APPENDIX A: 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 nonresponsive 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 requires 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 savings 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 a 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*):

$$U_{nj} = \beta' X_{nj} + \varepsilon_{nj} \quad (1)$$

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 cutoff 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 cutoff 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 cutoff 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).

$$W_{i,j} = \frac{T_{i,j}}{R_{i,j}} \quad (6)$$

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 older. 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 mid-level 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 toward 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
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]				

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)
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*				
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

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)
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
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
Cutoff point 1 (Infrequent to mid-level participation)	0 (by default)			
Cutoff 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.

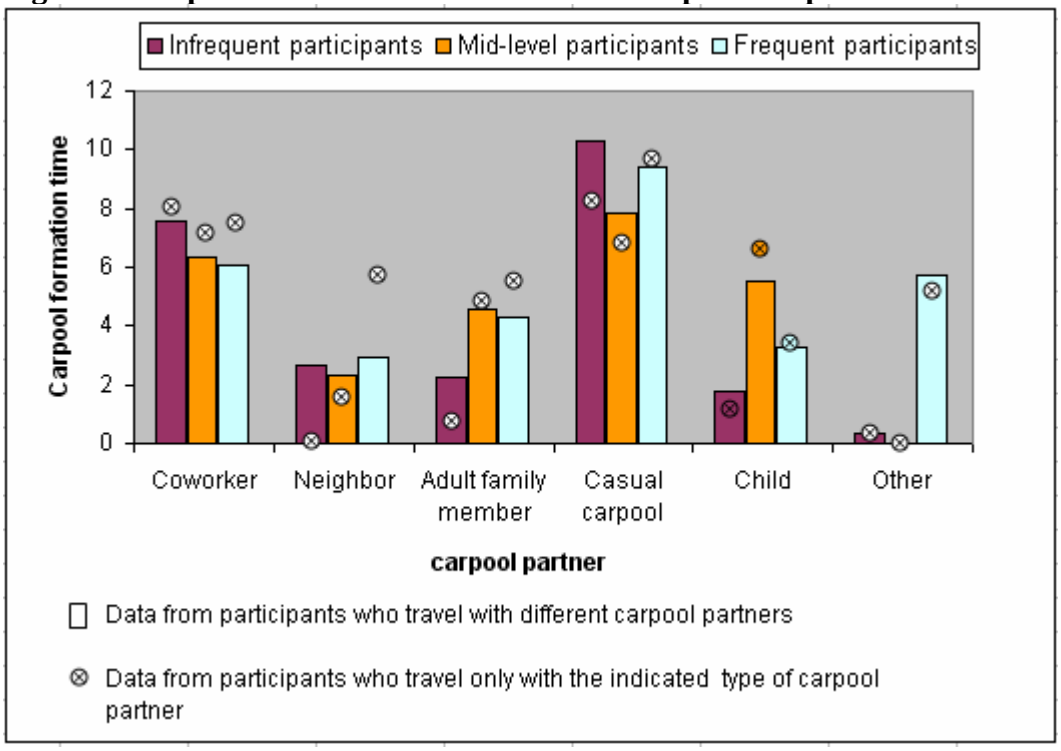
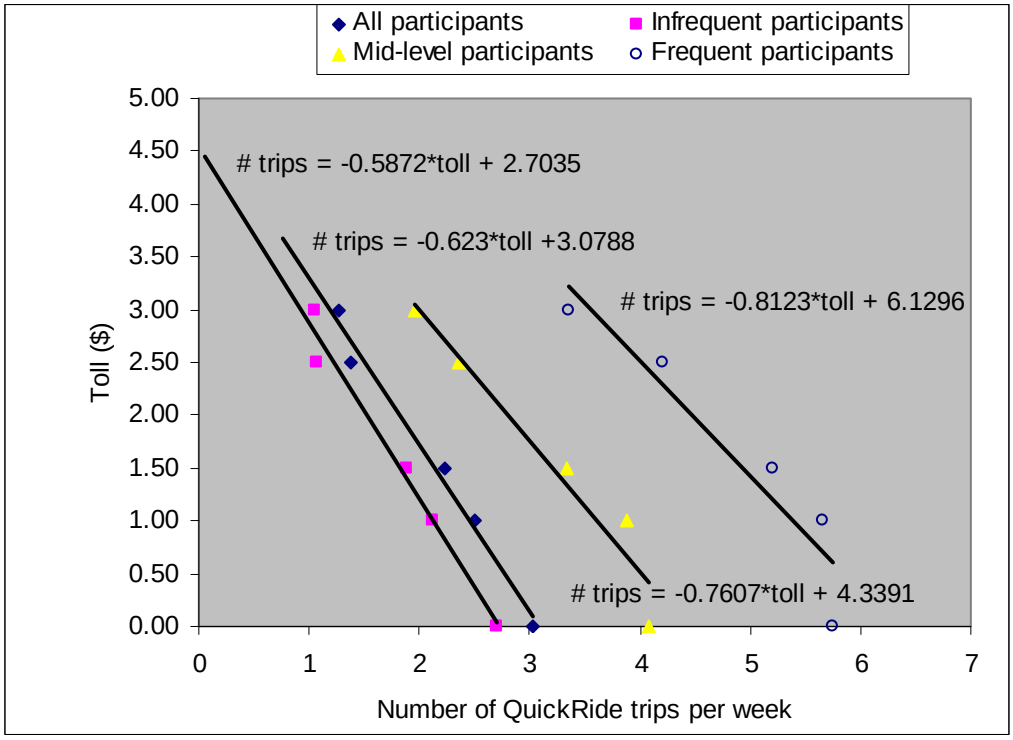


Figure 2. Stated number of QuickRide trips at various toll levels.



APPENDIX B: SUMMARY FOR QUICKRIDE FOCUS GROUPS

Description of Project

Three focus groups were held during the month of August to discuss the current QuickRide program and potential changes in the pricing structure. The first group was comprised of commuters that used Northwest 290 (NW 290) for the commute. The second group was commuters that used Interstate 10 West (I-10) for the commute (one participant was a QuickRide dropout). Collectively, the participants in the first two focus groups are referenced as "commuters." The third group consisted of current QuickRide Users.

Comments by Focus Group Participants

- **Commuters had little or no knowledge of the QuickRide program.**

Each group of commuters was asked what they knew about QuickRide. Only one participant in the NW 290 group knew about the QuickRide program. She knew about the program because her parents participated. Only one person in the I-10 group knew details about QuickRide – she was the one QuickRide dropout. One commuter using I-10 believed QuickRide was a vanpooling service. Another participant mentioned he had heard of the program but did not know any details about it.

More focus group participants knew there were restrictions on the number of persons in the HOV during specific hours. Most knew by reading the freeway signs, because an acquaintance received a ticket for not having HOV3 during restricted hours, or by remembering the original media description when the restrictions went into effect. Some had learned about the ability to use the HOV lane during the HOV3 times with HOV2 but did not know about the toll.

When the reasoning behind pricing HOV2 during HOV3 restricted hours was explained, some participants were persuaded the concept was a good idea. Others were still suspicious the program is just another way to charge money for a facility that is already paid for with other funds.

When asked how to best communicate information about QuickRide, the following suggestions were offered:

- television announcements,
- print media,
- electronic freeway signs,
- radio during peak hours,
- public service ads,
- employer benefit programs, and/or
- bill stuffers.

- **Commuters favor a lower toll for QuickRide access.**

Both commuter groups favored a toll lower than $2.00 per use. Suggested prices ranged from $0.50 to $1.00. One participant noted that a QuickRide toll should not be more than the typical toll on the (HCTRA) toll road.

Participants in the NW 290 focus group raised a concern that QuickRide is affordable only for those that drive expensive cars, and suggested the program is not fair to people who do not have as much disposable income as others.

The participants in both commuter groups said QuickRide would be of greater interest if the toll was reduced or if single occupant vehicles could have access for a price.

- **QuickRide Users are comfortable with the current toll.**

All QuickRide Users participating in the focus group believe the $2.00 toll is a good price for the time savings. The participants in the focus group believe the rate is equitable. At the same time, the QuickRide Users do not want the current toll increased.

- **Commuters and QuickRide Users value travel time savings on HOV.**

The most important benefit for using the HOV lane is to save travel time. The perception of several focus group participants was that the HOV lane saved as much as 50 percent of total commute travel time.

Another important benefit of the HOV lane is safety. Reliability was not as highly rated as travel timesavings and safety.

Many of the participants in the NW 290 and I-10 commuter focus groups commented on the need or ability to be flexible. Many could adjust commute times to avoid the most congested periods.

Opinions of Pricing Options

- **Time of day pricing received mixed reviews.**

The participants in the NW 290 focus group had mixed opinions about the various pricing options. In general, the group perceived $2.00 per use to be too high a price to pay; and some members of both groups felt the suggested prices in the examples were too high. Pricing by time of day was generally not well received, and several participants said they would be inclined to adjust commute times to avoid paying.

The I-10 group noted that time of day pricing cannot be too complicated (or too graduated) but this group liked time of day pricing over congestion pricing. The group also liked the idea of adding SOVs and time of day pricing together. There was concern about where and how time would be established – and if different times would apply to different points of access.

The QuickRide Users are concerned about where they would be charged. The members of the focus group said it is only fair to charge when a user enters the HOV lane, not when exiting because people access the lane further inbound (for example getting on I-10 inbound at Gessner as opposed to Highway 6). Focus group participants believed users end up entering the lane at a later time than the users farther outbound but are not being ticketed by METRO police for getting on as HOV2 after 6:45 AM.

- **Concept of congestion pricing is hard to explain.**

The concept of congestion pricing was not easily explained. To many, the idea of raising price as congestion in the HOV lane rises is counter-intuitive. Many commented "why pay to get access to a congested HOV lane?"

The NW 290 group noted the need for signs if congestion pricing is to be implemented. The signs will have to be far enough back to give the driver warning of the price. Signs and radio were mentioned as means to communicate dynamic pricing. The NW 290 group liked the idea of combining SOV access with congestion pricing.

In general, the focus group participants had a difficult time grasping how information can be presented in time to make an informed decision about QuickRide each day. Many are concerned about paying for access to an HOV lane that may be congested with no way to exit.

In general, there is a lack of confidence in technology to support the idea of dynamic, variable pricing and a lack of confidence in the ability of METRO to effectively patrol and enforce the HOV lane.

- **Commuter support SOV access to HOV; QuickRide Users are opposed.**

There was a more favorable reaction to allowing SOV access to the HOV with a toll. Several participants in both commuter focus groups said they would be willing to pay a fee to get access when driving alone. Both commuter groups included advocates of SOV access.

Every participant in the QuickRide User focus group is opposed to SOV eligibility for access to the HOV lane even at a higher price.

- **Flat rate pricing received modest support.**

Two participants in the commuter groups like the idea of flat rate pricing. One participant suggested she would like this pricing if she used the QuickRide program regularly. The other participant suggested breaking the flat rate into usage blocks. For instance 1-5 rides can be sold for a certain flat rate, and 6-10 rides are sold at another flat rate. This would combine usage and the flat rate scheme.

Overall the current QuickRide Users did not like the flat rate pricing option. Several cited the fact that they use it infrequently, vacation would cut usage and others have carpools that each have QuickRide passes and share the cost of the program.

- **I-10 focus group participants believe distance should be a factor in any pricing option.**

Most of the I-10 group (7 out of 9) agrees that distance is a factor when charging a toll. The focus group participants said that users who access the HOV at Highway 6 should have to pay more than the people that are getting on at Gessner.

Additional Information about HOV Operations

- **All focus groups supported expanded hours for the HOV lanes.**

There were no objections in any of the focus groups regarding expanding the hours of the HOV lane. Several mentioned they would like to see the HOV lane going both ways, 24 hours a day. One participant believes that people think the HOV lane is underutilized because most of the day they see an empty concrete lane. Another member suggested that the HOV lane close only for one hour between inbound and outbound traffic. She perceives this should be ample time to switch the flow of the lane.

- **Focus group participants believe enforcement of HOV lane restrictions can be improved.**

The QuickRide User focus group was particularly critical of the consistency of enforcement of the HOV lanes on I-10 and NW 290. Several persons raised concerns about the safety of existing procedures.

- **QuickRide Users are complimentary of the assistance of METRO in registering for the program.**

Each QuickRide User said he or she found it easy to get information about QuickRide, either by going to the METRO website or calling METRO. The users complimented the courtesy and responsiveness of the METRO staff.

- **QuickRide Users are tolerant of the inconsistencies in program administration.**

However, the QuickRide Users were not complimentary of program administration. Correspondence is not timely, and errors are often made on bills. However, the QuickRide Users said the benefits of the program outweigh the inconveniences.

QuickRide Users recommend allowing flexibility in the program, to permit QuickRide tags and transponders to be transferable to multiple cars within a carpool or within a family.

Attachment

Participant Characteristics

The following is a description of the participants in each group including gender, age, income level, education, marital status, number in household, and forms of transportation.

The first two groups are commuters who do not use QuickRide. A commuter is defined as someone who uses the specified freeway at least four weekdays inbound from 6:00AM – 9:00AM or outbound from 4:00PM to 7:00PM for at least six months. Group 1 includes commuters using Northwest 290. Group 2 includes commuters using I-10. Current QuickRide Users from both corridors comprise the third group.

Group 1: Northwest 290 Commuters

	Gender	Age	Income Level	Education	Marital Status	Number in House	Forms of Transportation
1	Male	46	$50,000 - $75,000	College Graduate	Single	1	Ride with carpool
2	Male	31	$35,000 - $49,999	Some College	Married w/children	4	Ride with carpool
3	Male	67	$35,000 - $49,999	High School Graduate	Married	2	Ride with carpool
4	Male	50	$50,000 - $75,000	Master or Ph.D.	Married w/children	4	Drive alone
5	Male	30	$50,000 - $75,000	Some College	Married w/children	4	Drive alone
6	Female	56	$50,000 - $75,000	College Graduate	Single Parent	2	Drive alone
7	Female	27	$50,000 - $75,000	Some College	Single Parent	3	Ride with carpool
8	Female	46	$50,000 - $75,000	Some College	Married	2	Drive alone or Ride with carpool
9	Male	34	$50,000 - $75,000	College Graduate	Married w/children	5	Drive alone

Group 2: Interstate 10 West (I-10) Commuters

	Gender	Age	Income Level	Education	Marital Status	Number in House	Forms of Transportation
1	Female	46	$75,000 - $99,999	Masters or Ph.D.	Married w/children	4	Ride with carpool
2	Male	36	$10,000 - $14,999	High School Graduate	Roommates	2	Drive alone, bus, ride with carpool
3	Female	59	$75,000 - $99,999	College Graduate	Roommates	2	Ride with carpool
4	Male	67	$35,000 - $49,999	College Graduate	Married	2	Ride with carpool
5	Male	49	$35,000 - $49,999	College Graduate	Married w/children	4	Ride with carpool
6	Male	33	$50,000 - $75,000	Some College	Married w/children	4	Bus
7	Male	41	$35,000 - $49,999	High School Graduate	Single	1	Drive alone and Ride with carpool
8	Female	25	$75,000 - $99,999	Some College	Other	3	Ride with carpool
9	Female	41	$35,000 - $49,999	Some College	Single	1	Drive alone
10	Male	44	$50,000 - $75,000	Some College	Roommates	2	Ride with carpool
11	Female	50	$35,000 - $49,999	College Graduate	Married	6	Ride with carpool

	Gender	Age	Income Level	Education	Marital Status	Number in House	Forms of Transportation	Freeway Used
1	Female	62	$75,000 - $99,999	Some College	Married	3	Drive alone, carpool	I-10
2	Female	37	$75,000 - $99,999	Some College	Married w/children	4	Drive alone, bus, carpool, slug	I-10
3	Male	48	$75,000 - $99,999	Some College	Married w/children	4	Bus, carpool	NW 290
4	Male	40	$50,000 - $74,999	Masters or Ph.D.	Married	2	Drive alone, picks up slug	I-10
5	Female	39	$75,000 - $99,999	High School Graduate	Married w/children	4	Bus, carpool	NW 290
6	Female	45	Over $100,000	College Graduate	Married w/children	n/a	Drive alone, bus	NW 290
7	Male	25-34	Over $100,000	Masters or Ph.D.	Married w/children	3	Park and ride bus	NW 290
8	Female	48	Over $100,000	Masters or Ph.D.	Married w/children	3	Carpool	I-10

Group 3: Current QuickRide Users

APPENDIX C:
COMPLIANCE LEVELS FOR CURRENT OPERATIONS

John Wikander
Ginger Goodin

Description of data collection

Data collection efforts occurred during three days in February, April, and October 2003. The February effort took place from Wednesday, February 26, through Friday, February 28, 2003; April data collection occurred from Wednesday, April 23, through Friday, April 25, while October data collection occurred from Wednesday, October 15, through Friday, October 17. These efforts focused on recording passenger counts and identifying vehicles enrolled in the QuickRide program. For the Katy HOV lanes, teams observed vehicles for both the morning (6:45 AM – 8:00 AM) and evening (5:00 PM – 6:00 PM) QuickRide periods, while the US 290 HOV lanes were observed for the morning period only.

For the Katy Freeway HOV lanes, observers were placed at two locations: the Post Oak HOV entrance/exit ramp and Eastern Extension slip ramp. Two-person teams were situated in TTI vans at locations normally used by METRO enforcement officers; at the Post Oak location, the van would be located near the access gate on the closed side of the entrance/exit ramp, while the van at Eastern Extension was situated in a wide gore/shoulder off to the side of the HOV lanes.

The US 290 data collection team consisted of three people; one person collected data at the Dacoma off ramp in a TTI van, while two people observed from a personal vehicle parked beside METRO enforcement officers at the Northwest Transit Center exit ramp. This was done to more accurately capture bifurcating traffic flow at the Dacoma ramp.

Each two-person team had an observer and a recorder; while both could observe traffic, the recorder's primary responsibility was to accurately mark down passenger occupancy and HOV compliance. A video recorder was used to provide an audio log of the observations; video quality was generally too poor to provide an accurate visual record of vehicle occupancy. The primary characteristics collected for each observed vehicle included vehicle type, number of passengers, and the presence of toll transponders and QuickRide hangtags. The specific classification regime for observed vehicles is discussed in detail in the next section.

Vehicle Classifications

Vehicle classification encompassed six general categories, some of which were also sub-categorized. The general categories are summarized as follows:

- **HOV 3+**: Includes passenger vehicles (trucks and cars) in which at least three occupants could be identified, as well as any identifiable vanpool vehicles (vans with some sort of vanpool designation markings)
- **2-person Vehicles**: Passenger vehicles (trucks and cars) having two clearly identified occupants

- **SOV**: Single Occupancy vehicles (trucks and cars) having only one clearly identified occupant
- **BUS**: Metro or other public transportation vehicle, excluding vanpools.
- **MC**: Motorcycle

A valid 2-person QuickRide vehicle must display both a toll transponder (hereafter referred to as a "toll") in the windshield area, as well as a small marquee labeled "QUICKRIDE" (referred to subsequently as a "pass") which is hung off the rearview mirror. Hence the four subcategories of the 2-person vehicle classification comprise the possible permutations of the presence of absence of each of these two items:

- **PASS / TOLL**: A 2-person vehicle which displays both a toll transponder (TAG) and a QuickRide hangtag (PASS). Such a vehicle is assumed to be abiding by all QuickRide regulations and is not considered a violator.
- **PASS / NO TOLL**: A 2-person vehicle displaying a QuickRide pass but no identifiable toll tag in the windshield or dashboard area. This type of vehicle is considered to be a violator.
- **NO PASS / TOLL**: A 2-person vehicle displaying an identifiable toll tag but not displaying a QuickRide pass. This type of vehicle is considered to be a violator.
- **NO PASS / NO TOLL**: A 2-person vehicle displaying neither a toll tag nor a QuickRide pass. Such a vehicle is considered to be a violator.

Single occupancy vehicles (SOV) were additionally classified into the following two categories:

- **POLICE**: A single occupancy vehicle displaying the characteristics of a marked police cruiser; i.e., emergency lights, spotlight, and agency insignia. This category also includes emergency vehicles such as ambulances, fire trucks, and tow trucks.
- **UNMARKED**: This category includes all law enforcement vehicles which are not marked police cruisers as well as the personal vehicles of law enforcement and security personnel. Such vehicles were identified either by vehicle configuration and/or by occupant behavior/appearance. For example, most law enforcement agents (police, FBI) would display their badges when driving by the data collectors. Security personnel and patrol officers could also be identified by their uniforms.
- **VIOLATOR**: All SOVs which cannot be identified as containing law enforcement or security personnel.

Data Analysis and Results

Results from the three data collection efforts have been summarized in Tables 1 through 3. The numbers in all tables represent the three-day totals for each vehicle category. The last three columns in each table give the aggregate number of violators and valid users, as well as the overall total of classifiable vehicles observed. All totals for the categories in the table are also expressed as row percentages; i.e., each entry for a given row in the table is expressed as a

percent of the total number of classifiable vehicles observed for that row. Shaded columns in the table denote violation categories.

The total violator and total valid user columns of Table 1 show that violation rates were uniform across the Katy and Northwest HOV lanes for both AM and PM periods. Operating under the definitions of violators explained previously, at least 61 percent of all HOT users could be classified as non-compliant. By far the most common class of violator was the 2-passenger vehicle lacking both a toll transponder and a QuickRide hangtag. Along the Katy HOT lanes, over 40 percent of users fell into this category of violator for both AM and PM periods.

Table 1. February 26-28, 2003 Data Collection

QuickRide Period	HOV 3+	2 person				SOV			Bus	MC	Total Violator	Total Valid	Grand Total
		Pass Toll	No Pass Toll	Pass No Toll	No Pass No Toll	Police	Unmarked	Violator					
Katy AM	1033 26.2%	107 2.7%	147 3.7%	331 8.4%	1594 40.4%	48 1.2%	87 2.2%	361 9.1%	192 4.9%	50 1.3%	2520 63.8%	1430 36.2%	3950
Katy PM	772 25.9%	95 3.2%	129 4.3%	235 7.9%	1194 40.0%	29 1.0%	91 3.0%	227 7.6%	159 5.3%	53 1.8%	1876 62.9%	1108 37.1%	2984
Northwest AM	1227 28.5%	257 6.0%	203 4.7%	512 11.9%	1491 34.7%	66 1.5%	299 7.0%	129 3.0%	86 2.0%	31 0.7%	2634 61.2%	1667 38.8%	4301

For the April data collection, shown in Table 2, violation rates remained relatively constant from those seen in February. Again, all facilities showed at least a 56% non-compliance rate. While overall non-compliance for the Katy PM period fell slightly (from 62.9% to 56%), the Katy AM noncompliance rate increased by nearly 3 percentage points (from 63.8% to 66.8%).

Table 2. April 23-25, 2003 Data Collection

QuickRide Period	HOV 3+	2 person				SOV			Bus	MC	Total Violator	Total Valid	Grand Total
		Pass Toll	No Pass Toll	Pass No Toll	No Pass No Toll	Police	Unmarked	Violator					
Katy AM	927 22.7%	144 3.5%	192 4.7%	402 9.9%	1648 40.4%	39 1.0%	72 1.8%	389 9.5%	192 4.7%	74 1.8%	2703 66.3%	1376 33.7%	4079
Katy PM	910 31.1%	146 5.0%	122 4.2%	222 7.6%	1045 35.8%	18 0.6%	52 1.8%	194 6.6%	157 5.4%	56 1.9%	1635 56.0%	1287 44.0%	2922
Northwest AM	1250 27.9%	281 6.3%	175 3.9%	575 12.8%	1590 35.5%	49 1.1%	293 6.5%	111 2.5%	84 1.9%	72 1.6%	2744 61.3%	1736 38.8%	4480

The October data, shown in Table 3, indicates a significant reduction in noncompliance rates across all QuickRide facilities and periods. Most notable is the reduction in the Northwest violation rate, which decreased from 61.3% in April to a much lower 38% in October. Katy AM violation rates also decreased from 66.3% to 56.3%, while violation rates for Katy PM fell from 56% in April to 47.9% in October. Most of the reductions in overall violation rates may be attributed to the sharp decline in unauthorized 2-person vehicles, specifically the category "No Pass / No Toll." Violation rates for this category declined sharply for Northwest, falling from

35.5% in April to only 16.9% in October. Katy AM and Katy PM experienced more modest drops in this violation category, declining from 40.4% and 35.8% to 33.7% and 30.4%, respectively. SOV violators also declined, in most cases dropping by nearly half.

The results from the October data collection are notable in that they serve to quantify the effect of a number of actions taken in mid-August, including increased level of enforcement, friendly reminder letters to enrollees and non-enrollees on the facility, and signs posting the $200 fine. Overall violations decreased 53% for Northwest, 26% for Katy AM, and 18% for Katy PM. These reductions were large enough to increase capacity in the HOT lanes by approximately 360 vehicles during the Katy AM peak hour, 200 vehicles in the Katy PM peak hour, and 1000 vehicles in the Northwest AM peak hour. Perhaps most encouraging, the number of high occupancy vehicles using the HOT facilities increased from April to October by 9.1%, 12%, and 22.1% for Katy AM, Katy PM, and Northwest AM periods, respectively.

