HOT Lanes in Houston—Six Years of Experience

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Abstract

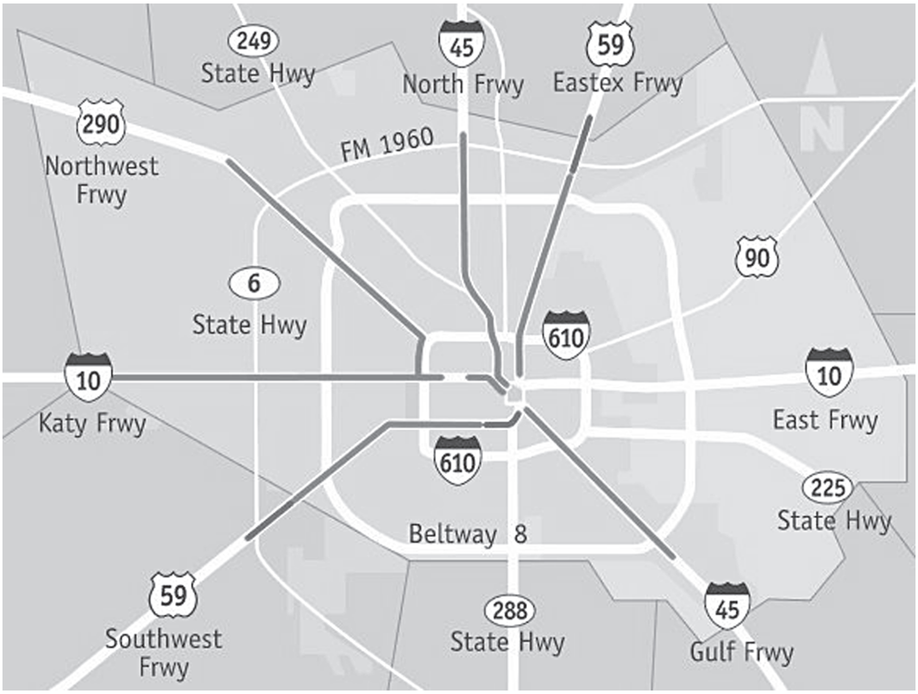
High occupancy/toll (HOT) lanes allow travelers to pay a toll to enter a high occupancy vehicle (HOV) lane when they do not meet the minimum occupancy restrictions of the lane. In cases where HOV lanes are not utilized to their full capacity, this provides an effective, and controlled, use of that spare capacity along with a revenue source to offset expenses. Although this is a promising concept, and many cities around the United States are examining the potential development of a HOT lane, only four HOT lanes currently exist. This research documents the findings of six years of experience with two HOT lanes in Houston, Texas. This includes an examination of the daily number of paying customers on the HOT lanes, benefits of the HOT lanes, socioeconomic and commute characteristics of HOT lane users, and their mode of choice when electing not to use the HOT lane.

Introduction

The Houston metropolitan area has had a long and successful history of using high-occupancy vehicle (HOV) lanes to move travelers quickly and efficiently. The first HOV lane opened to buses and registered vanpools in 1979 on the North Freeway (I-45). Despite these occupancy restrictions the lane was highly successful and carried nearly as many people in the peak period as the two adjacent freeway lanes combined (Turnbull 2003). As a result of this successful demonstration, this HOV lane was barrier separated and became a permanent fixture on this freeway.

Next, a permanent HOV lane was constructed on the Katy Freeway (I-10). Following this, HOV lanes were constructed on I-45 south of downtown Houston, US 59 both north and south of downtown Houston, and the Northwest Freeway (US 290) (see Figure 1). All of these HOV lanes are barrier separated, have adjacent park-and-ride lots, and have significant transit usage; many have direct freeway access (see Figure 2). The result is a system of bus rapid transit (BRT) lanes.

Figure 1. Houston's HOV Lanes



Source: Houston METRO (http://www.ridemetro.org/services/areahovmap.asp).

