little is known about drivers who choose to use the HOT lane option. This paper examines the commute and socio-economic characteristics of Houston's QuickRide participants by their frequency of QuickRide usage. The study was based on a survey of QuickRide enrollees conducted in March 2003.

It was found that QuickRide participation increases with increasing trip length, perceived time savings, and frequency of trips in the travel corridor. Participation decreases with increasing carpool formation times but is generally irresponsive to minor changes in the $2.00 toll. QuickRide is also more likely to be used for commute trips than other trips. Socio-economic characteristics such as age, household type and education also have significant effects on QuickRide trip frequency. However, household size, occupation, and hourly wage rate were not good indicators of the frequency of QuickRide usage.

Keywords: congestion or value pricing, HOT lanes, QuickRide, ordered logit model.

INTRODUCTION

In recent years, there has been growing interest in the use of high-occupancy/toll (HOT) lanes as an alternative to high-occupancy vehicle (HOV) lanes for managing traffic congestion and controlling air pollution (*1*). This interest in the concept of HOT lanes has resulted from attempts to optimize the use of HOV lanes as well as growing public dissatisfaction and to some extent, a "strong anti-HOV backlash" (*2, 3, 4, 5*). Of particular concern is the so-called empty lane syndrome—where drivers are held up in traffic congestion on the main freeway lanes while adjacent HOV lanes are operating significantly below capacity. HOT lanes attempt to optimize the use of HOV lanes by combining pricing strategies and occupancy restrictions to manage the number of vehicles using the facility. High occupancy vehicles that meet the minimum occupancy requirements are allowed to travel for free, while other vehicles that do not meet the occupancy levels required for free access to the HOV lanes are given the option of paying a toll to travel on the HOV lanes.

HOT lanes are an example of the concept of *value pricing* which involves charging an optional toll to allow access to a restricted traffic facility that usually provides a better level of service time savings compared to the free facility. HOT lanes differ from traditional toll roads in the sense that whereas the latter require all users to pay a fee, HOT lanes offer motorists a choice (*2*). Thus what makes the HOT lane concept appealing is that it improves travel options, provides reliable travel times, generates some revenue, and increases the overall efficiency of HOV facilities (*6*).

At present, there are four HOT lane facilities operating in the world (*6, 7*). These include:

- State Route 91 (SR 91) Express Lanes – Orange County, California
- I-15 FasTrak – San Diego, California
- Katy Freeway (I-10) QuickRide – Harris County, Texas, and
- Northwest Freeway (US 290) QuickRide – Harris County, Texas.

The SR 91 Express Lanes are a 10-mile (16.1 km), four-lane toll facility located in the median of the Orange County–Riverside County travel corridor. The project opened in 1995 as the first practical application of the concept of value pricing to a roadway facility in the United States (*7, 8*). As of August 2003, toll rates varied from $1.00 to $4.75 by time of day and day of week and vehicles with three or more occupants could use the facility at no cost during most periods of the day. Customers pay their toll from prepaid accounts using a FasTrak transponder (a portable radio transmission device attached to the windshield). The Express Lanes facility provides average time savings of 12 to 13 minutes (*9*).

The I-15 FasTrak is an 8 mile (12.9 km), reversible, two-lane HOV facility in the median of I-15, about 10 miles (16.1 km) north of San Diego, California which opened in December 1996. HOV-2+ vehicles (vehicles with two or more persons) may use the facility at no cost. However, single-occupancy vehicles (SOVs) have to pay a toll that varies from $0.50 to $4.00, depending on the level of traffic, and may go up to as high as $8.00 in cases of severe congestion. Electronic signs located at the entrance to the HOT lanes give motorists advance notice of the current toll. Customers must have a FasTrak account to use the HOT lanes. Under the worst traffic conditions, FasTrak participants can save up to 20 minutes of travel time (*10*).

The Katy HOV lane opened in 1984. It is a 13.3-mile (21.4 km), one-lane reversible facility located in the median of Katy (I-10) Freeway in Houston, Texas. In the beginning only transit and vanpools could use the lane. However, restrictions were gradually reduced and, by 1986, stabilized at allowing HOV-2+ carpools. At the HOV-2+ restriction level the facility became highly congested during peak periods. To reduce congestion, the occupancy requirement was raised to HOV-3+ in 1988 during peak traffic periods (*11*). However, this change resulted in significant excess capacity in the HOV lane during the peak periods (*12*). In January 1998, the QuickRide program was introduced, which allowed a limited number of two-person carpools to use the Katy HOV lane. Under this program, two-person carpools can pay a toll of $2.00 to use the HOV lane during peak periods (6:45–8:00 AM and 5:00–6:00 PM), while HOV-3+ vehicles continue to use the facility for free. The $2.00 toll is charged electronically to drivers displaying both a QuickRide hang tag and a transponder. Participants receive an average travel time saving of approximately 17 minutes.

