AN EXAMINATION OF FACTORS AFFECTING HIGH OCCUPANCY/TOLL LANE DEMAND

A Thesis

by

JUSTICE APPIAH

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2004

Major Subject: Civil Engineering

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ABSTRACT

An Examination of Factors Affecting High Occupancy/Toll Lane Demand.

(August 2004)

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Chair of Advisory Committee: Dr. Mark W. Burris

In recent years, high occupancy/toll (HOT) lanes have gained increasing recognition as a potential method of managing traffic congestion. HOT lanes combine pricing and vehicle occupancy restrictions to optimize the demand for high occupancy vehicle (HOV) lanes. Besides having all the advantages of traditional HOV lanes, HOT lanes can also generate revenue to help finance various operation and maintenance programs. At present there are four fairly well established HOT lane projects in the United States: two in Houston, Texas, and one each in San Diego, and Riverside County, California. After 6 years in operation, Houston's HOT lanes receive comparatively lower patronage than the two California projects. An understanding of why people choose to use HOT lanes will be vital to improving the performance of existing HOT facilities and will also shed light on policy decisions regarding future HOT lane investments. This study examined the relative importance of different parameters which could be expected to influence the demand for HOT lanes using standard statistical and discrete choice modeling techniques on survey data from Houston's HOT lane users.

The study showed that, controlling for other variables, trip length, the driver's perception of travel time savings offered by the HOT lanes, frequency of travel in the freeway corridor, trip purpose, and the amount of time spent on carpool formation were good predictors of HOT lane usage. Socioeconomic characteristics such as age and level of education were also good indicators of the frequency of HOT lane usage whereas household size, occupation, and hourly wage rate were not. Gender and annual household income were only loosely related to HOT lane usage. Inelastic responses to minor changes in the toll coupled by responses to a question regarding participants feeling towards the $2.00 toll, suggested that the toll was not a major deterrent to HOT lane usage. A primary deterrent was the need for one passenger to use the HOT lane when free use required two passengers. However, travelers who shared the toll with their carpool partners were likely to have made more frequent HOT lane trips than those who bore the entire cost.

DEDICATION

To the memory of my teacher and mentor Ms. Faustina Mensah

ACKNOWLEDGMENTS

I would like to thank my advisor, Dr. Mark Burris for his guidance and support during my studies at Texas A&M University. I will always remember his willingness to see to my welfare as well as those of his other students.

I would also like to thank Dr. Rilett and Dr. Zhang for their willingness to share their insights with me.

I would like to thank the Texas Transportation Institute for providing me the resources to undertake this study.

To Karun, and all my fellow students who helped in diverse ways, I say – thank you.

Above all, I would like to thank the Good Lord for his guidance and protection.

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1 INTRODUCTION

1.1 Background

The success of Orange County's express lanes and other value-pricing projects has engendered great interest among researchers and policy makers in the application of high occupancy toll (HOT) lanes as an alternative to high occupancy vehicle lanes for managing traffic congestion. It is also seen as having the added benefit of raising revenue to help finance traffic operation and road maintenance activities. 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 with the HOV lane concept. One issue that has been a source of concern to some members of the public, policy makers, and researchers 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 (*1*). For example, in November 1998, Gov. Christine Whitman of New Jersey announced the elimination of two HOV lanes on Routes I-287 and I-80 on the grounds that the HOV lanes failed three nationally recognized criteria – their ability to encourage carpooling, their ability to reduce or at least not increase congestion, and their ability to meet a minimum usage threshold (*Samuel, as stated in (1)*). There have also been expressions of misgivings in other areas such as the Twin Cities, Minnesota; Long Island, New York and the Hampton area in Virginia (*2*).

HOT lanes attempt to optimize the use of HOV lanes by combining pricing

This thesis follows the style and format of the *Transportation Research Record*.

strategies and occupancy restrictions to manage the number of vehicles using the facility. The lanes typically provide free or reduced-cost access to qualifying high occupancy vehicles (HOVs) and allow other vehicles that do not meet occupancy levels required for free travel on the HOV, the option of paying a toll to gain access to the HOV lanes (*3*).

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 such as an HOV lane (*4*). In the case of HOV facilities, drivers can choose between driving in the slow-moving main freeway lanes and the free-flowing HOV lanes. Drivers who travel in the main lanes can travel for free whereas those who wish to travel in the HOV lanes but do not meet the vehicle occupancy levels required for free travel have to pay a fee for the premium service. Thus HOT lanes improve travel options, provide reliable travel times, generate some revenue, and increase the overall efficiency of HOV facilities (*3*).

At present, there are four HOT lane facilities operating in the world all of which are in the United States (*5*). These include:

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

The SR 91 Express Lanes opened in 1995 as the first practical application of the concept of value-pricing to a roadway facility in the United States (*6*). This was followed by the I-15 FasTrak in 1996, Katy Freeway QuickRide in 1998, and the Northwest Freeway QuickRide in 2000. In view of the success of the four established

HOT projects numerous state departments of transportation are exploring the possibility of implementing HOT operations on their HOV lanes. Most of these projects have been funded but have not started operations (*7*).

Before implementing any HOT lane project, it is important to assess the potential demand for the facility and to identify and quantify factors expected to influence this demand. The four established projects in the United States provide some insight into identifying factors expected to influence the potential demand for proposed HOT projects. A primary factor is the vehicle occupancy requirements. Whereas single occupancy vehicles (SOVs) can use the HOT lanes in California for a fee, SOVs are never allowed to use Houston's HOT lanes. This could be one of many factors responsible for the relatively low patronage of Houston's HOT lanes compared to the HOT lanes in California where there is a high demand for HOT lane use by single occupant vehicles (*4*). Other factors such as characteristics of the trip maker (for example age, gender, individual attitudes and perceptions), characteristics of the trip (for example, trip purpose, trip length), and characteristics of the available alternatives are also expected to play important roles in HOT lane usage. An understanding of these factors will shed light on policy decisions such as predicting the chances of success or failure of potential projects, identifying localities with the highest probabilities of success, determining optimal toll levels and pricing strategies, and identifying appropriate strategies for dealing with equity concerns.

This research focuses on identifying factors expected to influence the demand for HOT lanes using data primarily from a survey of Houston's QuickRide enrollees conducted in March 2003.

1.2 Problem Statement

After over 6 years in operation (over 3 years on Northwest Freeway), the Houston QuickRide program receives low patronage when compared to the two California projects where there is a high demand for HOT lane use by single-occupant vehicles (*4*). In fact, demand for QuickRide is well below the targeted demand of 600 vehicles per peak hour. Thus one of the main objectives of converting HOV lanes into HOT use, to optimize usage of the existing infrastructure, is not entirely fulfilled. These projects provide important sources of data on HOT lane usage to help ensure future HOT lanes operate at the level of efficiency for which they were designed.

Building from the findings of Stockton *et al.* (*4*), recent analysis of QuickRide usage (*8, 9, 10*), data from a recent survey of both former and current QuickRide enrollees (11, *12*), and a review of literature on the two California projects (*3*, *6, 13, 14, 15, 16, 17*) this research explores the factors that underlie drivers' decision to use HOT lanes. The research hypothesizes that the inconveniences (disutilities) of forming a carpool, such as the lack of common origin-destination combinations, the need for advanced arrangements, and long carpool formation times, will be better determinants of the level of patronage of the Houston HOT lanes than the dollar value of the toll. A comprehensive study of Houston's HOT users' travel behavior that incorporates major issues such as the value of travel time of different groups of enrollees, their disutilities for carpooling, and analysis of toll price elasticities were undertaken. Standard statistical and disaggregate modeling techniques were used to test the above hypothesis.

1.3 Research Objectives

The goal of this research was to explore the reasons behind drivers' decision to use HOT lanes and to recommend strategies to improve the overall efficiency of these lanes. The specific objectives were:

- Determine socio-economic and commute characteristics of Houston's HOT lane users,
- Examine, both qualitatively and quantitatively, factors influencing the use of the Houston HOT lanes,
- Determine value of time of various groups of Houston HOT lane users,
- Test the hypothesis that the inconveniences (disutilities) of forming a carpool will be better determinants of the level of patronage of the Houston HOT lanes than the dollar value of the toll.

1.4 Organization

The thesis is organized into five sections. Section 1 provides background information on the concept of HOT lanes, states the problem, and defines the objectives of the research.

Section 2 reviews the available literature on HOT lanes. The section consists of an overview of traffic congestion in the United States and discusses the merits and demerits of some of the techniques used for congestion mitigation with particular emphasis on HOT lanes and the factors expected to influence demand for HOT lanes. Section 3 describes the study site and the methods used for data collection and analysis. The results are discussed in section 4. The section begins with a general overview of socioeconomic and travel characteristics of survey respondents, examines factors that influence the level of QuickRide usage among respondents, and develops an ordered logit model to relate the frequency of QuickRide usage to respondents socioeconomic and commute characteristics. This is followed by a discussion of the impact of occupancy requirements and time of day of travel on the choice between HOT lanes and main freeway lanes. The section also examines how the various factors influence QuickRide usage among three groups of survey respondents. Section 4 ends with a summary of the key findings of the research. Section 5 documents the conclusions of the research and provides suggestions for future research.

2 LITERATURE REVIEW

2.1 Traffic Congestion

Over the last few decades, the demand for travel has increased consistently as a result of increasing urbanization and increased economic activity. The Texas Transportation Institute's (TTI) urban mobility report provides some insight into the level of travel on the nation's roads between 1982 and 2001 (*18*). According to this report, passenger-miles of travel has increased by over 91 percent on freeways and major streets in the 75 urban areas studied. An even higher increase in travel (about 100 percent) occurred on the transit systems during the same period (*18*). However, in 70 out of the 75 areas documented in the 2003 urban mobility study, the provision of infrastructure had not matched this increase in travel demand (*18*). Consequently, the demand for use of sections of the road network often exceeds the supply of road space within the section, resulting in congested conditions. Congestion usually occurs within the urban road network, especially during the morning and evening rush hours and is costly and damaging to growth, environment, convenience and public safety (*19*). For example, in the year 2001, congestion resulted in 3.5 billion hours of delay and 5.7 billion gallons of excess fuel consumption in the 75 urban areas studied by TTI (*18*). This translates to a $69.5 billion 'total congestion bill'. For travelers in these 75 urban areas studied, average annual delay experienced per peak road traveler increased from 7 hours in 1982 to 26 hours in 2001 (*18*).

2.2 Managing Congestion

Congestion mitigation efforts are geared towards creating a better balance between the demand for road space and the supply of infrastructure so as to ensure more efficient utilization of existing road networks and to provide more capacity when and where it is most needed. Ramp metering, improved traffic signal timing and coordination would lead to better traffic operations. These can be further enhanced by information technology and intelligent transportation systems.

It is also possible to modify traveler behavior and manage congestion by adopting strategies to efficiently manage demand for travel. Travel demand management techniques, such as managed lanes, are designed to provide "unimpeded, high-speed, efficient person/vehicle throughput on some sections of the freeway or arterial during periods when the remainder of the freeway or arterial road is congested" (*20*). Managed lanes employ three main techniques in managing or mitigating traffic congestion. These are:

(1) Allowing only limited or controlled access to the managed lanes – this is usually accomplished by limiting the number of entry ramps and monitoring the location of on-ramps as well as the level of traffic demand at each access point (through ramp metering). Access management dates back to the introduction of the first interstate highways and "relies on the notion that by limiting access to a facility, the flow and throughput of the facility can be controlled and maintained at a high level of service" (*20*).

(2) Imposing restrictions on vehicle eligibility requirements – this includes "high occupancy vehicle (HOV) lanes, truck lanes, transit-only lanes, busways, and authorized vehicle (or permit) programs" (*20*). These facilities have been implemented in most major urban cities in the United States where the demand for travel exceeds the supply of road space but the option to expand general-purpose roadway capacity through new roadway construction may be limited. They may increase vehicle throughput in a travel corridor by separating slow-moving traffic from fast-moving traffic (for example, truck lanes) or by encouraging drivers to shift from driving alone to driving in carpools or transit thus allowing more people to travel in fewer vehicles through congested portions of the corridor.

(3) Charging a fee for the use of the facilities – this involves charging a toll for the use of a managed lane. The toll is directly related to the amount of congestion or delay a driver causes other motorists when using the road and may be fixed or varied by time of day or level of congestion. The basic objective is to encourage motorists to switch modes, such as to transit and carpools, or change time of day, route, or frequency of travel to the benefit of the overall efficiency of the system. Even though pricing strategies might provide some revenue to finance project costs, this is usually not a primary objective.

Improvements in less popular options like telecommuting, walking and biking (clearly marked bicycle lanes and pedestrian walkways) can also be effective supplements to the methods discussed above provided implementation efforts are backed by adequate funding and public education.

2.2.1 Building New Roads

Because congestion is partially a capacity problem, a remedial option that readily comes to mind is the addition of capacity through new roadway construction. However by the time congestion is a problem, the adjacent land has often been developed and there could be significant practical and political problems with acquisition of right-of-way. Thus new road building is no longer practicable in many urban areas except at unacceptable levels of financial and environmental costs (*19*). Moreover, experience has shown that traffic growth tends to accelerate when additional capacity is added through infrastructure expansion. For instance, panel data regression on 30 counties conducted by *Hansen et al*. between 1973 and 1990 showed that every 10 percent increase in lane-miles to existing highway generated a 9 percent increase in vehicle miles of travel beyond what can be attributed to other factors (*Hansen et al., as stated in (1)*).

A more pragmatic approach to the problem would be an efficient management of the system so as to derive maximum use of the available road space. A number of options such as actions to reduce vehicle use in congested areas, actions to improve mass transportation, and actions to improve internal transit management efficiency have been used either solely or in combination to ensure effective use of existing road space (*21*).

2.2.2 Improving Traffic Operations

Improving traffic operations through ramp metering, signal coordination, and appropriate incident management strategies could lead to smoother traffic flow and hence reduce congestion. "Ramp meters are modified traffic signals placed on the entrance ramps of urban freeways" (*22*). They are used to smooth-out the flow of vehicles entering the freeway (from adjacent ramps) and thus make it possible to maintain relatively high speeds on the freeway even during periods of high traffic demand. According to Schrank and Lomax, 2003 "ramp meters will not eliminate congestion in most cases, but may delay stop-and-go conditions for 15 to 30 minutes" (*22*).

Proper signal timing plans and coordination allows vehicles to travel more quickly with less chance of having to stop at every intersection, especially in the peak direction. General traffic operations can also be enhanced by instituting measures that could quickly detect and remove incidents (crashes and vehicle breakdowns) and return traffic flow to normal levels. In volume 2 of their 2003 urban mobility report, Schrank and Lomax showed that incident management strategies reduced freeway delay by about 5 percent in 56 urban areas, ramp metering reduced freeway delay by 4 percent in 26 areas, while signal coordination reduced delay by only 1.5 percent in the 75 areas studied.

2.2.3 Carpooling

A 1993 publication by Comsis Corporation defines carpooling as "the sharing of rides in a private vehicle among two or more individuals" (*23*). According to this publication, carpool programs had been in existence at large employers before World War II. However, the 1973 oil crisis prompted many public agencies and non-profit organizations to create area-wide programs via road signs, media campaigns, and employer outreach programs. After the 1979 oil crisis, Federal sponsors of rideshare programs modified carpooling efforts in urban areas to focus on employers as the means to promote carpooling (*23*).

Empty seats in single occupancy vehicles are a potential resource for expanding commuter capacity without increasing the number of vehicles on the roadways. The Washington State Department of Transportation's resource manual claims that as early as the mid-1980s, buses, carpools and vanpools traveling on the I-5 High Occupancy Vehicle (HOV) lanes north of Seattle carried over 25 percent of the people in only 5 percent of the vehicles, even though the lanes were operating at only 25 percent capacity (*24*). The manual goes on to state that 2600 vanpoolers in King County, Seattle eliminate 2000 vehicles from the roads and that each vanpool saves 8000 gallons of gas each year. It also provides estimates of cost savings provided by carpooling: an individual traveling alone pays approximately $248 per month; an individual traveling with three other people in a carpool pays $83 a month; and an individual traveling with seven other people in a vanpool pays $38 per month. In spite of the apparent benefits that could be derived from carpooling, the level of carpooling has decreased in recent years. In 1980, 19.7 percent of all work trips in the United States were made by carpooling. This dropped to 13.4 percent in 1990 and in the year 2000, carpool's share of work trips was only 11.2 percent (*25*).

Organized carpool programs are generally based on ride matching and marketing efforts to educate commuters about the advantages of carpooling. However, these programs are most effective when supported with strategies such as HOV facilities, preferential parking for carpoolers, provision of back-up rides, and carpool subsidies, that 'equalize' the commuting equation to make carpooling more attractive and/or drive alone less so (*23*).

2.2.4 High Occupancy Vehicle (HOV) Lanes

High Occupancy Vehicle lanes are lanes reserved for the exclusive use of buses, carpools and other high occupancy vehicles. The concept dates back to the late 1960s with the opening of the bus-only lane on the Shirley Highway in Washington D.C. in 1969 and the exclusive bus lane on the Route 495 approach to the Lincoln Tunnel in New Jersey in 1970 (*26*, *Kain et al., as stated in (1)*). In 1981, planners opened the Shirley HOV lane to vanpools and carpools with four or more people so as to improve peak performance. By 1973, ridership on the Shirley HOV lane during the morning peak was 13500 passengers – a significant increase over the 1969 morning peak ridership estimate of 3800 passengers (*Kain et al., as stated in (1)*).

As of 2000, approximately 2,300 lane-miles of HOV lanes were in operation on freeways and in separate rights-of-way in 28 metropolitan regions in the United States of

America. (*27*). The majority of mileage was in Houston and Dallas, Texas; Seattle, Washington; the Los Angeles and Orange County area and San Francisco Bay region in California; the Newark, New Jersey, and New York City area; and the Northern Virginia, Washington, D. C., and Maryland region (*26*). In 2003, there were over 130 HOV lane facilities operating on freeways within 23 metropolitan areas (*28*).

Many state and metropolitan areas have advanced numerous goals and objectives for their HOV investment - the need to move more people in fewer vehicles runs through almost all of them. Henderson, 2003 cites six primary goals and objectives of HOV priority treatment (*29*). These are:

- "Induce mode shift from driving alone to higher occupancy modes
- Increase the person-carrying capacity of highway corridors
- Reduce total travel time
- Reduce or defer the need to increase highway vehicle-carrying capacity
- Improve efficiency and economy of public transit operations
- Reduce fuel consumption"

HOV lanes provide increased speed and reliability for buses, vanpools, and carpools. The time savings offered by the HOV lanes serve as an incentive for solo drivers to change mode to carpooling, vanpooling, or the bus. Thus more persons are carried in a smaller number of vehicles. This can lead to reduced congestion and vehicular emissions on the main lanes (*29*).

HOV lanes enjoyed broad public support until the decommissioning of HOV lanes in New Jersey sparked a nationwide reappraisal of the benefits of HOV priority treatment (*Samuel, as stated in (1)*). In November 1998, Gov. Christine Whitman announced the elimination of two HOV lanes on Routes I-287 and I-80. She justified her reason on the grounds that the HOV lanes failed three nationally recognized criteria – their ability to encourage carpooling, to reduce or at least not increase congestion, and to meet a minimum usage threshold (*2*). In 1998, California State Assemblyman, Tom McClintock authored a bill requiring California to decommission those HOV lanes found to be chronically underperforming (*1*). There have also been expressions of misgivings in other areas such as the Twin Cities, Minnesota; Long Island, New York and the Hampton area in Virginia (*2*). The source of these criticisms has been multi-faceted – coming from politicians and some road users, the environmental movement as well as from the research community. According to Poole and Orski, 1999 many environmentalists have come to view the push for new HOV lane construction as little more than thinly disguised attempts to build more roads thus generating more vehicle trips, increasing pollution and promoting greater suburban sprawl. Joy Dahlgren, 1995 sums the concerns up in the statement, "we find ourselves confronted with a paradox: the HOV lane can retain its incentive only if the general lanes remain congested – a notion that appears to mock the ostensible goal of reducing congestion through the use of HOV lanes" (*30*).

According to Poole, 2002, the performance of carpool lanes has not matched the huge amounts invested in their construction. He supports his assertion with the fact that carpooling mode share has declined in 36 of the largest 40 metropolitan areas in the United States (*31*).

2.2.5 Congestion/Value Pricing

In most cases the additional capacity provided by the congestion management techniques discussed so far comes at no direct cost to drivers. Experience has shown that the new capacity tends to be filled up by new users from three sources: changing route, changing mode (for example from transit to drive alone), and changing the time of day of travel. Consequently the amount of traffic increases again when knew capacity is provided for free. This phenomenon is known as the "principle of triple convergence" (*7*). Moreover, the presence of a motor vehicle on a road slows (or delays) other traffic. This may not be significant if traffic volumes are low. However, as volumes approach capacity, each additional vehicle can significantly increase the average delay by reducing average travel speeds. This leads to higher vehicle operating costs per mile as drivers waste more time in congested traffic (*32*).

The basic idea of congestion pricing is to charge each motorist a fee that is directly related to the amount of congestion he or she causes in using the road. It is believed that if motorists are charged fees approximating their true marginal costs, then they will be encouraged to use the road only when and where the benefits they gain equal or exceed their own average costs plus congestion costs they impose on others (*33*, *34*, *35*). Congestion pricing is not impacted by the "principle of triple convergence" as it encourages motorists to switch modes, such as from single occupancy vehicles to transit and carpools, or change time of day, route, location, or frequency of travel to the benefit of the overall efficiency of the transportation system. Pricing could also be a source of revenue for infrastructure investments. According to Johansson and Mattson, 1995 the need for finding new ways of revenue generation, rather than a concern about efficiency, dictates the political interest in road pricing (*36*). Experience has shown that there could be adverse public reaction and political pressures to congestion pricing (*36*, *37*). Thus efforts put into devising appropriate charging structures could be wasted, unless due account is taken of public perceptions and attitudes (*38*). Johansson and Mattson, 1995 identify the toll paid for use of an otherwise free facility and inconveniences experienced by trip makers who shift to less preferred alternatives as the two negative effects produced by a congestion pricing program. Like other congestion management strategies, congestion pricing can not be implemented as a stand-alone transport policy, but it does create very favorable conditions for success when used in concert with other techniques like carpooling and efficient mass transportation systems.