Figure 2. Park-and-Ride Access to a Barrier-Separated HOV Lane via a T-Ramp

When the Katy HOV lane opened in 1984, only transit buses and registered vanpools could use it (Bullard 1991). To make better use of this road capacity, the restrictions were relaxed in stages until any vehicles with two or more occupants (HOV2+) were allowed. The lane soon became congested during peak traffic periods due to the high number of carpool vehicles using the lane. This prompted Houston METRO, the transit agency responsible for the operation of the HOV lanes, along with TxDOT, to restrict usage to HOV3+ during the morning peak period (6:45 a.m. to 8:15 a.m.) in 1988.[1] Soon after, congestion during the afternoon peak period (5:00 p.m. to 6:00 p.m.) necessitated HOV3+ restrictions then as well. Most recently, the morning peak period (6:45 a.m. to 8:00 a.m.) on the Northwest Freeway (US 290) also changed occupancy restrictions to HOV3+.

Not surprisingly, these occupancy restrictions (HOV3+) resulted in a considerable reduction in peak-period traffic and available capacity in the HOV lanes. However, less onerous restrictions (HOV2+) had resulted in excess demand and congestion on the lanes. One potential solution was to allow HOV2s to use the lanes for a price during the peak periods. This would limit demand to an acceptable level, make more efficient use of the lane, and provide a revenue source to help pay for the program. Thus, Houston's QuickRide program was created.

QuickRide began in January 1998 on the Katy Freeway and then in November 2000 on the Northwest Freeway. To use the HOV lanes during periods normally restricted to vehicles with three or more occupants, vehicles with two occupants pay a $2 toll and a $2.50 monthly fee. This form of HOV lane is often referred to as a high-occupancy/toll (HOT) lane. As of June 2004, there were only four HOT lanes in existence (all in the United States—these two in Houston and two in California). However, many cities are exploring the option of converting HOV lanes to HOT lanes (Value Pricing Homepage 2004).

In addition to making more efficient use of roadway capacity, HOT lanes offer travelers the additional choice of paying for fast, reliable travel. Evidence from California and Houston HOT lanes indicates few drivers use the lanes on a frequent basis (Burris and Appiah 2004; Sullivan 2000; Supernak et al. 2001). Rather, the majority of drivers use the lane infrequently, possibly when they are particularly pressed for time or cannot risk the unreliable travel times offered by the free lanes.

Travel options available to travelers using the Katy and Northwest corridors are therefore extensive. The options include:

- drive alone or with passengers on the main lanes (peak or off-peak);
- drive with one passenger on the HOV lanes:
    - for free in the off-peak or
    - for a $2 toll in the peak/QuickRide periods (defined as 6:45 to 8:00 a.m. on both Katy and Northwest Freeways and 5:00 to 6:00 p.m. on Katy);
- drive with two or more passengers for free on the HOV lanes;
- use transit (coach buses, as shown in Figure 3) with fare levels ranging from $1 to $3.50; and
- join a casual carpool, which travels on HOV lanes for free.[2]

Figure 3. Houston METRO Commuter Bus on HOV Lane

This myriad of choices provides travelers in these corridors more opportunity to optimize their travel behavior, and increases the net societal benefits of travel in the corridor. However, there is room for improvement, and changes to the QuickRide program are under investigation to further optimize the use of the HOV lanes (see the section "The Future of QuickRide"). Prior to these potential improvements it was critical to understand driver behavior and current use of the HOV lanes. Therefore, this article examines the benefits of the QuickRide program, usage patterns, and socioeconomic and travel characteristics of QuickRide users.

Benefits of the QuickRide Program

QuickRide offers HOV2 vehicles additional travel options that had not been available to them. HOV2 options now include:

- travel on the congested main lanes at any time,
- travel on the HOV lane during off-peak periods, and
- travel on the HOV lanes during peak periods for a $2 toll (QuickRide).

Therefore, HOV2s' primary benefits derive from either

- travel-time savings versus travel on the main lanes, or
- travel at their preferred time of day instead of the off-peak period.

To simplify this discussion, the benefits derived from travelers who switched modes to take advantage of QuickRide were assumed to be similar to the HOV2 travelers. For example, assume a pair of transit users formed an HOV2 to take advantage of the QuickRide program. Their travel time on the HOV lane would not change, but the travelers must have perceived some benefits to make this mode switch. These benefits were assumed to be similar in size to those benefits derived from HOV2s who received a faster travel time.