In view of the success of the Katy QuickRide program, the Metropolitan Transit Authority of Harris County converted the Northwest HOV lane to HOT use in November 2000 and it operates in similar manner to the Katy HOT lane facility, except that it is available only during the morning peak period (6, *11*). The afternoon peak period in this HOV lane is not congested and is open to HOV-2+ vehicles. It is a 14.6-mile (23.5 km), one-lane facility in the median of Northwest Freeway (US 290) which connects the northwest suburbs of Houston with downtown. Average travel time savings on the Northwest HOT lane is approximately 11 minutes.

A prominent feature of the QuickRide program is the fact that, unlike the two California projects where single occupant vehicles can use the HOT lanes for a fee, SOVs are not allowed to use the HOT lanes. This is a reflection of the HOT lane's limited capacity (one reversible lane) and the high travel demand on the Katy Freeway corridor—207,000 vehicles per day (*6*). QuickRide demand averaged 103 trips per day on the Katy HOT lane in 1998. After the introduction of QuickRide on the Northwest Freeway, total demand on the two facilities averaged 131 trips per day in 2000 and increased to 182 trips per day in 2002. These estimates are well below the targeted demand of 600 QuickRide vehicles per peak hour. In 1998, Stockton et al. conducted a survey to evaluate the effectiveness of the QuickRide program. Their study focused on issues such as the overall usage of QuickRide, changes in person throughput along the Katy Freeway corridor, and, to a lesser extent, the characteristics of QuickRide participants (*12*). However, their analyses were generally descriptive and based on a smaller sample size, whereas this research uses a larger sample size to determine significant differences between frequent, moderate, and infrequent QuickRide participants and develops a model to predict QuickRide use based on travel and socio-economic characteristics.

Building from the findings of Stockton et al. (*12*), recent analysis of QuickRide usage, and data from a recent survey of QuickRide enrollees, this study focuses on explaining the factors that underlie the decision to use QuickRide. The rest of this paper discusses the relevant theory behind the analyses, describes data and methods of analyses, presents analytical results, summarizes findings and conclusions, and makes recommendations for future research.

THEORY

The theoretical origins of travel demand estimation can be traced to consumer choice theory, which asserts that when faced with a number of possible alternatives the rational consumer makes the choice that maximizes his or her utility (or minimizes his or her disutility). The numerical value of the utility equation depends on the attributes of the available alternatives (for example, cost or travel time savings) and the trip maker (for example, income or age) and indicates how an individual ranks the set of alternatives and, hence, his or her preferred choice. The option with the highest utility is the travel choice that particular traveler is most likely to make. The option with the second highest utility is the next most likely choice and so on to the least likely. For QuickRide participants, the available modes for travel on the Katy Freeway corridor are: driving alone (not available on HOV lane), two-person carpools (available at all times on main lanes and during non-peak periods on HOV lane), QuickRide (two-person carpool + $2.00 toll during peak periods on HOV lane), 3+ person carpool, bus, and motorcycle. The utility for any particular mode is different for each individual. Greater understanding of these differences allows engineers and planners to develop programs that maximize the net societal benefits of the transportation system.

Standard discrete choice modeling techniques were used in this research. This model assumes that each decision-maker, n has a utility function (13):

$$U_{nj} = \beta' X_{nj} + \varepsilon_{nj} \tag{1}$$

where,

U_{nj} = utility of decision-maker, n for travel option j.
j = the set of alternatives available to the decision-maker,
X_{nj} = a vector of measurable attributes of each travel option,
β' = a vector of the coefficients of X_{nj},
ε_{nj} = unobservable factors (random utility), and
$\beta' X_{nj}$ = systematic utility

The fact that the measured variables do not include everything relevant to the individual's decision makes the choice process probabilistic (*14*). It has been shown that the choice probability depends on the systematic utility differences as well as the distribution of the random (unobserved) utility differences (*13, 14, 15, 16*). The most common model used is the *logit model,* which assumes that the random utilities follow the extreme value distribution (error terms are independently and identically distributed). The probability that decision-maker, n chooses mode i ($i \in j$) is given by:

$$P_{ni} = \frac{e^{\beta' X_{ni}}}{\sum_{all\ j} e^{\beta' X_{nj}}} \quad ; \quad \forall_j \neq i \tag{2}$$

In situations where the dependent variable is discrete and ordered in nature, the ordered logit model (a special case of logit models) is used. If, for example, there are three alternatives (for example 1 = poor, 2 = good, 3 = excellent), then two cut-off points (μ_0 and μ_1) can be estimated using maximum likelihood estimation. The decision is then represented as:

"poor" if $U_j < \mu_0$
"good" if $\mu_0 < U_j < \mu_1$
"excellent" if $U_j > \mu_1$

Using these cut-off points the probability of an alternative being chosen by decision-maker n is estimated as follows (*13*):

$$P_{n1} = \frac{1}{1+e^{-(\mu_0 - \beta' X_{nj})}} \tag{3}$$

$$P_{n2} = \frac{1}{1+e^{-(\mu_1 - \beta' X_{nj})}} - P_1 \tag{4}$$

$$P_{n3} = 1 - (P_{n1} + P_{n2}) \tag{5}$$

where,

P_{ni} = the probability of choosing alternative $i \in j$ (j = 1, 2, 3), and

μ_0, μ_1 are the two cut-off points.