2.2.6 High Occupancy/Toll Lanes

In the light of growing public dissatisfaction and strong anti-HOV backlash, the concept of High Occupancy / Toll Lanes is attracting much attention. HOT lanes combine pricing strategies and occupancy restrictions to manage the number of vehicles using the facility. HOT lanes typically provide free access to qualifying HOVs, and allow vehicles that do not meet the occupancy levels required for free travel, the option of paying a toll to gain access to the HOV lanes (*3, 20*).

A major concern with the HOT lane concept is equity. Pricing strategies usually charge the same amount for the same premium service regardless of who uses the service. The lower income travelers are less likely to afford to use the premium services and, therefore, must continue to endure congestion (*39*). For example, studies on the two HOT lane facilities in California indicate that HOT lane users tend to have higher incomes (*40*). An 'equity analysis of the Houston QuickRide project' by Burris and Hannay, 2003 also showed that QuickRide enrollees were found to have significantly higher incomes than drivers on the Katy Freeway main lanes (*41*). However, Kim, 2000 argues that revenue generated from drivers of single occupancy vehicles and other low occupancy vehicles should provide a cross-subsidy to high occupancy vehicles. For instance, the revenue generated can be used to implement a number of measures such as reduce tax levels, improve road facilities, and increase investment in public transport. Such measures might mitigate public concerns about the equity of providing premium express lane service that is used more by higher income travelers than middle and lower income travelers. The next section documents some characteristics of the existing HOT lane projects in the world.

2.3 Inventory of HOT Lane Projects

As of January, 2004 there were only four HOT lane facilities operating in the world. The four projects together cover approximately 84 lane miles of roadway and are located in two areas in the United States. The facilities were:

- The SR 91 Express Lanes and I-15 FasTrak lanes in Southern California, and
- The Katy Freeway and Northwest Freeway QuickRide lanes in Houston, Texas.

2.3.1 California's HOT Lane Projects

California has two major HOT lane projects: the State Route 91 (SR 91) Express Lanes in Orange County and the I-15 FasTrak lanes in San Diego.

The SR 91 Express Lanes project was the first HOT lane project in the United States (and also the first in the world). It is a 10 mile, four-lane toll facility located in the median of the Orange County-Riverside County travel corridor. The project opened in 1995 as a public-private partnership between Caltrans, the California Department of Transportation and a private company, California Private Transportation Company (CPTC). CPTC financed, built and operated the facility, using project revenues to repay its debt and make some profit (*3*). Ownership of the express lanes was transferred to the Orange County Transportation Authority in January 2003.

Initially, a flat toll applied during the entire duration of the morning and afternoon peaks until September 1997 when a variable pricing scheme was implemented (*3*). The toll varies from \$1.00 to \$4.75 by time of day and day of week (*3*). As of May 2003, access to the facility was free to vehicles with three or more occupants (HOV-3+) during most periods of the day. However, HOV-3+ drivers were required to pay half the basic toll when traveling eastbound between 4:00 p.m. and 6:00 p.m., Monday through Friday. 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 (*14*).

The I-15 FasTrak lanes are an 8 mile , reversible, two-lane facility located in the median of I-15, about 10 miles north of San Diego. The project started in December

1996. As of February 2004, HOV-2+ vehicles could use the facility at no cost. However single occupancy vehicles had to pay a toll that varied from $0.50 to $4.00 depending on the level of traffic in the HOT lane. This fee could go up to as high as $8.00 in case of severe congestion (*3*). 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 users can save up to 20 minutes of travel time (*15*).

2.3.2 Houston's HOT Lane Projects

As of February, 2004 two major freeways in Houston, the Katy Freeway (I-10) and the Northwest Freeway (US 290), had HOT lanes. HOT lane operations on these facilities are commonly known as QuickRide.

The Katy HOV lane has been in operation since 1984. It is a 13 mile, 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 allowed 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 (*4, 12*). However, this change resulted in significant excess capacity in the HOV lane during the peak periods (*4*). 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 could 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 1995, the Texas Department of Transportation (TxDOT) initiated a major investment study that would expand Katy's current 11 lanes to 18 lanes, with a total of four general use lanes, two managed lanes, and three frontage-road lanes in each direction. Construction began in 2003 and is expected to end in 2013. The project is estimated to cost $1.1 billion, and $225 million revenue is expected from the managed lanes over 25 years (*3*). In fact one major reason for implementing the QuickRide project was "to help manage congestion during the multi-year construction and to prepare the public for the transition to toll-managed lanes in the future" (*42*).

Due to the success of the Katy QuickRide program, the Metropolitan Transit Authority of Harris County converted the Northwest Freeway HOV lane to HOT use in November 2000 and it operates in similar manner to the Katy HOT lane facility, except that it is available only during the morning peak period (*41*). The afternoon peak period in this HOV lane is not congested and is open to HOV-2+ vehicles. It is a 15 mile, 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 Freeway HOT lane is approximately 11 minutes.

2.3.3 Emerging HOT Lane Projects

In view of the potential benefits of HOT lane projects, numerous state departments of transportation are exploring the possibility of implementing HOT operations on their HOV lanes. Most of these projects have been funded but have not started operations. The University of Minnesota's "value pricing home page" provides relevant information on some of these projects (*7*).

Examples include proposed HOT operations on I-394 in Minnesota and I-680 in California. Alameda County in California is investigating the feasibility of HOT lanes on a 17 mile section of I-880 and also on a 14 mile portion of I-680. In Denver, Colorado, a regional feasibility study of HOT lanes has been completed. This study identified the I-25/US 35 corridor as the most feasible location for a pilot HOT project "that would feature dynamic pricing of single occupant vehicles" (*7*). The North Carolina A & T State University is also leading a study aimed at assessing the feasibility of HOT lanes on I-40 (and other managed lane options) in the Piedmont and Research Triangle areas of North Carolina. In pre-implementation study on the Highway 217 in Portland, Oregon, the Citizen's Task Force has recommended that "value pricing (including HOT lanes) be considered whenever new highway capacity is added" (*7*). The Dallas Area Transit Authority, the Forth Worth Transportation Authority, the North Texas Tollway Authority, and the Texas Department of transportation have constituted a task Force to oversee the implementation of HOT projects on the I-30 in Dallas/Fort Worth and also to determine "the best approach to select and apply pricing strategies to transportation projects in the North Central Texas region" (*7*).

2.4 Characteristics of Demand for HOT Lane Usage

Kim, 2000 identified the following as major factors affecting the demand for HOT lane use in California: income, toll price, trip purpose, schedule flexibility, and travel delay on adjoining main lanes. In their evaluation of QuickRide usage in 1988, Stockton *et al.* also found that household size and income are good indicators of HOT use in Houston. They also found that QuickRide users were in general familiar with the Houston HOV system. This suggests that familiarity with the travel corridor is also expected to influence the demand for HOT lanes. According to Perez and Sciara, 2003 the decision to use an HOT lane (and hence the demand for HOT lanes) will be influenced by (*7*):

- Pricing strategy – fixed toll versus variable toll
- User eligibility/sign-up costs – cost of transponders, account deposit, credit cards
- Nature or purpose of trip – recreational versus commute
- Availability of alternate travel routes and vehicle operating cost on alternate routes as perceived by user
- Travel time savings offered HOT users
- Value of time/willingness of motorists to pay for improved travel conditions
- Predictability or reliability of HOT trip compared to alternative free route trip
- Travel patterns (O-D matrix) – is the HOT lane on a widely-traveled corridor?
- Information dissemination/adequate marketing programs? – do people have enough information on locations of entry/exit ramps, toll price, eligibility requirements, etc.

  - Attractiveness of carpooling – park and ride facilities, trip-matching, reduced parking cost for carpoolers, provision of back-up rides for emergencies, etc.

  These factors may be categorized broadly as:

- Characteristics of trip maker: this includes socioeconomic characteristics such as age, gender, education, occupation, hourly wage rate, household size, household income, number of vehicles available for use, and individual attitudes and perceptions such as how drivers perceive the concept of paying a toll to use a facility on which most drivers are traveling for free, as well as idiosyncratic preferences for a particular mode.
- Characteristics of the trip: this includes trip purpose, trip length, carpool formation time, HOT travel time savings, reliability of the HOT lane trip, HOT lane occupancy restrictions, frequency of travel in the freeway corridor containing the HOT lane, toll price and pricing scheme (fixed versus variable), and perceived travel costs on alternate free routes or alternate modes. Trip-end characteristics such as employment density, convenience of entry/exit locations on HOT lanes, parking charges, and employer incentives (for example parking subsidies for carpoolers), are also important.
- Available alternatives: for Houston's QuickRide drivers, the available modes for travel on the Katy or Northwest Freeway corridors 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 alternative chosen by a driver is a function of the factors described above. Mathematically,

$$C = f\,(a, m, t) \tag{1}$$

Where,

C = alternative chosen by driver, a = characteristics of available alternatives,

m= characteristics of the trip maker, and t = characteristics of the trip.

As noted earlier, understanding the influence of these factors on HOT usage can serve us a useful guide on policy decisions concerning potential HOT lane investments.

3 METHODOLOGY

3.1. Study Site

Data for this research were mainly obtained from a survey of travelers along two travel corridors in Houston, Texas - the Katy Freeway (I-10) and the Northwest Freeway (US 290). Figure 3.1 is a map of the study site showing the two travel corridors.

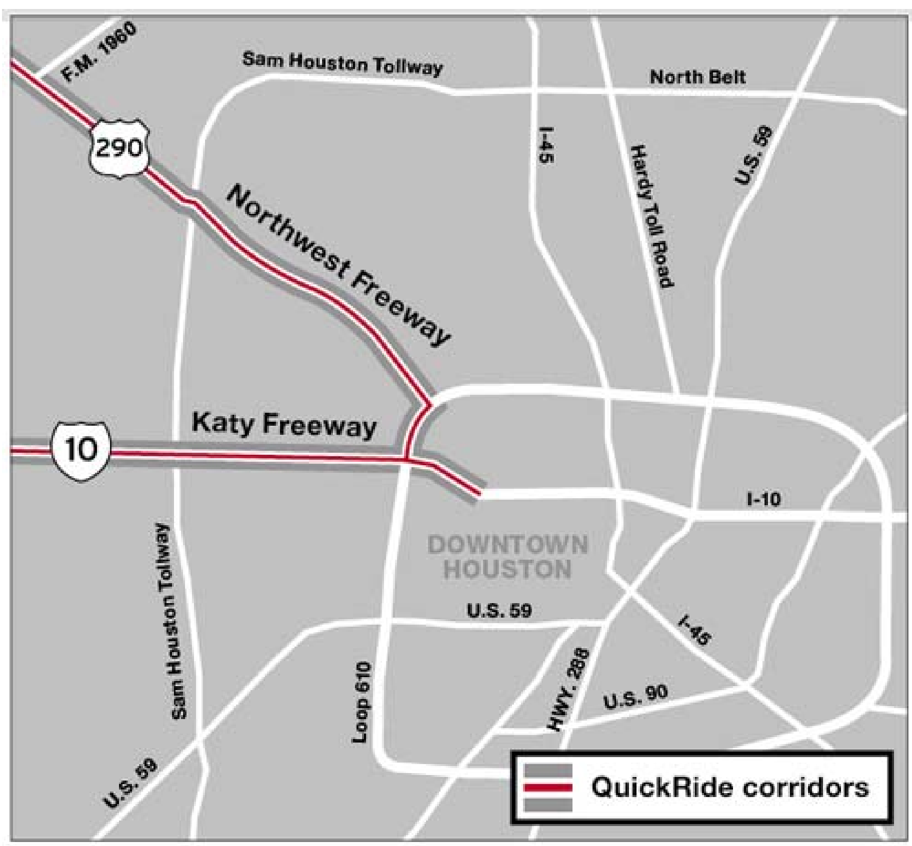


Figure 3.1 Houston's HOT Lanes[1]

[1] Source: http://tti.tamu.edu

The Katy HOV lane has been in operation since 1984. It is a 13.3 mile, one-lane reversible facility located in the median of Katy (I-10) Freeway in Houston, Texas. The Katy freeway is very congested, serving over 210,000 vehicles per day (*42*). To optimize the use of the HOV lane without compromising its level of service, the QuickRide program (HOT lane operations) was introduced. This program, which started in January 1998, allowed a limited number of two-person carpools to 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). However, carpools of three or more persons could use the facility for free at all times. The $2.00 toll is charged electronically to drivers displaying both a QuickRide hang tag and a transponder. Participants receive an average travel time saving of approximately 17 minutes.

The Northwest (US 290) HOV lane is a 14.6 mile one-lane facility located in the median of the Northwest Freeway which connects the northwest suburbs of Houston with downtown. It has been in operation since 1988. The Northwest Freeway is also congested and, at present, carries over 245,000 vehicles per day (*42*). The HOV lane was converted to HOT use in November 2000 and operates in similar manner to the Katy HOT lane facility, except that it is available only during the morning peak period (*3, 41*). Average travel time savings on the Northwest Freeway HOT lane is approximately 11 minutes.

3.2 QuickRide Usage Trends

Figure 3.2 shows the average number of QuickRide trips made in a day between 1998 and 2003.

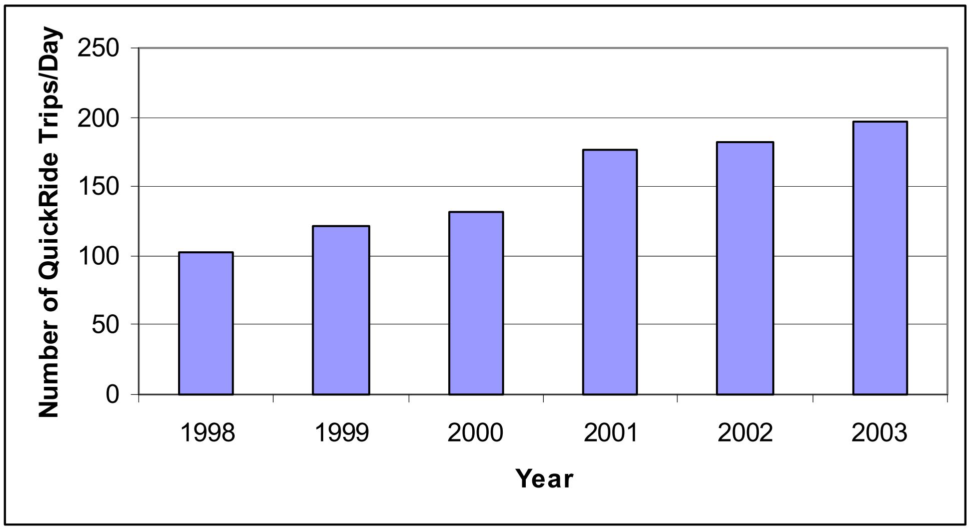


Figure 3.2 Average Daily QuickRide Demand on Houston's HOT Lanes

As shown in the graph, there has been a steady increase in demand for HOT lane (or QuickRide) use since its inception in 1998. In 1998, the average demand was 103 trips per day. This increased to 131 trips per day after the introduction of HOT operations on the Northwest Freeway. By the end of 2003, average demand had increased to 196 trips per day. Most of these trips took place during the morning rush hours on the Katy Freeway (see Figure 3.3). Except for the year of implementation (2000), the demand for QuickRide on the Northwest Freeway (US 290) has been higher than the demand during the afternoon peak on the Katy Freeway (Katy PM).

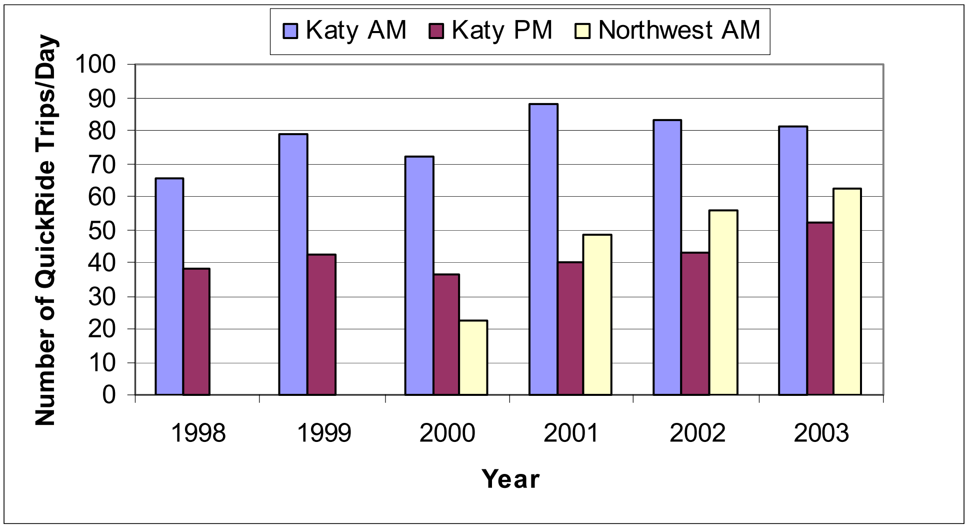


Figure 3.3 Average Daily QuickRide Demand by Route and Time of Day

In 2003, Burris studied QuickRide usage patterns between January 1998 and December 2002 using 157,951 QuickRide transponder readings (*8*). His studies showed that only a few enrollees made an appreciable number of QuickRide trips (10 or more trips per month). The majority of the respondents made practically no trips (see figure 3.4). A possible explanation is that some QuickRide transponders might not be registering with the Automatic Vehicle Identification equipment.

The report also examined the effect of QuickRide operations on the choice of departure times. This was done by examining the distribution of arrival times at the first of two QuickRide transponder reader locations (see figure 3.5) in a given direction. The distributions for various locations in the year 2002 are shown in Figures 3.6 through 3.8 (reproduced from reference 8). The graphs suggest that most drivers entered the HOT lanes in the middle of the peak period and that such drivers were not as likely to alter their departure times to avoid paying the QuickRide. It was relatively easier for those who entered at either end of the peak period to alter their time of travel (*8*).

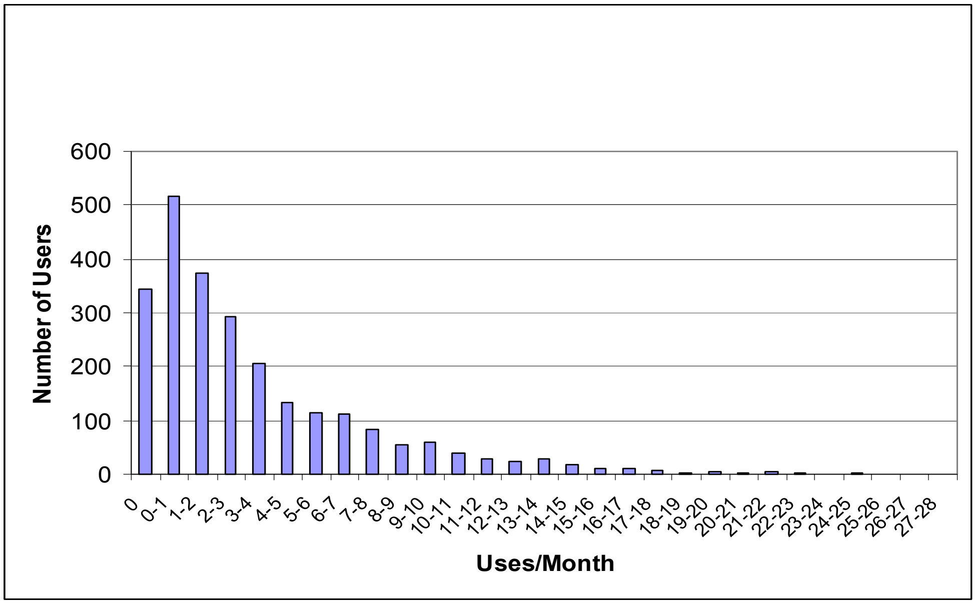


Figure 3.4 Average Monthly QuickRide Usage

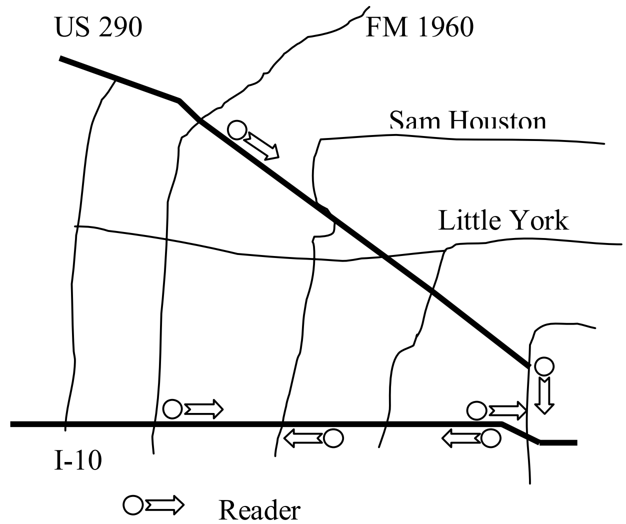


Figure 3.5 Locations of QuickRide Billing Readers (Not to Scale)

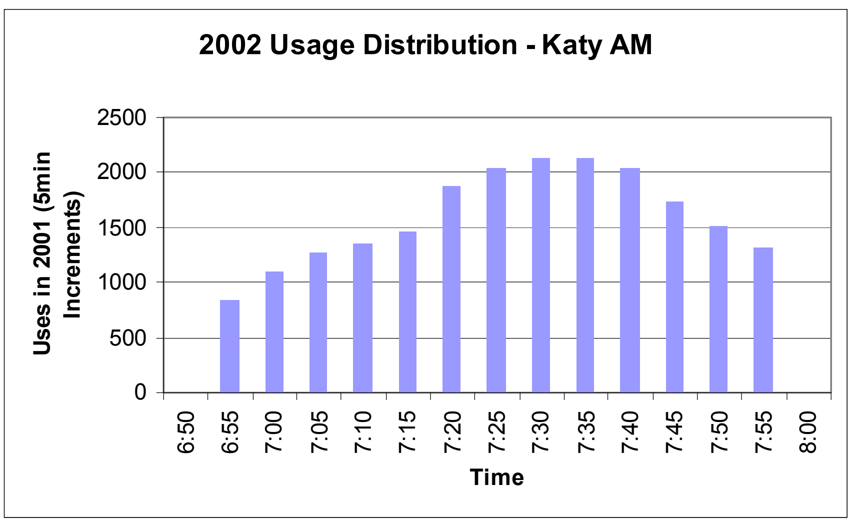


Figure 3.6 Distribution of Arrival Times at Location of 1st QuickRide Billing Readers – Katy Freeway, Inbound (Source, *8*)