Table 3. October 15-17, 2003 Data Collection

QuickRide Period	HOV 3+	2 person				SOV			Bus	MC	Total Violator	Total Valid	Grand Total
		Pass Toll	No Pass Toll	Pass No Toll	No Pass No Toll	Police	Unmarked	Violator					
Katy AM	1012 (28.5%)	179 (5.0%)	153 4.3%	347 9.8%	1194 33.7%	34 1.0%	86 2.4%	216 6.1%	190 5.4%	137 3.9%	1996 56.3%	1552 43.7%	3548
Katy PM	1019 36.5%	141 5.1%	112 4.0%	172 6.2%	848 30.4%	26 0.9%	67 2.4%	138 4.9%	159 5.7%	110 3.9%	1337 47.9%	1455 52.1%	2792
Northwest AM	1527 45.1%	277 8.2%	126 3.7%	361 10.7%	574 16.9%	47 1.4%	173 5.1%	53 1.6%	94 2.8%	157 4.6%	1287 38.0%	2102 62.0%	3389

APPENDIX D:
ANALYSIS AND CLASSIFICATION OF HOT LANE VIOLATIONS

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Executive Summary

For three consecutive days in February 2003, three consecutive days in April 2003, and another three consecutive days in October 2003, researchers examined the use of the Katy (I-10) Freeway and Northwest (US 290) Freeway high-occupancy toll (HOT) lanes during the morning and evening peak periods. Information collected included the type of vehicle, the number of vehicle occupants, the visible appearance of a toll transponder, and the visible appearance of a QuickRide hang pass. Using these data, researchers determined approximate violation rates for the HOT lanes monitored.[1] Details regarding the type and extent of HOT lane violations presented here are based on this information and actual transponder readings during the data collection periods.

While difficulties correlating all of the manually and electronically collected information make definitive results elusive, some general conclusions can be drawn. For vehicles in the QuickRide period with two occupants and a visible transponder:

- More than one-half of those vehicles recorded by the automatic vehicle identification (AVI) system as QuickRide enrollees were not visibly displaying their QuickRide hang pass.
- Approximately one-fourth of vehicles recorded were lacking both a QuickRide transponder and a QuickRide hang pass (these are likely HCTRA transponders and not enrollees of QuickRide).
- More than one-half of those vehicles with a transponder and QuickRide pass could not be matched to valid QuickRide transponder accounts. This is likely caused by either (a) vehicles with HCTRA accounts but no QuickRide account who are in violation of the HOT lane, or (b) a QuickRide patron whose transponder was not read.
- A very small number of former QuickRide enrollees, whose accounts were no longer valid, were recorded by the AVI system and were displaying an "out of date" hang pass.

Introduction

The objective of this analysis was to compare manually collected data on the use of the HOT lanes by two-person vehicles during the QuickRide period with data collected by electronic QuickRide billing readers on those lanes. Four HOT-lane entrance/exit locations were monitored during the morning and afternoon QuickRide periods on February 26–28, April 23–25, and

[1] An analysis of violation rates is provided in a separate report.

October 15-17, 2003. Manually collected data included vehicle type, number of passengers, and, for two-person vehicles, the presence of a visible windshield-mounted transponder and a QuickRide hang pass on the rearview mirror. The electronic data output included all transponders read on the HOT lane throughout the day. Transponders used in other local electronic billing programs, but not registered for use in the QuickRide program, were removed from this data set.

Due to infrastructure constraints and safety issues, data collectors could not be positioned in the immediate vicinity of the HOT lane billing readers. In order for researchers to compare the manually and electronically collected data, it was necessary to determine the precise time at which each vehicle passed the manual data collection point. This was accomplished using video/audio recordings made by data collectors during the HOT lane monitoring sessions. The clock on the video camera had previously been synchronized with that of the AVI reader. As each two-person vehicle displaying a toll transponder (with or without a QuickRide pass) passed the manual data collection point, the time displayed by the camera was noted by researchers reviewing the data. These data were then compared to information recorded by the closest AVI billing reader using an estimated time displacement.

Data Collection Sites

Researchers evaluated HOT lane violations at four data collection points: the Eastern Extension and Post Oak entry/exit points on the Katy Freeway and the Dacoma and Northwest Transit Center entry/exit points on the Northwest Freeway. The data were adjusted based on assumed average HOT lane speeds of 45 mph for the Katy Freeway collection points, 35 mph for the Dacoma collection point, and 20 mph at the Northwest Transit Center (see Table 1). Although somewhat slower than what may be expected, researchers felt that these average HOT lane speeds were representative of the monitored locations due to the presence of law enforcement and data collectors at the HOT lane entry and exit ramps, both of which reduce rates of speed. Speeds are also affected by the geometry of the roadway, particularly at the Northwest Transit Center.

Table 1. Readers Used for Electronic Data

Manual Data Collection Point	AVI Reader #	Distance between Collection Point and Reader (miles)	Assumed Speed (mph)	Time Displacement (seconds)
Katy: Eastern Extension	18	1.62	45	130
Katy: Post Oak	18	0.87	45	70
Northwest: Dacoma	41	0.11	35	11
Northwest: Northwest Transit Center	42	0.22	20	39

Data Collection Improvements

Review of the February HOT lane data and observations highlighted various issues that precluded analysis of data collected at the Northwest Freeway locations for that month. Many of these issues were addressed prior to the April data collection effort, but some remained beyond the control of the researchers. The most prevalent of these was the high variability in traffic speeds observed on the HOT lanes.

In some cases, speeds varied greatly from vehicle to vehicle and according to the time of day, location, weather conditions, the presence of law enforcement, and other factors. The resulting margin of error in the time displacement calculation has the potential to significantly skew the data. Speed guns were employed in April and October to minimize this problem; however, the use of portable AVI transponder readers much closer to the data collection sites is required to significantly reduce uncertainties concerning the travel time displacement.

Data correlation difficulties also resulted from unclear audio/video records. Clear and concise observer callouts of vehicle information are necessary for post-collection data analysis. Data collectors typically worked in teams of two. One person focused on observing vehicle information and calling it out for the audio record, while the other visually verified (or corrected) the observer's callout and recorded it. The quality of the video footage did not enable the researchers reviewing the tape to determine the classification of each vehicle visually; therefore, they had to rely upon the audio record of the data collectors for this information.

The speed of the vehicles and their proximity to one another during traffic bursts created challenges for data collectors. Erroneous observer callouts that were checked and changed by the recorder had to be audibly corrected to maintain the integrity of the audio record. This occasionally led to simultaneous or unintelligible callouts as vehicles passed the data collection site. This problem was greatly reduced during the April and October data collection event by focusing on the standardized use of a simpler, clearer vehicle classification method. For instance, "no pass, tag, two" identified a two-person vehicle with a transponder (toll tag) but no QuickRide pass. In some instances, the camera angle was also adjusted to ensure that researchers reviewing the tape had the same perspective as the data collectors so that there would be no confusion regarding the vehicle being commented on.

While it is important to recognize that these improvements increased confidence in the classification of violator types, they are unlikely to provide a basis for claiming a specific level of statistical accuracy based on analysis of the data.

Data

Tables of the data compiled from each of the 10 collection times can be found in the Appendix to this report. Time segments were chosen based on data collector feedback regarding favorable viewing conditions, weather, and other factors conducive to accurate data collection. The first column of each table indicates where the vehicle entered or exited the HOT lane. The second column indicates when the vehicle passed the manual observation point. The third column is the

estimated travel time (time displacement) between the manual observation point and the closest electronic billing reader. This value was calculated using an assumed average speed over the distance between the manual and electronic data collection sites. The fourth column indicates whether the observed vehicle displayed a QuickRide pass and a toll transponder, or only the transponder. It is important to note that failure to display a visible QuickRide pass does not necessarily mean that the vehicle is not enrolled in the QuickRide program. QuickRide enrollees may forget to display their passes, or their passes may be obscured by separate hang passes (for example, parking permits), windshield tinting, or other obstructions. The fifth column is the observed time plus the time displacement from column three. The sixth column contains the times obtained from the AVI system for all ***QuickRide*** transponders read during the data collection period. Note, many additional transponders were read by the AVI reader but only those transponder numbers with current or old QuickRide accounts were examined. The seventh column lists whether the transponder was valid or invalid. An invalid read indicates a toll transponder used by someone who had previously been registered for the QuickRide program but has since quit the program. The last column indicates the actual vehicle speed assuming a correct match was made between the manually and electronically collected data.

Data Analysis

As previously mentioned, several difficulties were encountered in the comparison of manually and electronically collected QuickRide data. A principal area of concern with respect to the data analysis was the assumed average vehicle speed. The distances between the manual data collection sites and the AVI billing reader locations necessitated the addition or subtraction of relatively large time displacements to the manually collected data. The margin of error inherent in this activity was compounded by variability in vehicle speed and the difficulty in estimating rates of speed over the entire displacement distance (much of which was outside of the data collectors' range of view). For example, it is possible that vehicles on the Katy East Extension were traveling at an average rate of speed of 60 miles per hour as opposed to 45 miles per hour between the manual and electronic data collection sites. This would yield a time displacement of 33 seconds less than that calculated. In an effort to reduce the level of uncertainty in this area, speed guns were used by data collectors in the April and October data collection efforts.

Another problem encountered in the data analysis was the disparity between the number of toll transponders observed by data collectors and the number recorded by AVI readers. The research team identified more two-person vehicles with transponders than were recorded by AVI readers. This could be explained by a number of factors, including the existence of non-QuickRide enabled toll transponders; faulty, dead, or disabled QuickRide transponders; data collector error; or reader malfunction. The extent of each of these potential problems is not known.

It is also possible that drivers are purposefully violating QuickRide regulations. A QuickRide enrollee who discovers the ability to use the HOT lane in a two-person vehicle during the QuickRide period with an old pass and a broken or disabled transponder may be inclined to continue that behavior in the absence of penalties. Data collectors occasionally observed drivers holding toll transponders against their windshield as they passed the manual data collection sites. This behavior combined with data that indicates the existence of a significant number of dormant

and rarely used QuickRide accounts appears to support at least the possibility of purposeful violation.

Results

February 27, 2003 – Katy Freeway, 5:15-5:45 PM (see Figure 1)

During the 30-minute data collection period, 46 two-person vehicles displaying transponders (tags) were observed (see Figure 1). Only 16 (35%) of those vehicles also had a QuickRide pass. For all 46 vehicles, 31 (67%) were matched with a valid QuickRide transponder, 1 (2%) was matched with an invalid QuickRide transponder, and 14 (31%) could not be matched with a QuickRide transponder read. For the 16 vehicles with a transponder and pass, 12 (75%) were identified by the AVI reader and 4 (25%) were not. For the 30 vehicles with a transponder only, 20 (67%) were identified by the AVI reader and 10 (33%) were not.

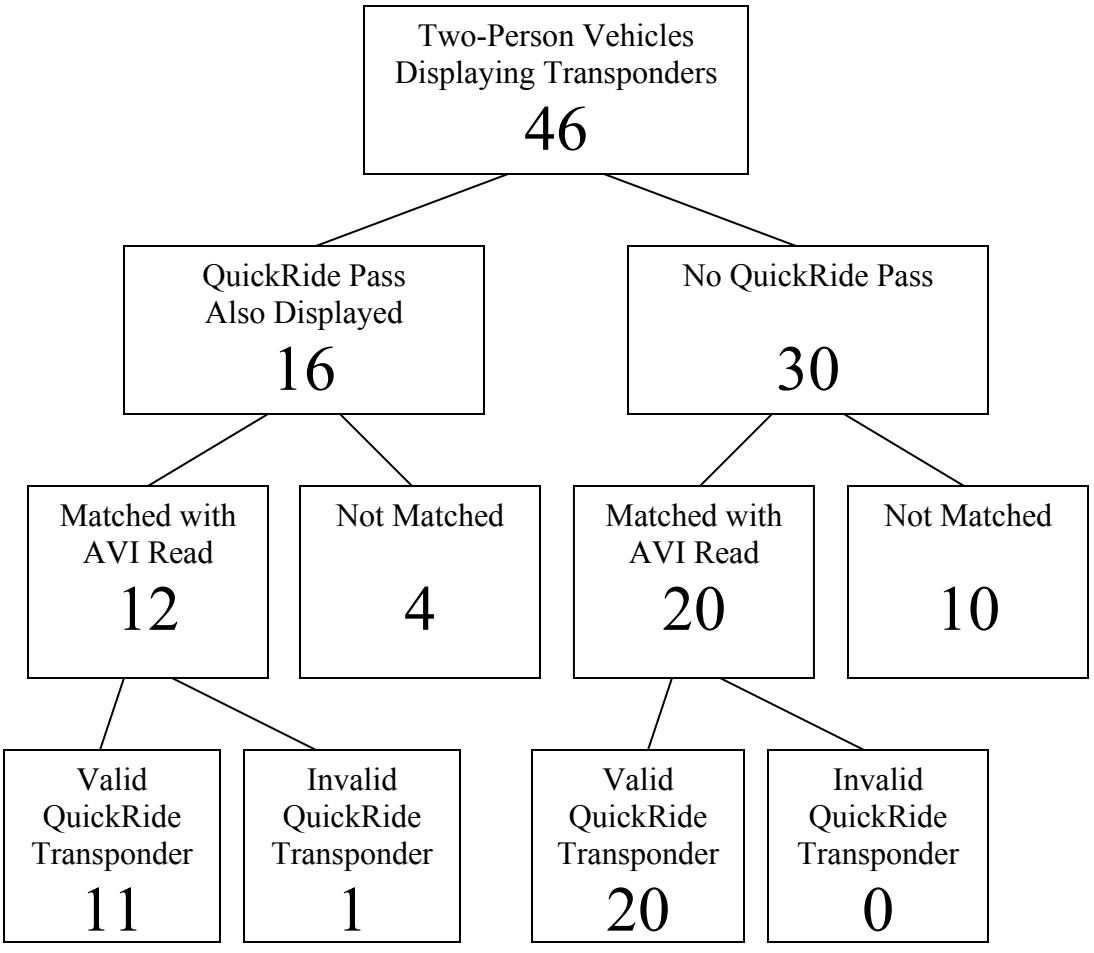


Figure 1: Data Analysis Results, Katy Freeway, 2/27/03.

April 24, 2003 – Katy Freeway, 5:15–5:45 PM (see Figure 2)

During the 30-minute data collection period, 63 two-person vehicles displaying transponders (tags) were observed (see Figure 2). Only 29 (46%) of those vehicles also had a QuickRide pass. For all 63 vehicles, 30 (48%) were matched with a valid QuickRide transponder, 2 (3%) were matched with an invalid QuickRide transponder, and 31 (49%) could not be matched with a QuickRide transponder read. Of the 29 vehicles with a transponder and pass, 14 (48%) were identified by the AVI reader and 15 (52%) were not. For the 34 vehicles with a transponder only, 18 (53%) were identified by the AVI reader and 16 (47%) were not.

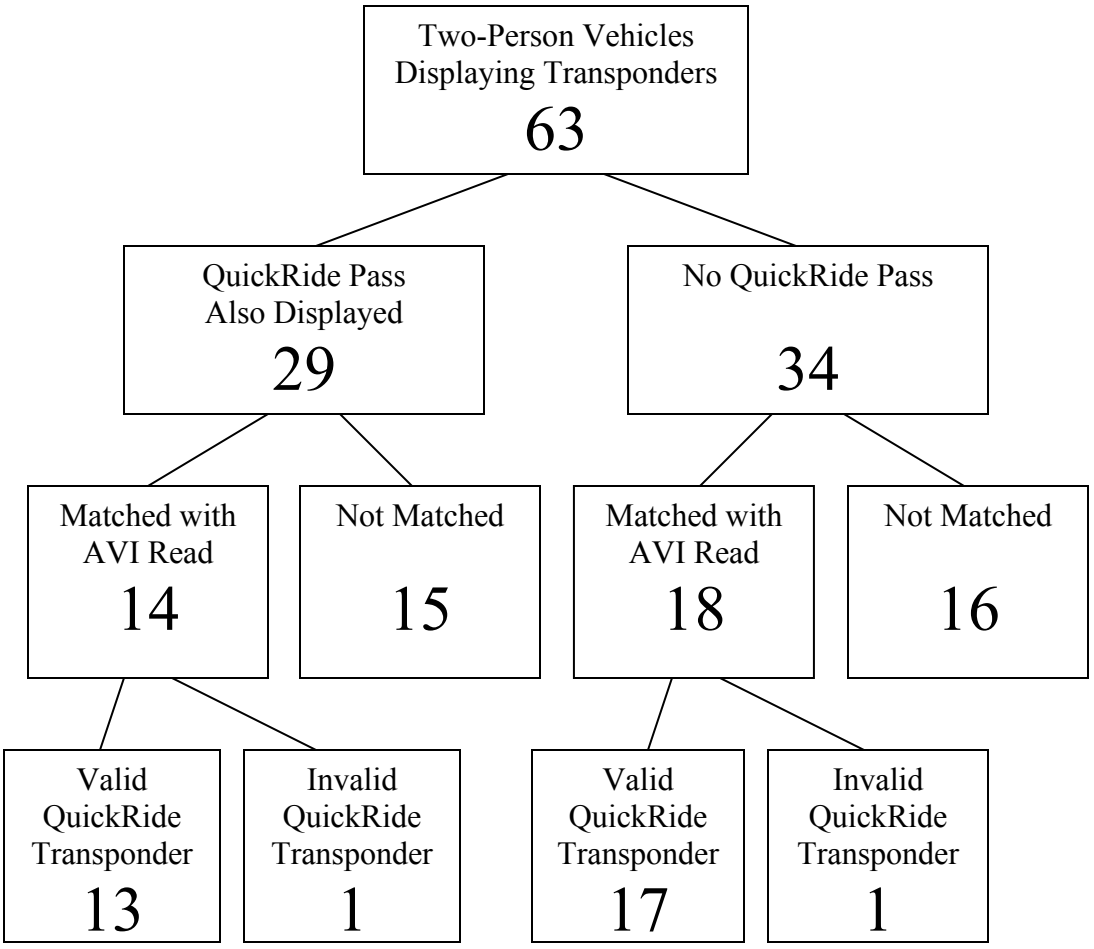


Figure 2: Data Analysis Results, Katy Freeway, 4/24/03.

April 25, 2003 – Northwest Freeway at Dacoma, 7:15–7:45 AM (see Figure 3)

During the 30-minute data collection period, 16 two-person vehicles displaying transponders (tags) were observed (see Figure 3). Only 5 (31%) of those vehicles also had a QuickRide pass. For all 16 vehicles, 9 (56%) were matched with a valid QuickRide transponder, 0 (0%) were matched with an invalid QuickRide transponder, and 7 (44%) could not be matched with a QuickRide transponder read. The AVI reader identified all of the 5 vehicles with a transponder and pass. For the 11 vehicles with a transponder only, 4 (36%) were identified by the AVI reader and 7 (64%) were not. All QuickRide transponders were valid transponders.

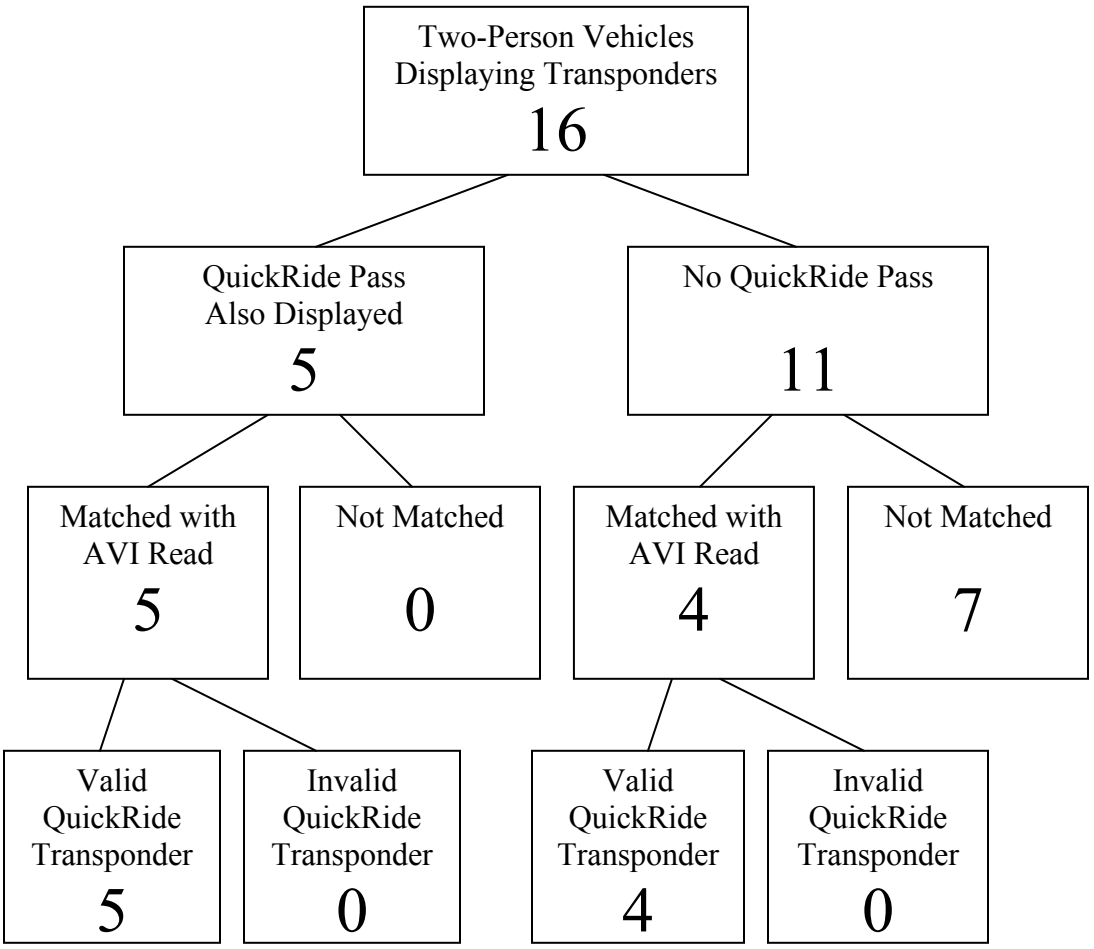


Figure 3: Data Analysis Results, Northwest Freeway at Dacoma, 4/25/03.

April 25, 2003 – Northwest Freeway at Northwest Transit Center, 7:15–7:45 AM (see Fig. 4)

During the 30-minute data collection period, 57 two-person vehicles displaying transponders (tags) were observed (see Figure 4). Only 31 (54%) of those vehicles also had a QuickRide pass. For all 57 vehicles, 25 (44%) were matched with a valid QuickRide transponder, 0 (0%) were matched with an invalid QuickRide transponder, and 32 (56%) could not be matched with a QuickRide transponder read. For the 31 vehicles with a transponder and pass, 13 (42%) were identified by the AVI reader and 18 (58%) were not. For the 26 vehicles with a transponder only, 12 (46%) were identified by the AVI reader and 14 (54%) were not. All QuickRide transponders recorded by the AVI system were valid.