METHODOLOGY

To begin, descriptive statistics of all survey respondents were examined to obtain an overall view of respondents. Respondents were then divided into three groups based on their frequency of QuickRide usage. It should be noted here that since QuickRide operates only in the morning peak period on the Northwest freeway, fewer trips were expected there than on Katy Freeway, where QuickRide operates during both the morning and afternoon peak periods. The three groups of respondents were (all trips are one-way):

1. Infrequent participants, defined as QuickRide enrollees who indicated they took a maximum of one QuickRide trip on either route (Katy or Northwest) in the week immediately preceding the survey,

2. Mid-level participants, defined as QuickRide enrollees who indicated they took 2–4 QuickRide trips on Katy or 2–3 QuickRide trips on Northwest in the week immediately preceding the survey, and

3. Frequent participants, defined as QuickRide enrollees who indicated they took 5–10 QuickRide trips on Katy or 4–5 QuickRide trips on Northwest in the week immediately preceding the survey.

To answer the fundamental question of whether or not there were significant differences ($p < 0.05$) between respondents in the three groups, several statistical tests were used. For *categorical* responses (for example, trip purpose or occupation), the chi-square contingency test was used. One-way analysis of variance (ANOVA) was used for three-way comparison of means of *continuous* data (for example, travel time savings or trip length). For *ordinal* data the Kruskal Wallis test for three-way comparison of means (for example, age or income) was employed.

An ordered logit model was then formulated with frequency of QuickRide participation as the dependent variable. The explanatory variables used in the model, their measurements, and expected (hypothesized) impact on QuickRide trip frequency are summarized in Table 1. The hypotheses were formulated based on intuitive reasoning and a thorough review of carpooling literature.

DATA

To gather the data required for a greater understanding of HOT lane use and build the models outlined above, a survey was mailed to all 1459 people enrolled in QuickRide as of December 2002. The survey included 36 questions regarding QuickRide enrollees' QuickRide and non-

QuickRide trips, their typical use of QuickRide, feelings toward alternate QuickRide tolling schemes, and their socio-economic characteristics. The survey was mailed in March 2003. Surveys returned by the beginning of April were included in the analysis (responses in the 14 surveys returned later may have been influenced by a QuickRide price change in April and were not included). A total of 93 surveys were returned by the post office due to incorrect addresses. Of the remaining 1366 surveys, 525 were returned on time for a 38.4 percent response rate (*17*).

Three slightly different surveys were mailed to QuickRide participants. The questions regarding the respondents' most recent trip varied based on QuickRide movement (Katy AM, Katy PM, or Northwest AM). The surveys were target mailed to the respondents based on their usage of these different QuickRide movements. In this manner respondents could specifically answer questions directed at their typical travel behavior, shortening and simplifying the survey instrument.

Once the data were entered and any data entry errors corrected, the surveys were weighted based on respondents' stated number of weekly QuickRide trips as compared to the average number of QuickRide trips that participants actually made per week during the last three weeks of March 2003. It was necessary to weight the surveys to account for both response bias and ex-post rationalization in survey responses. Both errors were expected as (a) participants who frequently used QuickRide were likely to be more interested/invested in the QuickRide program and therefore more likely to respond, and (b) respondents often overstate their actual participation rate. Based on the respondents' stated use of QuickRide it was fairly obvious both types of errors existed. To account for these biases, the surveys were weighted such that the proportions of survey respondents who indicated taking a specific number of QuickRide trips on a specific freeway equaled actual average QuickRide usage on that freeway for the last 3 weeks in March (see equation 6).

$$W_{i,j} = \frac{T_{i,j}}{R_{i,j}} \tag{6}$$

where,

$W_{i,j}$ = weighting factor for surveys on road i indicating a weekly usage of j,

$T_{i,j}$ = number of enrollees who averaged j QuickRide trips per week (based on the last three weeks preceding the survey) on freeway i based on QuickRide billing records,

$R_{i,j}$ = number of respondents on freeway i who indicated they made j QuickRide trips in the week immediately preceding the survey,

i = 1 for Katy Freeway and 2 for Northwest Freeway, and

j = 0–10 for Katy Freeway and 0–5 for Northwest Freeway.