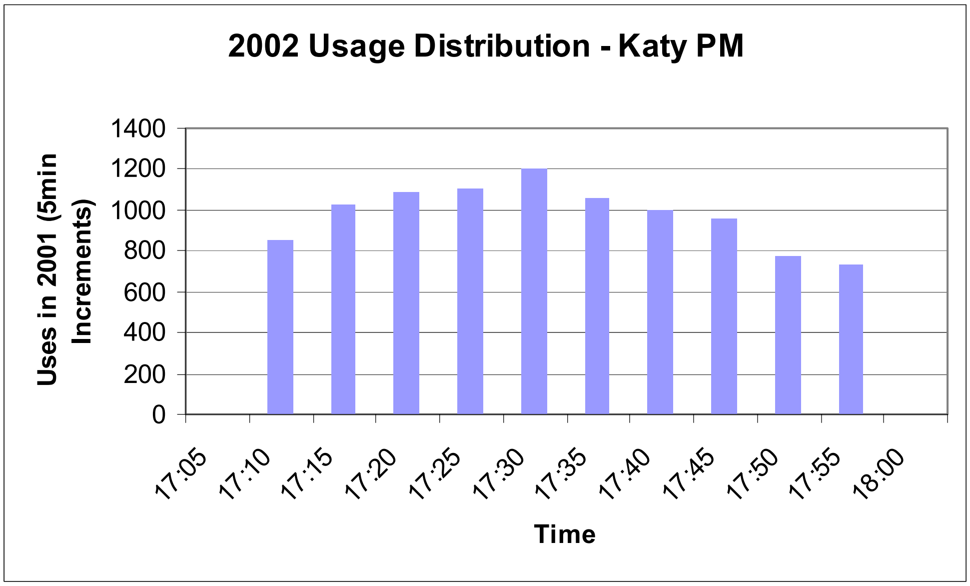


Figure 3.7 Distribution of Arrival Times at Location of 1st QuickRide Billing Readers – Katy Freeway, Outbound (Source, *8*)

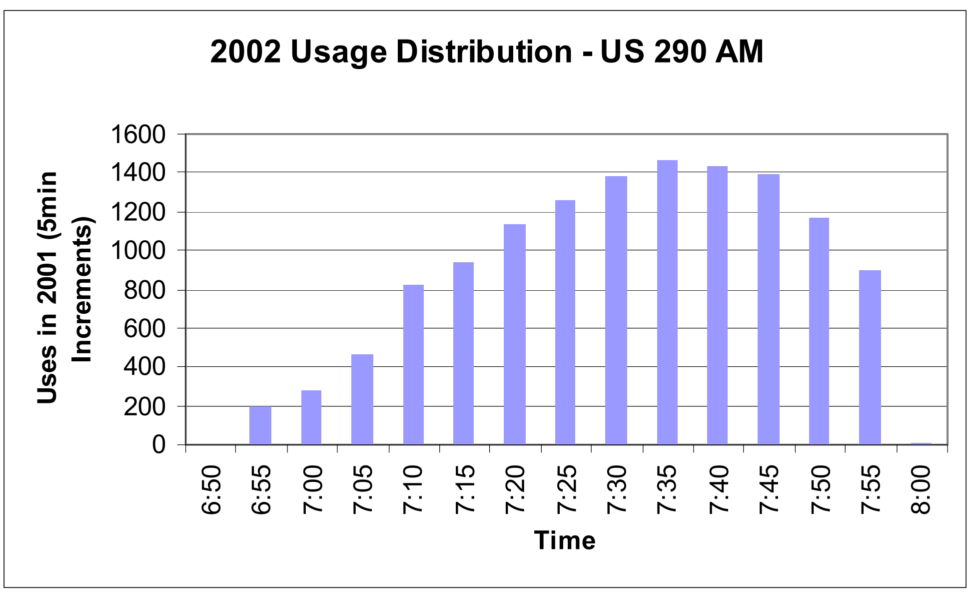


Figure 3.8 Distribution of Arrival Times at Location of 1st QuickRide Billing Readers – Northwest Freeway, Inbound (Source, *8*)

3.3 Survey Design and Administration

To gather the data required for a greater understanding of factors influencing QuickRide use, surveys were mailed in March 2003 to all 1459 people who were enrolled in QuickRide as of December 2002. The surveys were designed by Texas A&M University faculty and this author and conformed to requirements of the Texas A&M University Institutional Review Board's policies on the use of human subjects in research. In line with these requirements, participants were made aware that replying to the survey was non-obligatory and that all answers to the survey would be totally anonymous.

The survey included 36 questions regarding:

- participants' most recent QuickRide trip,
- participants most recent non-QuickRide trip,
- their typical use of QuickRide,
- their feelings toward alternate QuickRide tolling schemes, and
- their socioeconomic characteristics.

The questions regarding the respondents' most recent trip varied based on the route used and the period which the QuickRide trip occurred (Katy AM, Katy PM, or Northwest AM). Three slightly different surveys were mailed to current QuickRide participants. The surveys were target-mailed to respondents based on their usage of those different QuickRide movements. This approach shortened and simplified the survey instrument by focusing on questions relevant to the typical travel behavior of the respondents (see Appendix A for a sample of the survey instrument). Participants were expected to spend an average of 12 minutes in answering all 36 questions in the survey.

3.4 Data Collection and Reduction

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 in any analysis). The responses were entered into an EXCEL spreadsheet and carefully checked for data entry errors.

The post office returned a total of 93 surveys due to incorrect addresses. Of the remaining 1366 surveys, 525 were returned on time for a 38.4 percent response rate (*43*). However, both response bias and ex-post rationalization in survey responses 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 (*12*). Based on the respondents' stated use of QuickRide it was fairly obvious both types of errors existed. The distribution of respondents' stated weekly number of QuickRide trips was compared to the distribution of QuickRide trips recorded by automatic vehicle identification equipment located on the routes (see Figures 3.9 and 3.10).

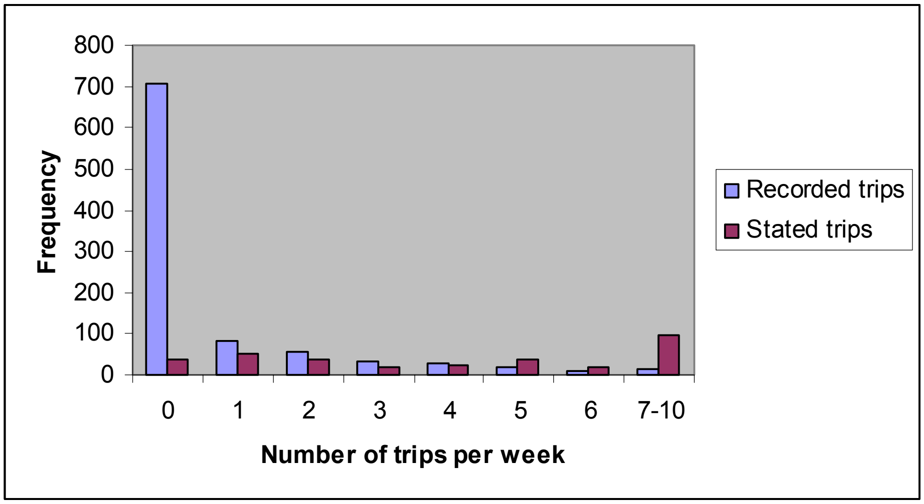


Figure 3.9 Katy Freeway QuickRide Users' Stated Versus Transponder-Recorded Number of QuickRide Trips

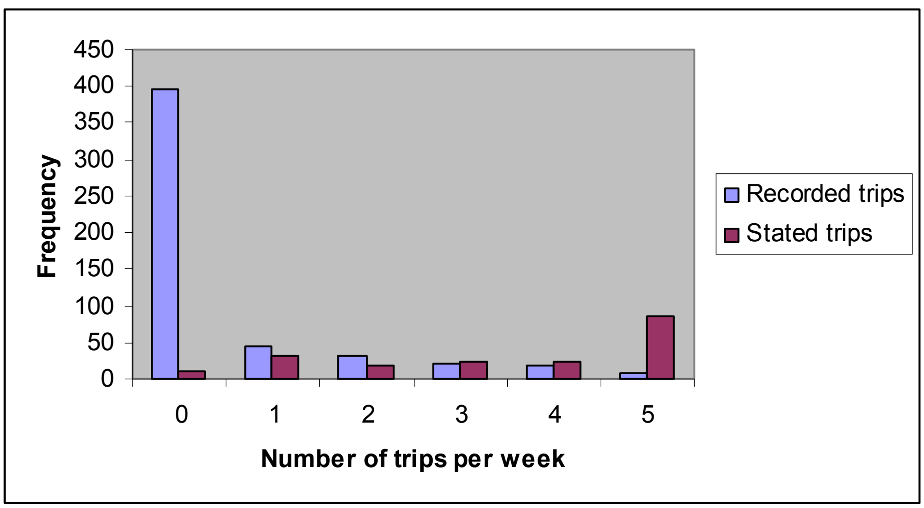


Figure 3.10 Northwest Freeway QuickRide Users' Stated Versus Transponder-Recorded Number of QuickRide Trips

From Figures 3.9 and 3.10, it is 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 4–5 trips per week on Northwest) were considerably overrepresented. This indicates three potential sources of error: (1) the small number of infrequent participants who responded were not representative of all infrequent participants; (2) some frequent participants were actually less frequent than indicated, skewing the characteristics of this group; and (3) some frequent participants' transponders were not registering with the automatic vehicle identification (AVI) equipment (this is a probable source of error and efforts are underway to fix this problem). 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 either freeway equaled actual average usage on that freeway for the last 3 weeks in March (see Equation 2). Without knowing the true number of trips made by each survey respondent (which cannot be determined because survey responses were anonymous), this weighting technique presents the best way to attempt to minimize the impact of these potential biases.

$$W_{i,j} = \frac{T_{i,j}}{R_{i,j}} \qquad (2)$$

where,

$W_{i,j}$ = weighting factor for survey respondents who traveled on road i and indicated a weekly QuickRide usage of j,

$T_{i,j}$ = number of enrollees who averaged j QuickRide trips per week on freeway i based on QuickRide billing records for the last three weeks of March 2003,

$R_{i,j}$ = 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 3.1.

Table 3.1 Weights for Data Analysis

Number of trips per week (j)	Katy Freeway			Northwest Freeway		
	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	19.69	10	396	39.60
0.5–1.49	51	83	1.63	31	43	1.39
1.5–2.49	38	54	1.42	19	30	1.58
2.5–3.49	20	32	1.60	23	20	0.87
3.5–4.49	22	26	1.19	23	19	0.83
4.5–5.49	35	17	0.49	86	9	0.11
5.5–6.49	19	9	0.47			
6.5–10	98	12	0.12			

It should also be noted that several Northwest Freeway survey respondents indicated more than five QuickRide trips per week. The most likely rationale for this might have been confusion between using QuickRide and simply driving on the HOT lane in the afternoon (when QuickRide does not operate on Northwest Freeway), and some respondents may have mistaken these trips for QuickRide trips. To account for this error, the stated number of weekly trips was divided by two for these respondents. Also, three Northwest respondents and three Katy respondents indicated more than 10 QuickRide trips per week. These responses were removed from the analysis, thus reducing the available data to 519 responses. Moreover, analysis of the current enrollees' survey 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 analysis was reduced to 511.

3.5 Other Data Sources

In addition to these surveys, several other sources of data were available for analysis, including:

1. A data set containing the transponder number, date, and time of every QuickRide trip ever charged (some QuickRide trips may have been missed due to equipment difficulties). This data set was used to build the weights described in the current enrollees' survey.
2. A data set containing travel speeds on both the main (free) lanes and the HOT lanes on Northwest Freeway and Katy Freeway. These speeds are recorded using the automatic vehicle identification readers along the corridors and record millions of travel speeds each year. The travel speeds provided

detailed information on the travel time savings gained through the use of QuickRide.

3. Results from a smaller survey of QuickRide enrollees conducted in 1998.

3.6 Data Analysis

Standard statistical methods and disaggregate modeling techniques were used to analyze the data. To begin, descriptive statistics of all survey responses were examined to obtain an overall view of respondents. Two characteristics were identified and studied in detail. These were (1) Participants' choice of route and time of travel and (2) participants frequency of usage of the program. The method of analysis involved classifying participants into various groups based on these characteristics and conducting a comparative analysis to identify any statistically significant differences between the groups and how these differences might impact the demand for HOT lane use. The characteristics and groups considered were:

1. Participants' preferred (most frequently used) route and time of travel. Three groups were identified—Katy AM, Katy PM, and Northwest AM.
2. Participants' frequency of QuickRide usage. The three groups considered here were:
    a. Infrequent participants, defined as QuickRide enrollees who indicated they took a maximum of 1 trip on either route (Katy or Northwest) in the week immediately preceding the survey,

b. Midlevel 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

c. 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.

It should be noted here that QuickRide operates only in the morning peak period on Northwest Freeway, hence the different definitions of frequency of use for the two freeways described above.

To answer the fundamental question of whether there were significant differences ($p < 0.05$) between respondents in these 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) and Student's t-test were used for three-way and two-way comparison of means of *continuous* data (for example, travel time savings or trip length). For *ordinal* data, the Kruskal Wallis test was used for three-way comparison of means (for example, age or income) while Mann-Whitney test was used for two-way comparison of means (*44, 45, 46*).

After identifying the characteristics of QuickRide users, discrete choice models were developed to quantify and provide further insights into the reasons behind drivers' decision to use QuickRide. In particular an ordered logit model of frequency of QuickRide usage and choice models (nested logit) of route, time-of-day, and occupancy were developed. These models were expected to help identify factors which have significant impact on the demand for HOT lanes and to provide a framework for predicting the chances of success or failure of potential HOT projects.

4 RESULTS

4.1 Descriptive Statistics

This section provided descriptive statistics of all survey responses. The objective was to obtain an overall view of socioeconomic and travel characteristics of respondents. The results are summarized in Appendix B.

4.1.1 Socioeconomic Characteristics

Most respondents were between 25 and 54 years old, had at least a college degree, earned an average of $30 to $50 an hour, were married and had annual household incomes greater than or equal to $100,000 per year. A greater proportion of the respondents were females (53 percent). There was an average of 2.99 persons per household. The average number of vehicles available to each household was 2.32. Most participants (65 percent) had professional and / or managerial careers. Figures 4.1 to 4.6 show the distribution of some individual demographics and household characteristics of survey respondents.

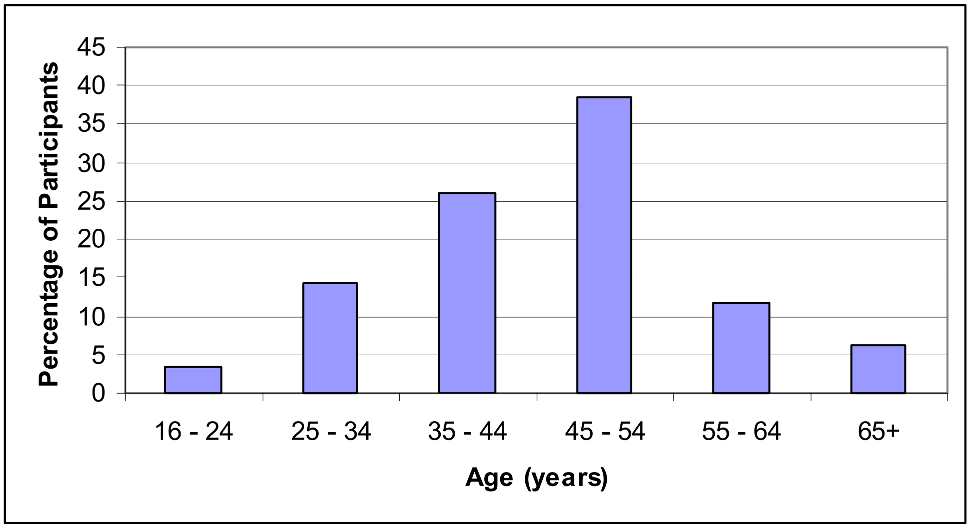


Figure 4.1 Ages of QuickRide Participants

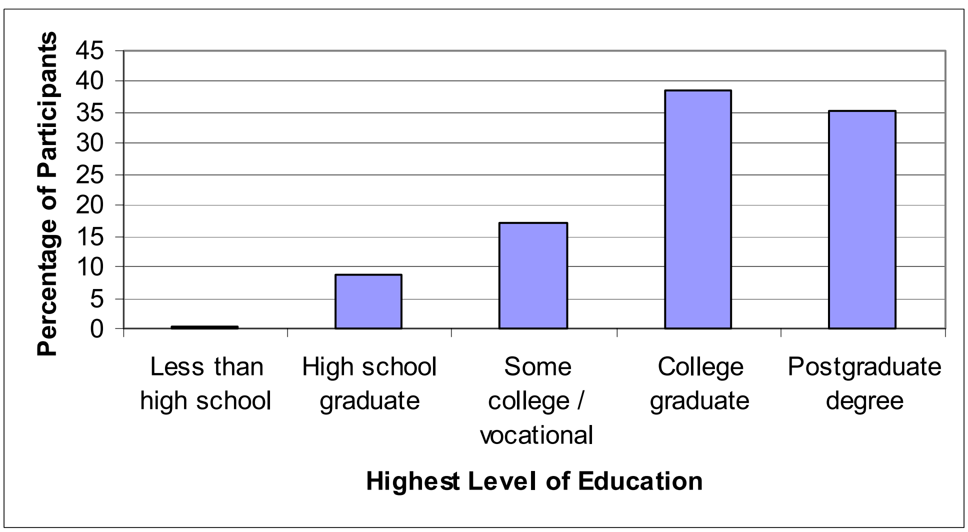


Figure 4.2 Levels of Education of QuickRide Participants

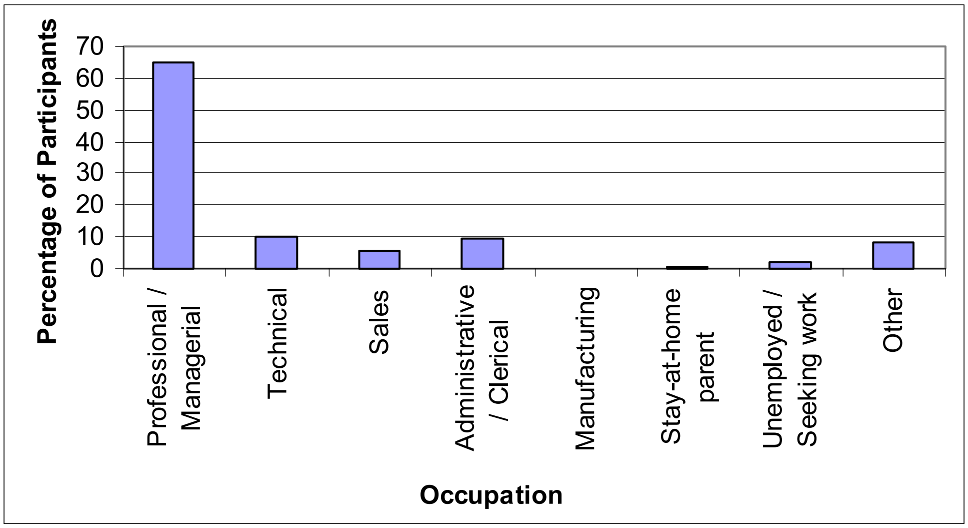


Figure 4.3 Occupations of QuickRide Participants

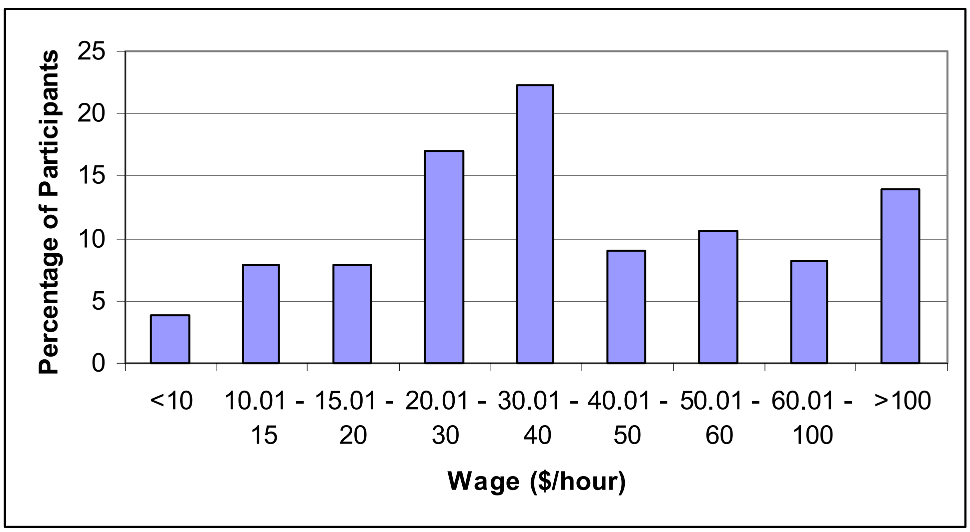


Figure 4.4 Hourly Wage Rates of QuickRide Participants

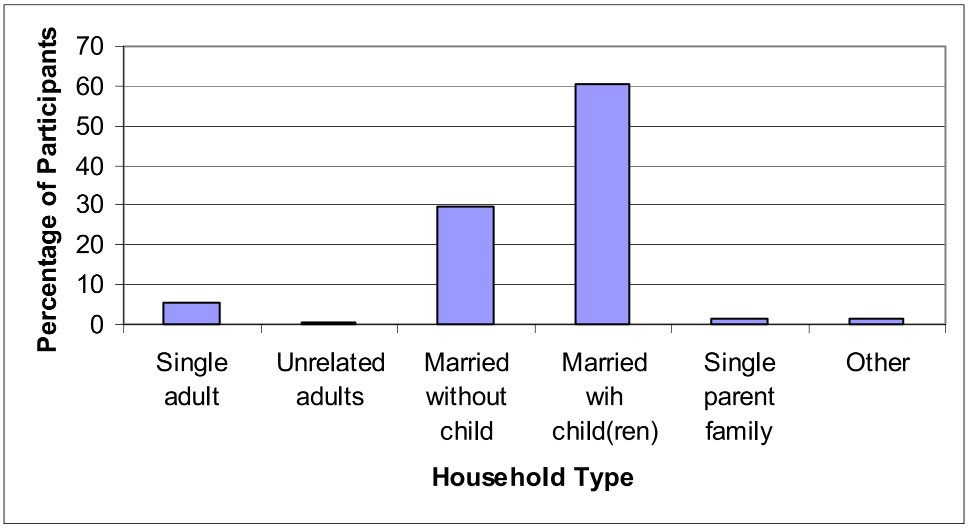


Figure 4.5 QuickRide Participants' Household Type

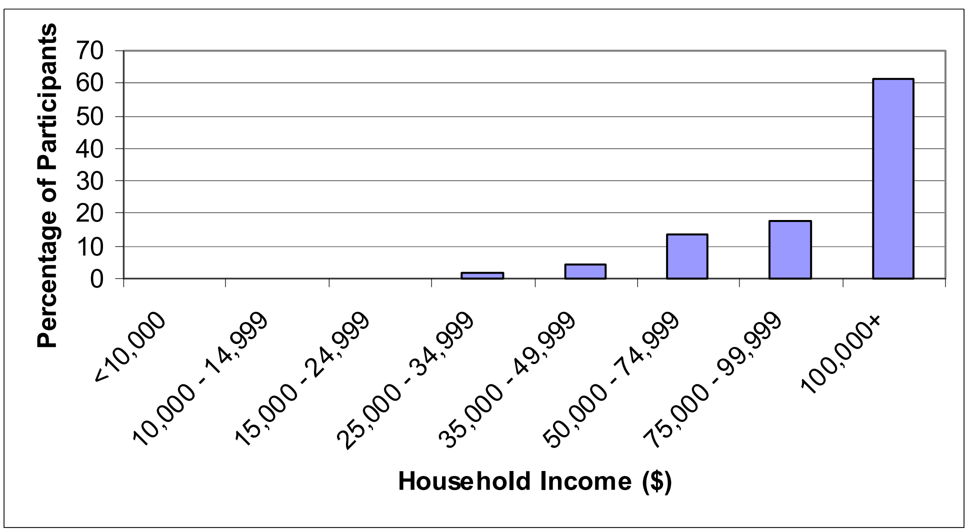


Figure 4.6 QuickRide Participants' Annual Household Income (2002)

4.1.2 Commute Characteristics

Respondents used QuickRide predominantly for commute trips (see Figure 4.7). The average QuickRide trip length was 45.3 minutes and participants perceived an average travel time savings of 29.8 minutes by using the HOT lanes rather than the main lanes. Trips 120 minutes or longer were considered unreasonable for travel in the Houston metropolitan area and were rejected as extreme values (19 responses were rejected based on this criterion).