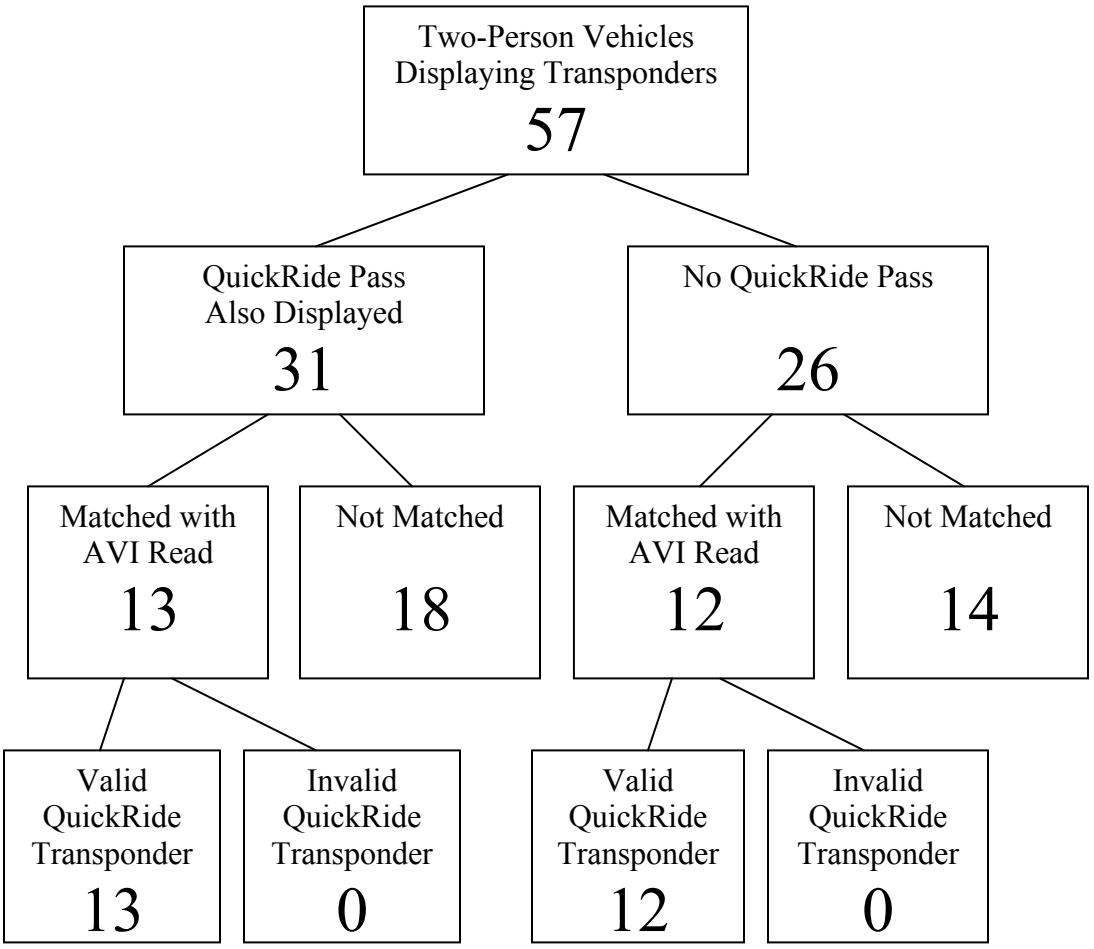


Figure 4: Data Analysis Results, Northwest Freeway at Northwest Transit Center, 4/25/03.

October 16, 2003 – Katy Freeway, 5:15-5:45 PM (see Figure 5)

During the 30-minute data collection period, 67 two-person vehicles displaying transponders (tags) were observed (see Figure 1). Only 33 (49%) of those vehicles also had a QuickRide pass. For all 67 vehicles, 28 (42%) were matched with a valid QuickRide transponder, 0 (0%) were matched with an invalid QuickRide transponder, and 39 (58%) could not be matched with a QuickRide transponder read. For the 33 vehicles with a transponder and pass, 15 (45%) were identified by the AVI reader and 18 (55%) were not. For the 34 vehicles with a transponder only, 13 (38%) were identified by the AVI reader and 21 (62%) were not.

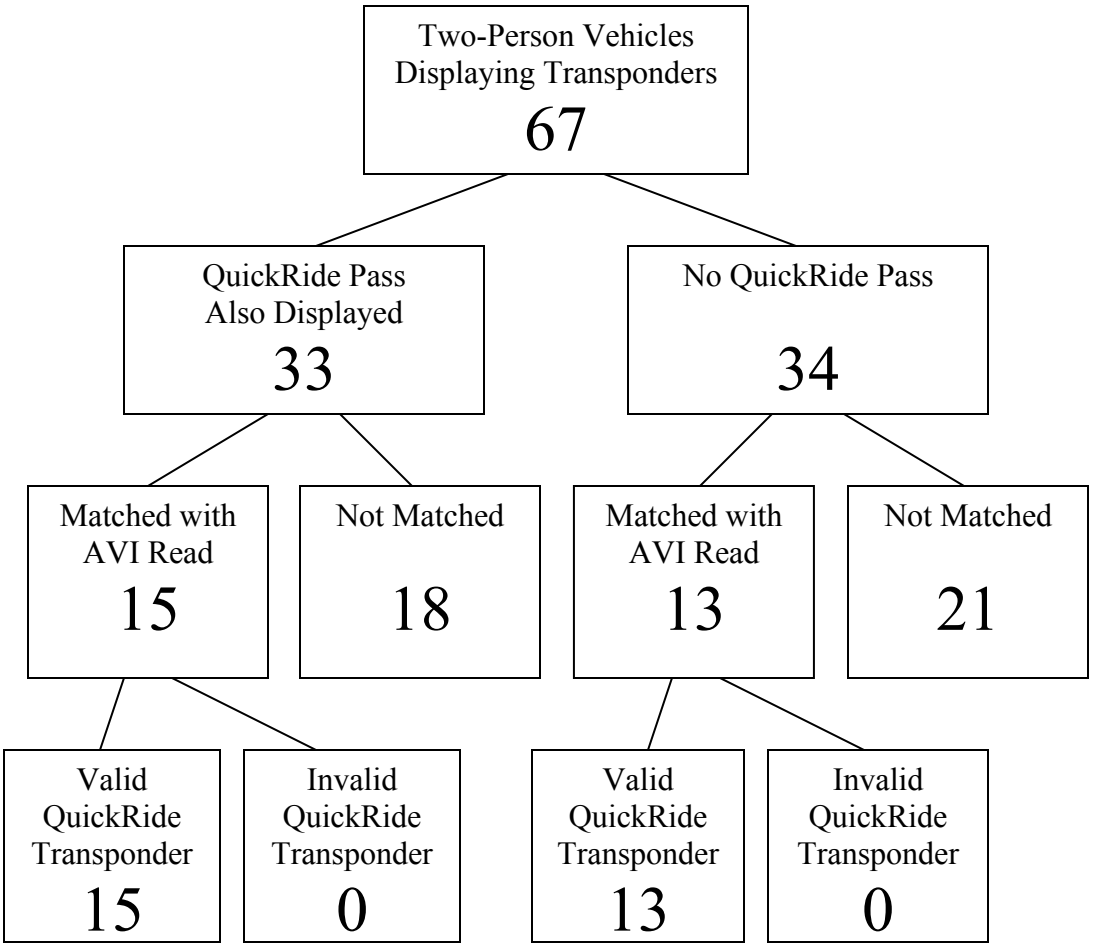


Figure 5: Data Analysis Results, Katy Freeway, 10/16/03.

October 17, 2003 – Katy Freeway, 5:00–5:30 PM (see Figure 6)

During the 30-minute data collection period, 67 two-person vehicles displaying transponders (tags) were observed (see Figure 2). Only 32 (48%) of those vehicles also had a QuickRide pass. For all 67 vehicles, 22 (33%) were matched with a valid QuickRide transponder, 0 (0%) were matched with an invalid QuickRide transponder, and 45 (67%) could not be matched with a QuickRide transponder read. Of the 32 vehicles with a transponder and pass, 10 (31%) were identified by the AVI reader and 22 (69%) were not. For the 35 vehicles with a transponder only, 12 (34%) were identified by the AVI reader and 23 (66%) were not.

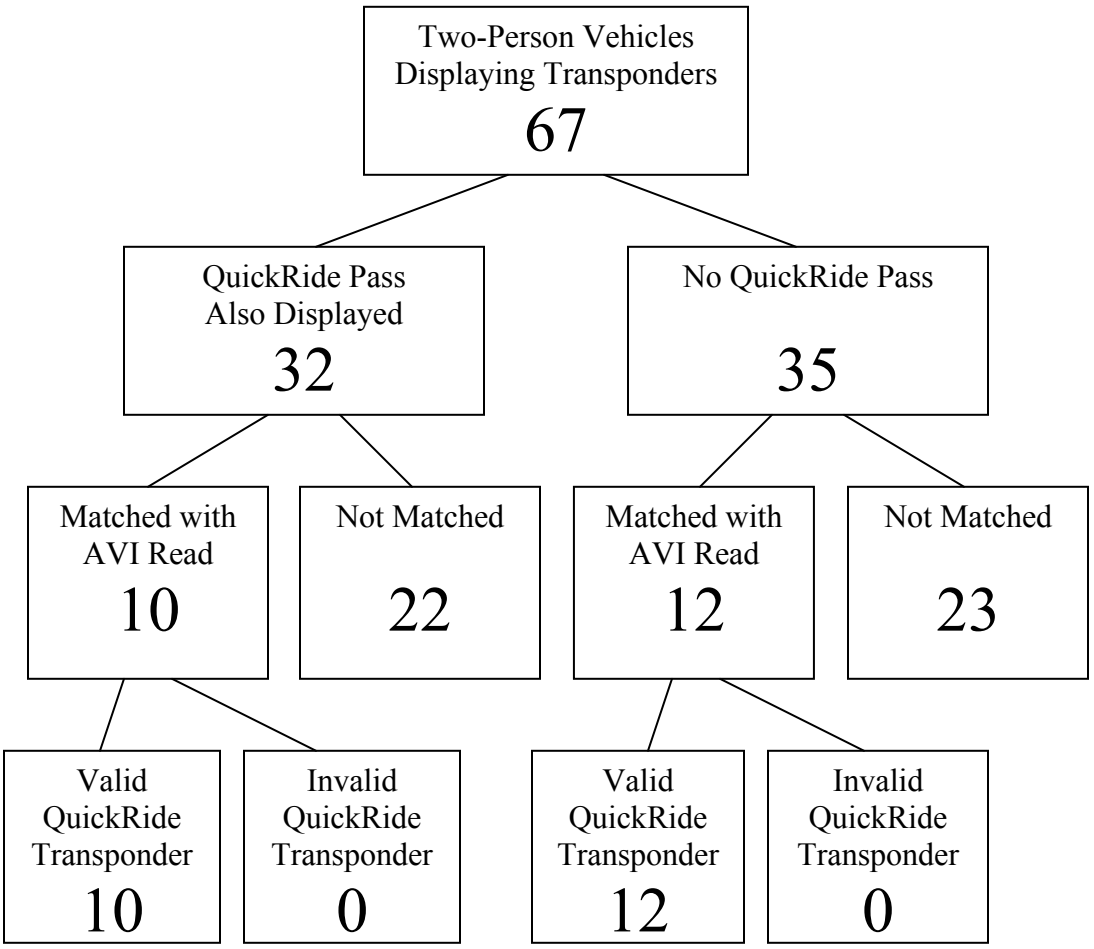


Figure 6: Data Analysis Results, Katy Freeway, 10/17/03.

October 16, 2003 – Northwest Freeway at Dacoma, 7:15–7:45 AM (see Figure 7)

During the 30-minute data collection period, 11 two-person vehicles displaying transponders (tags) were observed (see Figure 3). Only 4 (36%) of those vehicles also had a QuickRide pass. For all 11 vehicles, 5 (45%) were matched with a valid QuickRide transponder, 0 (0%) were matched with an invalid QuickRide transponder, and 6 (55%) could not be matched with a QuickRide transponder read. The AVI reader identified half of the 4 vehicles with a transponder and pass. For the 7 vehicles with a transponder only, 3 (43%) were identified by the AVI reader and 4 (57%) were not. All QuickRide transponders were valid transponders.

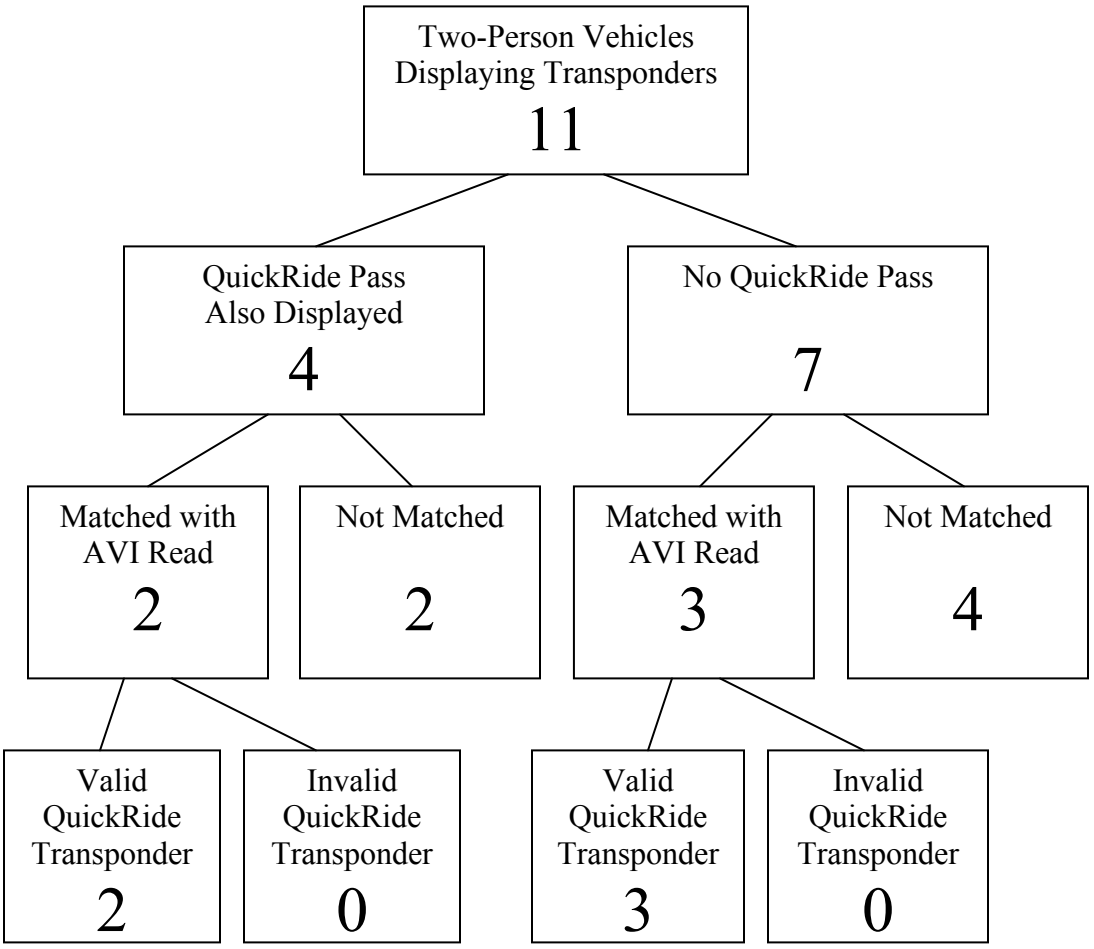


Figure 7: Data Analysis Results, Northwest Freeway at Dacoma, 10/16/03.

October 17, 2003 – Northwest Freeway at Dacoma, 7:15–7:45 AM (see Figure 8)

During the 30-minute data collection period, 12 two-person vehicles displaying transponders (tags) were observed (see Figure 4). Only 7 (58%) of those vehicles also had a QuickRide pass. For all 12 vehicles, 7 (58%) were matched with a valid QuickRide transponder, 0 (0%) were matched with an invalid QuickRide transponder, and 5 (42%) could not be matched with a QuickRide transponder read. The AVI reader identified 5 (71%) of the 7 vehicles with a transponder and pass. For the 5 vehicles with a transponder only, 2 (40%) were identified by the AVI reader and 3 (60%) were not. All QuickRide transponders were valid transponders.

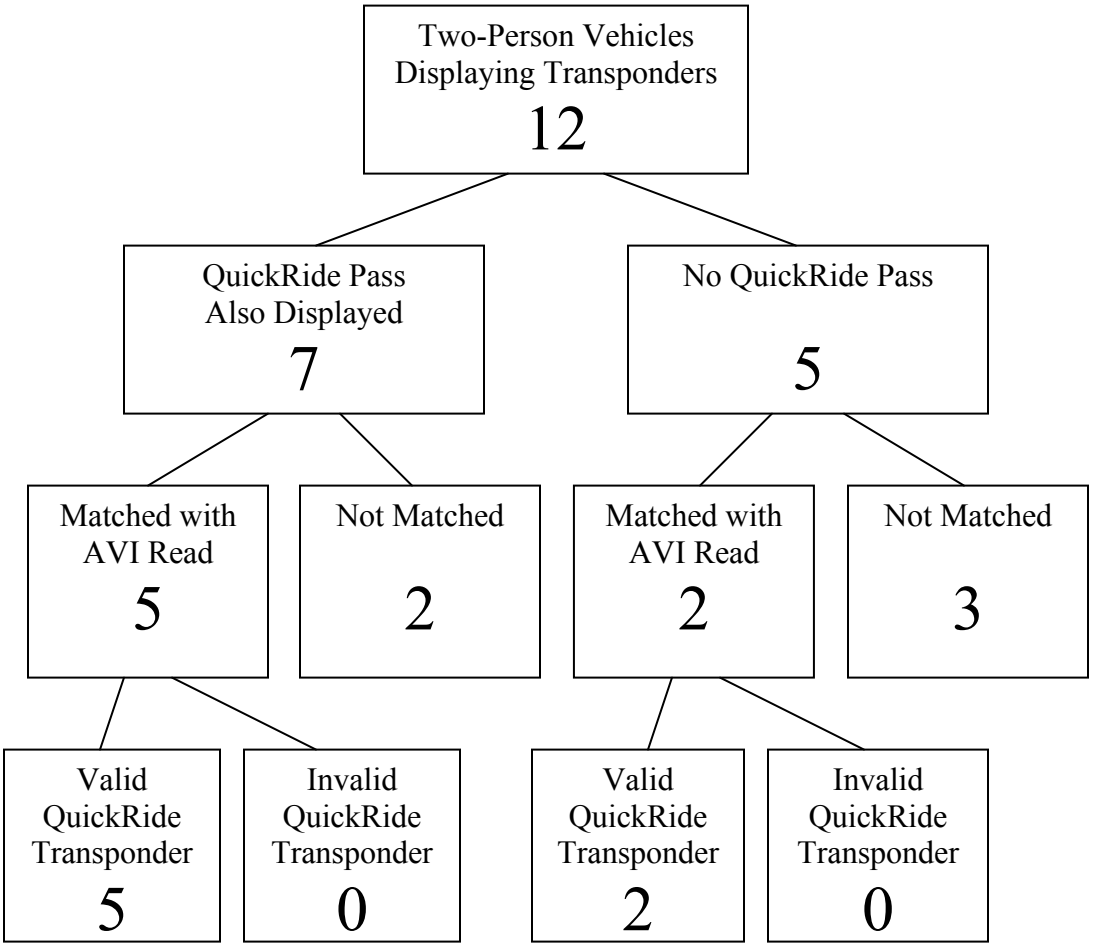


Figure 8: Data Analysis Results, Northwest Freeway at Dacoma, 10/17/03.

October 16, 2003 – Northwest Freeway at Northwest Transit Center, 7:15–7:45 AM (see Figure 9)

During the 30-minute data collection period, 55 two-person vehicles displaying transponders (tags) were observed (see Figure 5). 52 (95%) of those vehicles also had a QuickRide pass. For all 55 vehicles, 22 (40%) were matched with a valid QuickRide transponder, 0 (0%) were matched with an invalid QuickRide transponder, and 33 (60%) could not be matched with a QuickRide transponder read. For the 52 vehicles with a transponder and pass, 22 (42%) were identified by the AVI reader and 30 (58%) were not. For the 3 vehicles with a transponder only, 0 (0%) were identified by the AVI reader and 3 (100%) were not. All QuickRide transponders recorded by the AVI system were valid.

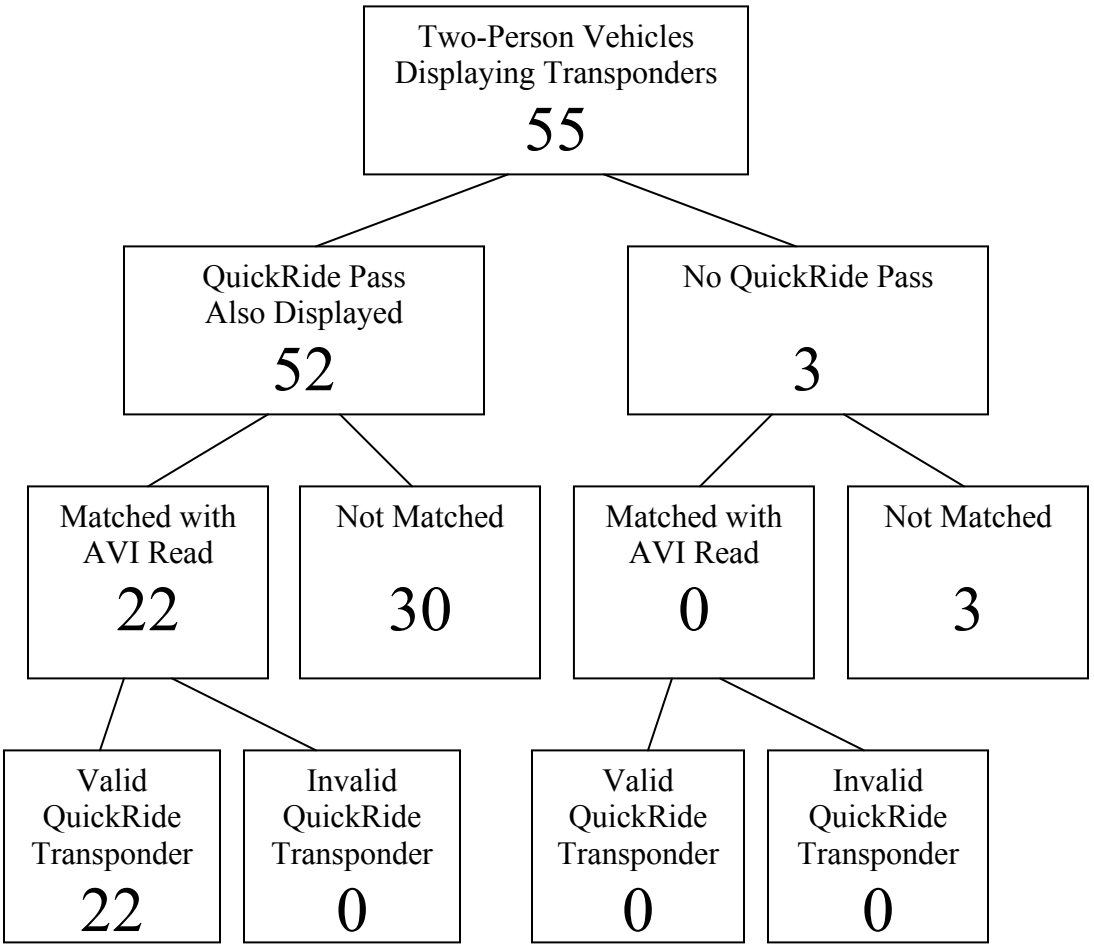


Figure 9: Data Analysis Results, Northwest Freeway at Northwest Transit Center, 10/16/03.

October 17, 2003 – Northwest Freeway at Northwest Transit Center, 7:15–7:45 AM (see Figure 10)

During the 30-minute data collection period, 56 two-person vehicles displaying transponders (tags) were observed (see Figure 6). 45 (80%) of those vehicles also had a QuickRide pass. For all 56 vehicles, 21 (38%) were matched with a valid QuickRide transponder, 1 (2%) was matched with an invalid QuickRide transponder, and 34 (61%) could not be matched with a QuickRide transponder read. For the 45 vehicles with a transponder and pass, 18 (40%) were identified by the AVI reader and 27 (60%) were not. For the 11 vehicles with a transponder only, 4 (36%) were identified by the AVI reader and 7 (64%) were not.

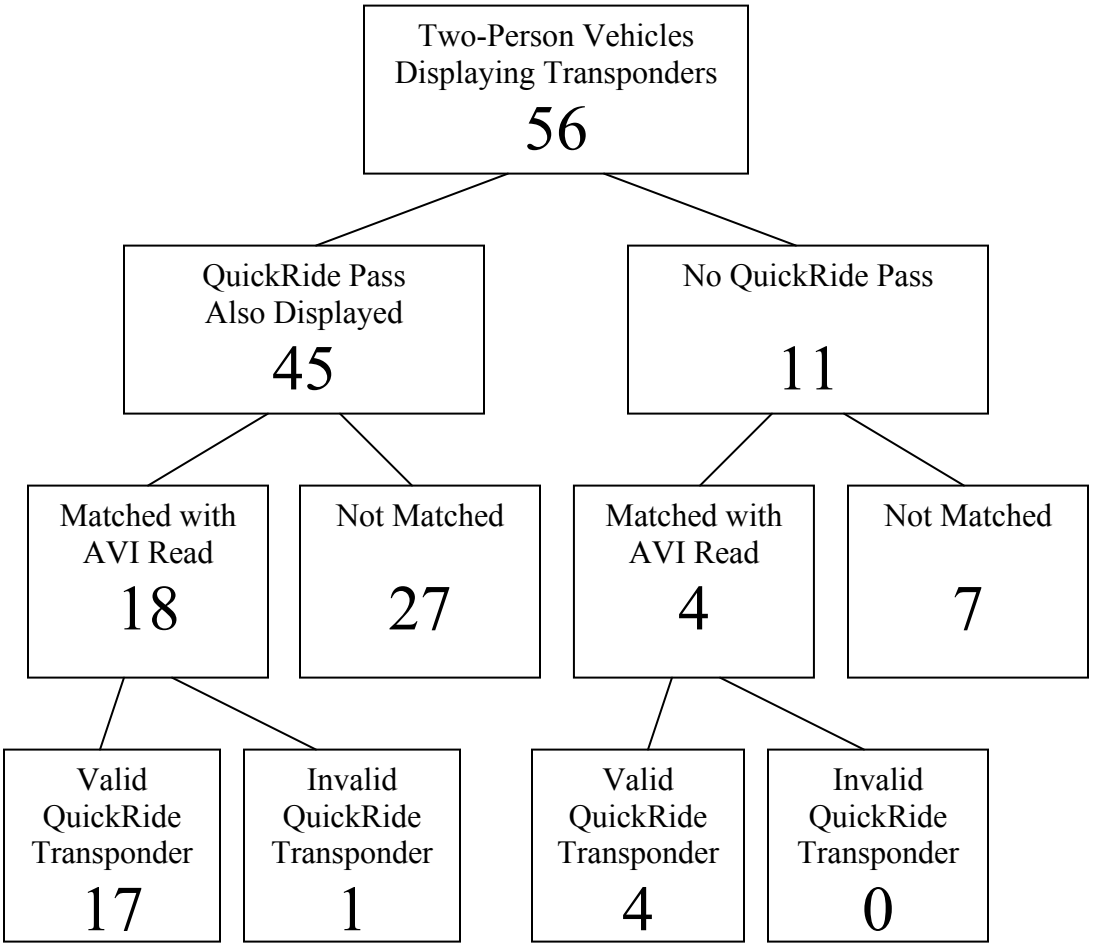


Figure 10: Data Analysis Results, Northwest Freeway at Northwest Transit Center, 10/17/03.