The resulting weights are shown in Table 2. Based on these data it was clear that infrequent participants (0–1 trips per week) were significantly underrepresented in survey responses and frequent participants (7–10 trips per week on Katy and 5 trips per week on Northwest) were considerably overrepresented. This indicates three potential sources of error: (a) the small number of infrequent participants who responded were not representative of all infrequent participants; (b) some frequent participants were actually less frequent than indicated, skewing the characteristics of this group, and (c) some frequent participant's transponders were not registering with the automatic vehicle identification (AVI) equipment (this concern is very likely and the research team is examining possible remedies). Without knowing the true number of trips made by each survey respondent (which cannot be determined since survey responses were anonymous), the best way to attempt to minimize the impact of these potential errors is through the weighting efforts described earlier.

It should also be noted that several Northwest survey respondents indicated more than five QuickRide trips per week. It was felt the most likely reason for this was confusion between using QuickRide and simply driving on the HOT lane in the afternoon (when QuickRide does not operate) and some respondents counted these afternoon trips when they should not have. Therefore, the stated number of weekly trips was divided by two for these respondents. Also, three respondents for Northwest and three for Katy indicated more than 10 QuickRide trips per week. These responses were removed from the analysis, thus reducing the available data to 519 responses. This analysis was limited to the respondents who either stated the number of QuickRide trips they made in the week immediately preceding the survey or stated the average number of QuickRide trips they made in a month or year. In all, eight respondents did not answer this question. Hence, the total number of cases available for our analysis was reduced to 511.

Aside from this survey, several other sources of data were available for this analysis, including:

1. A data set containing the transponder number, date, and time of every QuickRide trip ever taken. This data set was used to build the weights described above.
2. A data set containing travel speeds on both the main (free) lanes and the HOT lanes on Northwest and Katy Freeway. The travel speeds provided detailed information on the travel time savings gained through the use of QuickRide.
3. Survey results from a smaller survey of QuickRide enrollees conducted in 1998.

RESULTS

Table 3 provides a summary of descriptive statistics and statistical analysis of respondents' socio-economic and commute characteristics.

Individual Demographics

Frequent and mid-level QuickRide participants were significantly more likely to be 35 to 44 years old and significantly less likely to be 65 or more years old. Females represented 53.0 percent of all respondents. There were significantly more females than males in the mid-level and frequent participants group than in the infrequent participants group. Most respondents had an education beyond high school. College graduates or those with some college/vocational education were, however, significantly more likely to be mid-level or frequent participants than postgraduate degree holders. About 65 percent of respondents were employed in professional/managerial positions. Administrative/clerical workers were significantly more likely to be mid-level or frequent participants. Most respondents (22 percent) earned between \$30.01 and \$40.00 per hour in 2002. This was representative of the infrequent participants but not mid-level and frequent participants, most of who earned between \$20.01 to \$30.00 per hour.

Household Characteristics

Respondents reported an average of 2.99 persons per household with no significant differences between the three groups of participants. About 90 percent of respondents were married. Of these, 67 percent were married with child(ren). There were, however, more unrelated adults among the frequent participants than among the infrequent and mid-level participants. There were slightly more single-parent families among the mid-level and frequent participants than among infrequent participants. There was an average of 2.32 vehicles per household with no significant differences among the various groups. Only about 7 percent of respondents reported an annual household income below $50,000. About 62 percent of respondents stated an annual household income of $100,000 or more. Although rather high, it is not surprising as drivers in this corridor generally have higher than average incomes.

Commute Characteristics

Trip Purpose
A very high proportion (67 percent) of travelers in the data set were commuting when they used QuickRide. An even higher proportion of mid-level (90 percent) and frequent (83 percent) participants were on commute trips. No recreational trips were made by mid-level and frequent participants, whereas about 12 percent of infrequent participants' trips were for recreational purposes. Trips made to schools were significantly lower among mid-level participants than infrequent or frequent participants. Due to the location of a school near an exit on both freeways, it was not surprising frequent QuickRide participants were on a school-related trip. In fact a clear decrease in AM QuickRide participation occurs during school holidays.

QuickRide Trip Length
The trip length of respondents varied between 15 and 105 minutes with an average of 45.3 minutes. Mid-level participants made significantly longer trips than both frequent and infrequent participants, with infrequent participants making the shortest trips. It should be noted that some respondents reported unusually high trip lengths. All trip lengths greater than or equal to 120 minutes were considered unreasonable for travel in the Houston metropolitan area and were not used in the analysis (19 responses were rejected based on this criteria).

Perceived QuickRide Time Savings
Respondents perceived an average QuickRide travel time savings of 29.8 minutes, which is significantly higher than the actual values of 17.33, 15.04, and 10.51 minutes recorded for the Katy AM, Katy PM, and Northwest AM QuickRide periods, respectively. This was not surprising since QuickRide participants may be trying (subconsciously) to justify their choice. Similar results have been reported in other studies. Billheimer (*18*) reported that drivers in carpool lanes in the San Francisco Bay area perceived HOV time savings that were more than double the average savings recorded during the heaviest traffic period. As in Billheimer's study, mid-level and frequent QuickRide participants reported QuickRide travel time savings of more than 34 minutes (more than double that recorded on either Katy (AM/PM) or Northwest AM), with infrequent participants reporting a perceived travel time savings of 28.7 minutes.