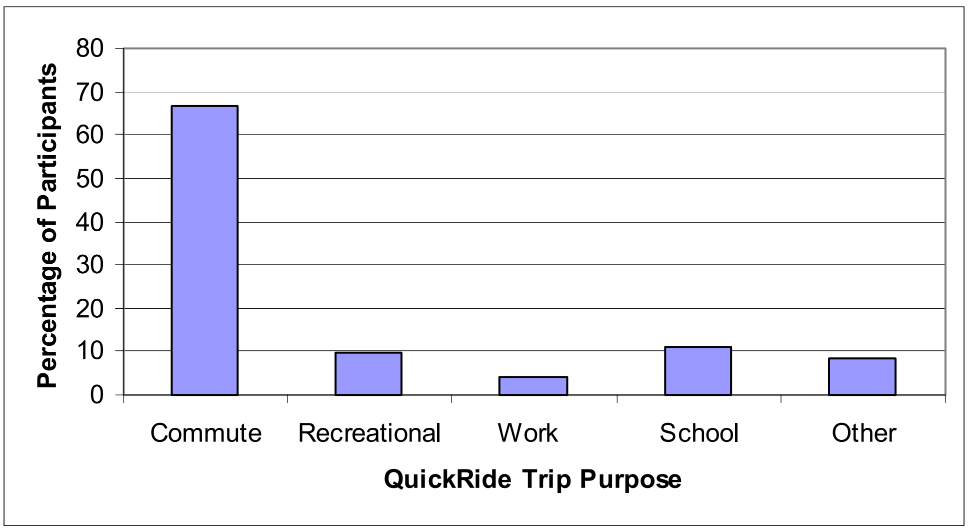


Figure 4.7 QuickRide Trip Purpose

Participants indicated that they usually travel with a child, an adult family member or a coworker when using QuickRide (see Figure 4.8). Only 7 percent of respondents said they usually travel in casual carpools (Note: a casual carpool is one which the drivers and passengers do not have pre-arranged plans to carpool. Instead, passengers wait at a designated location, usually a park and ride lot, for drivers to pick them up. Often these people will not know one another [*11*]). Participants spent as long as 23 minutes picking up and dropping off their carpool partners, with the average carpool formation time being 4.33 minutes. Carpooling with coworkers or casual carpoolers required average carpool formation times of 7.35 and 10.09 minutes, respectively (see Figure 4.9). This was significantly longer than the average time required for carpooling with an adult family member (2.66 minutes), a child (2.11 minutes), or a neighbor (2.56 minutes).

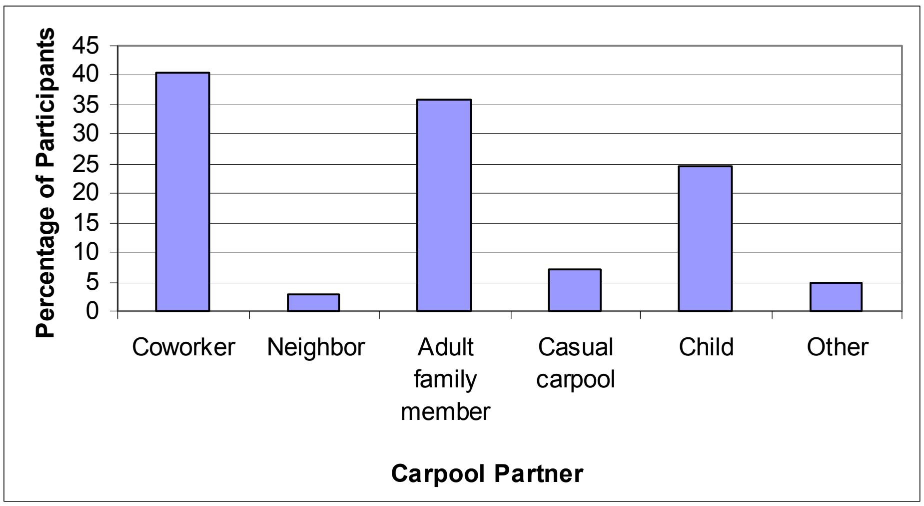


Figure 4.8 Usual QuickRide Carpool Partner

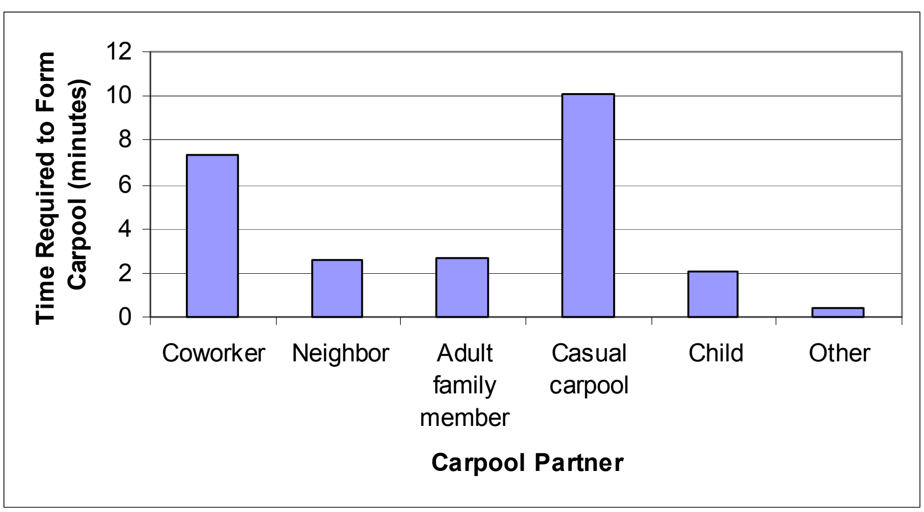


Figure 4.9 Carpool Formation Time for Various Carpool Compositions

4.1.3 Current Level of QuickRide Participation

Most participants enrolled in QuickRide to either avoid traffic congestion on the main lanes or to take advantage of the possibility of traveling with their carpool partner even during the rush hour (see Figure 4.10). Each participant made an average of 7.32 trips per week in the travel corridor (using all modes) in the week immediately preceding the survey indicating that less than 10 percent of all trips were made using QuickRide (0.64 per person per week).

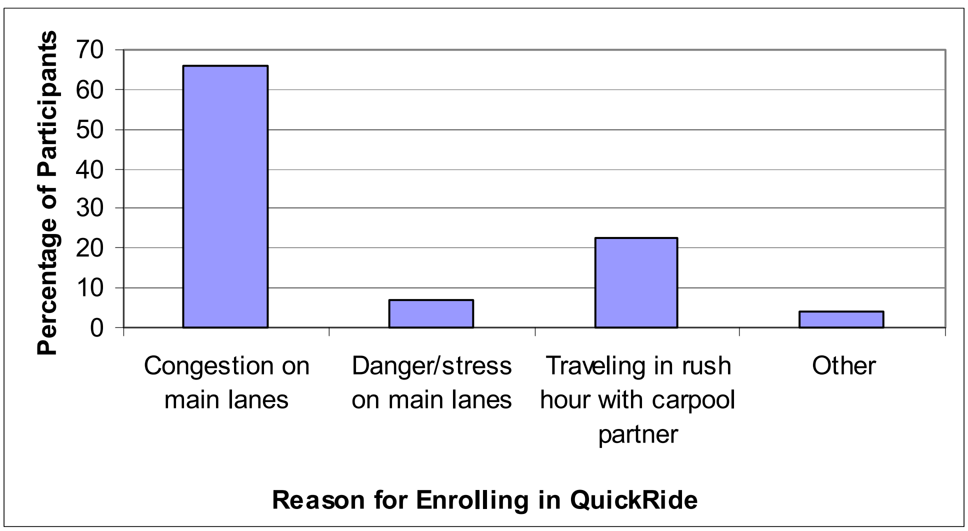


Figure 4.10 Why Participants Joined QuickRide

Respondents cited the difficulty of participating in carpools and the fact that their work schedules might permit them to adjust their travel time to less congested periods as major reasons for the relatively low levels of participation. Only 0.4 percent of respondents made fewer QuickRide trips because they perceived the same level of congestion on both the HOV lanes and main lanes. Other reasons are summarized in Table 4.1 together with the percentages of respondents citing each particular reason.

Table 4.1 Factors Influencing Current Level of QuickRide Usage

Reason	Percentage of Participants
Difficult to participate in carpool	33.1
Same congestion in HOV lane and main lanes	0.4
Inadequate time savings	1.8
Program is complicated and confusing	0.1
Flexible work schedule	14.7
Price of QuickRide	3.3
Sometimes forget	1.5
Other	45.1

Participants were generally satisfied with their time savings when using QuickRide. Only 1.8 percent of all participants considered the time savings inadequate, and an even smaller proportion (0.1 percent) found the QuickRide program complicated and confusing.

When asked to state what factors would cause them to make more frequent QuickRide trips, 80.5 percent of all respondents indicated they would increase their level of participation if they could drive alone on the HOT lane, while 28.5 percent indicated they would make more QuickRide trips if the toll were reduced (see Figure 4.11). It should be noted that respondents could select any number of probable answers from a list of options so that the total percentage for the distribution of responses exceeded 100 (see Question 21 of Appendix A).

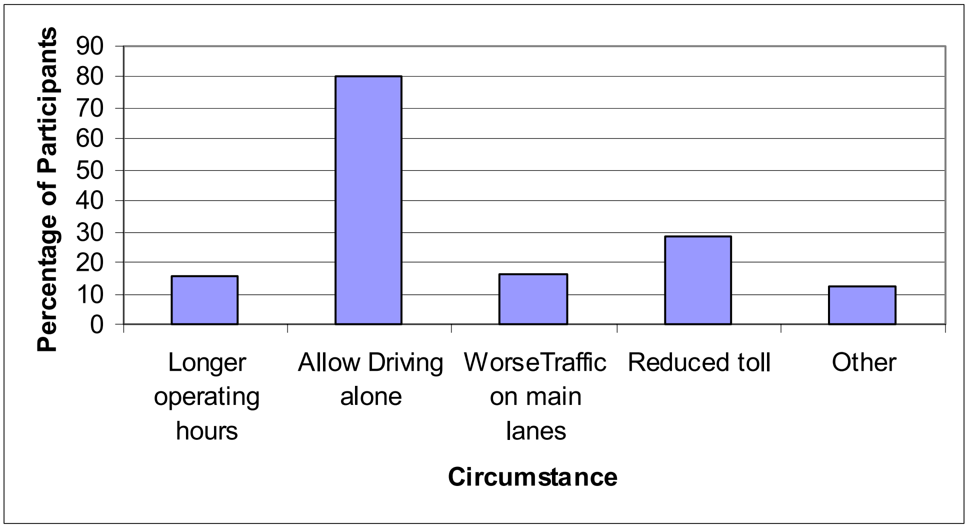


Figure 4.11 Circumstances under which Participants would Increase their Level of QuickRide Usage

4.1.4 Effect of the $2 QuickRide Toll on the Level of Participation

Approximately 27 percent of all respondents said their carpool partners contributed towards paying the $2 QuickRide toll. This was especially the case for participants who traveled with an adult family member or a coworker. However, only 6 percent of all respondents who traveled with casual carpoolers received some help in paying the toll from their passengers (see Figure 4.12).

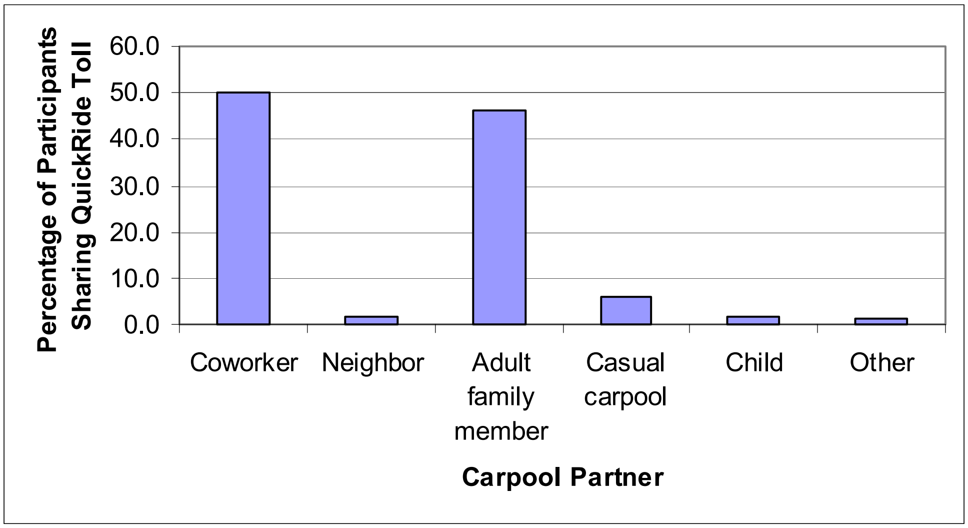


Figure 4.12 Participants Sharing QuickRide Toll with Carpool Partners

Most respondents (78.5 percent) were either indifferent to the \$2.00 toll or found the toll reasonable. Approximately 73 percent of participants reported that the toll had little or no significant impact on their decision to use QuickRide.

4.1.5 Perceptions about Other Pricing Options

4.1.5.1 **Flat QuickRide Toll** Respondents were asked to state the number of QuickRide trips they would make per week if the toll were \$1.00, \$1.50, \$2.50, or \$3.00. They were also asked to state the number of trips they would make if two-person carpools were allowed to use the HOT lane during peak periods without paying a fee. As expected, the average number of trips decreased as the toll increased. Figure 4.13 shows a linear regression of “average stated number of QuickRide trips” on “hypothesized QuickRide toll”. The slope of the regression equation was -0.62 yielding a coefficient of elasticity[2] of -0.68. This indicated that the expected (or stated) number of QuickRide trips was inelastic to changes in the $2 QuickRide toll.

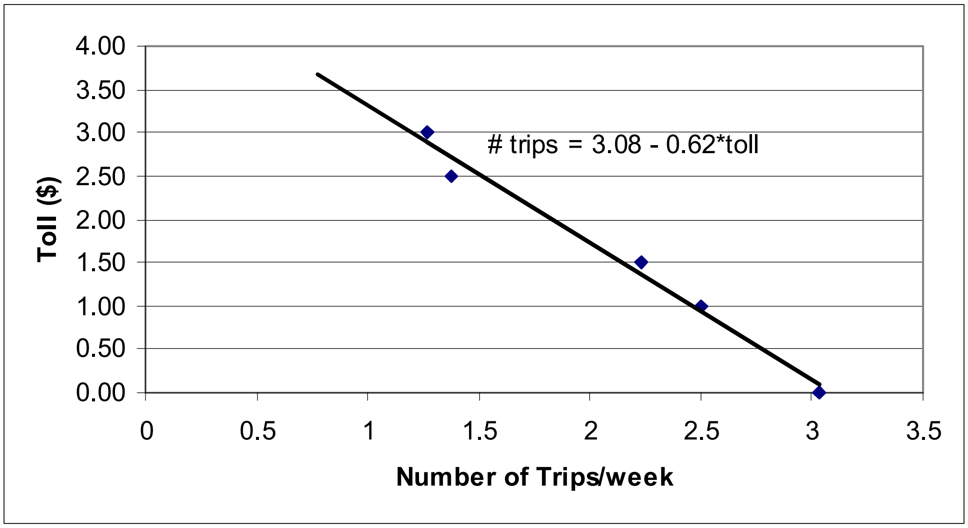


Figure 4.13 Stated Number of QuickRide Trips for Various Flat Toll Rates

4.1.5.2 **Variable QuickRide Toll** Participants were generally indifferent or opposed to the idea of varying the QuickRide toll with the time of day or the amount of congestion on the HOT lanes. Lowering the toll during specific off-peak periods and raising the toll during peak periods was opposed by 38.3 percent of participants, while 42.6 percent opposed varying the toll with the amount of traffic on the HOT lanes (see Table 4.2).

[2] Elasticity = Slope x (Toll / #Trips)

Table 4.2 Survey Respondents' Reaction to Potential QuickRide Pricing Options

	Varying toll by time of day (%)	Varying toll by amount of traffic in HOT lanes (%)
Strongly favor	14.3	13.8
Somewhat favor	14.5	12.2
Indifferent	32.8	31.4
Somewhat oppose	17.7	21.4
Strongly oppose	20.6	21.2

4.1.5.3 **SOV Buy-in** Of the four potential pricing options participants were asked to comment on, the ability to drive alone on the HOT lane at higher tolls was the most favored. Approximately 70 percent of participants favored allowing drivers to drive alone on the HOT lane for a higher toll than carpoolers, while 8.1 percent were indifferent. The number of weekly trips respondents indicated they would take as SOV drivers on the HOT lane varied with the toll as shown in Figure 4.14.

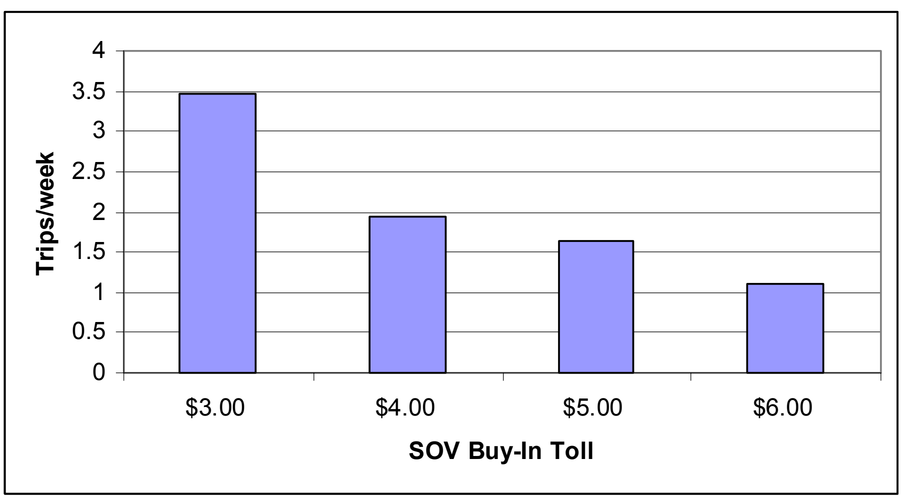


Figure 4.14 Stated Number of QuickRide Trips for Various SOV-Buy-In Toll Rates

4.1.6 Characteristics of Participants' Non-QuickRide Trips

Participants were asked about their non-QuickRide trips in the week prior to their receiving the survey. Approximately 54 percent of participants drove alone while approximately 30 and 13 percent traveled in two-person carpools and carpools of three or more persons, respectively (see Figure 4.15). The average number of trips on both freeways, irrespective of travel mode, was 7.3 per person per week. Commuting accounted for 70.6 percent of the non-QuickRide trips. On the occasions when participants traveled in the HOT lane in 3+ person carpools, an average of 6.88 minutes was spent picking up and dropping off all additional carpool partners (other than the usual QuickRide carpool partner).

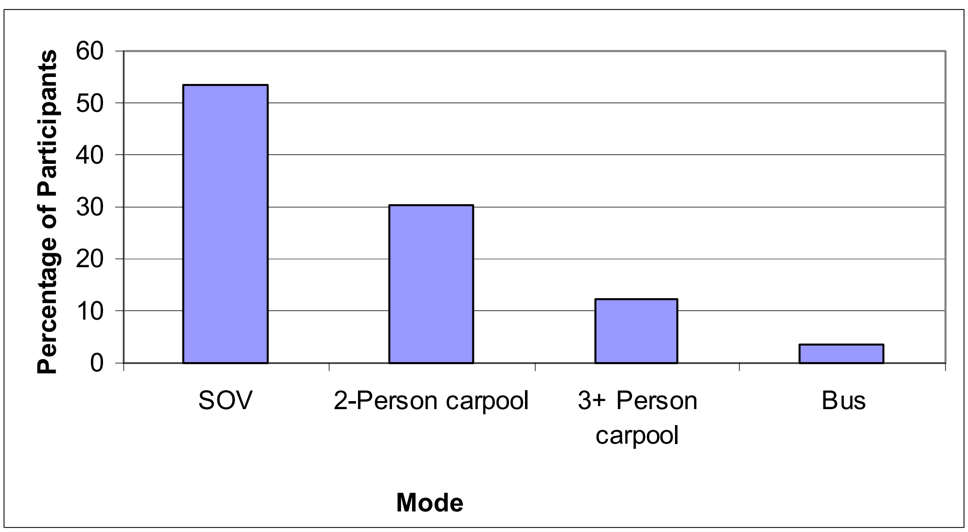


Figure 4.15 Modes of Travel Used by Participants when not Using QuickRide

Participants cited the lack of common trip times as the most important reason for not always carpooling with three or more people. The need for advanced arrangements, restrictions on choice of when to travel, and lack of common origin-destination combinations were also important reasons for not forming 3+ person carpools. Table 4.3 summarizes how participants, on average, rated various factors that inhibit carpooling on a scale of 1 to 10 (1 indicating not important and 10 indicating important).