Conclusion

Due to the above-mentioned problems, few definitive conclusions can be drawn from the data analysis. The speed of the vehicles coupled with difficulties inherent in the manual determination of vehicle occupancy and the existence of toll tags and passes presented challenges for the research team. Notwithstanding these challenges, the following general observations can be made regarding vehicles with two occupants displaying a transponder:

- More than one-half of the vehicles that were recorded by the AVI system as QuickRide enrollees were not displaying a visible QuickRide pass (see Figure 11, box *c*).
- A very small number of former QuickRide enrollees are continuing to use HOT lanes during the QuickRide period, despite having an invalid account and an "out of date" pass (boxes *i* and *k*).
- Approximately one-fourth of all observed two-person vehicles with transponders did not have either a QuickRide transponder or a pass. These may be HCTRA transponders that have not been registered for use in the QuickRide program (box *g*).
- The transponders of more than one-half of all two-person vehicles with a transponder and a QuickRide pass could not be matched to valid QuickRide transponder accounts. This is likely caused by either (a) vehicles with HCTRA accounts but no QuickRide account who are in violation of the HOT lane, or (b) a QuickRide patron whose transponder was not read. This appears to confirm the hypothesis of purposeful violation, or at least a lack of repair to inoperable transponders (box *e*).

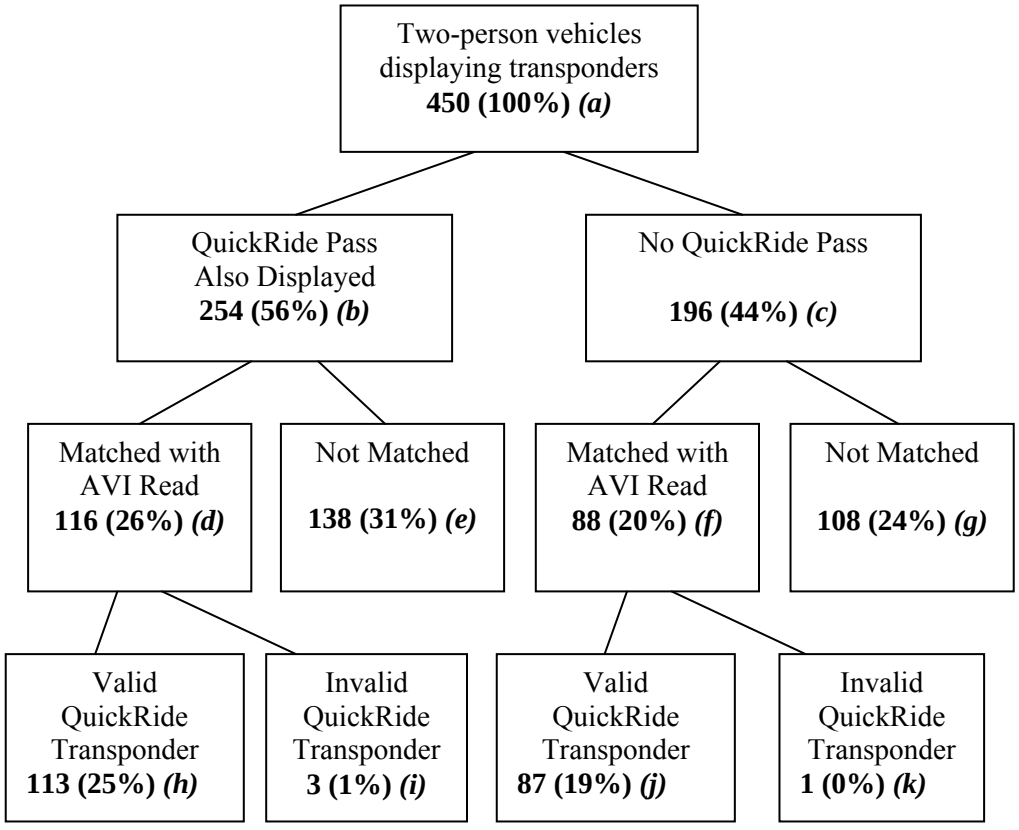


Figure 11. Data Analysis Results from all Periods.

In addition to these observations, potential improvements for future data collection efforts are suggested: (1) use of simple, clear data collection methods and terminology will enhance the ability of researchers to review and extract valuable information from video/audio records and (2) deployment of portable AVI readers at or in close proximity to the manual data collection points could greatly reduce or eliminate the margin of error associated with estimation of average vehicle speeds.

APPENDIX: COLLECTED DATA

Table A. Two-Person Vehicles with Transponders, Katy Freeway, 2/27/03.

Location	Time Observed	Time Displacement (45 mph)	Pass?	Estimated Read Time	Reader 18	Valid/Invalid	Actual Speed
East Ext.	17:15:09	02:10	Tag	17:17:19	17:17:12	Valid	47
East Ext.	17:16:16	02:10	Tag	17:18:26	17:18:35	Valid	42
East Ext.	17:17:04	02:10	Pass & Tag	17:19:14	17:18:48	Valid	56
East Ext.	17:17:36	02:10	Tag	17:19:46			
East Ext.	17:19:26	02:10	Tag	17:21:36	17:21:13	Valid	54
East Ext.	17:19:29	02:10	Pass & Tag	17:21:39	17:21:32	Valid	47
East Ext.	17:19:31	02:10	Pass & Tag	17:21:41	17:22:46	Valid	30
East Ext.	17:19:59	02:10	Pass & Tag	17:22:09	17:23:03	Valid	32
Post Oak	17:22:16	01:10	Pass & Tag	17:23:26	17:24:01	Valid	30
Post Oak	17:23:20	01:10	Pass & Tag	17:24:30	17:24:11	Valid	62
Post Oak	17:23:26	01:10	Tag	17:24:36			
East Ext.	17:22:33	02:10	Tag	17:24:43	17:25:46	Valid	30
Post Oak	17:24:54	01:10	Pass & Tag	17:26:04	17:25:53	Valid	53
East Ext.	17:24:49	02:10	Tag	17:26:59	17:26:24	Valid	61
East Ext.	17:24:59	02:10	Pass & Tag	17:27:09			
Post Oak	17:28:10	01:10	Tag	17:29:20	17:29:01	Valid	62
East Ext.	17:27:19	02:10	Tag	17:29:29	17:30:10	Valid	34
East Ext.	17:27:59	02:10	Pass & Tag	17:30:09	17:30:12	Valid	44
East Ext.	17:28:28	02:10	Pass & Tag	17:30:38			
East Ext.	17:28:58	02:10	Tag	17:31:08	17:31:42	Valid	36
Post Oak	17:30:34	01:10	Tag	17:31:44			
Post Oak	17:30:47	01:10	Tag	17:31:57			
East Ext.	17:29:31	02:10	Pass & Tag	17:31:41			
Post Oak	17:31:25	01:10	Pass & Tag	17:32:35			
East Ext.	17:30:14	02:10	Tag	17:32:24			
Post Oak	17:31:35	01:10	Tag	17:32:45			
East Ext.	17:31:09	02:10	Tag	17:33:19			
Post Oak	17:33:19	01:10	Pass & Tag	17:34:29	17:34:15	Valid	56
East Ext.	17:32:44	02:10	Tag	17:34:54	17:34:27	Valid	57
East Ext.	17:32:54	02:10	Pass & Tag	17:35:04	17:35:22	Valid	39
East Ext.	17:33:45	02:10	Pass & Tag	17:35:55	17:36:33	Valid	35
East Ext.	17:35:01	02:10	Tag	17:37:11	17:36:49	Valid	54
East Ext.	17:35:21	02:10	Tag	17:37:31	17:37:09	Valid	54
Post Oak	17:36:39	01:10	Tag	17:37:49			
East Ext.	17:36:56	02:10	Tag	17:39:06	17:38:56	Valid	49
Post Oak	17:38:14	01:10	Tag	17:39:24	17:39:12	Valid	54
Post Oak	17:38:17	01:10	Tag	17:39:27			
East Ext.	17:37:43	02:10	Tag	17:39:53	17:40:07	Valid	40
East Ext.	17:38:17	02:10	Tag	17:40:27	17:43:12	Valid	20
East Ext.	17:40:22	02:10	Tag	17:42:32	17:43:18	Valid	33
Post Oak	17:42:12	01:10	Tag	17:43:22	17:43:26	Valid	42
East Ext.	17:41:50	02:10	Tag	17:44:00	17:44:32	Valid	36
East Ext.	17:42:58	02:10	Pass & Tag	17:45:08	17:44:49	Invalid	53
Post Oak	17:44:18	01:10	Tag	17:45:28			
Post Oak	17:44:35	01:10	Tag	17:45:45	17:45:54	Valid	40
East Ext.	17:44:00	02:10	Tag	17:46:10	17:46:02	Valid	48

*only vehicles with transponders (tags) and two occupants are listed in this table.

Table B. Two-Person Vehicles with Transponders, Katy Freeway, 4/24/03.

Location	Time Observed	Time Displacement (45 mph)	Pass?	Estimated Read Time	Reader 18	Valid/Invalid	Actual Speed
Post Oak	17:15:19	01:10	Pass & Tag	17:16:29	17:16:58	Valid	32
Post Oak	17:15:21	01:10	Tag	17:16:31	17:17:15	Valid	28
Post Oak	17:16:43	01:10	Tag	17:17:53			
Post Oak	17:16:44	01:10	Pass & Tag	17:17:54			
East Ext.	17:15:55	02:10	Pass & Tag	17:18:05	17:18:03	Valid	46
Post Oak	17:17:08	01:10	Pass & Tag	17:18:18			
East Ext.	17:16:21	02:10	Pass & Tag	17:18:31	17:18:44	Valid	41
East Ext.	17:16:44	02:10	Tag	17:18:54	17:18:48	Valid	47
East Ext.	17:16:55	02:10	Pass & Tag	17:19:05			
Post Oak	17:18:15	01:10	Pass & Tag	17:19:25	17:19:29	Valid	42
Post Oak	17:18:17	01:10	Tag	17:19:27	17:19:35	Valid	40
East Ext.	17:18:32	02:10	Pass & Tag	17:20:42	17:20:09	Valid	60
East Ext.	17:19:03	02:10	Tag	17:21:13			
East Ext.	17:19:42	02:10	Tag	17:21:52			
East Ext.	17:19:53	02:10	Tag	17:22:03			
East Ext.	17:20:00	02:10	Tag	17:22:10			
Post Oak	17:21:39	01:10	Tag	17:22:49	17:22:48	Valid	46
East Ext.	17:20:53	02:10	Tag	17:23:03			
Post Oak	17:22:48	01:10	Tag	17:23:58	17:24:07	Valid	40
Post Oak	17:23:12	01:10	Tag	17:24:22	17:24:08	Valid	56
East Ext.	17:22:27	02:10	Pass & Tag	17:24:37	17:24:14	Valid	54
East Ext.	17:22:30	02:10	Pass & Tag	17:24:40			
East Ext.	17:22:35	02:10	Pass & Tag	17:24:45	17:24:44	Valid	45
East Ext.	17:22:42	02:10	Pass & Tag	17:24:52			
East Ext.	17:23:02	02:10	Pass & Tag	17:25:12			
Post Oak	17:24:48	01:10	Tag	17:25:58	17:25:36	Valid	65
East Ext.	17:24:01	02:10	Tag	17:26:11	17:26:18	Valid	43
Post Oak	17:25:42	01:10	Pass & Tag	17:26:52	17:26:38	Valid	56
East Ext.	17:24:45	02:10	Pass & Tag	17:26:55	17:26:49	Valid	47
East Ext.	17:25:21	02:10	Pass & Tag	17:27:31	17:27:23	Valid	48
East Ext.	17:25:28	02:10	Tag	17:27:38	17:28:27	Valid	33
East Ext.	17:26:59	02:10	Tag	17:29:09	17:28:59	Valid	49
East Ext.	17:27:15	02:10	Pass & Tag	17:29:25			
East Ext.	17:27:37	02:10	Pass & Tag	17:29:47	17:29:48	Invalid	44
Post Oak	17:29:11	01:10	Pass & Tag	17:30:21			
Post Oak	17:29:48	01:10	Tag	17:30:58			
Post Oak	17:30:12	01:10	Pass & Tag	17:31:22	17:31:16	Valid	49
East Ext.	17:29:32	02:10	Pass & Tag	17:31:42			
Post Oak	17:30:48	01:10	Tag	17:31:58			
Post Oak	17:32:21	01:10	Tag	17:33:31	17:33:20	Valid	53
East Ext.	17:31:22	02:10	Tag	17:33:32			
Post Oak	17:33:24	01:10	Tag	17:34:34	17:34:31	Valid	47
Post Oak	17:33:54	01:10	Pass & Tag	17:35:04			
East Ext.	17:32:58	02:10	Pass & Tag	17:35:08			
East Ext.	17:33:00	02:10	Tag	17:35:10			
Post Oak	17:34:51	01:10	Tag	17:36:01	17:37:20	Valid	21
Post Oak	17:36:20	01:10	Tag	17:37:30	17:37:45	Valid	37
Post Oak	17:37:46	01:10	Tag	17:38:56	17:38:50	Valid	49
East Ext.	17:36:50	02:10	Tag	17:39:00			
Post Oak	17:38:33	01:10	Pass & Tag	17:39:43	17:39:40	Valid	47
East Ext.	17:37:58	02:10	Pass & Tag	17:40:08			
East Ext.	17:39:48	02:10	Tag	17:41:58	17:42:05	Valid	43
Post Oak	17:42:23	01:10	Pass & Tag	17:43:33	17:43:24	Valid	52
East Ext.	17:41:26	02:10	Tag	17:43:36	17:43:32	Valid	46
Post Oak	17:42:30	01:10	Pass & Tag	17:43:40			
East Ext.	17:42:04	02:10	Pass & Tag	17:44:14			
Post Oak	17:43:50	01:10	Tag	17:45:00	17:44:57	Invalid	47

Post Oak	17:43:57	01:10	Tag	17:45:07			
East Ext.	17:43:06	02:10	Tag	17:45:16			
Post Oak	17:44:11	01:10	Tag	17:45:21			
East Ext.	17:44:21	02:10	Tag	17:46:31			
East Ext.	17:44:42	02:10	Pass & Tag	17:46:52			
East Ext.	17:44:43	02:10	Tag	17:46:53			

Table C. Two-Person Vehicles with Transponders, Northwest Freeway at Dacoma, 4/25/03.

Location	Time Observed	Time Displacement (35 mph)	Pass?	Estimated Read Time	Reader 41	Valid/Invalid	Actual Speed
Dacoma	7:16:41	0:00:11	Tag	7:16:30			
Dacoma	7:16:43	0:00:11	Tag	7:16:32			
Dacoma	7:17:02	0:00:11	Pass & Tag	7:16:51	7:16:49	Valid	31
Dacoma	7:18:43	0:00:11	Tag	7:18:32			
Dacoma	7:18:50	0:00:11	Tag	7:18:39			
Dacoma	7:20:42	0:00:11	Tag	7:20:31			
Dacoma	7:26:02	0:00:11	Tag	7:25:51			
Dacoma	7:26:09	0:00:11	Tag	7:25:58			
Dacoma	7:28:00	0:00:11	Tag	7:27:49	7:27:24	Valid	11
Dacoma	7:30:30	0:00:11	Tag	7:30:19	7:29:57	Valid	12
Dacoma	7:32:46	0:00:11	Pass & Tag	7:32:35	7:32:32	Valid	29
Dacoma	7:33:34	0:00:11	Pass & Tag	7:33:23	7:33:19	Valid	27
Dacoma	7:35:43	0:00:11	Pass & Tag	7:35:32	7:34:48	Valid	7
Dacoma	7:41:22	0:00:11	Tag	7:41:11	7:40:45	Valid	11
Dacoma	7:42:11	0:00:11	Pass & Tag	7:42:00	7:41:56	Valid	27
Dacoma	7:44:08	0:00:11	Tag	7:43:57	7:43:58	Valid	40

*only vehicles with transponders (tags) and two occupants are listed in this table.

Table D. Two-Person Vehicles with Transponders, Northwest Freeway at Northwest Transit Center, 4/25/03.

Location	Time Observed	Time Displacement (20 mph)	Pass?	Estimated Read Time	Reader 42	Valid/ Invalid	Actual Speed
NW Transit Center	7:15:50	0:00:39	Pass & Tag	7:15:11	7:15:16	Valid	23
NW Transit Center	7:16:30	0:00:39	Tag	7:15:51			
NW Transit Center	7:20:31	0:00:39	Tag	7:19:52	7:19:22	Valid	11
NW Transit Center	7:20:41	0:00:39	Tag	7:20:02			
NW Transit Center	7:21:00	0:00:39	Tag	7:20:21			
NW Transit Center	7:21:27	0:00:39	Tag	7:20:48			
NW Transit Center	7:23:51	0:00:39	Pass & Tag	7:23:12			
NW Transit Center	7:23:53	0:00:39	Tag	7:23:14			
NW Transit Center	7:23:56	0:00:39	Tag	7:23:17			
NW Transit Center	7:24:21	0:00:39	Pass & Tag	7:23:42			
NW Transit Center	7:24:27	0:00:39	Pass & Tag	7:23:48			
NW Transit Center	7:24:56	0:00:39	Tag	7:24:17	7:24:06	Valid	16
NW Transit Center	7:25:03	0:00:39	Pass & Tag	7:24:24			
NW Transit Center	7:26:03	0:00:39	Tag	7:25:24	7:25:15	Valid	16
NW Transit Center	7:26:18	0:00:39	Pass & Tag	7:25:39	7:25:24	Valid	14
NW Transit Center	7:26:24	0:00:39	Pass & Tag	7:25:45			
NW Transit Center	7:26:29	0:00:39	Pass & Tag	7:25:50			
NW Transit Center	7:26:35	0:00:39	Pass & Tag	7:25:56			
NW Transit Center	7:26:51	0:00:39	Pass & Tag	7:26:12			
NW Transit Center	7:27:00	0:00:39	Tag	7:26:21			
NW Transit Center	7:28:44	0:00:39	Tag	7:28:05			
NW Transit Center	7:28:57	0:00:39	Pass & Tag	7:28:18	7:28:19	Valid	20
NW Transit Center	7:29:40	0:00:39	Pass & Tag	7:29:01			
NW Transit Center	7:32:13	0:00:39	Pass & Tag	7:31:34	7:30:56	Valid	10
NW Transit Center	7:32:54	0:00:39	Tag	7:32:15	7:32:26	Valid	28
NW Transit Center	7:33:03	0:00:39	Pass & Tag	7:32:24	7:32:34	Valid	27
NW Transit Center	7:33:33	0:00:39	Pass & Tag	7:32:54	7:32:47	Valid	17
NW Transit Center	7:33:36	0:00:39	Tag	7:32:57	7:33:00	Valid	22
NW Transit Center	7:33:49	0:00:39	Pass & Tag	7:33:10	7:33:03	Valid	17
NW Transit Center	7:33:56	0:00:39	Tag	7:33:17			
NW Transit Center	7:33:58	0:00:39	Pass & Tag	7:33:19	7:33:31	Valid	29
NW Transit Center	7:34:24	0:00:39	Tag	7:33:45			
NW Transit Center	7:34:33	0:00:39	Tag	7:33:54			
NW Transit Center	7:34:51	0:00:39	Pass & Tag	7:34:12			
NW Transit Center	7:34:59	0:00:39	Pass & Tag	7:34:20			
NW Transit Center	7:36:10	0:00:39	Pass & Tag	7:35:31			
NW Transit Center	7:36:15	0:00:39	Pass & Tag	7:35:36	7:35:37	Valid	20
NW Transit Center	7:36:46	0:00:39	Pass & Tag	7:36:07			
NW Transit Center	7:36:57	0:00:39	Pass & Tag	7:36:18	7:36:17	Valid	19
NW Transit Center	7:37:00	0:00:39	Tag	7:36:21	7:36:27	Valid	24
NW Transit Center	7:37:02	0:00:39	Pass & Tag	7:36:23	7:36:39	Valid	34
NW Transit Center	7:37:45	0:00:39	Tag	7:37:06			
NW Transit Center	7:39:17	0:00:39	Pass & Tag	7:38:38	7:38:36	Valid	19
NW Transit Center	7:39:20	0:00:39	Pass & Tag	7:38:41	7:38:48	Valid	24
NW Transit Center	7:39:26	0:00:39	Tag	7:38:47			
NW Transit Center	7:39:30	0:00:39	Pass & Tag	7:38:51			
NW Transit Center	7:39:45	0:00:39	Pass & Tag	7:39:06			
NW Transit Center	7:40:01	0:00:39	Tag	7:39:22	7:39:37	Valid	32
NW Transit Center	7:40:25	0:00:39	Tag	7:39:46	7:40:01	Valid	32
NW Transit Center	7:41:38	0:00:39	Tag	7:40:59	7:41:12	Valid	30
NW Transit Center	7:42:41	0:00:39	Pass & Tag	7:42:02			
NW Transit Center	7:42:48	0:00:39	Tag	7:42:09			
NW Transit Center	7:42:54	0:00:39	Pass & Tag	7:42:15			
NW Transit Center	7:43:09	0:00:39	Tag	7:42:30	7:42:32	Valid	21
NW Transit Center	7:43:15	0:00:39	Pass & Tag	7:42:36	7:42:37	Valid	20
NW Transit Center	7:43:39	0:00:39	Tag	7:43:00	7:42:40	Valid	13
NW Transit Center	7:43:48	0:00:39	Tag	7:43:09			

*only vehicles with transponders (tags) and two occupants are listed in this table.

Table E. Two-Person Vehicles with Transponders, Katy Freeway, 10/16/03.