Usual Carpool Partner and Carpool Formation Time
Most respondents carpooled with a coworker (40.6 percent), an adult family member (35.9 percent), or a child (24.7 percent). Note that these percentages exceed 100 as they include respondents that selected multiple carpool partner types. Mid-level participants were significantly more likely to carpool with an adult family member or neighbor than both frequent

and infrequent participants. Respondents spent up to 23 minutes to pick up and drop off their carpool partners, with an average carpool formation time of 4.33 minutes. Mid-level and frequent participants were significantly more likely to spend more time forming carpools (5.32 minutes) than infrequent participants (4.14 minutes). One possible explanation would be that mid-level and frequent QuickRide participants have established carpools while infrequent participants only carpool when very convenient and therefore have low average formation times. Frequent and midlevel participants had significantly higher carpool formation times than infrequent participants when carpooling with a child or an adult family member (see Figure 1).

Frequency of Travel in the Katy/Northwest Freeway Corridor

The average number of one-way trips on both freeways, irrespective of travel mode, was 7.3 per week. Frequent QuickRide participants reported more trips on the corridors than mid-level participants, who in turn made more trips on the corridors than infrequent QuickRide participants.

Passenger's Contribution to Toll

Approximately 51 percent of frequent participants, 33 percent of mid-level participants, and 25 percent of infrequent participants said their carpool partners helped pay the $2.00 QuickRide toll. An average of approximately 50 percent and 46 percent of all respondents shared the toll with their passengers when traveling with either a coworker or an adult family member, respectively, while only approximately 6 percent of all respondents who traveled with casual carpoolers shared the toll with their passengers. Almost no respondent who traveled with a child or a neighbor shared the toll with the passenger.

Number of QuickRide Trips for Various Tolls Other Than $2.00

Respondents were asked the number of trips they would make per week if the QuickRide toll was $1.00, $1.50, $2.50, and $3.00. They were also asked to state the number of trips they would make if two-person carpools were allowed to use the HOV lane without paying a fee. As expected, the average number of trips decreased as the toll increased. Moreover, frequent participants consistently stated a higher number of trips than mid-level participants, who also stated more trips than infrequent participants. This suggests that varying the toll in the stated range is not likely to change the proportion of participants in the three groups. Additionally, at the various toll levels, there were small changes in number of QuickRide trips indicating inelastic responses to the toll (see Figure 2).

Ordered Logit Model of QuickRide Trip Frequency

Various combinations of independent variables were tested in the ordered logit model. However, only those variables that were significant at the 5 percent level and showed negligible correlation with other variables were used in the final model. Limdep 7.0 software was used for model estimation. Table 4 provides a summary of the modeling results.

As hypothesized, the model results show that QuickRide was more likely to be used for commute trips. It was predicted (at 5 percent level of significance) that the frequency of participation increased with travel characteristics such as, increasing trip lengths, high perceived travel time savings, and more frequent travel in the Katy or Northwest Freeway travel corridors. Conversely, the frequency of QuickRide usage was found to decrease with increasing carpool formation times. These results appear reasonable. For example, commute trips were usually time constrained and participants were likely to derive maximum benefits from using QuickRide. Since the $2.00 QuickRide toll was relatively small compared to the overall cost of a long trip it was not surprising that QuickRide trip frequency increased with increased trip length (*1, 8*). It was also reasonable that the program would be more attractive to participants who perceived greater QuickRide travel time savings than those who perceived little or no travel time savings. The finding that QuickRide trip frequency increased with frequency of use of the travel corridor (irrespective of travel mode) was also not surprising since frequent travelers would generally be more acquainted with traffic conditions in the corridor than occasional travelers (*1*).

Socio-economic characteristics such as age, household type, and education also had significant effects on QuickRide trip frequency. The results indicated that participants between 25 and 54 years of age were likely to use QuickRide more frequently than both young adults and persons over 54 years of age. At the 5 percent level of significance, household size, occupation, and hourly wage rate were not good indicators of the frequency of QuickRide usage. The results also suggested that participants who were married with no children were less likely to use QuickRide, while having a college degree and sharing the $2.00 QuickRide toll with a passenger increased the probability of using QuickRide.

The negative constant term was also reasonable and suggested that all things being equal, drivers were more likely to be infrequent participants of QuickRide. This result was consistent with QuickRide usage data that showed approximately 84 percent of QuickRide enrollees averaged between 0 and 1 QuickRide trips per week in 2002. Approximately 11 percent averaged between 1 and 2 trips per week and only 5 percent averaged more than 2 trips per week. (Note that this level of recorded participation may be slightly lower than actual usage due to the missed transponder reads, as mentioned earlier.)