Another difficult benefit to measure is the benefit of traveling at one's preferred time of day. There is an interesting body of research on this issue (Arnott et al. 1998; Arnott et al. 1996; Chen and Bernstein 1995; Chu 1995; Verhoef 2000; Small 1992), but empirical results are extremely limited. Therefore, the exact value of the disbenefit that occurs when a morning commute is taken at a suboptimal time is unknown but would include either a penalty for:

- leaving home early (lost sleep, reduced time with family, etc.), or
- arriving late to work.

Reducing either of these penalties is a direct benefit to the drivers, albeit one that is extremely difficult to estimate. In addition, it is difficult to determine what percentage of QuickRide trips are a result of shifting from the main lanes (resulting in travel-time savings) or shifting from the off-peak (resulting in the benefit of traveling at their preferred time of travel). Therefore, for the analysis outlined here, it was assumed that the benefits of those QuickRide users who altered their time of travel to the peak period (and therefore experienced no change in travel time) was approximately equal to the benefits obtained by those QuickRide users who reduced their travel time by shifting to the HOV lane (and therefore did not change their time of travel).

Although still an estimation, determining the value of travel-time savings is more straightforward. To estimate the travel-time savings offered by QuickRide, it was necessary to determine both the number of QuickRide trips and typical travel-time savings. Fortunately, Houston uses an extensive automatic vehicle identification (AVI) system on many of its freeways (main lanes and HOV lanes) to estimate vehicle speeds (Texas Department of Transportation 2004), and this data source provided millions of vehicle speeds. Surveys of HOV lane users and vehicle counts were used to estimate the average distance traveled on each HOV lane by QuickRide participants. These average travel distances were then divided by the average speed found using Equation 1 to determine average travel times for both the HOV lanes and the main lanes. Additionally, the number of QuickRide trips per day was recorded by the same AVI system for toll collection purposes (see Table 1). Multiplying the difference in travel times between the HOV and main lanes by the number of QuickRide users resulted in the average travel-time savings shown in Table 1. The average time to form a carpool, 4.33 minutes as reported in a survey of QuickRide participants, was subtracted from these travel-time savings prior to determining the value of travel-time savings.

$$Average\ \ Speed = \frac{\displaystyle\sum_{work\ days} \frac{\displaystyle\sum_{segments}\left[\frac{\sum observations}{\displaystyle\sum_{n=1}^{users}\frac{1}{speed_n}\times\ \#observations}\times Length_{segment}\right]}{\displaystyle\sum_{segments} lengths}}{\#\ \ work\ \ days\ \ in\ \ year} \tag{1}$$

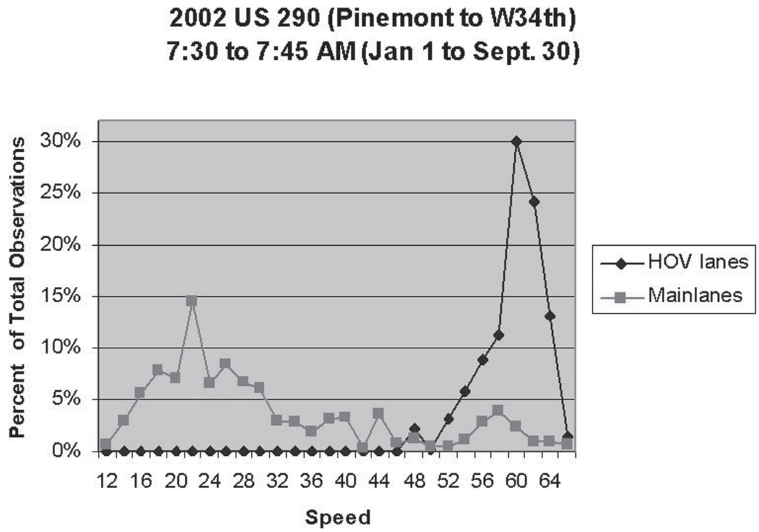
Combined with the benefit of travel-time savings, there is the benefit of a more reliable travel time. The HOV lane offers very reliable travel times where the travel time on the main lanes is much more unpredictable. For example, Figure 4 indicates average daily travel speeds from one section of the Northwest Freeway for the first nine months of 2002. On the main lanes, the speeds were most frequently between 15 mph and 30 mph but occasionally reached 60 mph. Traveling at these speeds—15 mph, 30 mph, and 60 mph—leads to greatly different travel times (40 minutes, 20 minutes, and 10 minutes, respectively) on a 10-mile section of highway.