Table 4.3 Relative Importance of Factors Responsible for Not Forming HOV-3+ Carpools

Factor	All Participants	Katy AM	Katy PM	Northwest AM
Need for advanced arrangements	7.32	7.12	7.13	7.74
Restrictions on choice of when to travel	7.96	7.22	8.27	8.41
Lack of common origin-destination combinations	7.11	6.01	7.18	8.20
Lack of common trip times	8.19	7.53	8.54	8.48
Others	6.61	9.52	3.34	6.12

Ranking out of 10, with 1 being unimportant and 10 indicating important

4.1.7 Value of Travel Time

The Value of time (VOT) was estimated using the weighted average of the ratio of the QuickRide toll to the difference between perceived travel time savings and carpool formation times. The more comprehensive and theoretically sound approach of evaluating the value of time as the ratio of the coefficient of time to cost in the utility equation was not used because the QuickRide toll was constant for all participants and was not modeled. Using the former approach, which assumed only time and toll matter, the implicit value of time (VOT) was estimated as \$5.63 per hour for all participants.

$$VOT = \frac{\sum_{i=1}^{n} \frac{C}{(t_i - e_i)/60}}{n} \tag{3}$$

where,

t_i = perceived QuickRide time savings by participant i,

e_i = time spent by participant i on carpool formation,

C = QuickRide toll (\$2.00 per trip), and

n = number of participants.

Table 4.4 shows how the value of time varies with attributes such as trip purpose and participants' socioeconomic characteristics.

The results show that participants aged between 25 and 64 years old valued their travel time savings higher than those below 25 or above 64. It was therefore expected that these participants were more likely to be frequent QuickRide users. Participants also valued their commute (\$6.74 / hour) and work related (\$5.44 / hour) trips higher than trips for other purposes. The results also show that participants with managerial and/or professionals careers, those with college degrees, those with annual household incomes greater than or equal to \$100,000, hourly wage rate greater than \$30, live in married households, and males placed relatively high values on their travel time savings.

These results could be important for HOT lane development since they might help identify segments of the population who are most likely to pay to avoid congestion.

Table 4.4 Value of Time for Various Groups of Respondents

Attribute	Mean ($/hour)	Standard deviation
Trip purpose		
Commute	6.74	4.99
Recreational	4.92	1.53
Work (Non-commute)	5.44	0.88
School	4.16	1.85
Other	4.14	2.23
Age		
16 to 24	3.57	2.05
25 to 34	8.18	9.44
35 to 44	5.74	3.94
45 to 54	5.24	2.94
55 to 64	5.63	2.91
65 or more	4.71	2.69
Gender		
Male	5.94	5.33
Female	5.40	3.39
Household type		
Single adult	5.34	2.32
Unrelated adults	4.01	2.19
Married without child	5.81	3.84
Married with child(ren)	5.77	4.9
Single parent family	5.35	5.86
Other	2.84	1.1

Table 4.4 Continued

Attribute	Mean ($/hour)	Standard deviation
Occupation		
Professional / Managerial	6.65	4.66
Technical	2.14	5.68
Sales	3.95	1.25
Administrative / Clerical	4.75	2.29
Other	4.77	1.65
Last year of school completed		
Less than high school	5.87	4.39
High school graduate	4.97	1.67
Some college / vocational	3.7	2.4
College graduate	6.32	6.36
Postgraduate degree	6.19	2.95
Hourly wage rate		
Less than $10	3.42	2.2
$10.01 to $15	5.01	3.09
$15.01 to $20	4.77	2.32
$20.01 to $30	3.89	5.34
$30.01 to $40	5.69	2.89
$40.01 to $50	8.58	8.75
$50.01 to $60	9.5	3.72
$60.01 to $100	5.63	3.5
Over $100	4.14	2.67

4.1.8 Summary

Most participants enrolled in the QuickRide program primarily to avoid traffic congestion on the main lanes. About the same number of males and females responded to the survey. Most respondents were between 45 and 54 years old and/or married, had at least a college degree, had professional or managerial careers, had annual household incomes of $50,000 or more, and an average wage rate of $30.01 to $50.00 per hour in 2002. The average household size was 2.99 persons and an average 2.32 vehicles were available to each household.

Each participant made an average of 0.64 QuickRide trips in the week preceding the survey. Most of these were commute trips. Most participants cited the difficulty of participating in carpools as the main reason for the relatively low patronage. They indicated a willingness to increase their current level of participation if they could drive alone on the HOT lanes for a higher toll (80.5 percent of participants) or if the current toll were reduced (28.5 percent of participants) for HOV-2. Of all respondents, 53.6 percent drove alone during their non-QuickRide trip (in the week preceding the survey), while 30.4 percent traveled in two-person carpools. For an average QuickRide trip length of 45.3 minutes, participants spent 4.3 minutes on carpool formation. The average QuickRide travel time savings perceived by participants was 29.77 minutes yielding an implicit value of time of $5.63/hour.

4.2 Factors Affecting the Frequency of QuickRide Usage

As discussed in section 3, respondents were categorized into three groups based on the number of QuickRide trips they made in the week immediately preceding the survey as well as their preferred route. The trip-based classifications were infrequent (0–1 trips per week on Katy or Northwest), midlevel (2–4 trips per week on Katy or 2–3 trips per week on Northwest), and frequent (5–10 trips per week on Katy or 4–5 trips per week on Northwest) QuickRide participants. This section identified factors influencing the level of usage of QuickRide and formulated hypotheses for modeling the demand for HOT lane usage. Appendix B provides a summary of the statistical tests conducted for comparing these groups of QuickRide users.

4.2.1 Individual Demographics

Frequent and midlevel QuickRide participants were significantly more likely to be 35 to 44 years old and significantly less likely to be 65 years of age or older. There were significantly more females than males in the mid-level and frequent participants group than in the infrequent participants group. College graduates or those with some college/vocational education were significantly more likely to be midlevel or frequent participants than postgraduate degree holders. Administrative/clerical workers were also significantly more likely to be midlevel 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 midlevel and frequent participants, most of whom earned between $20.01 and $30.00 per hour.

4.2.2 Household Characteristics

There were more unrelated adults per household among the frequent participants than infrequent and midlevel participants. There were also more single-parent families among the midlevel and frequent participants than among infrequent participants. Approximately 7 percent of respondents reported an annual household income below $50,000 with the proportion of mid-level participants in this group being significantly higher than both frequent and infrequent participants. About 62 percent of respondents stated an annual household income of $100,000 or more. Although rather high, this is not surprising, as drivers in these corridors generally have higher than average incomes.

4.2.3 Commute Characteristics

4.2.3.1 **Trip Purpose** A significantly higher proportion of midlevel (90 percent) and frequent (83 percent) participants used QuickRide for commute trips. No shopping/recreational trips were made by midlevel and frequent participants, whereas about 12 percent of infrequent participants' trips were for shopping/recreational purposes suggesting a significant difference between participants. Trips made to schools were significantly lower among midlevel participants than among infrequent and frequent participants (see Figure 4.16).

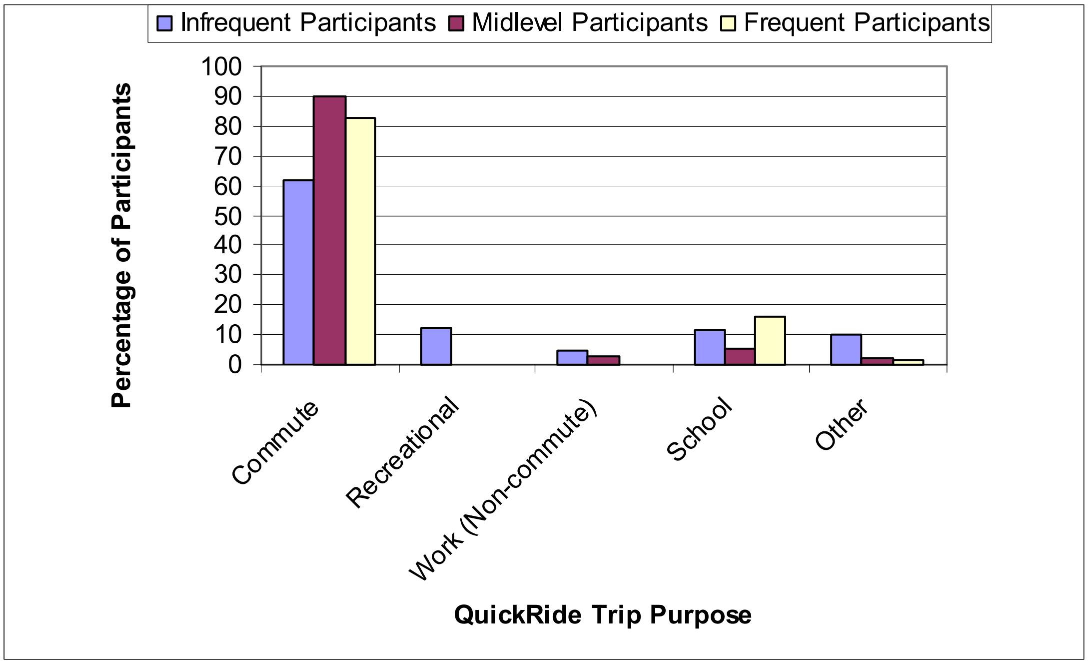


Figure 4.16 Distribution of QuickRide Trip Purpose

4.2.3.2 **Trip Length and Perceived QuickRide Time Savings** Mid-level participants made significantly longer trips than both frequent and infrequent participants, with infrequent participants making the shortest trips (see Figure 4.17). Midlevel and frequent QuickRide participants reported significantly higher perceived QuickRide travel time savings of more than 34 minutes (more than double that actually recorded during the QuickRide operating hours on both the Katy Freeway and the Northwest Freeway). Infrequent participants reported a perceived travel time savings of 28.7 minutes (see Figure 4.18).

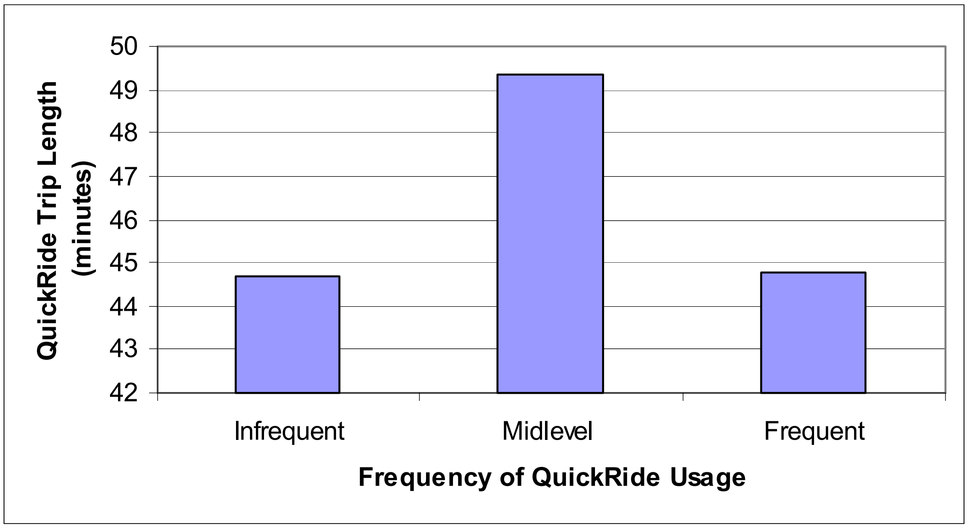


Figure 4.17 QuickRide Trip Lengths

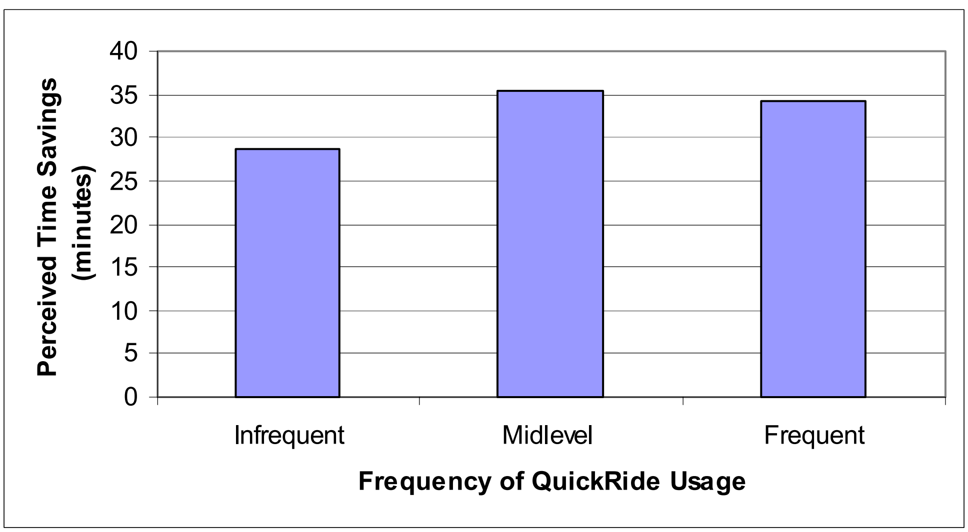


Figure 4.18 Perceived Travel Time Savings Using QuickRide

4.2.3.3 **Usual Carpool Partner and Carpool Formation Time** Midlevel participants were significantly more likely to carpool with an adult family member or neighbor than either frequent or infrequent participants. Midlevel and frequent participants were also significantly more likely to spend some extra time forming carpools (5.32 minutes) than infrequent participants (4.14 minutes). One possible explanation would be that midlevel and frequent QuickRide participants have established carpools while infrequent participants normally only carpool when it is very convenient for them and therefore have low average formation times (*12*). Frequent and midlevel participants had significantly higher carpool formation times than infrequent participants when carpooling with a child or an adult family member (see Figure 4.19).

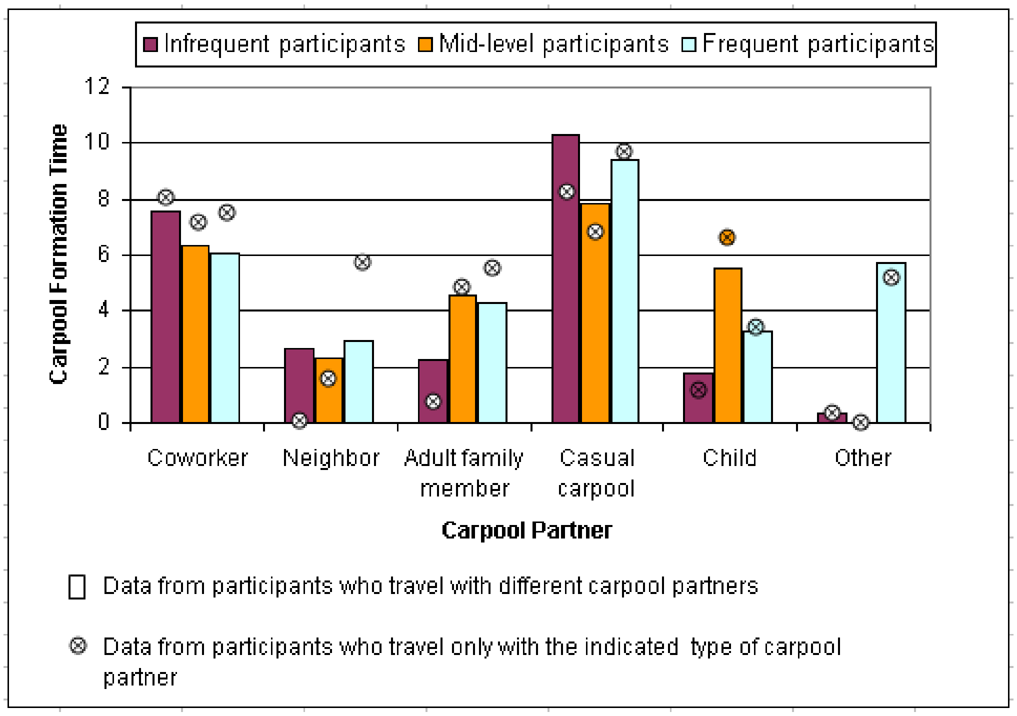


Figure 4.19 QuickRide Carpool Formation Times for Various Carpool Compositions

4.2.3.4 **Frequency of Travel in the Katy/Northwest Freeway Corridor** Frequent QuickRide participants reported significantly more non-QuickRide trips on the Katy and

Northwest Freeway travel corridors than both midlevel participants and infrequent QuickRide participants (see Figure 4.20).

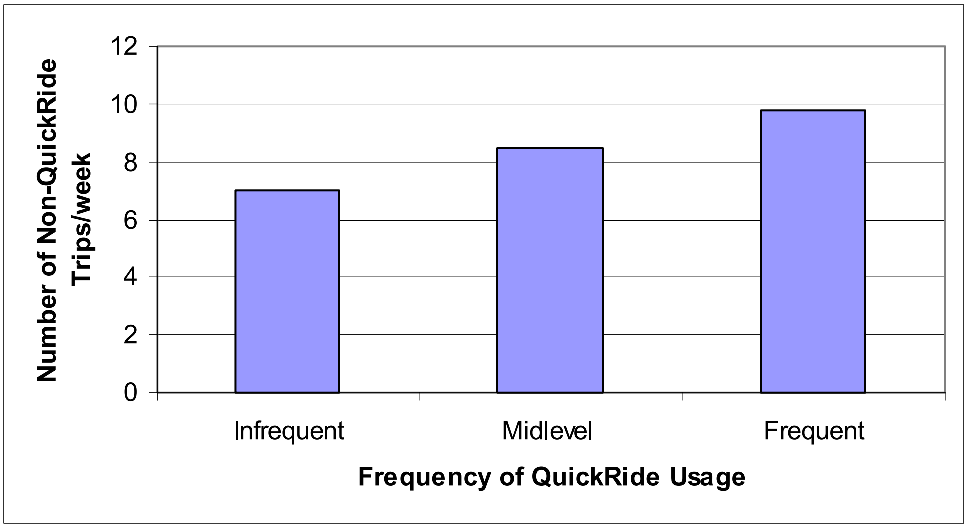


Figure 4.20 Average Number of Trips in Corridor Irrespective of Travel Mode

4.2.3.4 **Effect of Toll on Frequency of Participation** Approximately 51 percent of frequent participants, 33 percent of midlevel participants, and 25 percent of infrequent participants said their carpool partners helped pay the $2.00 QuickRide toll. In response to a question that asked for the number of QuickRide trips per week enrollees would be willing to take at toll levels between $0.00 and $3.00, frequent participants consistently stated a higher number of trips than midlevel participants while mid-level participants 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 the number of QuickRide trips, indicating inelastic responses to toll (see Figure 4.21). Elasticities were estimated to be -0.77, -0.54, and -0.36 for infrequent, midlevel, and frequent QuickRide participants respectively.

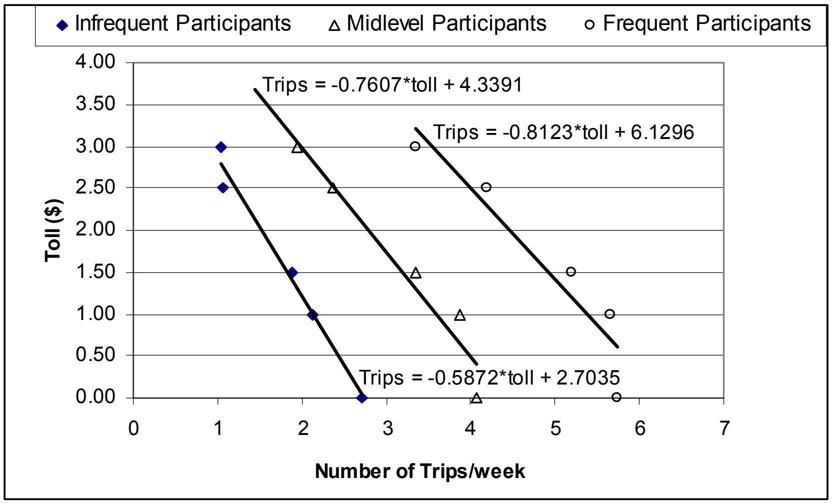


Figure 4.21 Stated Number of QuickRide Trips at Various Toll Levels

4.2.4 Summary

QuickRide was significantly more likely to be used by female participants, those aged between 35 and 44 years old as well as participants with administrative/clerical careers, college degrees as well as those who earned between $20.01 and $30.00 per hour in 2002. Participants were more likely to use QuickRide on commute trips than when they were on non-commute trips. Those who perceived higher travel time savings, traveled most frequently in the corridors, usually carpooled with an adult family member, spent much time on carpool formation, and/or shared the toll with their carpool partners were also significantly more likely to be frequent QuickRide participants. Frequent participants also had the most highly inelastic demand for QuickRide use.

4.3 Modeling the Frequency of QuickRide Usage

4.3.1 Background

To better understand which factors have the most significant influence on the decision to use the HOT lanes (QuickRide) and to quantify their importance, a discrete choice model was developed. This model provided insight into how these factors contributed or interacted with each other and ultimately how they affected the demand for the HOT lanes. Discrete choice models assume that each decision-maker, n has a utility function given by (*47*):

$$U_{nj} = \beta' X_{nj} + \varepsilon_{nj} \tag{4}$$

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 (*34*). 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 (*34, 47, 48, 49*). The most common model used is the *logit model,* which assumes that the random utilities follow the extreme value distribution (error terms are independent and identically distributed). The probability that decision-maker, n chooses mode i ($i \in j$) is given by:

$$P_{ni} = \frac{e^{\beta' X_{ni}}}{\sum_{all\ j} e^{\beta' X_{nj}}} \quad ; \quad \forall_j \neq i \tag{5}$$

In this analysis the dependent variable, QuickRide trip frequency, was discrete and ordered so the ordered logit model (a special case of logit models) was used. Thus a QuickRide participant's level of participation was represented as:

"Infrequent" if $U_{nj} < \mu_0$

"Midlevel" if $\mu_0 < U_{nj} < \mu_1$

"Frequent" if $U_{nj} > \mu_1$

where μ_0, μ_1 are the cut-off points between infrequent-midlevel and midlevel-frequent participation respectively.