SUMMARY AND CONCLUSIONS

The United States' experience with HOT lanes continues to grow with three projects in Houston, San Diego, and Riverside County being fairly well established. After 5 years in operation (3 years on Northwest Freeway), the Houston QuickRide program receives comparatively lower patronage than the two California projects. Standard statistical methods and an ordered logit model were used in this study to examine the characteristics of infrequent, mid-level and frequent QuickRide participants as a step in understanding the reasons for the low patronage.

The results indicated that the disutility of forming a carpool was a major deterrent to participation in the program. Conversely, inelastic response to minor changes in the toll, coupled by responses to a question regarding participants feeling towards the $2.00 toll, suggested that the toll was not a major deterrent to participation. The results also showed that commuters, participants with college education, those who shared the QuickRide toll with their carpool partner, and those between 25 and 54 years old were likely to make more QuickRide trips. It was also found that participants who perceived higher QuickRide travel time savings, traveled on the corridor more frequently, and/or undertook longer trips were likely to use QuickRide more often. Conversely, long carpool formation times decreased the likelihood of frequent use of QuickRide. Participants who had household incomes less than $50,000 in 2002 (approximately 7 percent of all participants) made an average of 0.93 QuickRide trips in the week immediately preceding the survey whereas those who earned more than $50,000 made 0.68 QuickRide trips during the same week. Thus participants from low-income households made proportionately more QuickRide trips than those from high-income households. However, the number of mid-level and frequent participants in the low-income group was so small that basing any conclusions on this result could be misleading.

A more comprehensive study of QuickRide participant's travel behavior that incorporates major issues such as equity, the value of time of different groups of enrollees, their disutilities for carpooling, and a more detailed analysis of toll price elasticities is recommended. A comparative analysis of current enrollees, former enrollees, non-users, and participants in the California HOT lane projects will also shed more light on driver's use of HOT lanes and the decisions behind their participation. Such studies will further help engineers and planners to understand the reasons behind drivers' decision to use QuickRide, determine optimal tolling levels, formulate more appropriate marketing strategies, and, most importantly, improve the overall efficiency of these programs to maximize the net benefits derived from travel.

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LIST OF TABLES AND FIGURES

TABLE 1 Definitions and Measurements of Explanatory Variables Used in Logit Model

Variable	Measurement	Predicted Effect*
Commute trip	1, if trip purpose = commute 0, otherwise	+
Trip length	QuickRide travel time (minutes)	+
Time savings	Difference between perceived QuickRide time savings and carpool formation time (minutes)	+
Frequency of travel in corridor	Total number of one-way trips per week in corridor	+
Shared toll	1, if carpool partner helps pay toll 0, otherwise	+
Education	1, if college graduate 0, otherwise	+
Household type	1, if married without a child 0, otherwise	–
Age	1, 25 to 54 0, 16 to 24 or 55 and older	+

* A '+' indicates the variable was predicted to increase the frequency of participation in QuickRide. The opposite effect was predicted for those variables with a '-'sign.

TABLE 2 Number of QuickRide Participants Making a Specific Number of Trips per Week

Number of trips per week	Katy			Northwest		
	Stated ($R_{1,\ j}$)	Observed ($T_{1,\ j}$)	Weight ($W_{1,\ j}$)	Stated ($R_{2,\ j}$)	Observed ($T_{2,\ j}$)	Weight ($W_{2,\ j}$)
0–0.49	36	709	19.6944	10	396	39.6000
0.5–1.49	51	83	1.6275	31	43	1.3871
1.5–2.49	38	54	1.4211	19	30	1.5789
2.5–3.49	20	32	1.6000	23	20	0.8696
3.5–4.49	22	26	1.1818	23	19	0.8261
4.5–5.49	35	17	0.4857	86	9	0.1047
5.5–6.49	19	9	0.4737			
6.5–10	98	12	0.1224			

TABLE 3 Socioeconomic and Commuting Characteristics of Survey Respondents by Frequency of Participation

Characteristic (Percent of Respondents in Each Category)	Frequency of QuickRide Use: All Participants (N = 1459)[b]	Infrequent Participants Katy: 0–1 trips/week Northwest: 0–1 trips/week (N = 1231)	Mid-level Participants Katy: 2–4 trips/week Northwest: 2–3 trips/week (N = 162)	Frequent Participants Katy: 5–10 trips/week Northwest: 4–5 trips/week (N = 66)
QuickRide trip purpose*				
Commute*	66.7	61.7	89.9	82.5
Recreation*	9.9	12.2	0	0
Work	4.1	4.6	2.7	0
School*	11.0	11.6	5.4	15.9
Other*	8.3	9.9	2.0	1.6
QuickRide trip length (minutes)[a]	45.32	44.70	49.37	44.78
Total trips/week on corridor[a]*	7.32	7.04	8.47	9.75
QuickRide trips/week[a]*	0.64	0.1	2.64	5.65
Perceived travel time savings[a]*	29.77	28.71	35.29	34.22
Usual carpool partner*				
Coworker	40.6	40.4	40.4	42.4
Neighbor*	2.8	1.9	8.6	6.1
Adult family member*	35.9	34.5	46.3	36.4
Casual carpool (slug)	7.1	7.4	6.2	4.5
Child	24.7	25.7	17.3	25.8
Other	4.8	5.1	2.5	3.0
Extra time to pick up/drop off QuickRide partner[a]*	4.33	4.14	5.32	5.32
Passenger's contribution to toll*				
Passenger helps pay toll	26.8	24.5	33.3	50.8
Passenger does not help pay toll	73.2	75.5	66.7	49.2