Table 1. 2001 Travel-Time Savings

	Time	Vehicles per Day	S_{main} (mph)	S_{HOV} (mph)	Time Savings (min/veh)
Katy AM	6:45–7:00	11.11	29.76	53.98	11.58
	7:00–7:15	19.48	27.25	59.81	15.35
	7:15–7:30	23.61	24.48	60.21	18.62
	7:30–7:45	23.49	23.37	60.11	20.08
	7:45–8:00	10.18	24.79	59.48	18.06
	Weighted Average (AM)		***25.50***	***59.22***	***17.33***
Katy PM	5:00–5:15	7.03	28.35	57.19	13.66
	5:15–5:30	14.15	26.13	58.34	16.23
	5:30–5:45	12.18	26.97	57.63	15.15
	5:45–6:00	6.71	28.61	58.70	13.76
	Weighted Average (PM)		***27.19***	***57.98***	***15.04***
Northwest AM	6:45–7:00	2.83	34.36	53.01	6.27
	7:00–7:15	8.01	31.89	57.91	8.62
	7:15–7:30	14.02	28.72	58.85	10.91
	7:30–7:45	16.15	27.44	59.52	12.02
	7:45–8:00	7.25	30.09	59.82	10.11
	Weighted Average (AM)		***29.35***	***58.72***	***10.51***

Average distance traveled on the Katy HOV lane was 12.8 miles, and on the Northwest HOV lane was 10.6 miles.

Figure 4. Example of the Speed Distribution on the HOV Lane and Main Lanes



Although it is difficult to estimate to exact value, there is clear evidence that travel-time reliability is valued at least as much as the travel-time savings itself (Small et al. 1999; Bates et al. 2001; Hensher 2001). To conservatively estimate this value of time and reliability, the average value of travel-time savings was assumed to be 35 percent of the QuickRide participant's wage rate (as reported in the survey discussed below). Research in this area has generally shown drivers to value their time in congested travel conditions at a higher rate than 35 percent of their hourly wage, so this should provide a conservative value of travel-time savings. Additionally, approximately 21 percent of carpools included a child, and that child's value of travel-time savings was assumed to be $0. This resulted in an average value of travel-time savings of $31.13 per hour per vehicle (or $15.56 per hour per person). Using this conservative value of time, actual and predicted QuickRide trips over 10 years, and current travel-time savings minus carpool formation times, the net present value of the benefits of QuickRide travel-time savings were estimated to be approximately $2.35 million.[1]

QuickRide participants also experience reduced vehicle operating costs and reduced fuel usage. Based on fleet average fuel usage, and typical fuel prices,[2] the total fuel savings was estimated to be approximately $13,500 over 10 years. This is an underestimation of actual fuel savings since these savings are based on MOBILE 5a modeling of the average speed readings recorded by the AVI equipment which is spaced at 3- to 5-mile intervals. These speed measurements fail to capture the fuel-intensive deceleration and acceleration patterns of vehicles that occurs on the main lanes during these peak periods. Even so, the value of fuel savings and emissions reduction was inconsequential when compared to the value of travel-time savings.

This brief analysis of benefits may considerably underestimate the true value of the QuickRide option. The 35 percent of wage rate personal value of time is an average, whereas the QuickRide users are mainly occasional users—presumably when their value of time is much higher than average. In addition, any benefit that may be experienced by main-lane users due to the small number of QuickRide participants leaving the main lanes is ignored.