Location	Time Observed	Time Displacement (45 mph)	Pass?	Estimated Read Time	Reader 18	Valid/Invalid	Actual Speed
Post Oak	17:15:46	0:01:10	Tag	17:16:56			
East Ext.	17:15:34	0:02:10	Tag	17:17:44	17:17:50	Valid	43
Post Oak	17:16:43	0:01:10	Pass & Tag	17:17:53	17:17:59	Valid	41
Post Oak	17:17:08	0:01:10	Tag	17:18:18			
East Ext.	17:16:15	0:02:10	Pass & Tag	17:18:25			
East Ext.	17:16:33	0:02:10	Pass & Tag	17:18:43			
Post Oak	17:18:19	0:01:10	Tag	17:19:29			
Post Oak	17:18:23	0:01:10	Tag	17:19:33			
Post Oak	17:18:34	0:01:10	Tag	17:19:44	17:19:40	Valid	47
East Ext.	17:17:58	0:02:10	Pass & Tag	17:20:08	17:20:05	Valid	46
East Ext.	17:18:18	0:02:10	Pass & Tag	17:20:28	17:20:48	Valid	39
East Ext.	17:19:14	0:02:10	Pass & Tag	17:21:24			
East Ext.	17:19:51	0:02:10	Tag	17:22:01	17:21:55	Valid	47
Post Oak	17:20:54	0:01:10	Tag	17:22:04			
East Ext.	17:20:24	0:02:10	Tag	17:22:34	17:22:36	Valid	44
Post Oak	17:21:36	0:01:10	Pass & Tag	17:22:46			
East Ext.	17:21:22	0:02:10	Tag	17:23:32			
Post Oak	17:22:49	0:01:10	Tag	17:23:59	17:23:54	Valid	48
Post Oak	17:22:54	0:01:10	Pass & Tag	17:24:04			
Post Oak	17:24:02	0:01:10	Tag	17:25:12	17:25:08	Valid	47
East Ext.	17:23:28	0:02:10	Pass & Tag	17:25:38	17:25:29	Valid	48
East Ext.	17:23:40	0:02:10	Pass & Tag	17:25:50			
Post Oak	17:25:27	0:01:10	Tag	17:26:37	17:26:23	Valid	56
Post Oak	17:25:39	0:01:10	Pass & Tag	17:26:49	17:26:43	Valid	49
East Ext.	17:25:11	0:02:10	Pass & Tag	17:27:21			
East Ext.	17:25:14	0:02:10	Tag	17:27:24			
Post Oak	17:26:57	0:01:10	Pass & Tag	17:28:07	17:28:02	Valid	48
Post Oak	17:27:05	0:01:10	Pass & Tag	17:28:15	17:28:08	Valid	50
East Ext.	17:27:06	0:02:10	Pass & Tag	17:29:16	17:28:56	Valid	53
East Ext.	17:27:09	0:02:10	Pass & Tag	17:29:19			
Post Oak	17:28:15	0:01:10	Pass & Tag	17:29:25			
East Ext.	17:27:19	0:02:10	Tag	17:29:29			
East Ext.	17:27:24	0:02:10	Pass & Tag	17:29:34			
East Ext.	17:28:01	0:02:10	Pass & Tag	17:30:11			
East Ext.	17:28:43	0:02:10	Tag	17:30:53	17:30:50	Valid	46
Post Oak	17:29:53	0:01:10	Pass & Tag	17:31:03			
Post Oak	17:30:01	0:01:10	Tag	17:31:11			
Post Oak	17:30:35	0:01:10	Pass & Tag	17:31:45	17:31:40	Valid	48
Post Oak	17:31:35	0:01:10	Pass & Tag	17:32:45			
Post Oak	17:31:39	0:01:10	Pass & Tag	17:32:49	17:33:00	Valid	39
East Ext.	17:31:22	0:02:10	Pass & Tag	17:33:32	17:33:28	Valid	46
Post Oak	17:33:35	0:01:10	Pass & Tag	17:34:45	17:35:08	Valid	34
Post Oak	17:34:45	0:01:10	Tag	17:35:55	17:35:28	Valid	73
East Ext.	17:33:54	0:02:10	Pass & Tag	17:36:04			
East Ext.	17:33:57	0:02:10	Pass & Tag	17:36:07	17:36:10	Valid	44
East Ext.	17:34:42	0:02:10	Pass & Tag	17:36:52			
Post Oak	17:35:55	0:01:10	Tag	17:37:05	17:37:46	Valid	28
East Ext.	17:36:07	0:02:10	Tag	17:38:17	17:38:09	Valid	48
East Ext.	17:36:41	0:02:10	Pass & Tag	17:38:51	17:38:41	Valid	49
Post Oak	17:38:00	0:01:10	Tag	17:39:10			
Post Oak	17:38:19	0:01:10	Tag	17:39:29			
Post Oak	17:38:24	0:01:10	Pass & Tag	17:39:34			
Post Oak	17:38:40	0:01:10	Tag	17:39:50			
Post Oak	17:39:17	0:01:10	Tag	17:40:27	17:40:21	Valid	49
Post Oak	17:39:19	0:01:10	Tag	17:40:29			
Post Oak	17:39:52	0:01:10	Pass & Tag	17:41:02	17:40:52	Valid	52
East Ext.	17:39:01	0:02:10	Pass & Tag	17:41:11			
East Ext.	17:39:56	0:02:10	Tag	17:42:06			
Post Oak	17:41:07	0:01:10	Pass & Tag	17:42:17			
Post Oak	17:41:21	0:01:10	Tag	17:42:31			
East Ext.	17:41:08	0:02:10	Tag	17:43:18			

Post Oak	17:42:47	0:01:10	Tag	17:43:57			
Post Oak	17:43:32	0:01:10	Tag	17:44:42			
Post Oak	17:43:34	0:01:10	Tag	17:44:44			
Post Oak	17:43:54	0:01:10	Tag	17:45:04			
East Ext.	17:44:20	0:02:10	Tag	17:46:30			
East Ext.	17:45:00	0:02:10	Tag	17:47:10	17:47:34	Valid	38

*only vehicles with transponders (tags) and two occupants are listed in this table.

Table F. Two-Person Vehicles with Transponders, Katy Freeway, 10/17/03.

Location	Time Observed	Time Displacement (45 mph)	Pass?	Estimated Read Time	Reader 18	Valid/Invalid	Actual Speed
East Ext.	17:00:59	0:02:10	Tag	17:03:09			
East Ext.	17:01:24	0:02:10	Pass & Tag	17:03:34			
East Ext.	17:01:46	0:02:10	Tag	17:03:56			
East Ext.	17:02:28	0:02:10	Tag	17:04:38			
Post Oak	17:03:32	0:01:10	Tag	17:04:42			
East Ext.	17:03:18	0:02:10	Tag	17:05:28			
East Ext.	17:03:38	0:02:10	Tag	17:05:48			
East Ext.	17:04:51	0:02:10	Pass & Tag	17:07:01	17:06:47	Valid	50
East Ext.	17:05:01	0:02:10	Tag	17:07:11			
East Ext.	17:05:23	0:02:10	Tag	17:07:33			
East Ext.	17:06:00	0:02:10	Pass & Tag	17:08:10			
Post Oak	17:07:15	0:01:10	Tag	17:08:25			
Post Oak	17:07:33	0:01:10	Tag	17:08:43			
Post Oak	17:07:44	0:01:10	Pass & Tag	17:08:54			
Post Oak	17:08:10	0:01:10	Pass & Tag	17:09:20			
East Ext.	17:07:47	0:02:10	Tag	17:09:57	17:10:02	Valid	43
Post Oak	17:09:08	0:01:10	Pass & Tag	17:10:18			
Post Oak	17:09:10	0:01:10	Pass & Tag	17:10:20			
Post Oak	17:10:10	0:01:10	Tag	17:11:20	17:11:01	Valid	61
East Ext.	17:09:14	0:02:10	Pass & Tag	17:11:24			
Post Oak	17:10:34	0:01:10	Tag	17:11:44			
East Ext.	17:10:43	0:02:10	Pass & Tag	17:12:53	17:12:25	Valid	57
East Ext.	17:10:46	0:02:10	Pass & Tag	17:12:56	17:12:54	Valid	46
Post Oak	17:12:02	0:01:10	Pass & Tag	17:13:12			
Post Oak	17:12:14	0:01:10	Pass & Tag	17:13:24			
East Ext.	17:11:42	0:02:10	Pass & Tag	17:13:52			
East Ext.	17:12:36	0:02:10	Pass & Tag	17:14:46			
East Ext.	17:14:33	0:02:10	Pass & Tag	17:16:43	17:16:16	Valid	57
East Ext.	17:14:38	0:02:10	Pass & Tag	17:16:48			
East Ext.	17:15:13	0:02:10	Tag	17:17:23	17:17:56	Valid	36
East Ext.	17:16:07	0:02:10	Tag	17:18:17			
Post Oak	17:18:01	0:01:10	Pass & Tag	17:19:11	17:18:52	Valid	61
East Ext.	17:17:07	0:02:10	Tag	17:19:17	17:19:07	Valid	49
Post Oak	17:19:15	0:01:10	Tag	17:20:25	17:20:36	Valid	39
Post Oak	17:19:25	0:01:10	Tag	17:20:35	17:20:39	Valid	42
Post Oak	17:19:29	0:01:10	Tag	17:20:39			
Post Oak	17:19:36	0:01:10	Tag	17:20:46			
East Ext.	17:19:00	0:02:10	Pass & Tag	17:21:10			
East Ext.	17:19:02	0:02:10	Pass & Tag	17:21:12			
Post Oak	17:20:12	0:01:10	Tag	17:21:22			
East Ext.	17:19:20	0:02:10	Tag	17:21:30	17:21:54	Valid	38
East Ext.	17:20:26	0:02:10	Pass & Tag	17:22:36	17:22:20	Valid	51
East Ext.	17:20:27	0:02:10	Tag	17:22:37			
East Ext.	17:20:30	0:02:10	Tag	17:22:40			
East Ext.	17:20:37	0:02:10	Tag	17:22:47			
East Ext.	17:21:22	0:02:10	Tag	17:23:32	17:23:26	Valid	47
East Ext.	17:21:39	0:02:10	Pass & Tag	17:23:49			
East Ext.	17:22:16	0:02:10	Pass & Tag	17:24:26	17:24:27	Valid	45
East Ext.	17:22:25	0:02:10	Tag	17:24:35			
Post Oak	17:23:39	0:01:10	Tag	17:24:49			
East Ext.	17:23:19	0:02:10	Pass & Tag	17:25:29	17:25:40	Valid	41
East Ext.	17:24:22	0:02:10	Tag	17:26:32	17:26:34	Valid	44
Post Oak	17:25:29	0:01:10	Pass & Tag	17:26:39	17:26:41	Valid	43
East Ext.	17:24:32	0:02:10	Tag	17:26:42			
Post Oak	17:25:39	0:01:10	Pass & Tag	17:26:49			
Post Oak	17:25:44	0:01:10	Tag	17:26:54			
Post Oak	17:25:52	0:01:10	Pass & Tag	17:27:02			
East Ext.	17:25:40	0:02:10	Tag	17:27:50			
East Ext.	17:25:43	0:02:10	Pass & Tag	17:27:53			
East Ext.	17:26:33	0:02:10	Pass & Tag	17:28:43			
Post Oak	17:27:43	0:01:10	Pass & Tag	17:28:53			
Post Oak	17:28:38	0:01:10	Tag	17:29:48	17:29:44	Valid	47

East Ext.	17:27:50	0:02:10	Pass & Tag	17:30:00			
East Ext.	17:28:12	0:02:10	Pass & Tag	17:30:22			
East Ext.	17:28:44	0:02:10	Tag	17:30:54	17:30:47	Valid	47
East Ext.	17:28:46	0:02:10	Tag	17:30:56	17:31:06	Valid	42
East Ext.	17:29:08	0:02:10	Pass & Tag	17:31:18	17:31:09	Valid	48

Table G. Two-Person Vehicles with Transponders, Northwest Freeway at Dacoma, 10/16/03.

Location	Time Observed	Time Displacement (35 mph)	Pass?	Estimated Read Time	Reader 41	Valid/Invalid	Actual Speed
Dacoma	7:20:30	0:00:11	Pass & Tag	7:20:19	7:20:14	Valid	25
Dacoma	7:24:11	0:00:11	Pass & Tag	7:24:00			
Dacoma	7:24:41	0:00:11	Tag	7:24:30	7:24:28	Valid	30
Dacoma	7:26:26	0:00:11	Tag	7:26:15			
Dacoma	7:27:56	0:00:11	Tag	7:27:45			
Dacoma	7:32:25	0:00:11	Tag	7:32:14			
Dacoma	7:32:38	0:00:11	Tag	7:32:27			
Dacoma	7:40:15	0:00:11	Pass & Tag	7:40:04	7:40:00	Valid	26
Dacoma	7:40:19	0:00:11	Pass & Tag	7:40:08			
Dacoma	7:40:53	0:00:11	Tag	7:40:42	7:40:48	Valid	79
Dacoma	7:41:42	0:00:11	Tag	7:41:31	7:41:24	Valid	22

*only vehicles with transponders (tags) and two occupants are listed in this table.

Table H. Two-Person Vehicles with Transponders, Northwest Freeway at Dacoma, 10/17/03.

Location	Time Observed	Time Displacement (35 mph)	Pass?	Estimated Read Time	Reader 41	Valid/Invalid	Actual Speed
Dacoma	7:20:18	0:00:11	Tag	7:20:07			
Dacoma	7:23:00	0:00:11	Tag	7:22:49	7:22:47	Valid	30
Dacoma	7:23:36	0:00:11	Pass & Tag	7:23:25			
Dacoma	7:26:45	0:00:11	Pass & Tag	7:26:34	7:26:31	Valid	28
Dacoma	7:27:20	0:00:11	Pass & Tag	7:27:09	7:27:05	Valid	26
Dacoma	7:31:59	0:00:11	Tag	7:31:48			
Dacoma	7:35:06	0:00:11	Pass & Tag	7:34:55	7:34:58	Valid	50
Dacoma	7:35:40	0:00:11	Tag	7:35:29			
Dacoma	7:36:40	0:00:11	Pass & Tag	7:36:29	7:36:26	Valid	28
Dacoma	7:40:30	0:00:11	Tag	7:40:19	7:40:25	Valid	79
Dacoma	7:40:56	0:00:11	Pass & Tag	7:40:45			
Dacoma	7:43:55	0:00:11	Pass & Tag	7:43:44	7:43:36	Valid	21

Table I. Two-Person Vehicles with Transponders, Northwest Freeway at Northwest Transit Center, 10/16/03.

Location	Time Observed	Time Displacement (20 mph)	Pass?	Estimamted Read Time	Reader 42	Valid/Invalid	Actual Speed
NW Transit Ctr	7:16:25	0:00:40	Pass & Tag	7:15:45			
NW Transit Ctr	7:17:05	0:00:40	Pass & Tag	7:16:25			
NW Transit Ctr	7:17:21	0:00:40	Pass & Tag	7:16:41	7:16:39	Valid	19
NW Transit Ctr	7:18:11	0:00:40	Pass & Tag	7:17:31	7:17:14	Valid	14
NW Transit Ctr	7:18:52	0:00:40	Pass & Tag	7:18:12			
NW Transit Ctr	7:19:54	0:00:40	Pass & Tag	7:19:14			
NW Transit Ctr	7:19:59	0:00:40	Pass & Tag	7:19:19	7:19:31	Valid	28
NW Transit Ctr	7:20:14	0:00:40	Pass & Tag	7:19:34	7:19:44	Valid	26
NW Transit Ctr	7:21:11	0:00:40	Pass & Tag	7:20:31	7:20:35	Valid	22
NW Transit Ctr	7:21:17	0:00:40	Pass & Tag	7:20:37			
NW Transit Ctr	7:22:23	0:00:40	Pass & Tag	7:21:43	7:21:30	Valid	15
NW Transit Ctr	7:22:43	0:00:40	Pass & Tag	7:22:03	7:21:52	Valid	16
NW Transit Ctr	7:23:05	0:00:40	Pass & Tag	7:22:25	7:22:25	Valid	20
NW Transit Ctr	7:24:02	0:00:40	Pass & Tag	7:23:22			
NW Transit Ctr	7:24:08	0:00:40	Pass & Tag	7:23:28			
NW Transit Ctr	7:24:28	0:00:40	Pass & Tag	7:23:48	7:23:57	Valid	26
NW Transit Ctr	7:24:51	0:00:40	Pass & Tag	7:24:11	7:24:14	Valid	21
NW Transit Ctr	7:25:01	0:00:40	Pass & Tag	7:24:21	7:24:19	Valid	19
NW Transit Ctr	7:25:06	0:00:40	Pass & Tag	7:24:26	7:24:23	Valid	18
NW Transit Ctr	7:26:09	0:00:40	Pass & Tag	7:25:29			
NW Transit Ctr	7:26:25	0:00:40	Pass & Tag	7:25:45			
NW Transit Ctr	7:27:16	0:00:40	Tag	7:26:36			
NW Transit Ctr	7:28:22	0:00:40	Pass & Tag	7:27:42	7:27:39	Valid	18
NW Transit Ctr	7:29:21	0:00:40	Pass & Tag	7:28:41			
NW Transit Ctr	7:30:05	0:00:40	Pass & Tag	7:29:25			
NW Transit Ctr	7:30:14	0:00:40	Pass & Tag	7:29:34			
NW Transit Ctr	7:30:21	0:00:40	Pass & Tag	7:29:41			
NW Transit Ctr	7:31:19	0:00:40	Pass & Tag	7:30:39			
NW Transit Ctr	7:31:22	0:00:40	Pass & Tag	7:30:42			
NW Transit Ctr	7:31:42	0:00:40	Pass & Tag	7:31:02			
NW Transit Ctr	7:32:40	0:00:40	Pass & Tag	7:32:00	7:31:49	Valid	16
NW Transit Ctr	7:33:58	0:00:40	Pass & Tag	7:33:18			
NW Transit Ctr	7:34:51	0:00:40	Pass & Tag	7:34:11			
NW Transit Ctr	7:34:54	0:00:40	Pass & Tag	7:34:14			
NW Transit Ctr	7:35:04	0:00:40	Pass & Tag	7:34:24	7:34:42	Valid	36
NW Transit Ctr	7:35:42	0:00:40	Pass & Tag	7:35:02			
NW Transit Ctr	7:36:11	0:00:40	Pass & Tag	7:35:31			
NW Transit Ctr	7:36:16	0:00:40	Pass & Tag	7:35:36			
NW Transit Ctr	7:37:04	0:00:40	Pass & Tag	7:36:24	7:36:23	Valid	19
NW Transit Ctr	7:37:32	0:00:40	Pass & Tag	7:36:52	7:36:56	Valid	22
NW Transit Ctr	7:37:39	0:00:40	Pass & Tag	7:36:59			
NW Transit Ctr	7:37:42	0:00:40	Pass & Tag	7:37:02			
NW Transit Ctr	7:38:12	0:00:40	Pass & Tag	7:37:32	7:37:43	Valid	27
NW Transit Ctr	7:38:41	0:00:40	Tag	7:38:01			
NW Transit Ctr	7:39:32	0:00:40	Pass & Tag	7:38:52	7:38:50	Valid	19
NW Transit Ctr	7:40:04	0:00:40	Pass & Tag	7:39:24			
NW Transit Ctr	7:40:16	0:00:40	Pass & Tag	7:39:36	7:39:42	Valid	23
NW Transit Ctr	7:42:17	0:00:40	Pass & Tag	7:41:37			
NW Transit Ctr	7:42:26	0:00:40	Pass & Tag	7:41:46			
NW Transit Ctr	7:43:15	0:00:40	Pass & Tag	7:42:35	7:42:30	Valid	18
NW Transit Ctr	7:43:36	0:00:40	Tag	7:42:56			
NW Transit Ctr	7:43:53	0:00:40	Pass & Tag	7:43:13			
NW Transit Ctr	7:44:26	0:00:40	Pass & Tag	7:43:46	7:43:33	Valid	15
NW Transit Ctr	7:44:35	0:00:40	Pass & Tag	7:43:55			
NW Transit Ctr	7:44:42	0:00:40	Pass & Tag	7:44:02			

*only vehicles with transponders (tags) and two occupants are listed in this table.

Table J. Two-Person Vehicles with Transponders, Northwest Freeway at Northwest Transit Center, 10/17/03.

Location	Time Observed	Time Displacement (20 mph)	Pass?	Estimated Read Time	Reader 42	Valid/Invalid	Actual Speed
NW Transit Ctr	7:15:33	0:00:40	Pass & Tag	7:14:53			
NW Transit Ctr	7:15:45	0:00:40	Tag	7:15:05	7:15:02	Valid	18
NW Transit Ctr	7:16:31	0:00:40	Tag	7:15:51			
NW Transit Ctr	7:16:46	0:00:40	Tag	7:16:06			
NW Transit Ctr	7:19:54	0:00:40	Tag	7:19:14			
NW Transit Ctr	7:20:09	0:00:40	Pass & Tag	7:19:29			
NW Transit Ctr	7:20:16	0:00:40	Pass & Tag	7:19:36			
NW Transit Ctr	7:20:19	0:00:40	Tag	7:19:39			
NW Transit Ctr	7:20:20	0:00:40	Pass & Tag	7:19:40			
NW Transit Ctr	7:20:39	0:00:40	Pass & Tag	7:19:59			
NW Transit Ctr	7:22:51	0:00:40	Pass & Tag	7:22:11			
NW Transit Ctr	7:23:35	0:00:40	Pass & Tag	7:22:55	7:23:07	Valid	28
NW Transit Ctr	7:24:59	0:00:40	Tag	7:24:19	7:24:11	Valid	17
NW Transit Ctr	7:25:21	0:00:40	Pass & Tag	7:24:41	7:24:32	Valid	16
NW Transit Ctr	7:25:32	0:00:40	Pass & Tag	7:24:52	7:24:42	Valid	16
NW Transit Ctr	7:25:56	0:00:40	Pass & Tag	7:25:16	7:25:13	Valid	18
NW Transit Ctr	7:26:15	0:00:40	Pass & Tag	7:25:35			
NW Transit Ctr	7:26:40	0:00:40	Pass & Tag	7:26:00			
NW Transit Ctr	7:27:01	0:00:40	Pass & Tag	7:26:21			
NW Transit Ctr	7:27:08	0:00:40	Pass & Tag	7:26:28			
NW Transit Ctr	7:27:23	0:00:40	Pass & Tag	7:26:43	7:26:45	Valid	21
NW Transit Ctr	7:28:36	0:00:40	Pass & Tag	7:27:56			
NW Transit Ctr	7:28:40	0:00:40	Tag	7:28:00			
NW Transit Ctr	7:28:41	0:00:40	Tag	7:28:01			
NW Transit Ctr	7:28:59	0:00:40	Pass & Tag	7:28:19			
NW Transit Ctr	7:29:05	0:00:40	Pass & Tag	7:28:25	7:28:35	Valid	26
NW Transit Ctr	7:29:24	0:00:40	Pass & Tag	7:28:44	7:28:55	Invalid	27
NW Transit Ctr	7:29:55	0:00:40	Pass & Tag	7:29:15			
NW Transit Ctr	7:30:11	0:00:40	Pass & Tag	7:29:31	7:29:24	Valid	17
NW Transit Ctr	7:31:31	0:00:40	Pass & Tag	7:30:51	7:30:38	Valid	15
NW Transit Ctr	7:32:59	0:00:40	Pass & Tag	7:32:19			
NW Transit Ctr	7:33:51	0:00:40	Pass & Tag	7:33:11			
NW Transit Ctr	7:33:56	0:00:40	Pass & Tag	7:33:16	7:33:19	Valid	21
NW Transit Ctr	7:34:35	0:00:40	Pass & Tag	7:33:55			
NW Transit Ctr	7:34:42	0:00:40	Tag	7:34:02	7:34:06	Valid	22
NW Transit Ctr	7:34:45	0:00:40	Pass & Tag	7:34:05			
NW Transit Ctr	7:35:04	0:00:40	Pass & Tag	7:34:24	7:34:31	Valid	24
NW Transit Ctr	7:35:57	0:00:40	Pass & Tag	7:35:17			
NW Transit Ctr	7:36:05	0:00:40	Pass & Tag	7:35:25	7:35:28	Valid	21
NW Transit Ctr	7:36:24	0:00:40	Pass & Tag	7:35:44			
NW Transit Ctr	7:37:09	0:00:40	Pass & Tag	7:36:29	7:36:41	Valid	28
NW Transit Ctr	7:37:39	0:00:40	Tag	7:36:59			
NW Transit Ctr	7:37:55	0:00:40	Pass & Tag	7:37:15			
NW Transit Ctr	7:38:27	0:00:40	Pass & Tag	7:37:47			
NW Transit Ctr	7:38:32	0:00:40	Pass & Tag	7:37:52			
NW Transit Ctr	7:38:38	0:00:40	Pass & Tag	7:37:58	7:38:02	Valid	22
NW Transit Ctr	7:38:48	0:00:40	Pass & Tag	7:38:08			
NW Transit Ctr	7:38:51	0:00:40	Pass & Tag	7:38:11			
NW Transit Ctr	7:39:18	0:00:40	Pass & Tag	7:38:38			
NW Transit Ctr	7:42:36	0:00:40	Pass & Tag	7:41:56	7:41:40	Valid	14
NW Transit Ctr	7:42:42	0:00:40	Pass & Tag	7:42:02	7:41:44	Valid	14
NW Transit Ctr	7:43:00	0:00:40	Pass & Tag	7:42:20	7:41:55	Valid	12
NW Transit Ctr	7:43:02	0:00:40	Pass & Tag	7:42:22	7:42:10	Valid	15
NW Transit Ctr	7:43:33	0:00:40	Pass & Tag	7:42:53			
NW Transit Ctr	7:43:58	0:00:40	Tag	7:43:18	7:43:12	Valid	17
NW Transit Ctr	7:44:05	0:00:40	Pass & Tag	7:43:25			

APPENDIX E:
TECHNICAL MEMORANDUM

Technical Memorandum 2-8
Field Implementation of Enforcement Strategies

John Wikander
Ginger Goodin

STRENGTHENED ENFORCEMENT PROCEDURES

Following initial violation data collection efforts in February and April 2003, TTI, in conjuction with METRO, identified several weaknesses in enforcement procedures. Chief among these were the following:

- Staffing of enforcement areas during QuickRide operational hours was typically sporadic, with officers conducting enforcement activities during one or two peak periods per week, on average.
- Enforcement efforts by METRO officers were inconsistent; some were observed to actively enforce vehicle eligibility requirements, where others were less keen in this regard. Contributing factors towards this disparity included unfamiliarity with the eligibility requirements (minimum number of occupants, the identification requirements for QuickRide users), and difficulties in seeing into vehicle cabins (this factor often limited officers to identifying single occupant vehicles).
- METRO officers were reluctant to enforce regulations regarding off-duty or unofficial use of the HOV lanes by law enforcement personnel. This resulted in a highly visible fraction of off-duty and unmarked law enforcement SOV violators (up to 7% of all vehicles observed during February and April 2003 at the Northwest Transit Center AM exit ramp), which engenders negative motorist perceptions.