Using these cut-off points the probability of a particular level of QuickRide usage by a decision-maker, n was obtained from the relations (*47*):

$$P_{n1} = \frac{1}{1 + e^{-(\mu_0 - \beta' X_{nj})}} \tag{6}$$

$$P_{n2} = \frac{1}{1+e^{-(\mu_1 - \beta' X_{nj})}} - P_1 \tag{7}$$

$$P_{n3} = 1-(P_{n1} + P_{n2}) \tag{8}$$

where,

P_{ni} = the probability of a given level of QuickRide usage $i \in j$ (j = 1, 2, 3).

4.3.2 Hypotheses

Based on a review of carpooling and tolling literature, intuitive reasoning, and results of the statistical analyses done in sections 4.2 and 4.3 the following variables were expected (hypothesized) to have influence the decision to use QuickRide and were thus considered in model development.

4.3.2.1 **Trip Purpose** It was hypothesized that travelers were more likely to have used QuickRide when they were on commute trips than on non-commute trips. This hypothesis was based on the fact that commute trips are generally time constrained and therefore, users were more likely to have received maximum benefits from using QuickRide.

4.3.2.2 **Trip Length** It was expected that, all things being equal, individuals who made longer trips were more likely to make more QuickRide trips than those who traveled shorter distances. This was because the QuickRide toll was expected to have been relatively small compared to the total cost of the trip and these travelers were more likely to have traveled the entire length of the HOT lane and more likely to have obtained the maximum travel time savings.

4.3.2.3 **Perceived QuickRide Time Savings** It was expected that QuickRide would have been more attractive to participants who perceived greater time savings using the program than those who perceived little or no time savings.

4.3.2.4 **Carpool Formation Time** It was hypothesized that QuickRide users who spent a significant portion of their time driving to pick up and drop off their carpool partners were less likely to have used the program compared to those who did not have to spend much time forming carpools.

4.3.2.5 **Frequency of Travel in the Katy/Northwest Freeway Corridor** Participants who traveled more frequently in the corridors were expected to be more acquainted with traffic conditions in the corridors and therefore, more likely to have taken advantage of the time savings offered by the HOT lanes compared to those who made only a few trips in the corridors. Hence it was hypothesized that frequent travel in the corridors would correspond to more frequent QuickRide use.

4.3.2.6 **Costs** Since the QuickRide toll was the same for all users it was not used in the model. However, it was expected that participants who shared the toll with their carpool partners were likely to have made more QuickRide trips.

4.3.2.7 **Usual Carpool Partner** It was expected that participants who carpooled with family members would have made more QuickRide trips since the inconvenience of forming a carpool was expected to have been minimal or non-existent for such users.

4.3.2.8 **Household Size** It was hypothesized that larger households were more likely to have used QuickRide more often than smaller households. This was because people living in the same household were likely to have found it easier to form carpools.

4.3.2.9 **Household Type** It was hypothesized that households of married couples with children were likely to have used QuickRide more often than other household types because of family responsibilities and limited spare time. Such households might also not have had as much difficulty forming carpools as might have been the case for single households.

4.3.2.10 **Vehicle Availability** The number of vehicles per household was expected to have been negatively correlated with the frequency of QuickRide use. The availability of many vehicles was more likely to have increased the chances of travelers driving alone rather than carpooling.

4.3.2.11 **Annual Household Income** It was expected that participants from households with higher annual incomes were more capable of paying the QuickRide toll and were thus expected to have made more QuickRide trips than those from lower income households.

4.3.2.12 **Individual Demographics** Individual demographics like age, gender, education, occupation and hourly wage rate were all expected to have impacted the frequency of QuickRide usage. It was expected that older travelers (over 55 years old) and people at younger ages were not likely to have used QuickRide as often as travelers between 25 and 54 years old. This was based on the assumption that younger travelers might not have had many constraints on their time or might not have been able to pay to make many QuickRide trips as the older and working participants. As they became older, a rise in financial capabilities and time constraints might have caused them to make more QuickRide trips. With old age, retirement, probable declining income and less childcare responsibilities might have caused people to make less QuickRide trips. Females were also expected to have made more QuickRide trips than males because of childcare and other family commitments. Highly educated individuals were more likely to have understood the benefits of QuickRide and were therefore more likely to have used it. It was also expected that travelers with professional and / or administrative positions might have made more QuickRide trips than travelers with other careers.

4.3.3 Model Estimation and Results

Various combinations of the 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 (*50*). The explanatory variables used in the model are defined in Table 4.5. Table 4.6 is a summary of the modeling results.

4.3.4 Summary

As hypothesized, the model results showed that QuickRide was more likely to have been used by commuters. It was predicted (at 5 percent level of significance) that the frequency of participation increased with commute characteristics such as, increasing trip lengths, high perceived travel time savings, and more frequent travel in the Katy or Northwest Freeway travel corridor. However, the frequency of QuickRide usage was predicted to decrease with increasing carpool formation times. These results were reasonable. For example, commute trips are usually time constrained and participants were likely to have derived 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 increasing trip length. It was also reasonable that the program was 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 increasing frequency of use of the travel corridor (irrespective of travel mode) was also not surprising since frequent travelers were generally expected to be more acquainted with traffic conditions in the corridor than occasional travelers (*13*).

Table 4.5 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	
Marital status	1, if married without a child	–
	0, otherwise	
Age	1, if 25 to 54 years old	+
	0, if 16 to 24 or 55 years 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 4.6 Model Estimation Results (Frequency of QuickRide Usage)

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
Marital status	-0.291	0.128	-2.27	0.023
Age (25–54)	0.628	0.223	2.82	0.005
College education	0.340	0.118	2.88	0.004
Cut-off point1	0 (by default)			
Cut-off point 2	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			

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 more 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 statistically significant. It 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.)

4.4 Modeling Choice of Lane, Time of Travel, and Vehicle Occupancy

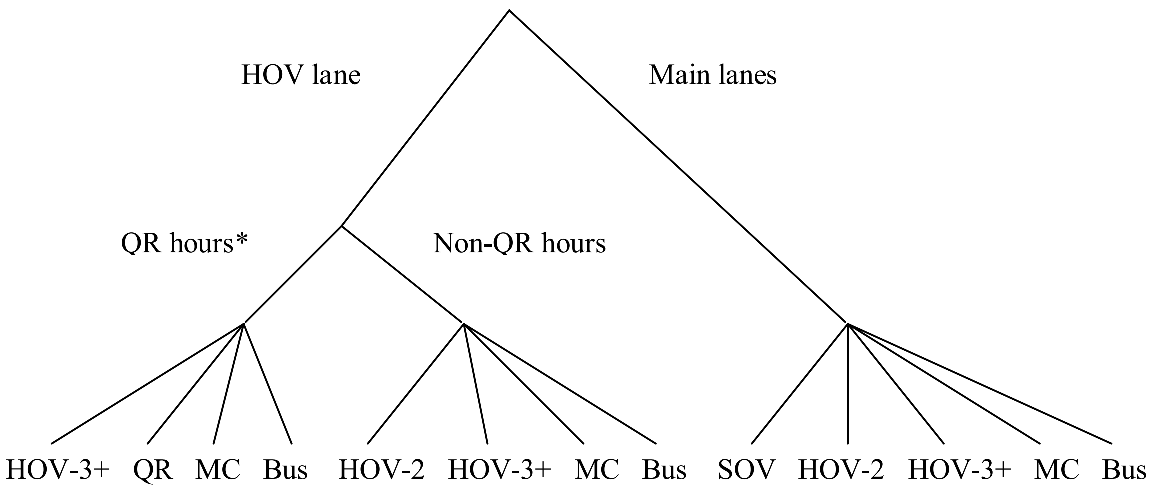
4.4.1 Background

In contrast to the two California HOT projects where drivers of single occupancy vehicles (SOVs) could pay a toll to use the HOT lanes, SOVs were not allowed on the HOT lanes in Houston. As of March, 2004 the Houston HOT lanes had a minimum vehicle occupancy requirement of 2 persons during the non-QuickRide hours and 3 persons during QuickRide hours. However, vehicles with two occupants were allowed on the HOT lanes for a $2 toll during QuickRide hours provided such vehicles displayed both a QuickRide hang tag and a transponder. These occupancy restrictions invariably affected the decision to use QuickRide vis-à-vis other travel modes that had little or no restrictions on vehicle occupancy.

In general, the following alternative travel modes were available to QuickRide enrollees when they used either the Katy Freeway or the Northwest Freeway travel corridor:

- Drive alone (SOV),
- Drive with one other person (HOV-2),
- Use QuickRide, QR (HOV-2 and $2 toll),
- Travel with two or more other persons (HOV-3+),
- Ride a motorcycle (MC), or
- Travel on a metro bus (Bus)

However, not all of these modes were available to all drivers at all times. There were some restrictions on mode choice depending on which lane (HOV versus main lanes) was used or what time of day (QuickRide hours versus non-QuickRide hours) the trip took place. Hence for any QuickRide enrollee traveling in any of these two corridors, the mode choice process or decision may be represented schematically by the tree diagram below.



*6:45 a.m. - 8:00 a.m. on both freeways, and 5:00 p.m. – 6:00 p.m. on Katy Freeway.

Figure 4.22: Mode Choice Options along Katy Freeway and Northwest Freeway

To help understand some of the factors that determined QuickRide travelers' choice of mode along the Katy Freeway and Northwest Freeway travel corridors, a nested logit model was developed for the choice between:

- Lanes (HOV lane versus main lanes),
- Departure times (QuickRide hours versus non-QuickRide hours), and
- Travel modes/vehicle occupancy (SOV, HOV-2, QuickRide, and HOV-3+).

The utility that each QuickRide driver, n obtained from alternative *i* in nest A_k (in Figure 4.22) is given by:

$$U_{nj} = V_{nj} + \varepsilon_{nj} \tag{9}$$

Where,

V_{nj} is the systematic (observed) utility component and ε_{nj} is a vector of random (unobserved) factors.

The probability of choosing a lower level alternative from nest A_k is obtained from the relation:

$$P_{ni} = \frac{e^{V_{ni}/\lambda_k}\left(\sum_{j\in A_k} e^{V_{nj}/\lambda_k}\right)^{\lambda_k - 1}}{\sum_{l=1}^{K}\left(\sum_{j\in A_l} e^{V_{nj}/\lambda_l}\right)^{\lambda_l}} \tag{10}$$

Where,

λ_k ($0<\lambda_k<1$), is a measure of the degree of independence in the random utility component among the alternatives in nest A_k and K is the number of nests (*47*).

Equation 9 may be decomposed into the product of two standard logit probabilities as shown below:

$$P_{nA_k} = \frac{e^{W_{nk}+\lambda_k I_{nk}}}{\sum_{l=1}^{K} e^{W_{nl}+\lambda_l I_{nl}}} \tag{11}$$

$$P_{ni/A_k} = \frac{e^{Y_{ni}/\lambda_k}}{\sum_{j\in A_k} e^{Y_{nj}/\lambda_k}} \tag{12}$$

where,

$$I_{nk} = \ln \sum_{j\in A_k} e^{Y_{nj}/\lambda_k} \tag{13}$$

$$U_{nj} = W_{nk} + Y_{nj} + \varepsilon_{nj} \tag{14}$$

- Equation 11 is the marginal probability of choosing an alternative within nest A_k
- Equation 12 is the conditional probability of choosing alternative i given that nest A_k is chosen
- W_{nk} is a component of the systematic utility, V that is constant for all alternatives within a nest, and
- Y_{nj} is a component of the systematic utility that varies within a nest
- I_{nk} is the logsum or inclusive value and serves as a link between the upper and lower level models by bringing information from the lower level model into the upper level model (*17, 47, 49*).

4.4.2 Hypotheses, Model Estimation, and Results

Each survey respondent was requested to provide information on characteristics of the most recent QuickRide trip in either the Katy Freeway or Northwest Freeway travel corridor as well as those of the most recent non-QuickRide trip in the same corridor. Thus information on trip characteristics were obtained from respondents rather than calculated from the network. As each respondent provided two cases of responses, the total number of cases available for this analysis is 1022. It should be noted that no respondent traveled by motorcycle while only two respondents traveled by bus. Therefore, these two modes were not expected to have significant effects on mode choice (at least not among those QuickRide enrollees who responded to the survey). Consequently the analysis focused on the choice between using QuickRide, driving alone, traveling in two-person carpools, and traveling in carpools of 3 or more persons.

Model estimation was done in a bottom-up approach and it involved the sequential estimation of distinct multinomial (or binary) logit models for the lower level nests, estimation of the inclusive values (logsums), and combining these to estimate marginal choice probabilities for the upper level modes. The explanatory variables used in model estimation and their measurements are provided in Table 4.7. The expected (hypothesized) impacts of these variables on the choice process are discussed when each stage of the modeling effort is carried out. Issues of interest were the effect of the $2 QuickRide toll on mode choice as well as how time spent on carpool formation affected QuickRide usage. Other issues were the effect of trip length and socio-economic characteristics (for example age, household size, vehicle availability, and income) on mode choice.

Table 4.7 Variable Definition for Nested Logit Model

Variable	Measurement
Trip length	Travel time (minutes)
Carpool formation time	Time to pick up/drop off carpool partner(s)
Household income ($)	$5 if income Less than $10,000
	$12.5 if income is $10,000 to $14,999
	$20 if income is $15,000 to $24,999
	$30 if income is $25,000 to $34,999
	$42.5 if income is $35,000 to $49,999
	$62.5 if income is $50,000 to $74,999
	$87.5 if income is $75,000 to $99,999
	$150 if income is $100,000 or more
Male	1, if male
	0, if female
Household size	Number of persons per household
Vehicle availability	Number of vehicles per household
Commute trip	1, if trip purpose = commute
	0, otherwise
Work trip	1, if trip purpose = work related (other than commuting)
	0, otherwise
Recreational trip	1, if trip purpose = recreational/social/shopping/entertainment/ personal errands
	0, otherwise

4.4.2.1 **Model 1 Travel on HOV Lane during QuickRide Hours** For QuickRide enrollees who traveled on the HOV lane during QuickRide hours, the available alternatives were using QuickRide or traveling in carpools of three or more persons (Note that since only two respondents traveled by bus and none traveled by motorcycle these options were not modeled) . Using QuickRide entailed traveling with one other person and paying a $2 toll while traveling in three-person carpools involved traveling with at least two other persons (no fee was charged). Since there was no toll for the HOV-3+ option, drivers who used this option chose between paying the $2 QuickRide toll and finding at least one more passenger to travel free. In some cases finding additional passenger(s) may have involved extra time beyond that required to find a single QuickRide passenger. It was expected that, all other things being equal, participants who indicated they spent little or no additional time finding the extra passenger(s) required for HOV-3+ were more likely to have selected this option (with no fee) than QuickRide (with its $2 toll). The length of a trip was also expected to affect the decision to use QuickRide or HOV-3+. It was expected that travelers who made longer trips were more likely to have opted for QuickRide than HOV-3+. This was because as trip length increased, the QuickRide toll was expected to have become a smaller proportion of the total cost of the trip.

Socio-economic characteristics like gender, household size, and household income were also expected to have influenced mode choice. For instance, previous studies had shown that females carpooled more often than males *(13*). It was therefore expected that females were more likely to have patronized HOV-3+ than QuickRide. It was also hypothesized that large households were more likely to have made HOV-3+ trips than smaller households since the inconvenience of carpool formation might have been minimal. Moreover, households with high incomes were expected to have made more QuickRide trips than HOV-3+ trips.

As shown in Table 4.8, QuickRide enrollees who chose the QuickRide option when traveling on the HOV lanes during the morning and afternoon QuickRide operating hours were more likely to have been males and/or participants with high annual household incomes. Increasing trip length and QuickRide carpool formation time increased the likelihood of HOV-3+ usage in preference to HOT (QuickRide) usage among current enrollees.

Table 4.8 Model Results – Choice Model for Travel on HOV Lane during QuickRide Hours

Variable	Alternative	Coefficient	Standard Error	t-stat	p-value
Trip length	HOV-3+	-0.027	0.108	-2.45	0.014
	QR	-0.027	0.108	-2.45	0.014
Carpool formation time	HOV-3+	-0.200	0.056	-3.56	0.000
	QR	-0.200	0.056	-3.56	0.000
Income	HOV-3+	0	-	-	-
	QR	0.0126	0.003	4.76	0.000
Male	HOV-3+	0	-	-	-
	QR	1.063	0.493	2.16	0.031
Number of Observations	494				
Log likelihood function	-101.76				
Percent correct	92.5				

4.4.2.2 **Model 2 Travel on HOV Lane during Non-QuickRide Hours** QuickRide enrollees who traveled on the HOV lanes during the non-QuickRide hours could choose between driving in 2-person carpools and traveling with at least three persons in their cars (Bus and motorcycle were not modeled). For this group of QuickRide drivers, this model explored the effect of variables such as trip length, carpool formation time, household size, and gender on the choice between HOV-2 and HOV-3+. It was expected that females were more likely to have traveled in HOV-3+ carpools. Larger households were also expected to be more likely to have used HOV-3+ than smaller households. It was also expected that longer trips were more likely to have been made by HOV-3+ than by HOV-2.

The results showed QuickRide enrollees with high household income were more likely to have traveled in two person carpools (HOV-2) than carpools of three or more persons (HOV-3+) when traveling on the HOT lanes during the non-QuickRide operating hours with males more likely to have used HOV-3+ than HOV-2. An increase in the time required to form 2-person carpools increased the likelihood of use of HOV-3 (see Table 4.9).

Table 4.9 Model Results – Choice Model for Travel on HOV Lane during Non-QuickRide Hours

Variable	Alternative	Coefficient	Standard Error	t-stat	p-value
Carpool formation time	HOV-3+	-0.183	0.073	-2.51	0.012
	HOV-2	-0.183	0.073	-2.51	0.012
Income	HOV-3+	-0.024	0.608	-3.94	0.000
	HOV-2	0	-	-	-
Male	HOV-3+	2.069	0.775	2.67	0.008
	HOV-2	0	-	-	-
Number of Observations	71				
Log likelihood function	-35.93				
Restricted log likelihood	-46.37				
Likelihood ratio index	0.23				

4.4.2.3 **Model 3 Travel on Main Lanes – All Times** This model examined QuickRide enrollees' mode choice behavior on the main lanes. It was expected that holding all other variables constant, QuickRide drivers were more likely to have driven alone in the main lanes, especially for longer trips. It was also expected that high income earners were more likely to have driven alone when using the main lanes. The availability of more vehicles was also expected to have enhanced the chances of choosing SOV over carpools (HOV-2 or HOV-3+). However, as in many previous studies of carpooling behavior, it was expected that females were more likely to have carpooled than males. Larger households were also expected to have found carpooling less inconvenient than smaller households. Therefore it was hypothesized that the likelihood of carpooling (HOV-2 or HOV-3+) would have been higher in larger households.

The results showed that when traveling in the main lanes, QuickRide enrollees were more likely to have driven alone (SOV) or driven in two person carpools than carpools of three or more persons (see Table 4.10). Long carpool formation times favored the choice of SOVs over HOV-2 and HOV-3+. As expected, participants from larger households were more likely to have carpooled than smaller households.

Table 4.10 Model Results – Choice Model for Travel on Main Lanes

Variable	Alternative	Coefficient	Standard Error	t-stat	p-value
Constant	SOV	1.542	0.888	1.74	0.082
	HOV-2	1.542	0.888	1.74	0.082
	HOV-3+	0	-	-	-
Trip length	SOV	-0.050	0.013	-3.86	0.000
	HOV-2	-0.050	0.013	-3.86	0.000
	HOV-3+	-0.050	0.013	-3.86	0.000
Carpool formation time	SOV	0	-	-	-
	HOV-2	-0.157	0.032	-4.98	0.000
	HOV-3+	-0.157	0.032	-4.98	0.000
Household size	SOV	-0.660	0.247	-2.67	0.008
	HOV-2	-0.660	0.247	-2.67	0.008
	HOV-3+	0	-	-	-
Number of Observations	45				
Log likelihood function	-100.74				
Restricted log likelihood	-131.80				
Likelihood ratio index	0.24				

4.4.2.4 **Model 4: Choice of Departure Time** This model estimated the upper level utility equations for models 1 and 2. Information from models 1 and 2 were incorporated into the specification by entering the inclusive values (logsums) as explanatory variables. The impact of some socio-economic characteristics on QuickRide drivers' choice of departure time (non-QuickRide hours versus QuickRide hours) was also examined.

The results indicated that female participants and/or those between 35 and 44 years old were more likely to have started their trips during the QuickRide operating hours (see Table 4.11). The positive constant term also indicated that, on the average, participants started their trips during the QuickRide operating hours. This made sense as the QuickRide operating hours coincided with the morning and afternoon rush hours when most travel took place along both corridors. The inclusive value was also significantly different from one which indicated high correlation among the alternatives in the lower nest. Thus the nested logit formulation was reasonable.

Table 4.11 Model Results – Choice Model for Departure Time

Variable	Alternative	Coefficient	Standard Error	t-stat	p-value
Inclusive value	QR hours	0.011	0.164	-6.05*	0.000
	Non-QR hours	0.011	0.164	-6.05*	0.000
Constant	QR hours	1.620	0.177	9.16	0.000
	Non-QR hours	0	-	-	-
Male	QR hours	-0.524	0.288	-1.82	0.069
	Non-QR hours	0	-	-	-
Age 35 to 44	QR hours	0.896	0.336	2.66	0.008
	Non-QR hours	0	-	-	-
Number of Observations	565				
Log likelihood function	-258.14				
Restricted log likelihood	-266.10				
Likelihood ratio index	0.03				

* tstat based on the hypothesis H_o: $\lambda = 1$ versus H_1: $\lambda \neq 1$.

4.4.2.5 **Model 5: Choice of Lane** This model is the upper level model for models 3 and 4. Information from models 3 and 4 were transferred by entering the inclusive values (logsums) as explanatory variables. The effect of socio-economic and trip characteristics on lane choice was also explored. It was expected that trip purpose would be an important variable in predicting the choice of lane. In particular it was expected that more commute trips, work trips and school trips were likely to have been made in the HOV lanes than in the main lanes while trips for recreational, social, entertainment or shopping purposes were more likely to have been made on the main lanes.