Characteristic (Percent of Respondents in Each Category)	Frequency of QuickRide Use			
	All Participants (N = 1459)[b]	Infrequent Participants Katy: 0–1 trips/week Northwest: 0–1 trips/week (N = 1231)	Mid-level Participants Katy: 2–4 trips/week Northwest: 2–3 trips/week (N = 162)	Frequent Participants Katy: 5–10 trips/week Northwest: 4–5 trips/week (N = 66)
Impression about $2.00 toll				
Very reasonable	26.9	27.8	22.8	21.2
Somewhat reasonable	29.5	28.3	36.4	34.8
Neutral	22.1	21.7	22.8	27.3
Somewhat unreasonable	19.0	20.1	14.2	12.1
Very unreasonable	2.5	2.2	3.7	4.5
QuickRide trips at various tolls[a]				
Free*	3.03	2.7	4.08	5.74
$1.00*	2.50	2.12	3.88	5.66
$1.50*	2.23	1.88	3.34	5.20
$2.50*	1.38	1.07	2.36	4.2
$3.00*	1.27	1.05	1.95	3.35
Age*				
16 to 24	3.4	3.3	4.3	3.0
25 to 34	14.3	14.0	16.1	15.2
35 to 44*	26.0	24.2	36.0	33.3
45 to 54	38.4	38.9	36.0	36.4
55 to 64	11.6	12.3	6.8	10.6
65+*	6.2	7.3	0.6	1.5
Gender*				
Male	47	48.5	39.6	37.9
Female	53	51.5	60.4	62.1
Household type*				

Characteristic (Percent of Respondents in Each Category)	Frequency of QuickRide Use			
	All Participants (N = 1459)[b]	**Infrequent Participants Katy: 0–1 trips/week Northwest: 0–1 trips/week (N = 1231)**	**Mid-level Participants Katy: 2–4 trips/week Northwest: 2–3 trips/week (N = 162)**	**Frequent Participants Katy: 5–10 trips/week Northwest: 4–5 trips/week (N = 66)**
Single adult	5.7	5.4	6.9	9.0
Unrelated adults*	0.4	0.2	0.6	4.5
Married without child	29.9	30.8	29.4	14.9
Married with child(ren)	60.5	60.7	57.5	62.7
Single parent family*	1.7	1.0	5.0	6.0
Other	1.7	1.8	0.6	3.0
Household size[a]	2.99	2.99	3.05	2.99
Vehicles per household[a]	2.32	2.30	2.44	2.27
Occupation*				
Professional/Managerial	64.8	65.2	62.2	64.6
Technical	10.1	10.6	8.3	4.6
Sales	5.5	5.5	5.8	4.6
Administrative/Clerical*	9.3	7.9	16.7	16.9
Manufacturing	0.0	0.0	0.0	0.0
Stay-at-home parent*	0.4	0.3	0.6	3.1
Unemployed/Seeking work	1.6	1.8	0.6	0.0
Other	8.4	8.8	5.8	6.2
Last year of school completed*				
Less than high school*	0.2	0.0	1.3	1.5
High school graduate	8.8	9.1	8.1	6.1
Some college/Vocational*	17.0	15.8	21.3	28.8
College graduate*	38.6	37.2	46.3	45.5
Postgraduate degree*	35.3	37.9	23.1	18.2

Characteristic (Percent of Respondents in Each Category)	Frequency of QuickRide Use			
	All Participants (N = 1459)[b]	**Infrequent Participants Katy: 0–1 trips/week Northwest: 0–1 trips/week (N = 1231)**	**Mid-level Participants Katy: 2–4 trips/week Northwest: 2–3 trips/week (N = 162)**	**Frequent Participants Katy: 5–10 trips/week Northwest: 4–5 trips/week (N = 66)**
Hourly wage rate (per hour)				
Less than $10	3.8	4.3	1.4	1.9
$10.01 to $15	7.8	8.4	3.6	7.4
$15.01 to $20*	7.8	6.9	12.9	9.3
$20.01 to $30*	17.0	16.0	19.4	27.8
$30.01 to $40	22.2	23.5	17.3	13.0
$40.01 to $50*	8.9	7.9	14.4	13.0
$50.01 to $60	10.5	11.4	6.5	5.6
$60.01 to $100	8.1	8.1	8.6	7.4
Over $100	13.9	13.6	15.8	14.8
Annual household income*				
Less than $10,000*	0.1	0.0	0.7	0.0
$10,000 to $14,999	0.0	0.0	0.0	0.0
$15,000 to $24,999*	0.1	0.0	0.7	0.0
$25,000 to $34,999	2.0	2.1	1.3	1.7
$35,000 to $49,999	4.6	4.2	7.4	5.2
$50,000 to $74,999	13.7	13.1	15.4	19.0
$75,000 to $99,999	17.8	17.7	18.8	17.2
$100,000 or more	61.7	62.9	55.7	56.9