In August 2003, METRO implemented the following TTI recommendations on a short-term basis in order to immediately enhance compliance:

- **Elevated Enforcement.** Enforcement areas along the Katy and Northwest HOV lanes during QuickRide hours were staffed daily during a one-month test period.

- **Standardized policing procedures** were developed to improve efficiency of operations.

- **Public Outreach.** Friendly reminder letters were sent to enrollees and to non-enrollees who were using the facilities to explain the policies for vehicle eligibility and provide information on the QuickRide program. Additional signs were posted along the Katy and Northwest HOV lanes communicating a maximum $200 fine for violations.

The details of these activities are described below.

ELEVATED ENFORCEMENT

Observed Enforcement Activities

During the month of October 2003, elevated enforcement levels were maintained during QuickRide operation hours along I-10 (6:45 – 8:00 AM, 5:00 – 6:00 PM) and US 290 (6:45 – 8:00 AM only). Table 1 summarizes the enforcement activities observed at four enforcement locations during the violation data collection efforts in mid-October 2003. Enforcement activity was observed to be highest at the Eastern Extension and US 290 locations, as these offered the most favorable geometry for intensive enforcement efforts.

Table 1. Observed Enforcement Activity on I-10 and US 290 during October 2003

Enforcement Location	Enforcement Presence		Apprehensions Observed AM / PM
	AM QuickRide Period	PM QuickRide Period	
I-10 at Post Oak	10/15/2004: Yes 10/16/2004: Yes 10/17/2004: Yes	10/15/2004: No 10/16/2004: No 10/17/2004: No	12 / 0 6 / 0 6 / 0
I-10 at Eastern Extension	10/15/2004: Yes 10/16/2004: Yes 10/17/2004: Yes	10/15/2004: Yes 10/16/2004: Yes 10/17/2004: No	12 / 12 12 / 12 6 / 0
US 290 at Northwest Transit Center	10/15/2004: No 10/16/2004: Yes 10/17/2004: Yes	10/15/2004: No 10/16/2004: No 10/17/2004: No	0 / 0 0 / 0 0 / 0
US 290 at Dacoma	10/15/2004: No 10/16/2004: Yes 10/17/2004: Yes	10/15/2004: No 10/16/2004: No 10/17/2004: No	0 / 0 18 / 0 15 / 0

Effect on Compliance

Results from the April and October data collection efforts have been summarized in Table 2 and Table 3. The numbers in the tables represent the three-day totals for each vehicle category. The last three columns in each table give the aggregate number of violators and valid users, as well as the overall total of classifiable vehicles observed. All totals for the categories in the table are also expressed as row percentages; i.e., each entry for a given row in the table is expressed as a percent of the total number of classifiable vehicles observed for that row. Shaded columns in the table denote violation categories.

Table 2. April 23-25, 2003 Data Collection

QuickRide Period	HOV 3+	2 person				SOV			Bus	MC	Total Violator	Total Valid	Grand Total
		Pass Toll	No Pass Toll	Pass No Toll	No Pass No Toll	Police	Unmarked	Violator					
Katy AM	927 22.7%	144 3.5%	192 4.7%	402 9.9%	1648 40.4%	39 1.0%	72 1.8%	389 9.5%	192 4.7%	74 1.8%	2703 66.3%	1376 33.7%	4079
Katy PM	910 31.1%	146 5.0%	122 4.2%	222 7.6%	1045 35.8%	18 0.6%	52 1.8%	194 6.6%	157 5.4%	56 1.9%	1635 56.0%	1287 44.0%	2922
Northwest AM	1250 27.9%	281 6.3%	175 3.9%	575 12.8%	1590 35.5%	49 1.1%	293 6.5%	111 2.5%	84 1.9%	72 1.6%	2744 61.3%	1736 38.8%	4480

The results from the October data collection are notable in that they serve to quantify the effect of increased enforcement. Overall violations decreased 53% for Northwest, 26% for Katy AM, and 18% for Katy PM. These reductions were large enough to significantly increase the carrying capacity by 200-300 vehicles on the Katy (I-10) HOV lanes, and 1000 vehicles on the Northwest (US 290) HOV lanes. The Katy AM period experienced a 13% decrease in vehicles, while the Katy PM and Northwest AM periods saw 5% and 24% reductions in traffic. Perhaps most encouraging, the number of high occupancy vehicles using the HOT facilities increased from April to October by 9.1%, 12%, and 22.1% for Katy AM, Katy PM, and Northwest AM periods, respectively. However, the drop still did not meet a violation rate target value of 10% to 15%. Due to resource constraints and other agency priorities, the increased enforcement presence was not sustained beyond October 2003.

Table 3. October 15-17, 2003 Data Collection

QuickRide Period	HOV 3+	2 person				SOV			Bus	MC	Total Violator	Total Valid	Grand Total
		Pass Toll	No Pass Toll	Pass No Toll	No Pass No Toll	Police	Unmarked	Violator					
Katy AM	1012 (28.5%)	179 (5.0%)	153 4.3%	347 9.8%	1194 33.7%	34 1.0%	86 2.4%	216 6.1%	190 5.4%	137 3.9%	1996 56.3%	1552 43.7%	3548
Katy PM	1019 36.5%	141 5.1%	112 4.0%	172 6.2%	848 30.4%	26 0.9%	67 2.4%	138 4.9%	159 5.7%	110 3.9%	1337 47.9%	1455 52.1%	2792
Northwest AM	1527 45.1%	277 8.2%	126 3.7%	361 10.7%	574 16.9%	47 1.4%	173 5.1%	53 1.6%	94 2.8%	157 4.6%	1287 38.0%	2102 62.0%	3389

STANDARDIZE POLICE PRODURES

The following policies and procedures were developed by TTI in consultation with METRO, and consist of core information necessary for proper understanding of vehicle eligibility requirements and helpful procedures for discriminating between various types of HOV violators.

Policing Policy

The QuickRide (QR) program operates during the following time periods:

Days Open	Hours of Operation	Freeway	Direction	Minimum Occupancy
Monday - Friday	6:45 a.m. – 8:00 a.m.	Northwest and Katy Freeway	Inbound	3 people or 2 people if QuickRide participants
	5:00 p.m. – 6:00 p.m.	Katy Freeway	Outbound	3 people or 2 people if QuickRide participants

Officers assigned to HOVL enforcement operation during the QR time periods will adhere to all policies and procedures of the Department while working their assignment. Officers will be responsible for the enforcement of traffic laws and HOVL violations during their duty hours.

A valid 2-person QuickRide vehicle must display both a toll transponder (hereafter referred to as a "toll") in the windshield area, as well as a small marquee labeled "QUICKRIDE" (referred to subsequently as a "pass") which is hung off the rearview mirror (see Figure 1).

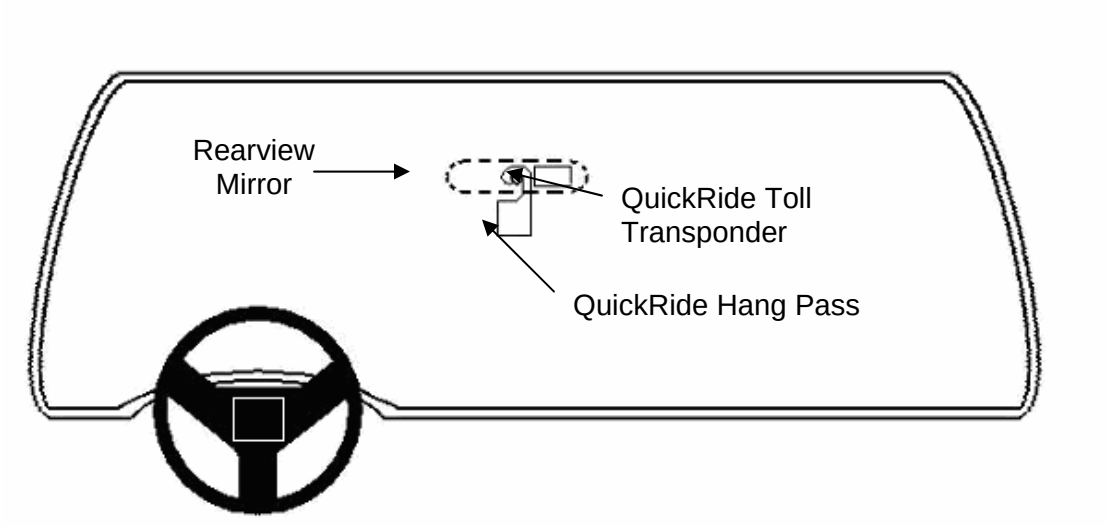


Figure 1. Proper Mounting Location of QuickRide Transponder and Hang Pass

Hence the four subcategories of the 2-person vehicle classification comprise the possible permutations of the presence of absence of each of these two items:

- **PASS / TOLL**: A 2-person vehicle which displays both a toll transponder (TAG) and a QuickRide hangtag (PASS). Such a vehicle is assumed to be abiding by all QuickRide regulations and is not considered a violator.

- **PASS / NO TOLL**: A 2-person vehicle displaying a QuickRide pass but no identifiable toll tag in the windshield or dashboard area. This type of vehicle is considered to be a violator.
- **NO PASS / TOLL**: A 2-person vehicle displaying an identifiable toll tag but not displaying a QuickRide pass. This type of vehicle is considered to be a violator.
- **NO PASS / NO TOLL**: A 2-person vehicle displaying neither a toll tag nor a QuickRide pass. Such a vehicle is considered to be a violator.

In addition, Single Occupant Vehicles (SOVs) are prohibited at all times on the Katy and Northwest HOV facilities.

Description of HOVL Violations During QR Periods

A motorist that enters the Katy or Northwest Freeway HOV lanes during the QuickRide period will be charged with a moving violation under the following conditions:

- Only one person is in the vehicle. The driver is charged for violation of the vehicle occupancy regulation.

- Two people are in the vehicle, but a QuickRide hang pass and toll transponder are not properly displayed in the front windshield (see diagram below for proper positioning). The driver is charged for violation of the vehicle occupancy regulation.

- Two people are in the vehicle and a QuickRide hang pass and toll transponder are displayed, but the toll transponder is dead, disabled, or linked to an invalid QuickRide account. QuickRide transponders and accounts must be active; otherwise, the participant will be removed from the program and users of the credentials will be subject to fines for violation of the vehicle occupancy regulation. This verification is performed by roadside and handheld AVI readers, discussed later in this report.

Current recommendations for standard policing procedures are listed in Table 4 below. As may be seen in the table, informational literature and QuickRide program information will perform an important role in both speeding processing and maintaining enforcement consistency.

Table 4. Recommended Standard Policing Procedures

Violation Category	Characteristics	Corrective Action Needed
1	No transponder displayed No QuickRide pass displayed	Collect identification, issue warning Issue citation
2	Transponder displayed No QuickRide pass displayed	Collect identification, issue warning, provide program information

	No transponder read	Issue citation
3	No transponder displayed QuickRide pass displayed	Confirm enrollment, provide program information
4	Transponder displayed QuickRide pass displayed No transponder read	Check transponder, provide program information Issue citation
5	Single-occupancy vehicles	Issue citation

Public Outreach

Reminder letters were mailed by October 2003 to 1500 enrollees and non-enrollees in the QuickRide program. These letters provided education to motorists, describing the QuickRide operation, including hours of operation, requirements to comply, and information on the process for enrollment. These letters served as a means of combating the following observed behavior of HOV users:

- From discussions with METRO officers and observations during the data collection efforts, it became apparent that many existing QuickRide users were lax in displaying all required identification information while using the HOV facilities.
- Based on data collected in October 2003, approximately 15 percent of all violators are able to evade tolls by using a transponder issued by the Harris County Toll Road Authority (HCTRA) in place of the one issued by METRO. METRO allows QuickRide customers to use a HCTRA transponder, but this transponder must first be registered with METRO in order for it to be recognized by the QuickRide ETC system. It is also impossible to visually differentiate HCTRA and METRO transponders from one another except under close visual inspection. This presents an opportunity for violators to evade detection by METRO enforcement personnel by enrolling in QuickRide, but failing to register their HCTRA transponder.

Draft copies of the letters are shown in Figures 2 and 3. In addition, trifold brochures containing similar information were created, for distribution by METRO officers to apprehended motorists during the month of April 2004.

[METRO Letterhead]

Dear Houston Commuter:

As a Houston area High Occupancy Vehicle (HOV) lane user, you may recognize that the Metropolitan Transit Authority's (METRO) HOV network provides commuters with a fast and efficient alternative to congestion. Built primarily for buses, the HOV lanes also promote ridesharing through vanpools and carpools.

Houston commuters who form carpools use the HOV lanes as a convenient way to avoid freeway congestion. Minimum occupancy requirements are standard on all HOV lanes, with 2 person carpools being common. These carpools are permitted to travel the HOV lanes at designated times. The exceptionally busy Northwest (290) and Katy freeways require larger carpools for the use of the HOV lanes during certain peak hours. During the morning and evening rush hours on the Katy freeway and the morning rush hours on the Northwest freeway, a minimum of 3 people per vehicle is needed to ride the HOV lane. **METRO is increasing enforcement of the Houston area HOV system, therefore it is important to be aware of the minimum occupancy requirements at all times.**

HOV Lane Schedules:

Days Open	Hours of Operation	Freeway	Direction	Minimum Occupancy
Monday - Friday	5:00 a.m. – 6:45 a.m.	All HOV lanes	Inbound	2 people
	6:45 a.m. – 8:00 a.m.	Northwest and Katy Freeway	Inbound	3 people or 2 people if QuickRide participants
		All other HOV lanes	Inbound	2 people
	8:00 a.m. – 11:00 a.m.	All HOV lanes	Inbound	2 people
	2:00 p.m. – 5:00 p.m.	All HOV lanes	Outbound	2 people
	5:00 p.m. – 6:00 p.m.	Katy Freeway	Outbound	3 people or 2 people if QuickRide participants
		All other HOV lanes	Outbound	2 people
	6:00 p.m. – 8:00 p.m.	All HOV lanes	Outbound	2 people
Saturday	5:00 a.m. – 8:00 p.m.	Katy Freeway	Outbound	2 people
Sunday	5:00 a.m. – 8:00 p.m.	Katy Freeway	Inbound	2 people

It is often difficult to form the larger carpools required during rush hours, so METRO provides an alternative for Houston drivers. METRO's QuickRide program allows participants to ride the HOV lanes in 2-person carpools. QuickRide participants pay a $2 trip fee which is deducted from their QuickRide account. By joining the QuickRide program, you can have the luxury of a fast commute with only one other person.

QuickRide Permits:

Enforcement of vehicle occupancy regulations is essential for the success of the Houston HOV system. METRO's Police & Traffic Management Department is responsible for monitoring the use of the HOV lane and enforcing these regulations. METRO's QuickRide participants are provided with a Fee Tag transponder and an Auto ID hang tag. **These identification permits must be displayed so that the program can be adequately enforced.** METRO Police may ask users to pull to the side of the lane to check Fee Tags and vehicle occupancy. Individuals who are not participants in the QuickRide program will be easily recognized as HOV lane violators when less than 3 people are present in the vehicle. Drivers may be charged for violation of the vehicle occupancy regulation and are subject to a maximum fine of $200.00.

QuickRide Application:
If you frequently travel the Katy or Northwest (290) freeways but are unable to form a 3-person carpool, the QuickRide program may be ideal for your rush hour commute. To enroll in the QuickRide program, find a friend and form a carpool. (The QuickRide program is not available to single occupant vehicles.) Then you can fill out a METRO QuickRide application. The application may be printed off the METRO website at http://www.hou-metro.harris.tx.us/pdf/qrapp.pdf. You may also contact METRO RideShare at 713-224-RIDE or toll free at 1-888-606-RIDE to receive an application.

Your QuickRide Account:
Once your METRO QuickRide application is accepted, an account will be opened and the proper permits sent. Your METRO QuickRide account must be secured with a credit card. An initial charge of $15 is required for the use of the Fee Tag transponder. Many QuickRide participants already have a transponder from the Harris County Toll Road Authority (EZ Tag). This transponder may be used as the Fee Tag in the QuickRide program. You will not be issued or charged for an additional transponder. **It is necessary that METRO have a record of your EZ Tag number so it can be used for your new QuickRide account.**

As a QuickRide participant, you pay a monthly fee of $2.50 which is charged to your credit card. An initial balance of $40 is necessary to open a QuickRide account. This amount is also deducted from your credit card when the account is established. With each one way HOV trip, during QuickRide hours, the transponder is read. The trip is recorded and the $2 fee is automatically deducted from your prepaid balance. A minimum balance of $10 is required at all times. Your account will be kept current with a $30 charge to your credit card every time the account balance falls to $10 or less. METRO will issue a monthly statement detailing your account activity.

As a participant of the QuickRide program, it is only necessary to have one passenger in your vehicle. If you have two, that is not a problem. You can simply remove your QuickRide Fee Tag and place it in the provided static shield pouch. This way, your transponder (Fee Tag) will not be read and you will not be charged for that trip.

Thank you!

Figure 2. Friendly Reminder Letter for Non-QuickRide HOV Users

[METRO LETTERHEAD]

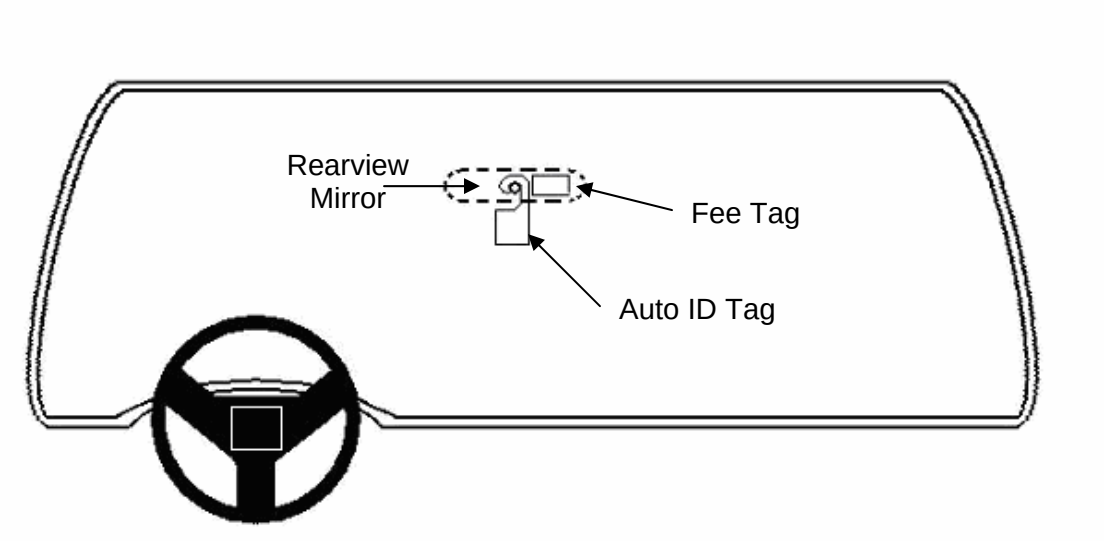
Dear QuickRide Participant:

Thank you for your participation in the QuickRide program. We hope the program meets your expectations and provides you with a quick trip to your destination. **To ensure the success of the QuickRide program, it is essential that you follow the regulations on the proper display of the QuickRide permits.** These regulations will be strictly enforced in order to maintain the integrity of the program.

Procedure:
Upon enrollment in the QuickRide program, you were issued a transponder (Fee Tag) and an Auto ID hang tag. Many QuickRide participants already had a transponder from the Harris County Toll Road Authority (EZ Tag). This transponder can also be used in the QuickRide program but it must be registered with the program.

As a QuickRide participant, it is important to display valid permits while traveling (with 2 people in your vehicle) on the Katy or Northwest (US 290) High Occupancy Vehicle (HOV) lanes. The transponder (Fee Tag / EZ Tag) must be properly mounted in the vehicle that is registered with the Metropolitan Transit Authority (METRO). This will record the trips taken on the HOV lane when you are unable to have 3 or more people in your vehicle. Additionally, while traveling on the HOV lanes, the Auto ID hang tag must be displayed on the rear view mirror. This tag verifies your participation in the QuickRide program.

Proper Mounting Location of QuickRide Permits:



The transponder (Fee Tag/EZ Tag) must be attached to the inside of the front windshield by the Velcro tabs provided. It should be placed in the top center portion of the windshield to the right of the rear view mirror support. Please note that the transponder is not attached to the rearview

mirror itself. The transponder should be located below any tinting of the front windshield. It is important that the transponder not be placed in a position that blocks the view of the hang tag. When 3 or more people are in the vehicle the transponder can be placed in the static free bag to avoid a charge.

METRO's Police & Traffic Management Departments are responsible for monitoring the use of the HOV lane; therefore, it is important for all QuickRide participants to properly display the Fee Tag and Auto ID hang tag. METRO Police may ask users to pull to the side of the lane to check the Fee Tag and vehicle occupancy. **The Auto ID hang tag will enable the Police to more easily identify participants without checking the Fee Tag.**

Violations of the QuickRide Program:
Failure to follow the QuickRide procedures for displaying permits is a ticketable offense. A participant in the QuickRide program will be charged with a moving violation (ticketed) under the following conditions:

- Entering the HOV lane during the time of QuickRide operations with less than two persons in the vehicle. The participant is charged for a violation of the vehicle occupancy regulation that carries a maximum fine of $200.00.

- Entering the HOV lane during the time of QuickRide operations with two persons, but without the QuickRide transponder properly attached to the front windshield. It is a violation if the participant is enrolled in the program, but is not properly displaying the transponder while traveling the lane. The participant is charged for violation of the vehicle occupancy regulation that carries a maximum fine of $200.00.

- Entering the HOV lane during the time of QuickRide operations with two persons, but with an invalid QuickRide transponder (Fee Tag / EZ Tag) in the vehicle. The participant's account will be kept current by a $30 charge to their credit card every time the participant's account balance falls to $10 or less. If a charge is rejected, the participant must provide another acceptable credit card number to METRO before the account balance reaches zero; otherwise, the participant will be removed from the program and will be subject to fines for violation of the vehicle occupancy regulation. There is a $10 charge for each lost or replaced hang tag.

With your help, the QuickRide program will provide a travel option that significantly decreases your travel time. Be sure to stay updated on all of METRO's alternative transportation solutions by visiting http://www.ridemetro.org/

Thank you for your participation in the QuickRide program

Figure 3. Friendly Reminder Letter for Non-QuickRide HOV Users

TECHNOLOGY ENHANCED ACTIONS

Two AVI readers were installed for the purpose of assisting METRO enforcement officers in identifying valid QuickRide customers. These readers provide visual confirmation of QuickRide enrollment in the form of an indicator light and were originally located at the Eastern Extension enforcement area along the Katy (I-10) HOT lanes. Both portable and fixed AVI equipment were utilized.

FIXED VIOLATION ENFORCEMENT AVI READER

The fixed AVI site reads the EZ Tag on vehicles traveling westbound on the HOT lane during the PM QuickRide period, determines if the tag is a valid Quick Ride program tag, and actuates an LED indicator light if the tag is valid. The valid tag list residing on the lane controller was updated by TTI manually by downloading a text file (provided by METRO) via the USB port of the AVI controller assembly from a CD, using the CD-ROM drive on the laptop contained within the lane controller cabinet. The equipment at the fixed AVI site included a lane controller, lane controller software, reader card, RF modulator, UTA antenna and mount, UPS, NEMA cabinet, LED signal, and associated conduit and cable. The fixed AVI site was powered by a solar/battery system installed on the gantry at the HOV slip ramp. Figure 4 shows the gantry mounting location for the fixed AVI enforcement reader. The view in Figure 4 is facing east.

Figure 4: Transcore fixed AVI enforcement reader

SOLAR-POWERED PORTABLE VIOLATION ENFORCEMENT AVI READER

The trailer-mounted solar-powered AVI site read the EZ Tag on vehicles traveling eastbound on the HOV lane during the AM QuickRide period, determined if the tag is a valid QuickRide program tag, and actuated an indicator light on if the tag is valid. The portable AVI equipment

was updateable in the same fashion as the fixed AVI equipment. The equipment included in the trailer-mounted solar-powered AVI site included a lane controller, lane controller software, reader card, RF modulator, UTA antenna and mount, UPS, NEMA cabinet, LED signal, associated conduit and cable, telescoping mast, solar power system and equipment trailer painted international orange. Figure 5 shows the portable AVI equipment at the AM enforcement site near the Eastern Extension slip ramp.