Model 5 showed that commute trips, work related trips and recreational trips were all more likely to have been made in the main lanes with recreational trips being the most likely, followed by commute trips (see Table 4.12). Work-related trips were the least likely. Participants between 25 and 34 years old were also more likely to have used the HOV lanes than the main lanes. The average preference was travel in the HOV lanes as indicated by the positive constant term. The high t_{stat} value for the inclusive value also indicates that the nested logit formulation was reasonable.

Table 4.12 Model Results – Lane Choice

Variable	Alternative	Coefficient	Standard Error	t-stat	p-value
Inclusive value	Main lane	0.158	0.062	-13.49*	0.000
	HOV lane	0.158	0.062	-13.49*	0.000
Constant	Main lane	0	-	-	-
	HOV lane	2.481	0.345	7.19	0.000
Commute trip	Main lane	0	-	-	-
	HOV lane	-1.176	0.245	-4.80	0.000
Work trip	Main lane	0	-	-	-
	HOV lane	-1.049	0.462	-2.27	0.023
Recreational trip	Main lane	0	-	-	-
	HOV lane	-1.322	0.356	-3.71	0.000
Age 25 to 34	Main lane	0	-	-	-
	HOV lane	0.719	0.254	2.83	0.005
Number of Observations	733				
Log likelihood function	-416.11				
Restricted log likelihood	-442.71				
Likelihood ratio index	0.06				

* tstat based on the hypothesis H_o: $\lambda = 1$ versus H_1: $\lambda \neq 1$.

4.4.3 Summary

The discussion above indicated that carpool formation time was a major determinant of QuickRide drivers' mode choice behavior. Models 2 and 3 suggested that drivers were generally more likely to choose the mode with the least restrictions on vehicle occupancy (SOV in model 3, HOV-2 in model 2) especially if the carpool formation times were "reasonable" (significantly less than perceived time savings). However, increasing carpool formation time increased the likelihood of HOV-3+ usage over QuickRide usage among current enrollees who traveled on the HOV lanes during QuickRide hours (model 1). Similarly, participants who traveled on the HOV lanes during the non-QuickRide operating hours preferred HOV-3+ to HOV-2 when the latter required higher carpool formation times. This suggested a tradeoff between carpool formation time and the $2 QuickRide toll. That is, when the QuickRide carpool formation times were "reasonable" (significantly less than HOV-3+ carpool formation time), drivers were willing to pay $2 to avoid the inconvenience of traveling in carpools of three or more persons and also to enjoy some travel time savings. However, when the QuickRide carpool formation time exceeded the HOV-3+ carpool formation time participants lost the incentive (travel time savings) to pay to use QuickRide and thus opted for HOV-3+. Instituting programs that encourage carpooling and minimize carpool formation times might therefore enhance the likelihood that travelers would use the HOT lanes.

4.5 Examining Participants by Route and Time of Travel

Sections 4.1 to 4.4 examined factors expected to have influenced the choice of HOT lanes (QuickRide) over other competing alternatives and also examined factors that influenced the frequency of HOT lane usage. This section compared the characteristics of QuickRide participants who usually travel in the eastbound direction of the Katy Freeway during the morning peak period (Katy AM), with those who normally traveled westbound on the Katy Freeway during the afternoon peak (Katy PM), as well as participants who traveled eastbound on the Northwest Freeway during the morning peak (Northwest AM). Such a discussion can be useful for guiding policy decisions aimed at identifying localities with the highest likelihood of success and identifying factors relevant to predicting the chances of success or failure of potential HOT lane projects. For example, characteristics of Northwest AM participants could be useful in situations where HOT lanes are proposed for a corridor that traverses a region with trip end characteristics similar to that of the northwest suburbs of Houston and downtown Houston.

Because there were no significant differences between the frequency of QuickRide usage among Katy AM, Katy PM, and Northwest AM participants (see Figure 4.23) the discussion was limited to only those variables identified in sections 4.1 and 4.4 as having had the greatest influence on the frequency of QuickRide usage. It should be noted that whereas there were no significant differences in the frequency of QuickRide usage among the three groups of respondents, the explanatory variables showed significant differences (see Table 4.13). This discussion helped to identify which of these variables combined and interacted most effectively to influence the demand for QuickRide usage among these groups of participants. A detailed statistical analysis of participants by choice of route and time of day has been provided in Appendix C.

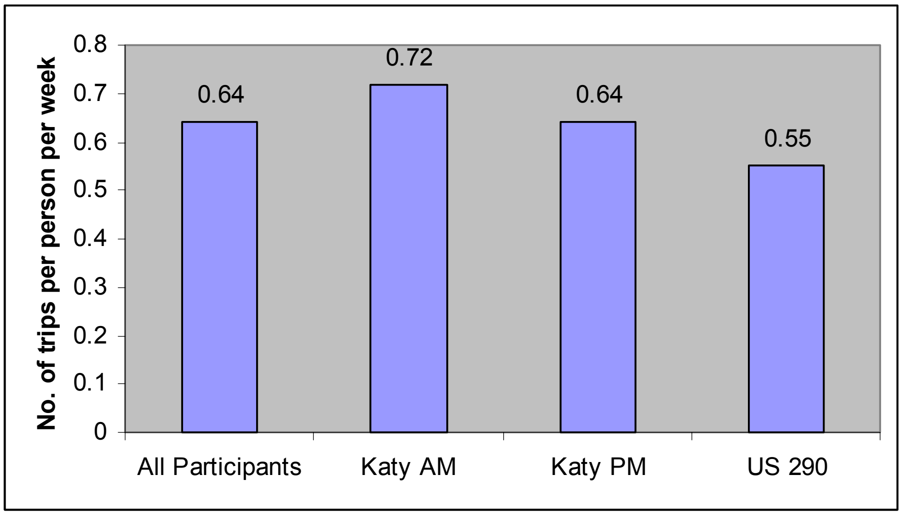


Figure 4.23 Frequency of QuickRide Usage by Route and Time of Day

Table 4.13 Factors Affecting QuickRide Usage

Variable	Katy AM	Katy PM	Northwest AM
Participants between 25 and 54 years old (%)*	72.2	74.2	89.5
Participants married without a child (%)*	33.5	24.0	32.1
College graduates (%)*	44.6	42.3	29.0
Commute trip (%)*	60.8	61.4	76.9
QuickRide trip length (minutes)*	46.59	54.9	38.9
Perceived time savings (minutes)*	34.7	29.5	25.0
Carpool formation time (minutes)	4.2	4.7	4.1
Participants sharing toll with passengers (%)*	22.2	32.1	26.0
Total number of trips in corridor per week*	7.3	8.6	6.2

* Significant difference (at the 0.05 level) between groups of survey respondents.

4.5.1 Socioeconomic Characteristics

Northwest AM participants were significantly more likely to have been between 24 and 54 years old than both Katy AM and Katy PM participants. They were also significantly more likely to have had postgraduate degrees than Katy AM and Katy PM participants. A significantly lower proportion of Katy PM participants were married with no children than Katy AM and Northwest AM participants.

The modeling results in section 4.3 indicated that the frequency of QuickRide usage was expected to increase as the proportion of participants with college degrees and/or between 25 and 54 years old increased but decrease if a high proportion of participants were married without any children. Thus the relatively low proportion of college graduates and the relatively high proportion of participants between 25 and 54 years old among Northwest AM participants were the most important socioeconomic factors responsible for the frequency of QuickRide usage among participants in this group. The converse was true for Katy AM and Katy PM participants. The influence of participants who were married with no children was not as significant among Katy PM participants as it was among Katy AM and Northwest AM participants.

4.5.2 Travel Characteristics

Section 4.3 also showed that commuters and/or participants who shared the QuickRide toll with their carpool passengers were significantly more likely to have made more QuickRide trips. The results also showed that demand for QuickRide (frequency of usage) was expected to increase as the trip length, perceived travel time savings, and familiarity with the travel corridor (measured by the frequency of travel in the corridor) increased but decrease with increasing carpool formation times. Thus travel characteristics that had the most impact on HOT lane use among Northwest AM participants were shorter trip lengths, smaller perceived travel time savings, lower frequency of travel on the corridor and the high proportion of commuters. The converse was true for Katy AM and Katy PM participants.

The level of QuickRide usage among all participants was low (less than 1 trip/person/week). In response to a question that asked participants to state the factors responsible for the low patronage, most respondents cited the difficulty of participating in carpools as the major reason for the relatively low levels of participation (see Table 4.14). A significantly higher proportion of Northwest AM participants (51.2 percent) found carpooling difficult compared to Katy AM and Katy PM participants. This difficulty in carpooling was mainly due to the lack of common trip times. Other reasons were the need for advanced arrangements, restrictions on choice of when to travel, and the lack of common origin-destination combinations. However, as shown in Table 4.15, the impact of restrictions on choice of travel time and the lack of common O-D combinations on carpooling were significantly not as important among Katy AM participants as they were among Katy PM and Northwest AM participants.

Table 4.14: Factors Influencing Current Level of QuickRide Usage

Reason	Katy AM (%)	Katy PM (%)	Northwest AM (%)
Difficult to participate in carpool*	23.5	25.6	51.2
Congestion in HOT lane	0.2	0.6	0.5
Inadequate time savings*	0.4	4.9	0.0
Program is complicated and confusing	0.2	0.0	0.0
Flexible work schedule*	19.2	18.5	6.0
Price of QuickRide*	6.0	1.5	2.1
Sometimes forget*	0.0	4.3	0.2
Other*	50.3	44.5	40.0

* Significant difference (at the 0.05 level) between groups of survey respondents.

Table 4.15 Relative Importance of Factors Responsible for Low Carpooling Amongst Katy AM, Katy PM and Northwest AM Participants

Factor	Katy AM	Katy PM	Northwest AM
Need for advanced arrangements	7.1	7.1	7.7
Restrictions on choice of when to travel*	7.2	8.3	8.4
Lack of common O-D combinations*	6.0	7.2	8.2
Lack of common trip times*	7.5	8.5	8.5
Others	9.5	3.3	6.1

*Ranking out of 10, with 1 being unimportant and 10 indicating important.

* Significant difference (at the 0.05 level) between groups of survey respondents.

4.6 Summary of Findings

This section examines the key findings of this research with the aim of identifying those factors (parameters) which can be expected to influence the demand for HOT lanes.

4.6.1 Trip Characteristics

4.6.1.1 **Trip Length** The study showed that demand for HOT lanes increased as the trip length increased. This was consistent with most studies on carpooling tendencies (*51*). For example, a study of carpooling tendencies on the SR 91 Freeway in Orange County indicated that only 5 percent of drivers who traveled for 20 to 30 minutes carpooled whereas 21 percent of those who traveled for 90 to 110 minutes carpooled (*52*).

4.6.1.2 **Perceived QuickRide Time Savings** This study showed that demand for HOT lanes increased with increasing perceived time savings. In fact, participants perceived QuickRide travel time savings of more than double that actually recorded during the QuickRide operating hours on both the Katy Freeway and the Northwest Freeway. Similar results had been reported in other studies (*53*). According to Dowling *et al.*, the tendency to overestimate travel time savings makes carpool lanes attractive to drivers and "suggests that there may be a psychological advantage in providing a carpool lane even when the available time savings appear minimal" (*51*).

4.6.1.3 **Carpool Formation Time** For an average trip length of 45.3 minutes, participants spent 4.3 minutes (9.5 percent of trip length) picking up and dropping off their carpool partners and this emerged as one of the potential barriers to HOT lane usage. The carpool formation times reported in this study were consistent with those reported by Billheimer in a survey of Bay area carpoolers (*54*). He reported that for an average trip of 47 minutes carpoolers spent 4.8 minutes (10.2 percent of their time) traveling to pick up passengers.

4.6.1.4 **Vehicle Occupancy** Travelers were generally more likely to choose the mode with the least restrictions on vehicle occupancy. As carpool formation time increased, the likelihood of QuickRide (HOV-2 + $2) usage decreased whereas the likelihood of HOV-3+ usage increased (for participants who traveled on HOT lane during the QuickRide operating hours). Participants who traveled on the HOV lanes during the non-QuickRide operating hours were also more likely to choose HOV-3+ rather than HOV-2 as 2-person carpool formation time increased. As noted earlier, this suggested a trade off between the $2 toll and carpool formation time where participants had a lower disincentive to pay to use QuickRide when the carpool formation times were long. This observation was more likely to have been the case for the high percentage of infrequent QuickRide participants who were significantly less likely to spend time on carpool formation. Unlike midlevel and frequent QuickRide participants who might have had well established carpools, infrequent participants probably carpooled only when it was very convenient.

4.6.1.5 **Familiarity with Freeway Corridor** This study used the frequency of travel in the Katy/Northwest freeway corridor as an indicator or measure of the level of familiarity with the corridors. As hypothesized, participants who used the corridors most often were significantly more likely use the HOT lanes. However, a study of SR 91 express lane users by Li, 2001 showed that trip frequency had no significant impact on HOT lane use (*13*).

4.6.1.6 **Trip Purpose** As in Li's study of SR 91 express lane users, this study indicated that HOT lanes were significantly more likely to be used for commute trips.

4.6.1.7 **Toll** In response to a question on QuickRide participants perception of the $2 toll and the extent to which it factored into their decision to use QuickRide, approximately 79 percent said they were either indifferent to the $2.00 toll or found the toll reasonable while approximately 73 percent reported that the toll had little or no significant impact on their decision to use QuickRide. These responses coupled by inelastic responses to minor changes in toll suggested that the toll was not a major deterrent to frequent participation in the QuickRide program. However, it should be noted that sharing the toll with a QuickRide partner increased the frequency of usage (see section 4.3).

4.6.2 Socioeconomic Characteristics

Socio-economic characteristics such as age, household type, and education were expected to have had significant effects on the demand for HOT lanes. 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. However, household size, occupation, and hourly wage rate were not good indicators of HOT usage (at 5 percent level of significance). The results also suggested that participants who were married with no children were less likely to have used QuickRide, while having a college degree increased the probability of using QuickRide. Gender and household income were only weakly related with HOT usage. Participants who had an annual household income 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 any conclusions based on these figures could be misleading.

In his study of SR 91 express lanes users Li, 2001 concluded that household income and age were good indicators of HOT lane use, but gender and other household characteristics had no significant effects (*13*).

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The United States' experience with HOT lanes continues to grow with four projects: two in Houston, Texas, and one each in San Diego, and Riverside County, California being fairly well established. In view of the relative success of these HOT facilities and the potential benefits of HOT lane conversion, a number of states are considering the feasibility of converting their HOV lanes into HOT lane use. This requires a critical assessment of the factors expected to influence the demand and potential for success of future HOT lanes so as to guide policy decisions regarding HOT lane investments. It is expected that the four HOT facilities currently operating in the country should greatly facilitate such studies. After over 6 years in operation (over 3 years on Northwest Freeway), the Houston QuickRide program receives comparatively lower patronage than the two California projects. This research used standard statistical methods and discrete modeling techniques to examine the characteristics of Houston's QuickRide participants as a step in understanding the reasons for the low patronage and identifying those factors expected to influence the demand for HOT lanes.

The results indicated that the disutility of forming a carpool was a major deterrent to HOT lane usage. Moreover, inelastic responses to minor changes in the toll coupled by responses to a question regarding participants feeling towards the $2.00 toll, suggested that the toll was not a major deterrent. The results also showed that commuters, participants with college education, those who shared the toll with their carpool partners, and/or those between 25 and 54 years old were likely to make more HOT lane trips. It was also found that drivers who perceived higher HOT travel time savings, those who traveled on the corridor more frequently, and/or those who undertook longer trips were likely to use HOT lanes more often whereas long carpool formation times decreased the likelihood of using HOT lanes. Gender and annual household income were only loosely related to HOT lane usage.

5.2 Recommendations

It is important to note that because this analysis was based on drivers who were enrolled in the QuickRide program as of December 2002, the responses might not reflect the entire driver populace, especially "non-carpoolers who stress the need for convenience and minimal door-to-door travel times in justifying their decision to drive alone" (*51*). Therefore a more comprehensive analysis of current enrollees, former enrollees, non-users, and participants in the California HOT lane projects is recommended. Such a study should incorporate major issues such as equity, the value of time of different groups of drivers, their disutilities for carpooling, and a more detailed analysis of toll price elasticities. These will shed more light on driver's use of HOT lanes and the decisions behind their level of usage, 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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APPENDIX A

Survey Instrument for Katy AM Participants[3]

Part I*: Please tell us about your most recent trips on the Katy Freeway traveling towards downtown Houston during the work week (Monday to Friday). We are interested in both the last time you used QuickRide and the last time you did not.*
Note: If it has been a long time since you used QuickRide to travel towards downtown and you can't remember the details of the trip then only describe the non-QuickRide trip.

	Using QuickRide (Paid $2)	**Not Using QuickRide**
1. What was the purpose of the trip?	❑ Commuting (to or from work) ❑ Recreational/ Social/Shopping/ Entertainment/ Personal errands ❑ Work related (other than commuting) ❑ School Other (*specify*):	❑ Commuting (to or from work) ❑ Recreational/ Social/Shopping/ Entertainment/ Personal errands ❑ Work related (other than commuting) ❑ School Other (*specify*):
2. What time of day did your trip start? (for example, when did you leave your driveway?)	***a.m. p.m.*** ☐ (*circle one*)	***a.m. p.m.*** ☐ (*circle one*)
3. What time did your trip end? (for example, when did you arrive at the parking lot at work?)	***a.m. p.m.*** ☐ (*circle one*)	***a.m. p.m.*** ☐ (*circle one*)
4. Near what major cross streets did your trip start? *Example: Kinsgsland Blvd and Mason Creek*	☐	☐
5. Near what major cross streets did your trip end? *Example: Main St. and Texas Ave.*	☐	☐
6. How many people, including yourself, were in the vehicle?	*2*	❑ 1 □ 2 ❑ 3 □ 4 ❑ 5 or more ❑ Took a bus ❑ Motorcycle
7. Did you use the HOV lane?	*Yes*	❑ Yes ❑ No

[3] Identical surveys were sent to Katy PM and Northwest AM participants

Part II: Questions Regarding Your Use of the QuickRide Program

8. How did you first learn of the QuickRide program? (*Check only one*)
   - ❑ TV
   - ❑ Mail
   - ❑ Newspaper
   - ❑ Radio
   - ❑ Family / Friend
   - ❑ On the bus
   - ❑ I don't remember
   - ❑ Other (*specify*): ______________________________

9. Which of the following most influenced your decision to join QuickRide? (*Check only one*)
   - ❑ To avoid traffic congestion on the main lanes
   - ❑ It is too dangerous or stressful to drive at peak periods on the main lanes
   - ❑ I could now travel even during the peak period with my carpool partner
   - ❑ Other (*specify*): ______________________________

10. How many ***total trips*** did you make during the past full work week (Monday to Friday) on both the HOV lane and the main lanes? (*Count each direction of travel as one trip.*)

11. How many ***QuickRide trips*** did you make during the past full work week (Monday to Friday) (*Count each direction of travel as one trip.*)?

[ ]

If none, please indicate how often you use QuickRide

[ ] times per month / year (*circle one*)

12. About how much time do you think using QuickRide saves you on a typical one-way trip on the HOV lane compared with using the main lanes?

[ ]

13. To what extent does the $2.00 toll factor into your decision to use QuickRide?
   - ❑ Very significant
   - ❑ Somewhat significant
   - ❑ None/No impact
   - ❑ Somewhat insignificant
   - ❑ Very insignificant

14. What is the main reason you do not use QuickRide more often than you do now? (*Check only one*)

- ❑ I find it difficult to participate in a carpool
- ❑ The HOV lane is sometimes as congested as the main lanes
- ❑ The HOV lane does not offer me enough time savings
- ❑ The program is complicated and confusing
- ❑ My work schedule allows me to adjust my time of travel to less congested periods
- ❑ The price of QuickRide
- ❑ I sometimes forget
- ❑ Other (*specify*): ____

15. Who do you normally travel with when using QuickRide? (*Check all that apply*)
    - ❑ Co-worker / Person in the same or a nearby office building
    - ❑ Neighbor
    - ❑ Adult family member
    - ❑ Impromptu / casual carpool (also known as slugging)
    - ❑ Child
    - ❑ Other (*specify*): ______________________________________

16. How much extra time does it take you to pick up and drop off this passenger?

    [ ] minutes

17. Does the passenger help pay the QuickRide toll?
    - ❑ Yes
    - ❑ No

18. Do you find the $2 QuickRide toll…
    - ❑ Very reasonable
    - ❑ Somewhat reasonable
    - ❑ Neutral
    - ❑ Somewhat unreasonable
    - ❑ Very unreasonable

If you sometimes travel in the HOV lane with ***three or more*** *persons in the car answer Questions 19 and 20. Otherwise skip to Question 21.*

19. How much extra time does it take for you to pick up and drop off the second (and third, fourth, etc.) passenger compared to your trips with you and one passenger?

    [ ]

20. Please rate the following reasons why you do not always carpool with three or more people. A rating of 1 indicates the reason is not a factor while a 10 indicates the reason is always an important factor. Circle your answers.

NOT A FACTOR IMPORTANT FACTOR ← IMPORTANT FACTOR →

The need for advanced arrangements	1 2 3 4 5 6 7 8 9 10
Restrictions on my choice of when to travel	1 2 3 4 5 6 7 8 9 10
Lack of common origin-destination combinations	1 2 3 4 5 6 7 8 9 10
Lack of common trip times	1 2 3 4 5 6 7 8 9 10
Other (*specify*)________________________	1 2 3 4 5 6 7 8 9 10

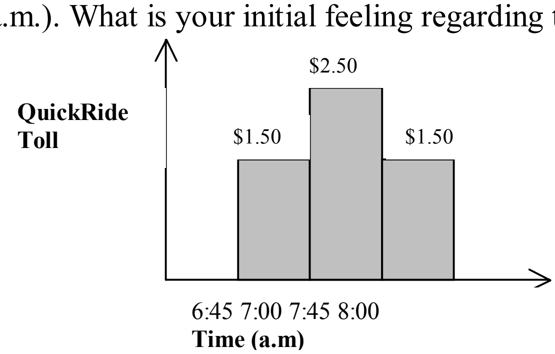
Part III: The questions in this part of the survey are to find out your views on a number of potential options for improving QuickRide. The issues raised are only hypothetical and do not represent local, state or federal policy.