Conversely, there are no costs experienced by either the existing HOV-lane users or the main-lane users. Since traffic on the HOV lane maintains free flow, users of the lane are not negatively impacted by the addition of the QuickRide vehicles. Therefore, despite the net societal benefit of the program being relatively small, it is beneficial since net societal costs to travelers are nonexistent.[3]

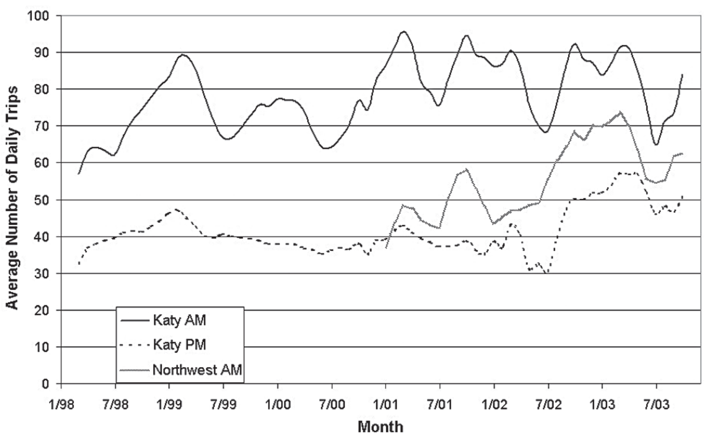
QuickRide Usage

This section provides an in-depth examination of those travelers taking advantage of QuickRide due to the benefits discussed above. The data used in these analyses were from:

- billing records of all recorded QuickRide trips from the inception of the program in 1998, and
- a survey conducted in April 2003 of all current and former QuickRide enrollees.

QuickRide has experienced a slow and steady increase in usage since it began in 1998. Usage patterns include a significant decrease on Fridays[4] and decreases that generally correspond to grade school holidays, including the summer break (see Figure 5). These latter decreases are primarily caused by the absence of carpools where one member is a grade school child and to a lesser extent by decreased traffic levels in the main lanes, resulting in less congestion and less incentive to pay for QuickRide. For 2003, there were an average of 86.4 QuickRide users during the morning period on Katy Freeway, 54.9 during the afternoon period on Katy Freeway, and 66.8 during the morning period on the Northwest Freeway. This total of 208.1 QuickRide trips per day is relatively small, but with limited capacity on the single HOV lanes total usage must remain limited.

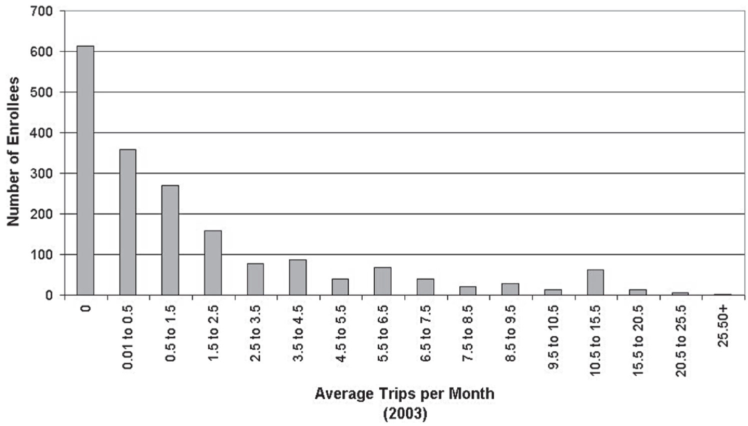
Figure 5. QuickRide Billed Trips per Month (Five-Month Moving Averages)



QuickRide billing records for 2003 show that QuickRide enrollees take a QuickRide trip on an infrequent basis (see Figure 6).[1] In fact, the majority of enrollees made an average of fewer than 1.5 QuickRide trips per week. These results are similar to what has been recorded on the California HOT lanes (Shivashanker et al. 2004, Sullivan 2000).

These usage patterns appear to indicate that most drivers feel the travel-time savings is worth the $2 toll (plus the need for a second occupant) only occasionally. They appear to use QuickRide only when they need the additional travel-time savings and it is convenient to carpool with one other person. The requirement for drivers to carpool is a larger deterrent to QuickRide usage than is the $2 toll (Burris and Appiah 2004). The following section takes an in-depth look at who is using the QuickRide program and their perception of travel-time savings.