Figure 4. TransCore solar powered portable AVI reader

INITIAL SITING OF ENFORCEMENT READERS

The fixed AVI system was initially located on the I-10 Katy HOV lane at the eastern terminus of the HOV lane. This AVI site had been used for violation enforcement during the PM (westbound) operation of the HOV lane. The trailer-mounted solar-powered AVI site was also located on the I-10 Katy HOV lane near Loop 610 and was used for enforcement during AM QuickRide operation. Figure 5 shows the approximate deployment locations for the fixed and portable AVI readers.

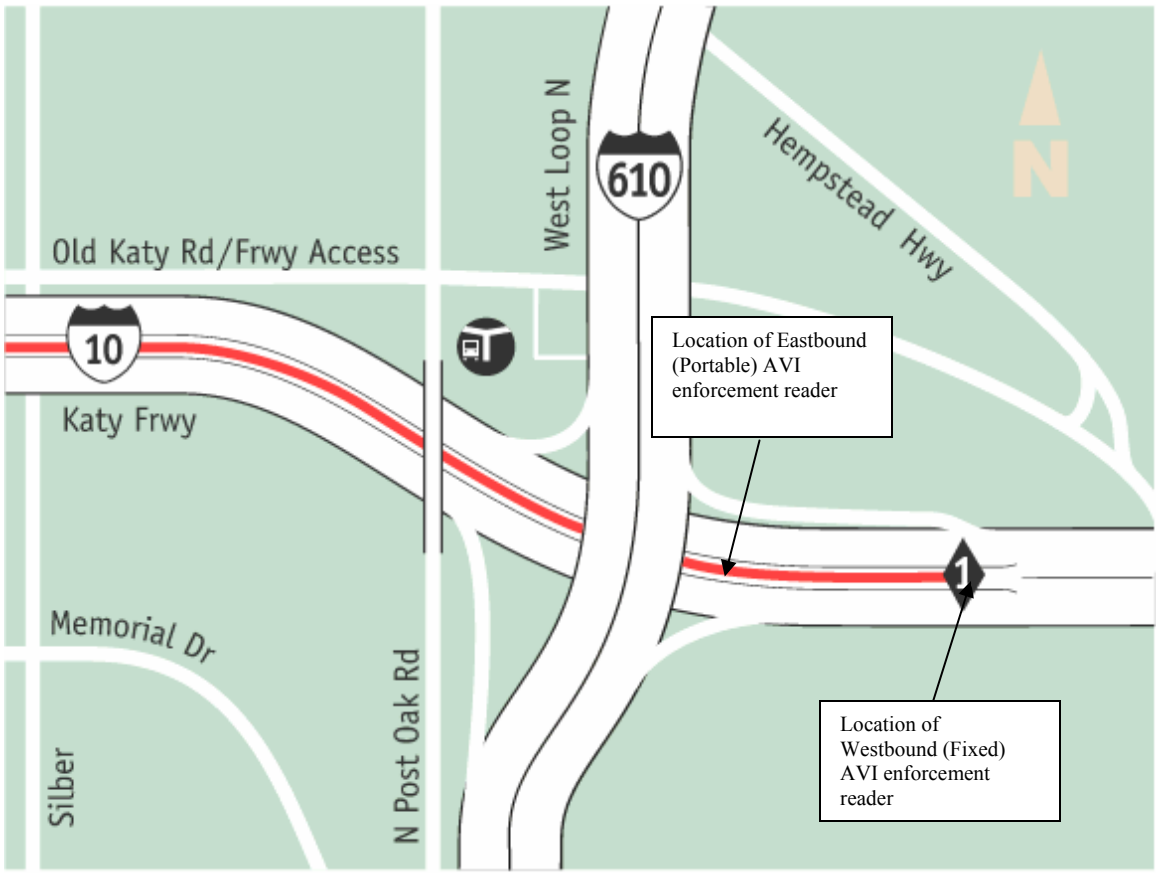


Figure 5. Site locations for AVI enforcement readers

FIELD TEST OF ENFORCEMENT READERS

In April 2004, the two AVI readers were installed at the Eastern Extension enforcement area on the Katy Freeway (I-10) to assist METRO officers in identifying valid QuickRide customers. The initial test date occurred Thursday, April 8th. With the installation of the AVI enforcement readers, the officer's task was simplified. First the officer looked for the number of occupants. For those vehicles with two occupants, the officer checked for a green light indication to confirm a valid QuickRide account. With two occupants and no green light, the officer assumed the driver to be a violator. A brief orientation with METRO officers took place before the PM QuickRide period, followed by a test from 5:00-6:00 PM. The test ran for 30 days.

SOV violators were issued citations. All other QuickRide violators were issued a warning for the first 30 days. Officers were provided with a pre-printed "warning card" to distribute to apparent violators. The warning card offered the following information:

- type of violation (e.g., not enrolled in QR, enrolled but apparent inoperable transponder, enrolled but using un-registered HCTRA EZ tag);
- procedure for remedying each specific type of violation (METRO phone number and website);

- description of QR program,
- graphic showing proper display of QR "permits;" and
- HOV lane hours of operation.

Copies of the official warnings issued by the officers were retained for the purpose of tracking repeat violators.

In addition to the technology, a "warning card" was developed for officers to hand out as an alternative to a finable citation during the first 30 days of the test period. The warning card provided information on the QuickRide program; hours of operations, transponder and occupancy requirements, and procedures for verifying enrollment should the driver actually have a transponder on board (e.g., dead transponder battery, HCTRA transponder not enrolled, expired credit card). After the 30-day trial period the officers began ticketing violators. During the months of April and May 2004, the enforcement area at the Eastern Extension on Katy was fully staffed with two to three officers daily during both peak periods.

The impacts of the technology features are reflected in the third data collection performed in late April 28 through April 30, 2004. The violation rate at the Eastern Extension enforcement area, where the test was conducted, dropped to 29% to 33%, while violation rates remained the same or higher at other locations. The violation rates, while improved, still did not reach the 10% to 15% target violation rate (see Tables 5 and 6).

Table 5. Katy Eastern Extension, AM QuickRide Period

Collection Date	HOV 3+	2 person				SOV			Bus	MC	Total Violator	Total Valid	Grand Total
		Pass Toll	No Pass Toll	Pass No Toll	No Pass No Toll	Police	Unmarked	Violator					
Feb 2003	494 23.0%	73 3.4%	46 2.1%	155 7.2%	876 40.9%	25 1.2%	57 2.7%	250 11.7%	136 6.3%	32 1.5%	1327 61.9%	817 38.1%	2144
Apr 2003	368 17.2%	90 4.2%	83 3.9%	188 8.8%	849 39.8%	23 1.1%	36 1.7%	319 14.9%	133 6.2%	46 2.2%	1439 67.4%	696 32.6%	2135
Oct 2003	501 30.1%	89 5.3%	37 2.2%	138 8.3%	486 29.2%	20 1.2%	46 2.8%	160 9.6%	118 7.1%	72 4.3%	821 49.3%	846 50.7%	1667
Apr 2004	736 38.5%	150 7.8%	21 1.1%	126 6.6%	445 23.2%	37 1.9%	144 7.5%	55 2.9%	133 6.9%	67 3.5%	647 33.8%	1267 66.2%	1914

Table 6. Katy Eastern Extension, PM QuickRide Period

Collection Date	HOV 3+	2 person				SOV			Bus	MC	Total Violator	Total Valid	Grand Total
		Pass Toll	No Pass Toll	Pass No Toll	No Pass No Toll	Police	Unmarked	Violator					
Feb 2003	458 25.3%	68 3.8%	57 3.2%	143 7.9%	725 40.1%	21 1.2%	56 3.1%	133 7.4%	119 6.6%	29 1.6%	1058 58.5%	751 41.5%	1809
Apr 2003	551 31.1%	94 5.3%	53 3.0%	133 7.5%	628 35.5%	9 0.5%	25 1.4%	124 7.0%	119 6.7%	35 2.0%	938 53.0%	833 47.0%	1771
Oct 2003	609 38.1%	80 5.0%	42 2.6%	97 6.1%	470 29.4%	19 1.2%	43 2.7%	61 3.8%	113 7.1%	64 4.0%	670 41.9%	928 58.1%	1598
Apr 2004	684 47.9%	98 6.9%	26 1.8%	69 4.8%	284 19.9%	19 1.3%	50 3.5%	32 2.2%	108 7.6%	58 4.1%	411 28.8%	1017 71.2%	1428

FEATURES OF NEW AVI VIOLATION ENFORCEMENT SYSTEMS

Each AVI Violation Enforcement System is designed to monitor HOV traffic and indicate the presence of a valid QuickRide transponder in vehicles using the HOV lane. The system includes the following components:

- An embedded Linux microcontroller handles all control functions of the system, including the comparison of incoming transponder IDs to a list of valid QuickRide IDs.
- A CDMA cellular modem provides encrypted wireless TCP/IP communications between the system and an off-site computer.
- An 802.11b (WiFi) access point is included for close-range encrypted TCP/IP wireless communications.
- A relay-activated high-visibility green LED signal provides visual confirmation when a valid QuickRide transponder is read by the system.
- A NEMA cabinet houses the AVI reader controller, RF modulator, microcontroller, and CDMA and WiFi communications hardware.

The AVI Violation Enforcement System has two different configurations. One configuration is designed for fixed installations on overhead gantry structures. The other configuration utilizes a mobile equipment trailer mounting with a telescoping boom for the AVI antenna. System power in both configurations is provided by lead acid batteries charged by photovoltaic panels.

GENERAL OPERATION

The AVI Violation Enforcement System performs transponder verification in the following sequence. The AVI controller captures transponder reads from oncoming vehicles. The transponder ID is passed to the microcontroller, which compares the ID to a list of valid QuickRide IDs stored in the microcontroller. If a match to a valid ID is found, the microcontroller activates the LED signal for an adjustable time interval via relay.

The list of valid QuickRide IDs stored on the microcontroller may be updated by uploading a text file containing the new list. Several methods are available for uploading updated lists. TCP/IP communications are provided through an Ethernet port as well as over CDMA encrypted wireless transmission; a USB port is also available for updating by USB keyfob.

The AVI violation enforcement system also logs received transponder IDs in nonvolatile memory, and is capable of transmitting these IDs via CDMA modem to off-site locations for

monitoring and data collection purposes. All CDMA wireless transmissions use encrypted Virtual Private Network (VPN) tunneling for data security.

Secure system access to the microcontroller is provided through Ethernet and CDMA wireless modem, and may be used to modify operational parameters of the AVI Violation Enforcement System.

The WiFi (802.11b) communications capability of the AVI Violation Enforcement System permits short-range (100 foot) secure communication with similarly enabled devices. This communication mode will be used primarily to upload the valid ID list from the system to handheld AVI enforcement readers, which are described in subsequent sections of this document.

SITING OF AVI VIOLATION ENFORCEMENT SYSTEMS

Four AVI Violation Enforcement Systems will be deployed along the Northwest (US 290) HOV lane. One of these systems will be configured for fixed installation, while the other three systems will be configured as portable trailer units.

Two AVI Violation Enforcement Systems will be located along the Dacoma entrance and exit ramps to the HOV lane on US 290. Figure 6 indicates the approximate deployment locations of these systems. The fixed configuration AVI system will be mounted to the gantry structure on one entrance ramp to the HOV lane at the Dacoma wishbone ramp. A trailer-mounted AVI enforcement system will be located beside one exit ramp and will be used for enforcement during the AM (eastbound) operation of the HOV lane, as indicated in Figure 7.

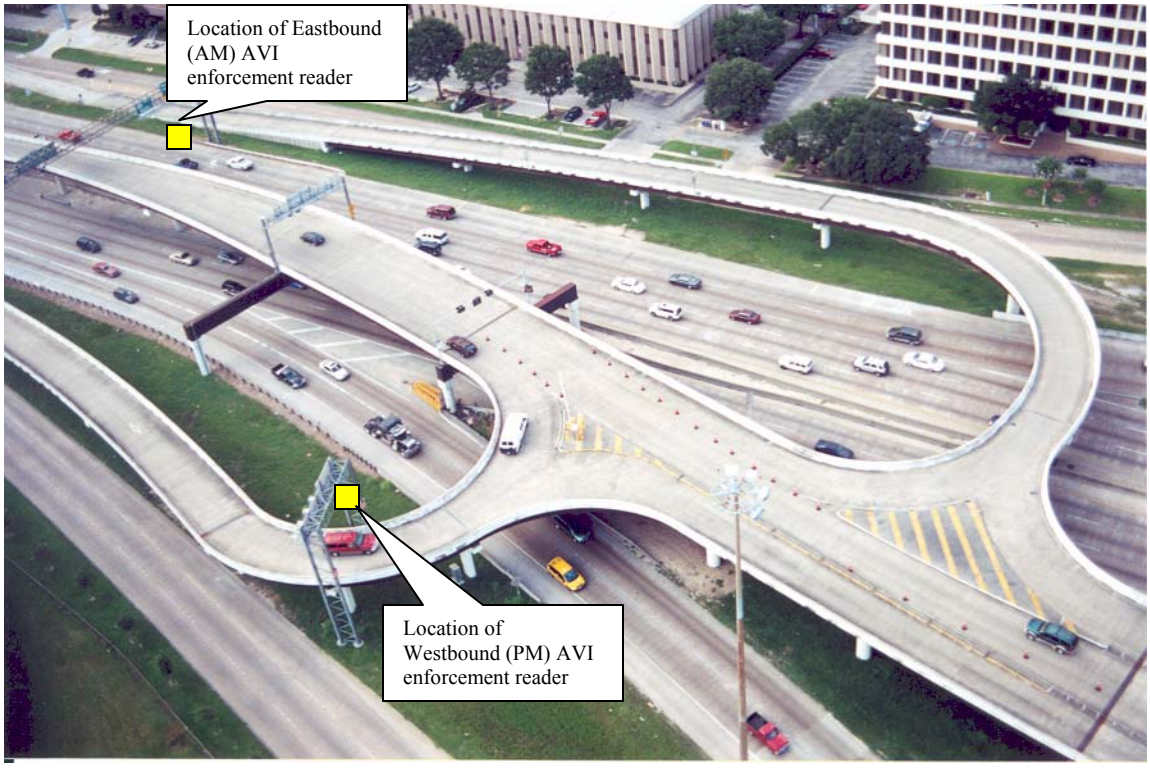


Figure 6. Aerial view of AVI Violation Enforcement locations at the Dacoma wishbone ramps along the US 290 HOV lane

Figure 7. Mobile AVI Violation Enforcement Unit US-290 HOV Lane – Dacoma Exit Ramp

Two trailer-mounted AVI Violation Enforcement Systems will be located along the Northwest Transit Center (NWTC) entrance and exit ramps to the HOV lane on US 290. Figure 8 indicates the approximate deployment locations of these systems. One trailer-mounted system will be located near the gate at the NWTC HOV ramp, as indicated in Figure 9. This AVI site will be used for violation enforcement during the AM (eastbound) operation of the HOV lane. Another trailer-mounted AVI enforcement system will be located along the PM approach to the ramp, as indicated toward the center of Figure 10.

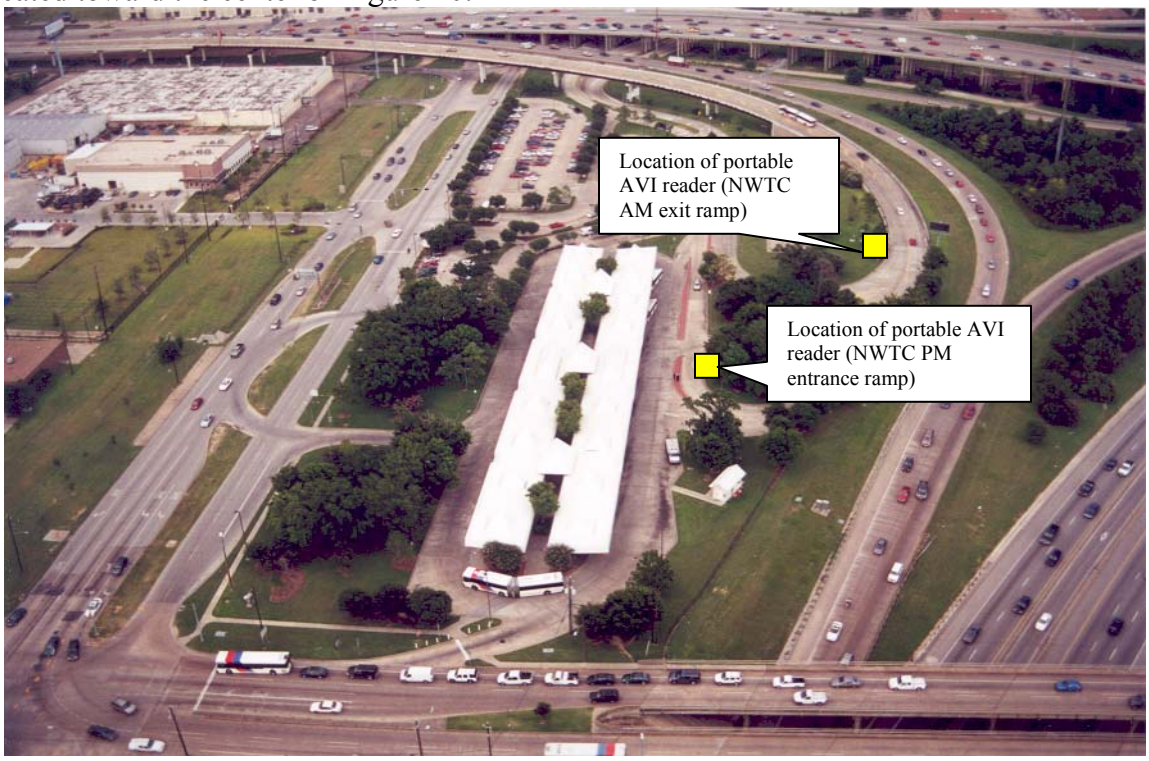


Figure 8. Aerial view of AVI Violation Enforcement locations at NWTC ramps along the US 290 HOV lane

Figure 9. Relocated Mobile AVI Violation Enforcement Unit Northwest Transit Center Exit Ramp

Figure 10. New Mobile AVI Violation Enforcement Unit Northwest Transit Center Entrance Ramp

HANDHELD AVI ENFORCEMENT READERS

In addition to the AVI violation enforcement systems, two handheld violation enforcement readers are being developed. These handhelds are intended to provide METRO enforcement officers with an additional means of verifying valid QuickRide transponders and identifying faulty transponders.

Features

- An Intermec Series 750 handheld computer running the PocketPC operating system handles all control functions, including the comparison of incoming transponder ID's to a stored, updateable list of valid QuickRide ID's.

- 802.11b (WiFi) capability is included for close-range encrypted TCP/IP wireless communications.

- The AVI reader is integrated into a pistol-grip cradle for the Intermec 750, yielding a rugged ergonomic design (see Figure 11).

- A charging cradle is included; this cradle also provides USB and network connectivity for the handheld. Lithium Ion rechargeable batteries furnish power for the handheld enforcement reader.

Figure 11. Intermec 750 with integrated AVI reader and pistol grip

OPERATION

The handheld AVI Violation Enforcement reader can read transponders over an approximate range of 3 feet, and is suitable for scanning vehicles which have been stopped in the enforcement area. The main end-user functions of the handheld enforcement reader are transponder verification and the updating of the valid QuickRide ID list stored on the Intermec 750 handheld computer:

- Transponder verification is performed when an enforcement officer places the handheld reader near a vehicle's transponder. The AVI reader in the handheld transmits the transponder ID to the Intermec 750, which will query the list of valid QuickRide ID's and present the officer with graphical results of the ID comparison on the large color display of the Intermec 750. The scanned transponder ID is shown on the screen over either a green (valid ID) or red (invalid ID) background, along with a short text message indicating the validity of the transponder. A malfunctioning or inactive transponder will display a blank red screen.

- Updates of the valid QuickRide transponder list will be performed via secure wireless communication with any of the AVI Violation Enforcement Systems; in the alternative, the USB and network connections in the charging cradle may be utilized for this purpose.

Message	**Meaning**
List Not Found	Download failed
Fetching Tag List	Download in progress
Tag List Downloaded	Download complete
No Tag Read	Tag was not read
Not Found	Tag is not on the tag list
Found	Tag is on the tag list

QR Screen Field Descriptions
Field Description Tag ID Tag ID number appears here after the read.
Tag Status Indicates tag status after the read.
(message field) Messages appear in this field. (See the QR Screen Messages table.) A progress field appears below this field while tag list downloads.
Handheld Date and time of the list currently loaded into the handheld reader.
Roadside Reader Date and time of the list currently loaded in the roadside reader.

1. Turn on the handheld reader and use the stylus to touch **Start>Programs>QR Verification** to launch the application.

2. Place the handheld reader within range of the wireless access point (WAP) device on the roadside reader. **(Note:** If the handheld reader is NOT in range, the **Download Tag List** button is disabled and the **Roadside Reader** field is blank.)

3. Use the stylus to touch the **Download Tag List** button. The most recent Tag List is downloaded to the handheld reader. In the **Tag List Date** section, the **Handheld** field updates to show the date and time of the list currently loaded on the handheld reader and the **Roadside Reader** field displays the date and time of the list currently on the roadside reader. **Note:** If the dates and times in the **Handheld** and **Roadside Reader** fields are NOT the same, perform another tag list download.

Verify a Trip Tag

1. Turn on the handheld reader and use the stylus to touch **Start>Programs>QR Verification** to launch the application.
2. Place the handheld reader within range of the Trip Tag (approximately 3 feet) and aim it directly at the tag.
3. Pull and release the handheld reader trigger. The reader beeps to indicate a tag read. The **Tag Status** field displays the status of the Trip Tag.

If the tag is not read by the reader:

1. Use the stylus or keypad to type the tag ID found on the Trip Tag.
2. Touch the **Verify** button. The **Tag Status** field displays the status of the Trip Tag.

APPENDIX F:
ADJUDICATION OF HOV CITATIONS

Leslie Stengele
Ginger Goodin
Casey Toycen

Description of data collection

TTI sought HOV citation and warning data from the agencies within the region that adjudicate HOV citations. These agencies include the following: City of Houston, Harris County, Fort Bend County, DPS, and City of Katy. METRO police issue the citations, but the citations are processed through the local entities, which also retain all of the associated fines. The vast majority of all HOV citations are adjudicated within the City of Houston, and the City of Houston was the only agency of those listed above that had a computerized process for sorting through records and assembling data on a large quantity of citations.

City of Houston Citation Data

The following list requested from the Houston City Clerk pertains to all tickets written within the two-year period beginning October 16, 2001, through October 14, 2003, and includes the categories of information within their database:

Column	Information
A.	Number (as printed on ticket) of HOV Citation
B.	Time of each citation
C.	Place of each citation
D.	Reason for Citation, as written by officer
E.	Court proceedings (Did this citation go to court?)
F.	Plea of each citation that appears in court
G.	Verdict of each citation
H.	Reason for verdict
I.	Fee of each citation
J.	Fee paid on time
K.	Current status of each citation (i.e., pending, dismissed, closed, etc.)

Figure 1 is a map showing the six HOV facilities in Houston. During the two-year period in which HOV citation data were collected, the six HOV facilities in Houston produced 10,807 citations. At the close of the two-year period, 45% (4,863) of citations assigned to the court docket went to court, 34% (3,708) were pending and only 21% (2,236) had paid the fine before their court date (Figure 2).