Notes to Table 3
No response data were excluded by individual question number; therefore the sum of respondents from individual categories may not equal the total of all respondents. Multiple responses were allowed for usual carpool partners and hence the sum of percentages of responses for all categories exceeds 100 percent.
* Significant difference (at the 0.05 level) between groups of survey respondents. Statistical tests used included:

- Kruskal-Wallis for 3-way comparison (by group number) of ordinal data (for example; age, education, and income).
- One-way ANOVA for 3-way comparison (by group number) of continuous data (for example; trip length, travel time savings).
- Chi-square test for 3-way comparison of nominal data (for example; trip purpose, gender, household type, and occupation).

a. These entries represent mean responses (not proportions).
b. N values based on weighted data. Actual number of surveys was 128, 122, and 261 for infrequent, mid-level, and frequent participants, respectively.

TABLE 4 Model Estimation Results

Variable	Coefficient	Standard Error	t-stat	p-value
Constant	-5.908	0.465	-12.70	0.000
Commute trip	1.385	0.168	8.24	0.000
Trip length	0.024	0.005	4.92	0.000
Time savings	0.023	0.006	4.02	0.000
Frequency of travel in corridor	0.100	0.016	6.05	0.000
Shared toll	1.181	0.102	11.58	0.000
Married without a child	-0.291	0.128	-2.27	0.023
Age (25–54)	0.628	0.223	2.82	0.005
College education	0.340	0.118	2.88	0.004
Cut-off point 1 (Infrequent to mid-level participation)	0 (by default)			
Cut-off point 2 (Mid-level to frequent participation)	1.488	0.211	7.05	0.000
	Summary Statistics			
Number of observations		350		
Log likelihood function		-173.61		
Restricted log likelihood		-352.22		
Likelihood ratio index		0.51		

FIGURE 1 Carpool formation times for various carpool compositions.

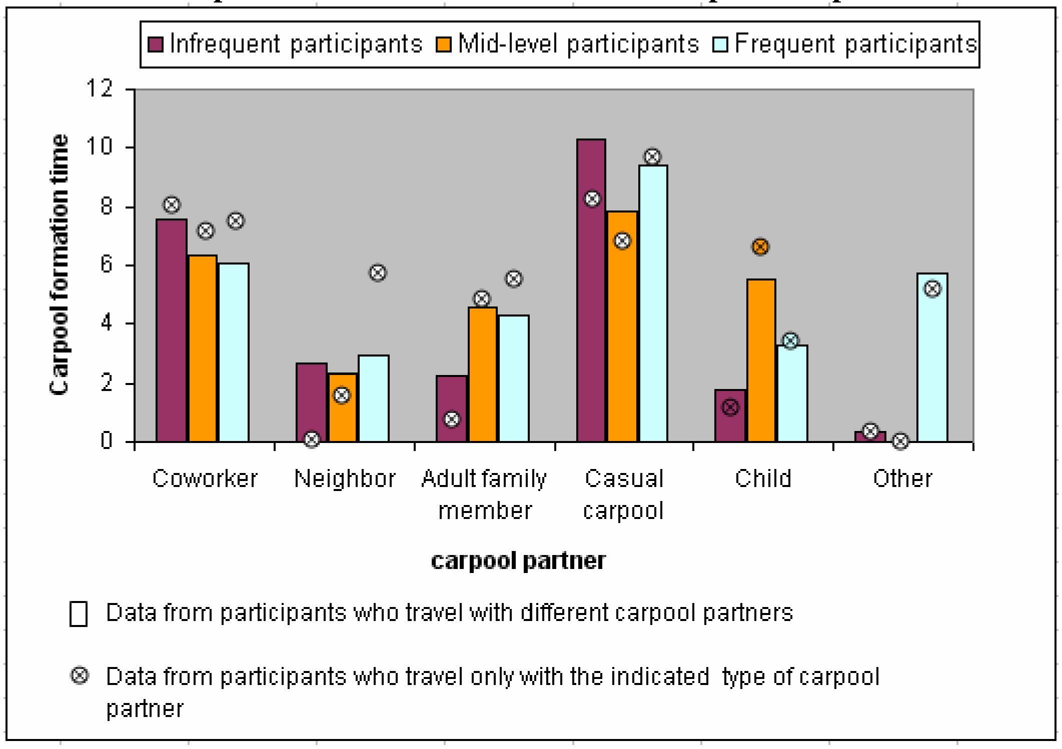

FIGURE 2 Stated number of QuickRide trips at various toll levels.