Figure 6. Number of Monthly QuickRide Trips by Transponder Identification Number



Characteristics of QuickRide Participants

The results from two surveys were examined to determine the characteristics of QuickRide participants. The first survey was conducted in April 1998, shortly after QuickRide began. A total of 185 QuickRide enrollees, out of a total of 387 enrollees, completed and returned their survey for a response rate of 48 percent. The second survey was mailed in March 2003 to all 1,459 QuickRide enrollees. A total of 93 surveys were returned due to bad addresses. Of the remaining 1,366 surveys, 525 were completed and returned for a response rate of 38 percent.

The 1998 survey results provided insight into QuickRide participants' previous/alternate mode of travel (Stockton et al., 2000) (see Table 2). Similar results were obtained in the 2003 survey (see Table 3). As shown in Table 3, when not using QuickRide, the majority of trips are made by single-occupant vehicles (SOVs) followed by HOV2s in off-peak hours. These travelers use approximately 45 percent more vehicles when not using QuickRide. Therefore, the QuickRide program increases average vehicle occupancy on the corridor.

Table 2. Previous Mode and Time of Travel of QuickRide Enrollees

Mode of QuickRide Enrollees Before QuickRide	*AM*			*PM*		
	Shoulders[a]	*Peak*[b]	*Total*	*Shoulders*[a]	*Peak*[b]	*Total*
Drive Alone	12.7%	38.0%	50.7%	24.5%	33.2%	57.7%
Two-Person HOV, HOV Lane	7.0%	---	7.0%	6.8%	---	6.8%
Two-Person HOV, Freeway	10.7%	12.0%	22.7%	3.6%	25.7%	29.3%
3+ HOV	2.3%	2.4%	4.7%	-2.4%[c]	-3.7%[c]	-6.1%[c]
Vanpool	0.0%	2.0%	2.0%	0.0%	2.3%	2.3%
Bus	0.6%	10.0%	10.6%	1.6%	3.7%	5.3%
Other	0.0%	2.4%	2.4%	0.0%	4.7%	4.7%
Total	33.2%	66.8%	100.0%	34.1%	65.9%	100.0%

Notes: a=periods before and after the peaks.
b=peak periods defined as 6:45 a.m. to 8:00 a.m. and 5 p.m. to 6 p.m.
c=a negative value indicates increased 3+ carpool usage by QuickRide enrollees

Source: Stockton et al. 2000.

Table 3. Distribution of Vehicle Occupancy for Non-QuickRide Trips

Occupancy During Non-QuickRide Trips (persons)	*Percentage of Current QuickRide Participants*	*Corresponding Number of Vehicles*
1	53.6	53.6
2	30.4	15.7
3	6.6	2.2
4	2.0	0.5
5 or More	3.9	0.8
Bus	3.5	0
Total	100	72.8

The survey also examined commute characteristics of travelers while they were using QuickRide. Some of these results are discussed below. (For a more complete analysis of these survey results, see Burris and Appiah (2004)).

Travelers perceived QuickRide saved them approximately twice as much time as was typically saved on the HOV lane. For example, QuickRide participants who most often take advantage of QuickRide on the Katy Freeway in the morning estimated they saved an average of 34.7 minutes (± 1.13 minutes at a 95% confidence interval) where average savings (for the entire year of 2002) was approximately 17.3 minutes. This is probably a combination of QuickRide users (1) overestimating their time savings due to drivers' dislike of congested travel conditions (Small et al. 1999); (2) using QuickRide when they were particularly pressed for time, again causing them to overestimate their time savings; and (3) using QuickRide on days when main-lane congestion was worse than average. However, the third possibility is unlikely since the number of QuickRide trips was relatively constant on a day-to-day basis, regardless of main-lane congestion. For example, the average number of QuickRide trips during the Katy Freeway morning period for September 2003 was 93.9 ± 5.6 (at a 95% confidence interval) with a standard deviation of 12.7 trips per day.