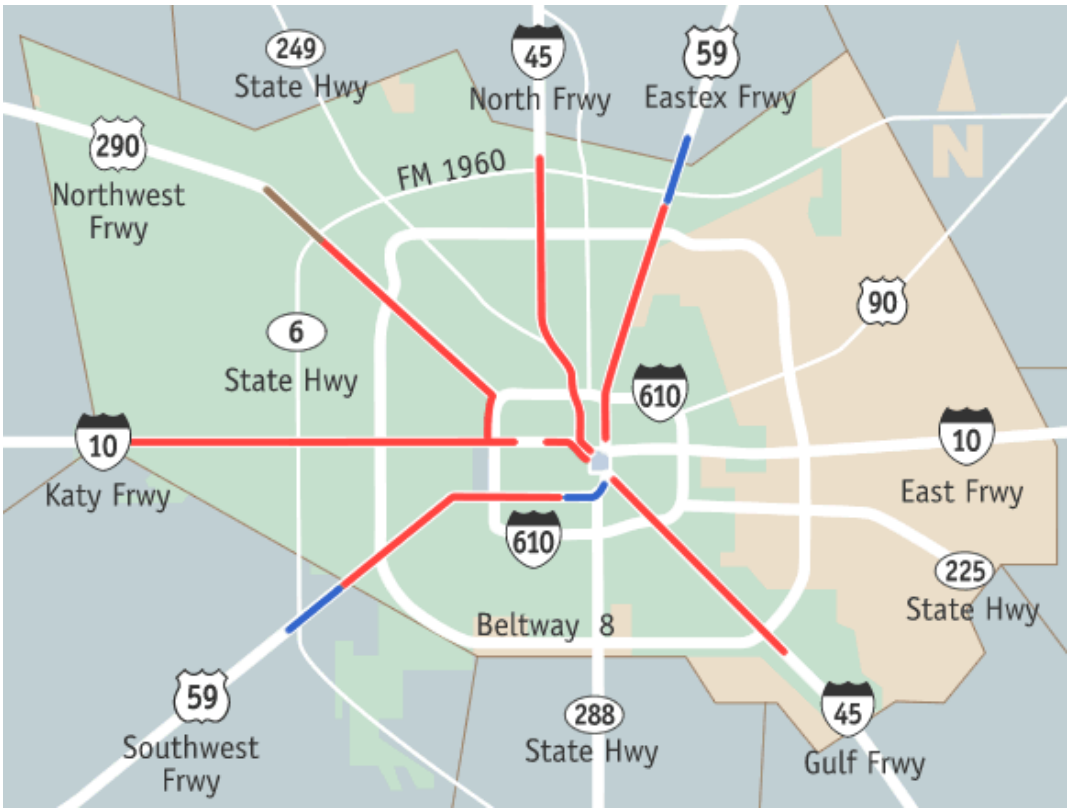


Figure 1. Houston HOV System

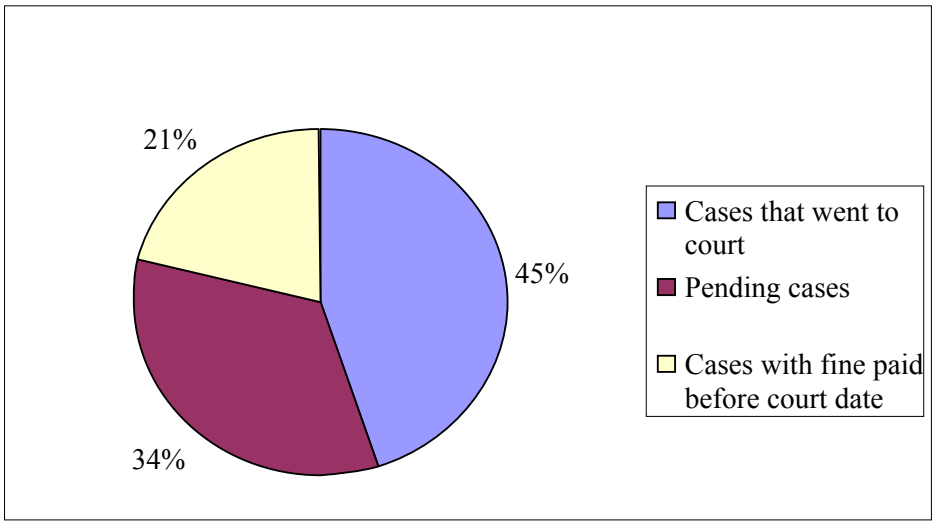


Figure 2. Composition of Citations Assigned to the Court Docket

The following section describes findings associated with an analysis of the data.

Citation Dismissals

Of the 4,863 citations that went to court, 3,158 cases were dismissed compared to only 1,705 that went through and received a verdict (Figure 3).

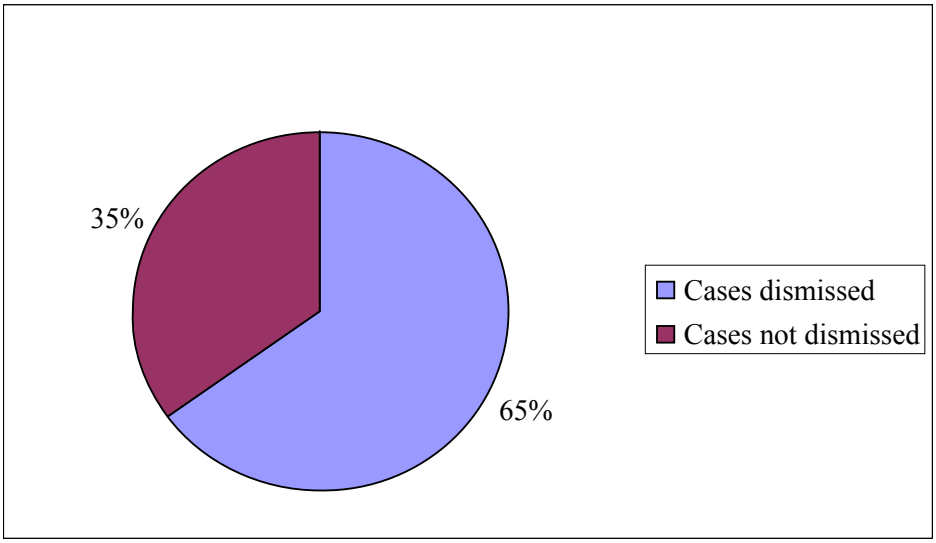


Figure 3. Composition of Cases That Reached Full Court Hearing

The reasons for citation dismissal are presented in Table 1. The reason for dismissal listed in the vast majority (70%) of the cases was "officer not present," meaning the officer did not appear in court for the trial. According to METRO, the primary reason for officers not appearing in court is that cases are scheduled during peak HOV operating hours in the morning. Anecdotal evidence indicates that defendants frequently request repeated continuances in the hopes that at some point the officer will not appear in court.

Table 1. Reasons for Citation Dismissal

Dismissal Reason	Quantity	Percentage
Officer Not Present	2,213	70%
Driving Safety Course	695	22%

Deferred Disposition	10 1	3%
Officer Present – Not Ready	35	1%
Insufficient Evidence	35	1%
Defective Complaint	26	< 1%
Nolle Prosequi (not prosecuted)	26	< 1%
Absolute Defense	12	< 1%
Civilian Witness Absent	7	< 1%
Defective Ticket Information	5	< 1%
Post Compliance with Fee	2	< 1%
Post Compliance without Fee	1	< 1%
Total	**3,158**	**100 %**

Results of Court Cases Involving HOV Citations

Table 2 highlights the number of pleas by category for court cases that were heard. In 62% of the 1,705 citations that went through trial, the defendants plead no contest. Only 2% - 30 cases–the plea entered was "not guilty."

Table 2. Plea by Those Attending Court Case (Not Dismissed)

Case Plea	Quantity	Percentage
No Contest	1,058	62%
Guilty	617	36%
Not Guilty	30	2%
Total	**1,705**	**100%**

1675 cases 98% of pleas are guilty or no contest

Table 3 shows the resolution of the court cases. In a large majority of the cases that went to court, the defendants were found guilty.

Table 3. Verdict of Court Cases

Case Verdict	Quantity	Percentage
Guilty	1,635	96%
CPF Commitment	49	3%
Not Guilty	8	< 1%
Judgment Removed	5	< 1%
Guilty by Jury	1	< 1%
Unknown	7	< 1%

Total	**1,705**	**100%**

The average fine paid due to court requirements was $116.86 compared to $123.43 for those 2,236 fines paid before the court date. A total of 202 cases never had to pay a fine. Of those 202 cases 83 had a guilty verdict.

27 violators who were found guilty opted for doing community service in lieu of paying a fine. There were 3 cases in which no fine was paid before the court date and did not appear in court.

Citations by Freeway

The following section dissects citations by HOV facilities. The 10,807 citations assigned to the court docket are divided into Houston's six HOV facilities (Table 4). A large majority, 68%, of citations occurred on Katy Freeway, even though the HOV facilities are similar in length. Figure 4 represents a graphical explanation of the citation location.

Table 4. Citation Location by HOV Freeway

Location	Quantity	Percentage
Katy Freeway	7,334	68%
Northwest Freeway	962	9%
North Freeway	670	6%
Southwest Freeway	623	6%
Gulf Freeway	461	4%
Eastex Freeway	27	< 1%
Unknown	730	7%
Total	**10,807**	**100%**

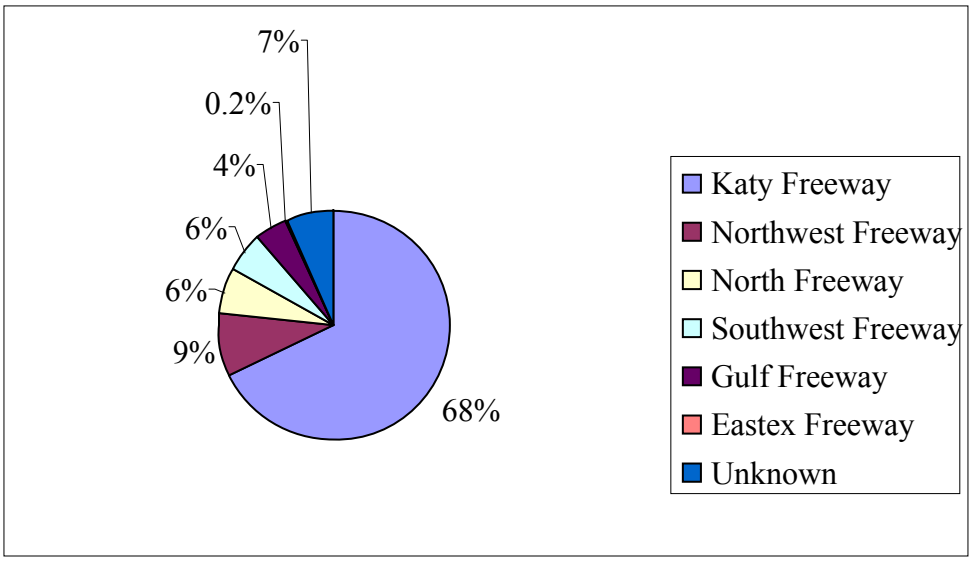


Figure 4. Citations Issued by Freeway

Katy Freeway Citations

Violations on the Katy Freeway mostly occurred during QuickRide hours, 6:45 am to 8:00 am and 5:00 pm to 6:00 pm. Of the 4,870 citations that occurred during those time periods 3,530 went to court while 1,340 cases were still pending. Figure 5 shows the percentage of cases that went to court and those cases that got dismissed.

Northwest Freeway Citations

The Northwest Freeway had the second highest amount of incidents with 962 violations with 71% of those happening during QuickRide hours from 6:45 am to 8:00 pm. Of the 583 cases that went to court, 239 were dismissed leaving 344 cases that were not dismissed. Figure 6 represents percentage of cases that were not dismissed and were dismissed.

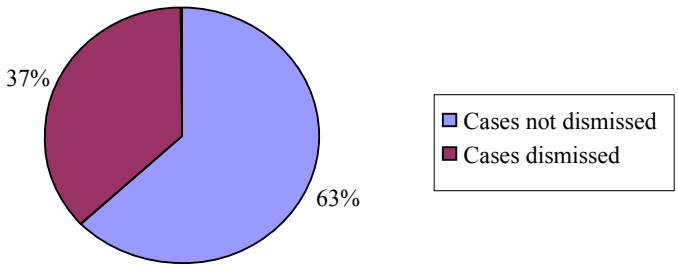


Figure 5. QuickRide Cases That Went to Court on Katy Freeway

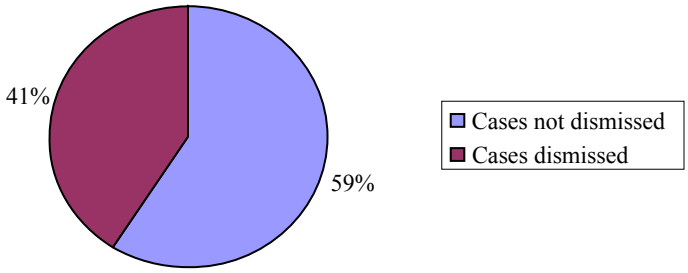


Figure 6. QuickRide Cases That Went to Court on Northwest Freeway

Harris County

Each of the 16 Justice of the Peace (JP) courts in Harris County is responsible for all citations that are processed in their court. There is no central organization responsible for the entirety of Harris County. To retrieve records of the HOV citations, each Justice of the Peace Office would have to be contacted separately. Each office acts independently so its management of records is done differently. Upon contacting the traffic clerk in each JP office, the following was determined:

- 12 of the 16 precincts receive very few to no HOV citations. They either have a small amount of HOV lanes in their precinct, or they are located within the city limits of Houston.

- 3 additional precincts believe they have received some tickets either in the past or currently. (Only one office received a substantial number of tickets for a short period during a HOV striping change.) This is still a relatively small number of citations.

- 1 precinct has a few HOV citations. However, a case number or last name is required to obtain additional information.

- The Justice of the Peace offices in Fort Bend and Waller counties were contacted as well. All of the offices said they did not receive HOV citations. One Fort Bend County JP office indicated that Sugar Land Police Department might have records of HOV citations. In contacting them, this is also not the case.

These courts receive a small number of tickets compared to the City of Houston.

APPENDIX G:
EXAMINATION OF NEWLY INSTALLED ANTENNAS

Mark Burris and Justin Winn
Houston Value Pricing Project, January 2004

PURPOSE

The purpose of this analysis was to determine the difference in performance after replacing certain automatic vehicle identification antennas on the Katy (I-10) Freeway and the Northwest (US 290) Freeway HOT lanes in Houston. The antennas connected to readers 39 and 46 (located just northwest of the Pinemont exit on the Northwest Freeway) were replaced on Sunday, October 12, 2003. The antennas connected to readers 15 and 18 (located between the Gessner and Post Oak exits on the Katy Freeway) were replaced on Tuesday, October 14, 2003. The existing Transcore AA3100 Yagi Antennas were replaced with Transcore AA3152 Universal Toll Antennas. The total replacement cost was $10,318.00.

DATA COMPARISON

In an effort to determine changes in performance due to the new antennas, data from the replaced antennas were (1) compared to data from nearby antennas and (2) compared to data from the same location prior to the installation of the new antennas. On the Katy Freeway, readers 15 and 18 were compared to readers 14 and 19, respectively (see Figure 1). On the Northwest Freeway, readers 39 and 46 were compared to readers 40 and 45, respectively (see Figure 2). The total number of daily reads during the peak period (6:30-8:15 in the morning and 4:45-6:15 in the evening) was collected for both the week prior to installation (Oct. 6 – Oct. 10) and the week following installation (Oct. 20 – Oct. 24). The total of number of daily reads was then averaged for the entire week. The zero values that occurred on readers 14 and 19 were removed when determining the averages.

RESULTS

I-10 Katy Freeway

The resulting data can be seen in Tables 1 and 2. Unfortunately, the data does not provide definitive results. First, the reads on antennas 15 and 18 (which were both replaced) were compared before and after replacement (see Figure 1). They both showed a small increase in average reads during the week following replacement. This may provide an indication that the antennas are capturing additional reads or there were simply more vehicles on the road with transponders. Additionally, the percentage increase was only 1.2% on antenna 15 and 4.4% on antenna 18.

Next, the reads collected on the antennas were compared to those collected by nearby antennas that were not replaced. In this case, antenna 18 was compared to antenna 19, while antenna 15 was compared to antenna 14. When compared to antennas 14 and 19, new antennas 15 and 18 have a greater number of average reads in both the week before replacement and the week after. Therefore, no relative improvement was evident. The difference in the number of reads between antennas 18 and 19 is unusual, because there are no exit points on the HOV lane between the locations of these antennas. Therefore, the number of reads should be equal for these two. However, it has been reported that antennas 14 and 19 are connected to the same reader, which has not been performing consistently.

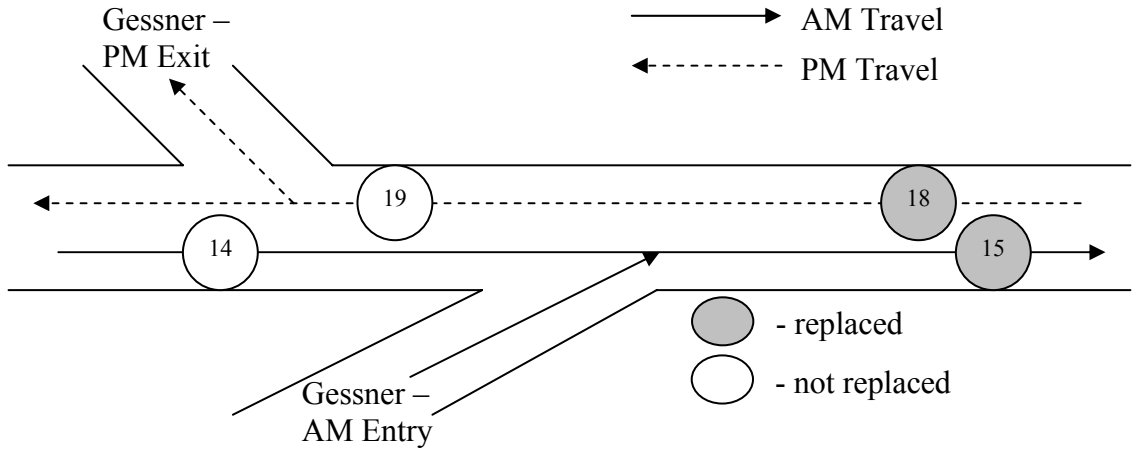


Figure 1. Readers on Katy Freeway

Table 1. Data Collected before Antenna Installation – Katy Freeway Comparison

Antenna	Oct. 6	Oct. 7	Oct. 8	Oct. 9	Oct. 10	Average
15	682	761	660	673	608	677
14	538	573	547	0	0	553
18	516	522	491	388	472	478
19	563	84	487	0	475	402

*shading indicates an antenna that was replaced

Table 2. Data Collected after Antenna Installation – Katy Freeway Comparison

Antenna	Oct. 20	Oct. 21	Oct. 22	Oct. 23	Oct. 24	Average
15	688	698	707	714	616	685
14	544	489	615	571	424	529
18	500	497	520	476	502	499
19	514	486	509	421	499	486

*shading indicates an antenna that was replaced

I-10 Katy Freeway – Extended Data

An additional comparison was done for antennas 18 and 19 using more data from before and after the antenna installation. In this comparison, data was used from the three weeks before and three weeks after installation, excluding weekends. The data from these thirty days and their averages can be seen in Tables 3 and 4. Using this larger set of data, it was

Table 3. Extended Data: Antennas 18 and 19 before Installation

Date	Antenna 18	Antenna 19
9/22	516	529
9/23	512	0
9/24	578	590
9/25	546	521
9/26	512	0
9/29	547	582
9/30	548	562
10/1	558	295
10/2	570	551
10/3	547	292
10/6	516	563
10/7	522	84
10/8	491	487
10/9	388	0
10/10	472	475
AVERAGE	**522**	**461**

Table 4. Extended Data: Antennas 18 and 19 after Installation

Date	Reader 18	Reader 19
10/20	500	514
10/21	497	486
10/22	520	509
10/23	476	421
10/24	502	499
10/27	531	521
10/28	586	543
10/29	587	524
10/30	527	513
10/31	489	514
11/3	464	457
11/4	502	0
11/5	506	562
11/6	461	527
11/7	538	562
AVERAGE	**512**	**511**

found that the average number of reads on antenna 18 decreased by 1.9% after the installation of the new antenna while the number of reads on antenna 19 increased by 10.8%. This could

indicate a decreased reading success rate, or simply a smaller number of vehicles with transponders. Additionally, the difference in reads on antenna 19 is possibly explained by the unreliability of the reader performance. When comparing antennas 18 and 19, it was found that the difference in the number of reads collected by each was 11.7% before installation and dropped to just 0.2% after installation.

Another potential factor influencing the number of recorded tag reads is the reader's ability to dial into the modem bank and download its data. If the modem bank is busy then the data cannot be transmitted. If this happens too many times in a row the storage capacity of the reader can be exceeded and data is lost.

US 290 Northwest Freeway

A similar investigation was performed on the new antennas installed on the Northwest Freeway (see Figure 2). The resulting data can be seen in Tables 5 and 6. Similar to the Katy Freeway scenario, this data did not provide definitive results. First, the change in number of transponder reads on antennas 39 and 46 (both of which were replaced) after installation was calculated. There was a decrease in the average number of daily reads at both antennas after they were replaced. The number of reads on antenna 39 decreased by 30.3%, and the number of reads on antenna 46 decreased by 7.7%. This could indicate a reduced ability to identify transponders or simply fewer vehicles with transponders on the lanes.

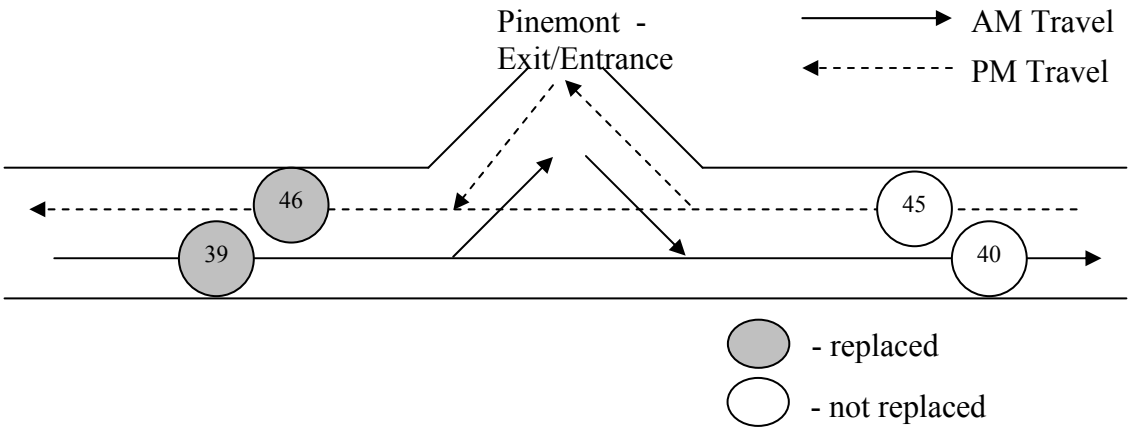


Figure 2. Readers on Northwest Freeway

These antennas also had a larger number of average reads than their comparison antennas (40 and 45). In this case, antenna 39 was compared to antenna 40, while antenna 46 was compared to antenna 45. However, unlike the situation at antennas 18 and 19, these pairs of readers have an HOV lane entry/exit point located between them. Antennas 39 and 46 are located just northwest of the Pinemont Park & Ride location, while antennas 40 and 45 are located southeast of it. Based on typical traffic flows, the number of reads on antenna 39 should exceed those at

40. Also, the number of reads on antenna 45 should be nearly the same (but not exactly the same) as the number of reads at antenna 46.

Table 5. Data Collected before Installation – Northwest Freeway Comparison

Antenna	Oct. 6	Oct. 7	Oct. 8	Oct. 9	Oct. 10	Average
39	203	215	232	265	191	221
40	211	174	171	198	232	197
46	194	211	200	218	218	208
45	70	64	88	38	57	63

*shading indicates an antenna that was replaced

Table 6. Data Collected after Installation – Northwest Freeway Comparison

Antenna	Oct. 20	Oct. 21	Oct. 22	Oct. 23	Oct. 24	Average
39	150	175	151	180	115	154
40	169	168	153	108	135	147
46	186	229	198	186	159	192
45	81	106	127	165	26	101

*shading indicates an antenna that was replaced

SUGGESTIONS FOR ADDITIONAL ANALYSIS

Unfortunately, the data collected does not accurately provide a definitive answer to whether or not the new antennas are more accurate than the old ones. One possible cause of this is the time period that was analyzed. Each data point represents the number of reads made by the antenna during the QuickRide period. It is possible that the reader or antenna may have random down times during this time. For instance, antennas 18 and 19 should have exactly the same number of reads. However, the data shows that they do not. Perhaps by using a smaller time segment, the two antennas can more accurately be compared. It may be possible to analyze the data in 15-minute segments, but the distance between the two antennas would likely become a factor. Alternatively, obtaining the number of reads for the entire day might provide sufficient information.

The antennas on the Northwest Freeway present another problem as there are no antennas that should provide the exact same reads as the new antennas. Antennas 39 and 46 are mounted on the same gantry just northwest of the Pinemont Park & Ride entrance/exit. Unfortunately, there is not another pair of antennas (upstream or downstream) between antennas 39/46 and an entry/exit point. Therefore, it would be very difficult to gather accurate data from the readers to compare antennas. One possible solution is to connect both the new and old antennas to the same reader. However, this may prove too expensive.

The next step would likely be an in-depth analysis of transponder reads on both the mainlanes and the HOV lane to try to determine if the new antennas are better tuned to focus on the HOV lane only. Additionally, the possible loss of data due to communication failure (busy modem banks) should be examined.