21. Which of the following would cause you to use QuickRide more often? (*Check all that apply*)
- ❑ Longer QuickRide operating hours
- ❑ Being able to pay to drive alone on HOV lane
- ❑ Increased traffic on main freeway lanes
- ❑ Reduced QuickRide toll
- ❑ Other (*specify*) ____________________________________

22. In Question 10, you indicated the number of QuickRide trips you made in the previous week. How many trips would you have made if the following tolls were charged instead of $2.00?

Toll Number of QuickRide trips per week
(count each direction of travel as one trip)
Free ________
$1.00: ________
$1.50: ________
$2.50: ________
$3.00: ________

23. To maintain smooth traffic flow, the $2.00 QuickRide toll could be tied to the time of day. As shown in the graph below, lower tolls may be charged for travel in specific off-peak periods (for example, 6:45 to 7:00 a.m.) and higher tolls during the peak periods (for example, 7:00 to 7:45 a.m.). What is your initial feeling regarding this option? (*Check only one*)



- ❑ Strongly favor
- ❑ Somewhat favor
- ❑ Indifferent
- ❑ Somewhat oppose
- ❑ Strongly oppose

24. The QuickRide toll could also change with the amount of traffic in the HOV lane. For example if the HOV lane is not too congested then the toll might be less than $2. However, if it was very congested the toll may be more than $2 to maintain the smooth flow of traffic. What is your initial feeling regarding this option? (*Check only one*)

- ❑ Strongly favor
- ❑ Somewhat favor
- ❑ Indifferent
- ❑ Somewhat oppose
- ❑ Strongly oppose

25. How do you feel about allowing people to drive alone on the HOV lane for a higher toll than carpoolers?

- ❑ Strongly favor
- ❑ Somewhat favor
- ❑ Indifferent
- ❑ Somewhat oppose
- ❑ Strongly oppose

26. If you could drive alone on the HOV lane for the toll listed below, how often would you drive alone on the HOV lane?

Toll	*Number of trips per week (count each direction of travel as one trip)*
$3.00	____________
$4.00	____________
$5.00	____________
$6.00	____________

Part IV: User Information

The following questions will be used for statistical purposes only and individual responses will remain confidential. All of your answers are very important to us and in no way will they be used to identify you.

27. What is your age?

- ❑ 16 to 24
- ❑ 25 to 34

- ❑ 35 to 44
- ❑ 45 to 54
- ❑ 55 to 64
- ❑ 65 and over

28. What is your gender?
    - ❑ Male
    - ❑ Female

29. Please describe your household type.
    - ❑ Single adult
    - ❑ Unrelated adults (e.g. room mates)
    - ❑ Married without child
    - ❑ Married with child(ren)
    - ❑ Single parent family
    - ❑ Other (*specify*): ____

30. Including yourself, how many people live in your household?

31. All together, how many motor vehicles (including cars, vans, trucks, and motorcycles) are available for use by members of your household?

32. What category best describes your occupation?
    - ❑ Professional / Managerial
    - ❑ Technical
    - ❑ Sales
    - ❑ Administrative / Clerical
    - ❑ Manufacturing
    - ❑ Stay-at-home parent
    - ❑ Unemployed / Seeking work
    - ❑ Other *(specify)*: ____

33. What is the last year of school you have completed?
    - ❑ Less than high school
    - ❑ High school graduate
    - ❑ Some college / Vocational
    - ❑ College graduate
    - ❑ Postgraduate degree

34. What is your best estimate of your hourly wage rate?
    - ❑ Less than $10

- $10.01 to $15
- $15.01 to $20
- $20.01 to $30
- $30.01 to $40
- $40.01 to $50
- $50.01 to $60
- $60.01 to $100
- Over $100

35. What was your annual household income before taxes in 2002?
    - Less than $10,000
    - $10,000 to $14,999
    - $15,000 to $24,999
    - $25,000 to $34,999
    - $35,000 to $49,999
    - $50,000 to $74,999
    - $75,000 to $99,999
    - $100,000 or more

36. Please list any comments or suggestions you have regarding QuickRide:

APPENDIX B

Characteristics of Frequent, Midlevel and Infrequent Participants

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)	Midlevel 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)
Q1: 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
Q1: Non-QuickRide trip purpose*				
Commute	70.6	70.4	73.7	65.1
Recreation	14.1	13.4	15.8	23.3
Work	2.8	2.4	6.1	2.3
School	6.1	6.6	1.8	7.0
Other	6.5	7.2	7.4	2.3
Q2&3: QuickRide trip length (minutes) [a]	45.32	44.70	49.37	44.78
Q2&3: Non-QuickRide trip length (minutes) [a]	53.04	52.44	56.38	56.26
Q6: Non-QuickRide vehicle occupancy				
1	53.6	55.1	39.5	60.5
2	30.4	29.0	42.7	25.6
3	6.6	6.0	10.5	9.3
4	2.0	1.4	5.6	4.7
5+	3.9	4.3	1.6	0.0
Bus	3.5	4.2	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)	Midlevel 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)
Q7: HOV lane use during Non-QuickRide Trip				
Used HOV lane	40.4	39.8	49.2	27.9
Did not use HOV lane	59.6	60.2	50.8	72.1
Q8: How user first learned about QuickRide*				
TV	0.4	0.3	0.6	1.5
Radio	2.6	2.4	5.1	1.5
Mail	3.6	3.7	3.8	1.5
Newspaper*	23.7	25.0	17.2	16.9
Family/Friend	39.8	39.3	41.4	46.2
On the bus	0.1	0.0	0.6	0.0
Don't remember*	18.1	19.8	8.9	10.8
Other*	11.6	9.7	22.3	21.5
Q9: Factor that most influenced decision to join QuickRide				
Avoid main lane congestion	66.2	64.6	74.8	73.4
Avoid danger/ stress on main lane	7.3	7.3	7.5	6.3
Able to travel with carpool partner	22.6	24.2	15.1	14.1
Other	3.9	3.9	2.5	6.3
Q10: Total trips/week on corridor*	7.32	7.04	8.47	9.75
Q11: QuickRide trips/week[a]*	0.64	0.1	2.64	5.65
Q12: Perceived travel time savings*	29.77	28.71	35.29	34.22
Q13: Extent toll factor into decision to use QuickRide*				
Very Significant	6.4	4.7	16.1	12.3
Somewhat significant	20.3	19.6	21.1	30.8
Non/No impact	41.1	41.6	38.5	38.5

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)	Midlevel 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)
Somewhat insignificant	19.8	22.3	6.2	6.2
Very insignificant	12.5	11.8	18.0	12.3
Q14: Reason for less frequent use*				
Difficult to participate in carpool*	33.1	35.4	20.1	22.4
HOV lane sometimes congested*	0.4	0.0	1.9	3.4
Not enough time savings	1.8	2.0	0.6	0.0
Program complicated and confusing*	0.1	0.0	0.6	0.0
Flexible work schedule*	14.7	13.0	26.0	19.0
Price of QuickRide*	3.3	2.5	7.8	6.9
Sometimes forget	1.5	1.7	0.6	0.0
Other	45.1	45.3	42.2	48.3
Q15: 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
Q16: Extra Time to pick up and/drop off QuickRide partner [A]*	4.33	4.14	5.32	5.32
Q17: 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
Q18: 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

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)	Midlevel 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)
Very unreasonable	2.5	2.2	3.7	4.5
Q19: Extra time to pick up and drop off 2^{nd}, 3^{rd}, … passengers (when user travels in HOV lane with 3+ persons)[a]*	6.88	7.41	5.12	4.91
Q20: Why participant does not always form 3+ carpool [a]				
Need for advanced arrangements	7.32	7.41	7.25	6.15
Restrictions on choice of when to travel*	7.96	8.21	6.95	7.34
Lack of common origin-destination combinations*	7.11	7.36	5.95	6.72
Lack of common trip times*	8.19	8.44	7.08	7.71
Other	6.61	6.28	6.68	8.57
Q21: What would increase frequency of participation?*				
Longer QuickRide operating hours*	15.8	14.6	18.5	31.8
Driving alone for a higher fee	80.5	80.8	79.0	77.3
Increased traffic on main lanes*	16.2	14.6	25.0	22.7
Reduced QuickRide toll*	28.4	27.0	35.4	37.9
Other	12.1	12.4	9.9	10.6
Q22: QuickRide trips for various tolls				
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
Q23: Impression about varying toll by time of day				

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)	Midlevel 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)
Strongly favor	14.3	14.4	16.0	9.1
Somewhat favor	14.5	13.1	23.5	18.2
Indifferent	32.8	34.8	23.5	21.2
Somewhat oppose	17.7	18.1	14.2	18.2
Strongly oppose	20.6	19.6	22.8	33.3
Q24: Impression about tying toll to level of congestion in HOV lane*				
Strongly favor	13.8	14.3	14.2	4.6
Somewhat favor	12.2	11.6	14.2	18.5
Indifferent	31.4	33.6	22.2	13.8
Somewhat oppose	21.4	21.5	18.5	27.7
Strongly oppose	21.2	19.1	30.9	35.4
Q25: Impression about allowing SOVs on HOV lane for a higher toll*				
Strongly favor	47.2	49.0	40.4	40.4
Somewhat favor	22.2	22.0	23.0	24.6
Indifferent	8.1	8.7	5.6	3.1
Somewhat oppose	4.6	3.7	6.2	16.9
Strongly oppose	17.9	16.6	24.8	23.1
Q26: Number of SOV trips if allowed for a fee [A]				
$3.00	3.46	3.51	3.05	3.59
$4.00	1.94	1.92	2.16	1.77
$5.00*	1.64	1.74	1.16	0.90
$6.00	1.11	1.15	0.93	0.61
Q27: Age*				
16 to 24	3.4	3.3	4.3	3.0
25 to 34	14.3	14.0	16.1	15.2

Characteristic (Percent of respondents in each category)	Frequency of QuickRide Use			
	All Participants (N = 1459)[b]	Infrequent Participants Katy: 0-1 trips/week Northwest: 0-1 trips/week (N = 1231)	Midlevel 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)
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
Q28: Gender*				
Male	47	48.5	39.6	37.9
Female	53	51.5	60.4	62.1
Q29: 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
Q30: Household size [a]	2.99	2.99	3.05	2.99
Q31: Vehicles per household [a]	2.32	2.30	2.44	2.27
Q32: Occupation*				
Professional/Managerial	64.8	65.2	62.2	64.6
Technical	10.1	10.6	8.3	4.6
Sales	5.5	5.5	5.8	4.6
Administrative/Clerical*	9.3	7.9	16.7	16.9
Manufacturing	0.0	0.0	0.0	0.0
Stay-at-home parent*	0.4	0.3	0.6	3.1
Unemployed/Seeking work	1.6	1.8	0.6	0.0
Other	8.4	8.8	5.8	6.2
Q33: 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

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)	Midlevel 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)
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
Q34: Hourly wage rate				
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
Q35: 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

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. Where users could select more than one answer the total response for that question may exceed 100%.

* Significant difference (at the 0.05 level) between groups of survey respondents. Statistical tests used included:

- Kruskal-Wallis test 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.

APPENDIX C

Characteristics of Participants by Route and Time of Travel

Characteristic (Percent of respondents in each category)	Route and Time of Day			
	All Participants (N = 1459)[b]	Katy AM Participants (N = 473)	Katy PM Participants (N = 469)	Northwest AM Participants (N = 517)
Q1: QuickRide trip purpose*				
Commute*	66.7	60.8	61.4	76.9
Recreation*	9.9	10.6	21.7	0.3
Work*	4.1	5.9	6.8	0.3
School*	11.0	12.3	7.8	11.9
Other*	8.3	10.3	2.4	10.7
Q1: Non-QuickRide trip purpose*				
Commute*	70.6	76.0	49.4	83.8
Recreation*	14.1	16.7	22.5	3.8
Work*	2.8	0.6	7.1	1.1
School*	6.1	6.4	12.7	0.3
Other*	6.5	0.3	8.3	11.0
Q2&3: QuickRide trip length (minutes)* [a]	45.32	46.59	54.86	38.94
Q2&3: Non-QuickRide trip length (minutes)* [a]	53.04	52.1	59.21	48.61
Q6: Non-QuickRide vehicle occupancy*				
1	53.6	57.1	37.3	65.8
2	30.4	25.1	36.7	29.1
3	6.6	3.0	12.9	4.0
4	2.0	3.6	1.6	0.8
5+	3.9	5.7	6.0	0.3
Bus	3.5	5.5	5.5	0.0
Q7: HOV lane use during Non-QuickRide trip				
Used HOV lane	40.4	44.3	44.9	32.0

Characteristic (Percent of respondents in each category)	Route and Time of Day			
	All Participants (N = 1459)[b]	Katy AM Participants (N = 473)	Katy PM Participants (N = 469)	Northwest AM Participants (N = 517)
Did not use HOV lane	59.6	55.7	55.1	68.0
Q8: How user first learned about QuickRide*				
TV	0.4	0.4	0.4	0.4
Radio*	2.6	5.5	1.3	0.8
Mail*	3.6	4.5	5.4	1.1
Newspaper*	23.7	16.6	16.9	37.4
Family/Friend*	39.8	44.3	40.7	34.5
On the bus	0.1	0.2	0.0	0.0
Don’t remember	18.1	20.7	14.8	18.9
Other*	11.6	7.7	20.6	6.9
Q9: Factor that most influenced decision to join QuickRide*				
Avoid main lane congestion	66.2	66.7	66.4	65.7
Avoid danger/stress on main lane*	7.3	14.5	6.3	1.1
Able to travel with carpool partner*	22.6	18.3	26.9	22.7
Other*	3.9	0.4	0.5	10.5
Q10: Total trips/wk on corridor* [a]	7.32	7.26	8.6	6.22
Q11: QuickRide trips/wk* [a]	0.64	0.72	0.64	0.55
Q12: Perceived travel time savings* [a]	29.77	34.66	29.51	24.98
Q13: Extent toll factor into decision to use QuickRide*				
Very significant	6.4	3.0	3.6	12.4
Somewhat significant	20.3	13.5	30.0	17.6
Non/No impact	41.1	40.0	42.8	40.5
Somewhat insignificant	19.8	22.8	10.4	26.0
Very insignificant	12.5	20.7	13.2	3.6
Q14: Reason for less frequent use*				
Difficult to participate in carpool*	33.1	23.5	25.6	51.2
HOV lane sometimes congested	0.4	0.2	0.6	0.5

Characteristic (Percent of respondents in each category)	Route and Time of Day			
	All Participants (N = 1459)[b]	Katy AM Participants (N = 473)	Katy PM Participants (N = 469)	Northwest AM Participants (N = 517)
Not enough time savings*	1.8	0.4	4.9	0.0
Program complicated and confusing	0.1	0.2	0.0	0.0
Flexible work schedule*	14.7	19.2	18.5	6.0
Price of QuickRide*	3.3	6.0	1.5	2.1
Sometimes forget*	1.5	0.0	4.3	0.2
Other*	45.1	50.3	44.5	40.0
Q15: Usual carpool partner*				
Coworker*	40.6	47.5	33.0	41.1
Neighbor*	2.8	5.7	1.7	1.2
Adult family member*	35.9	48.4	43.5	17.6
Casual carpool (slug)*	7.1	5.9	15.1	1.0
Child*	24.7	22.2	16.2	34.8
Other*	4.8	4.4	9.2	1.2
Q16: Extra time to pick up/drop off QuickRide partner [a]	4.33	4.19	4.70	4.11
Q17: Passenger's contribution to toll*				
Passenger helps pay toll	26.8	22.2	32.1	26.0
Passenger does not help pay toll	73.2	77.8	67.9	74.0
18: Impression about $2.00 QuickRide toll*				
Very reasonable	26.9	26.7	32.7	21.5
Somewhat reasonable	29.5	41.5	20.9	26.2
Neutral	22.1	23.1	21.4	21.8
Somewhat unreasonable	19.0	8.3	20.1	28.7
Very unreasonable	2.5	0.4	4.9	1.9
Q19: Extra time to pick up and drop off 2nd, 3rd, … passengers (when user travels in HOV lane with 3+ persons)*[a]	6.88	3.33	9.14	7.85
Q20: Why participant does not always form 3+ carpool [a]				

Characteristic (Percent of respondents in each category)	Route and Time of Day			
	All Participants (N = 1459)[b]	Katy AM Participants (N = 473)	Katy PM Participants (N = 469)	Northwest AM Participants (N = 517)
Need for advanced arrangements	7.32	7.12	7.13	7.74
Restrictions on choice of when to travel*	7.96	7.22	8.27	8.41
Lack of common origin-destination combinations*	7.11	6.01	7.18	8.2
Lack of common trip times*	8.19	7.53	8.54	8.48
Other*	6.61	9.52	3.34	6.12
Q21: What would increase frequency of participation?*				
Longer QuickRide operating hours*	15.8	19.9	25.6	3.3
Driving alone for a higher fee	80.5	79.7	82.3	79.5
Increased traffic on main lanes*	16.2	11.0	25.0	13.0
Reduced QuickRide toll*	28.5	32.6	28.6	24.6
Other	12.1	14.8	11.1	10.4
Q22: QuickRide trips for various tolls				
Free*	3.03	4.78	3.96	0.99
$1.00*	2.50	4.20	2.79	0.93
$1.50*	2.23	3.66	2.76	0.67
$2.50*	1.38	2.78	1.16	0.48
$3.00*	1.27	2.61	1.05	0.42
Q23: Impression about varying toll by time of day				
Strongly favor	14.3	12.1	27.0	4.0
Somewhat favor	14.5	17.1	13.7	13.0
Indifferent	32.8	36.6	31.9	30.0
Somewhat oppose	17.7	13.5	1.7	37.3
Strongly oppose	20.6	20.7	25.7	15.7
Q24: Impression about tying toll to level of congestion in HOV lane*				
Strongly favor	13.8	22.8	16.4	2.5

Characteristic (Percent of respondents in each category)	Route and Time of Day			
	All Participants (N = 1459)[b]	Katy AM Participants (N = 473)	Katy PM Participants (N = 469)	Northwest AM Participants (N = 517)
Somewhat favor	12.2	19.7	11.9	5.1
Indifferent	31.4	22.2	26.4	45.3
Somewhat oppose	21.4	17.8	17.0	29.3
Strongly oppose	21.2	17.5	28.3	17.9
Q25: Impression about allowing SOVs on HOV lane for a higher toll*				
Strongly favor	47.2	43.6	40.2	58.1
Somewhat favor	22.2	29.0	14.1	23.6
Indifferent	8.1	4.9	17.5	1.9
Somewhat oppose	4.6	1.7	9.6	2.5
Strongly oppose	17.9	20.9	18.6	13.9
Q26: Number of SOV trips if allowed for a fee [a]				
$3.00*	3.46	3.96	3.33	3.08
$4.00*	1.94	2.52	1.67	1.67
$5.00*	1.64	2.68	1.48	0.83
$6.00*	1.11	1.89	0.81	0.67
Q27: Age*				
16 to 24*	3.4	0.4	9.6	0.8
25 to 34*	14.3	3.2	16.7	22.9
35 to 44*	26.0	32.7	10.7	33.8
45 to 54	38.4	36.3	46.8	32.8
55 to 64	11.6	18.7	15.1	1.1
65+*	6.2	8.7	1.1	8.6
Q28: Gender*				
Male	47	44.8	63.8	33.2
Female	53	55.2	36.2	66.8
Q29: Household type*				
Single adult*	5.7	5.8	9.8	2.1
Unrelated adults	0.4	0.0	0.4	0.6

Characteristic (Percent of respondents in each category)	Route and Time of Day			
	All Participants (N = 1459)[b]	Katy AM Participants (N = 473)	Katy PM Participants (N = 469)	Northwest AM Participants (N = 517)
Married without child*	29.9	33.5	24.0	32.1
Married with child(ren)	60.5	57.9	60.4	63.0
Single parent family*	1.7	2.9	0.4	1.7
Other*	1.7	0.0	4.9	0.4
Q30: Household size [a]	2.99	2.92	3.01	3.06
Q31: Vehicles per household [a]	2.32	2.33	2.29	2.33
Q32: Occupation*				
Professional/Managerial	64.8	63.2	66.1	65.3
Technical*	10.1	13.6	5.6	11.0
Sales*	5.5	10.4	5.2	0.8
Administrative/Clerical*	9.3	2.8	12.6	12.5
Manufacturing	0.0	0.0	0.0	0.0
Stay-at-home parent*	0.4	1.1	0.2	0.0
Unemployed/Seeking work*	1.6	0.0	4.7	0.2
Other*	8.4	8.9	5.6	10.0
Q33: Last year of school completed*				
Less than high school	0.2	0.4	0.0	0.2
High school graduate	8.8	6.4	10.8	9.5
Some college/Vocational	17.0	17.4	19.1	14.7
College graduate*	38.6	44.6	42.3	29.0
Postgraduate degree*	35.3	31.2	27.7	46.6
Q34: Hourly wage rate				
Less than $10*	3.8	0.5	11.5	0.2
$10.01 to $15*	7.8	5.9	5.9	11.0
$15.01 to $20*	7.8	7.2	13.2	3.6
$20.01 to $30	17.0	18.7	18.0	14.6
$30.01 to $40*	22.2	13.9	6.5	42.9
$40.01 to $50*	8.9	15.5	8.4	3.4
$50.01 to $60*	10.5	7.0	2.2	21.1
$60.01 to $100*	8.1	4.5	19.1	1.9

Characteristic (Percent of respondents in each category)	**Route and Time of Day**			
	All Participants (N = 1459)[b]	**Katy AM Participants (N = 473)**	**Katy PM Participants (N = 469)**	**Northwest AM Participants (N = 517)**
Over $100*	13.9	26.7	15.2	1.2
Q35: Annual household income*				
Less than $10,000	0.1	0.0	0.3	0.0
$10,000 to $14,999	0.0	0.0	0.0	0.0
$15,000 to $24,999	0.1	0.0	0.0	0.3
$25,000 to $34,999*	2.0	5.2	0.0	0.5
$35,000 to $49,999*	4.6	6.2	5.8	2.1
$50,000 to $74,999*	13.7	16.9	17.3	6.2
$75,000 to $99,999*	17.8	8.8	9.5	36.1
$100,000 or more*	61.7	62.9	67.3	54.8

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. Where users could select more than one answer the total response for that question may exceed 100%.

* Significant difference (at the 0.05 level) between groups of survey respondents. Statistical tests used included:
- Kruskal-Wallis test 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 174, 145, and 192 for Katy AM, Katy PM, and US 290 participants, respectively.

VITA

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