QuickRide participants most frequently carpooled with a coworker (35%), followed by an adult family member (31%), a child (21%), a casual carpool (6%), a neighbor (3%), or other (4%). The 21 percent of carpools formed with a child was not surprising as significant drops in the number of QuickRide trips were observed to correspond with school holidays (see Figure 5). QuickRide participants estimated they required an average of 4.3 minutes to pick up their carpool partner. The majority of participants (73%) did not have the passenger help pay the $2 toll. Finally, the majority of QuickRide trips (67%) were for commuting, followed by school (11%), recreation (10%), and other (8%).

A brief examination of the survey respondents' socioeconomic characteristics reveals a group who are primarily (61%) married with child(ren) or (30%) married without children. Most (65%) are in professional or managerial positions, 64 percent are between the ages of 35 to 54, 74 percent have a college degree, and 79 percent have a household income greater than $75,000 per year. The number of males and females responding to the survey was similar.

Based on these survey findings it was clear that QuickRide users generally have high household incomes and placed a premium on their time. Additional research is currently underway to determine the differences between this group of commuters and other commuters along the Katy and Northwest Freeway corridors.

The Future of QuickRide

The QuickRide program may see significant changes in the near future, with alternate pricing and occupancy restrictions under investigation. The following actions are currently being considered:

1. expanding the HOV3+ restriction (and the QuickRide program) to the afternoon peak period on the Northwest Freeway,
2. expanding the HOV3+ restriction (and the QuickRide program) to the shoulders of each peak period in conjunction with time-of-day variable pricing where the shoulder toll is less than the peak-period toll, and
3. allowing SOVs to pay to use the lane during off-peak periods.

The first two options listed above include expansion of the current HOV3+ occupancy restrictions. This is under consideration due to building congestion on the two freeways during the shoulders of the peak and on the Northwest Freeway in the afternoon peak period. Figures 7 and 8 show average daily travel speeds on the HOV lanes for the year 2002. From these figures it is clear that demand during these periods is beginning to cause deterioration in the level of service on the HOV lane—which must be prevented to maintain the attractiveness of the lane and use of HOV and transit. The periods with the slowest speeds are just before and just after the QuickRide (and HOV3+ restriction) period. Based on analysis of the composition of vehicles during the day, it is clear that the demand and congestion is primarily caused by HOV2s who travel just before or just after the peak period.

To alleviate this congestion but still allow some HOV2s to use the lane, QuickRide may also be expanded to these shoulder periods. Research is underway to determine the proper QuickRide toll during the shoulder periods to smooth the demand for the HOV lane during the peak and shoulder times.

Figure 7. Vehicle Flow on the Katy HOV Lane

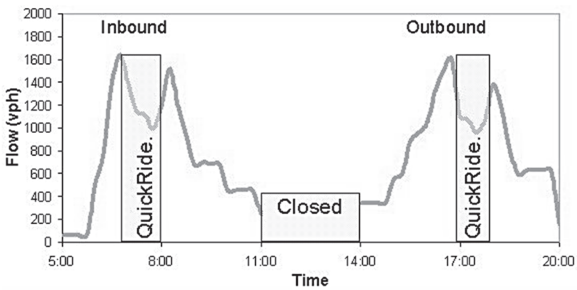


Figure 8. Vehicle Flow on the Northwest HOV Lane

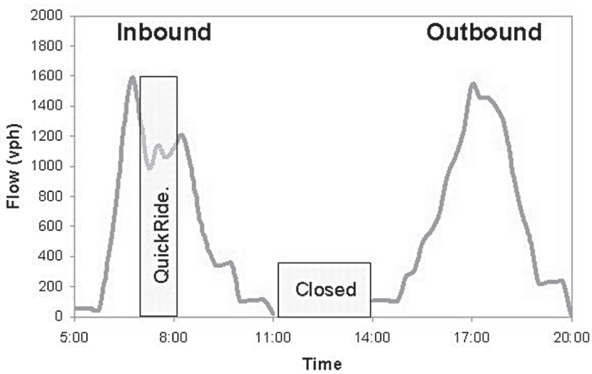
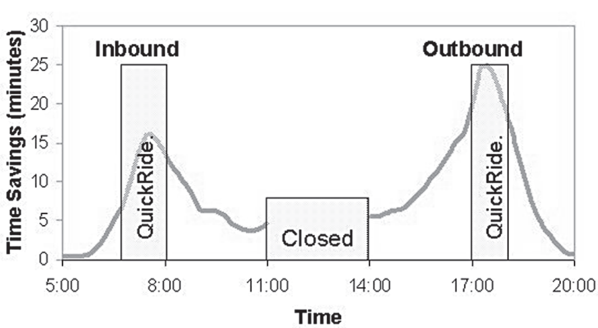


Figure 9. Average Travel-Time Savings Using the Katy HOV Lane Instead of the Main Lanes



Another option under investigation is allowing SOVs to use the lane during off-peak periods. Congestion on the main lanes is such that significant travel-time savings can be obtained well after the morning shoulder periods and before the afternoon shoulders (see Figure 9). Additionally, there is excess capacity in the HOV lanes during those periods.

Therefore, SOV vehicles may be willing to pay a toll to use the lanes during this period. Research is currently underway to determine the costs and revenue from this option. Particularly important is to determine the pricing mechanism and price levels for SOVs to ensure the HOV lanes remain free flowing during all periods of the day.

In the longer term, managed lanes are under construction and are slated to open on the Katy Freeway by 2010. In this scenario the middle four lanes (two per direction) will be toll lanes. These lanes represent new capacity on the Katy Freeway. The exact pricing scenarios are not set, but buses will not be charged a toll and carpools may be offered a reduced toll level.

Conclusions

The Houston QuickRide program currently offers HOV2s the option of traveling on the Katy and Northwest HOV lanes for $2 when the lanes are normally restricted to HOV3+. This provides HOV2s another travel option, allowing its drivers to further optimize their travel behavior, and results in net societal benefits.

The QuickRide program receives relatively modest usage (an average of 208 trips per day in 2003) partially due to the limited amount of room available on either of the single HOV lanes. This relatively limited usage is comprised of a large number of users taking advantage of QuickRide on an infrequent basis (less than 2.5 trips per month). Despite the limited usage, the program provides a net societal benefit, primarily due to travel-time savings obtained by QuickRide participants.

The future of QuickRide holds several potential changes. Due to congestion on either side of the HOV3+ period (when HOV2+ is allowed), the HOV3+ period may be expanded. The expanded periods may have a lower toll, resulting in a variable HOT toll price based on time of day. Further into the future, SOVs may be charged for the privilege of using the HOV lane in the off-peak periods, using a dynamic pricing mechanism that will be priced based on the congestion level in the lane. Based on the findings from the first six years of operation, researchers are examining the optimal configuration, pricing levels, enforcement methods, signage, and public awareness needed to successfully implement these changes and increase the net societal benefits of the program.

Endnotes

[1] The time period changed to 6:45 a.m. to 8:00 a.m. in 1990 and has not changed since.

[2] Casual carpoolers are well aware of the different occupancy restriction on the HOV lanes based on the time of day. In almost all cases, during peak periods two "slugs" (casual carpoolers who get a ride in another person's vehicle) get into each vehicle, while during off-peak periods only one "slug" gets in each vehicle.

[3] Using the federal government Office of Management and Budget's real 10-year discount rate of 3.1 percent.

[4] The typical fuel price is the price at the pump minus any taxes since taxes are a transfer of wealth and do not constitute a net societal benefit.

[5] There were start-up costs and ongoing maintenance and operational costs paid by METRO. The toll revenues are used to pay the ongoing operational and maintenance costs.

[6] Using time series analysis and an ANOVA analysis, it was found that Friday QuickRide volumes were significantly lower than the rest of the week at the 5 percent significance level.

[7] Actual usage could be greater than that captured by the billing readers due to malfunctions of the equipment or willful violators. Research is underway to address this problem and minimize the number of violators on the lane. However, based on violation data, it is clear that not all enrollees are being charged when they take a QuickRide trip. Therefore, these violators are also benefiting from the program—but are not included in the benefit analysis.

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