The Impact of HOT Lanes on Carpools

Mark Burris, Professor, Zachry Department of Civil Engineering, 3136 TAMU, Texas A & M University, College Station, TX 77845 USA. Phone: 1-979-845-9875. E-Mail: MBurris@tamu.edu (Corresponding Author)

Negin Alemazkoor, Graduate Research Assistant, Texas A&M Transportation Institute, 3135 TAMU, Texas A&M University, College Station, TX 77843 USA. Phone: 1-979-888-4028.
Email: n-alemazkoor@ttimail.tamu.edu

Rob Benz, Research Engineer, Texas A&M Transportation Institute, 701 North Post Oak Suite 430, Houston, Texas 77024 USA. Phone: 1-713-613-9218. Email: r-benz@tamu.edu

Nicholas S. Wood, Assistant Transportation Researcher, Texas A&M Transportation Institute, 505 E. Huntland Drive Suite 455, Austin, TX 78752 USA. Phone: 512-467-0946. E-mail: nickwood@tamu.edu

Abstract

This research investigated the change in carpooling on U.S. roadways once high occupancy/toll (HOT) lanes began on those roadways. HOT lanes generally allow carpools to travel on the lane for free while charging a toll for single occupant vehicles (SOVs) to use the lane. In most cases these lanes were previously high occupancy vehicle (HOV) lanes where carpools traveled for free and SOVs were not allowed. Note that clean fueled SOVs were allowed in some cases. Thus carpoolers could now switch to being a SOV and still access the benefits of the HOT lane – for a toll. This may cause some carpools to break up and become SOVs, thus adding to the amount of traffic and emissions on the roadway.

Carpooling on eight roadways with HOT lanes was examined. As best as possible, data on the number of carpools on the facility in the year before and the year after converting from HOV lanes to HOT lanes was examined. Overall, carpooling decreased on most of the corridors, stayed the same on a couple of corridors, and on the one corridor that added the HOT lanes (SR-91) carpooling increased. Despite these results it is still difficult to draw definitive conclusions as (a) carpool preference tends to vary by facility, (b) there were many exogenous factors also playing a role in the amount of carpooling, (c) there is inherent difficulty obtaining occupancy counts and those counts can fluctuate a great deal day to day and month to month. Overall though, it does appear that carpooling is often negatively impacted by converting a HOV lane to a HOT lane.

Keywords: High-occupancy toll lanes, managed lanes, high-occupancy vehicle lanes, carpooling
JEL Classification Codes: R40, R480

Introduction

This special issue of the journal of transportation economics is focused on road pricing projects in the United States. The papers presented in this issue include a wide range of pricing projects, from parking pricing, to toll bridges, high occupancy/toll (HOT) lanes, interstate tolling, and vehicle miles traveled fees. Conversely, experience with road pricing in the United States has been focused mostly on HOT lanes. Almost all of these HOT lanes were high occupancy vehicle (HOV) lanes prior to their conversion to HOT lanes. An important aspect of this conversion, and something that is not well understood, is the impact on carpools. This paper attempts to summarize findings from HOT lanes around the United States in an effort to shed more light on the relationship between HOT lanes and carpools.

One factor that may mitigate the impact of HOT lanes on carpooling is that so many carpools are comprised of family members. Commuting in America III estimated that 80 percent of 2-person carpools are comprised of family members (Pisarski, 2006) http://onlinepubs.trb.org/onlinepubs/nchrp/CIAIII.pdf. This estimate is similar to results from multiple surveys the authors have conducted in Texas. It would be logical that the option to drive alone as an SOV on the HOT lane would not be very enticing for this group of carpoolers.

The following sections of the paper examine individual HOT lanes from around the United States. When available, data on the number of carpools the year before and the year after was examined. This provided a snapshot of what happened to carpools on the facility in that timeframe – but any changes could not always be attributed to the change from HOV to HOT lane. Despite this shortcoming the following provides the most comprehensive assessment of the impact of HOT lanes on carpools to date and will shed some light on this issue.

State Route 91 Express Lanes (SR-91X)

The California SR-91 Express Lanes run 10 miles (16 km) in the freeway median between the SR 91/SR 55 junction in Anaheim and the Orange/Riverside County Line. The toll facility has two lanes in each direction, separated from four adjacent general purpose lanes (GPLs) in each direction, by a soft barrier consisting of a painted buffer with plastic pylons. It is an express facility with no intermediate exits or entrances. Only passenger cars and small trucks are allowed on the Express Lanes. Variable tolls (http://www.91expresslanes.com/schedules.asp) are used to manage the Express Lanes to ensure that traffic remains free flowing.

The SR-91X lanes is the only HOT lane that was not previously an HOV lane. It represented new capacity. It also required HOV2s (high occupancy vehicles with 2 people in the vehicle) to pay a toll – where many HOT lanes allow HOV2+ to travel for free. Despite these unique features there is much that can be learned regarding the impact of these lanes on carpools. Particularly because the lanes underwent changes in tolling of carpools during their existence:

- Prior to the construction of the SR-91X lanes in 1996 all vehicles traveled for free on the corridor,
- During 1996, 1997 and part of 1998 HOV3+ traveled toll free on the Express Lanes, all other vehicles paid a variable toll,
- From May 1998 to 2002 HOV3+ paid 50 percent of the HOV2 and single occupancy vehicle (SOV) toll rate,
- From 2003 on HOV3+ were free except during peak times (defined as 4 p.m. to 6 p.m. eastbound) when they pay 50 percent of the toll rate.

After one year of operation of the new SR 91X, there was a 40 percent increase in HOV3+ vehicles (496 to 725) in the 2-hour peak period on the SR 91 corridor. This large increase could be due to the low base number of HOV3+ vehicles on the SR 91 corridor since there was previously no HOV lane. In addition, average daily traffic rose 14 percent in the first year of Express Lane (EL) operation. Sixty percent of that increase was new traffic. It is estimated that during the afternoon peak period, this induced traffic contributed to a 39 percent increase in the pre-Express level of HOV3+ (Sullivan, 1998). Since SR 91 ELs treat HOV2s as paying vehicles similar to SOVs, only 30 percent of HOV2s used the SR 91 Express Lanes as compared to 60 percent in conventional HOV lanes and a small increase in the number of HOV2s was observed (Sullivan, 1998).

In January 1998 when HOV3+ users were charged a 50 percent toll, about a third of the HOV3+ traffic (about 2,000 vehicles per day) left the 91X lanes, and HOV3+ traffic in the GPLs increased by the same amount. These changes occurred mostly during the shoulder hours and throughout the week, although much less on Friday afternoon. Following these changes, the total p.m. peak HOV3+ traffic in the corridor remained the same (Sullivan, 2000).

Jianling Li analyzed the effects of removing the toll for HOV3+ in 2003 (except for weekdays eastbound from 4 p.m. to 6 p.m.) (unpublished work at UT Arlington in 2007). Due to constraints of available data, the analysis focused only on the eastbound counts for May 2003. It was found that the average HOV3 hourly traffic counts for all hours of weekdays rose from 81 before the toll change to 99 after the toll change (an increase of 22 percent, statistically significant at $p<0.05$). For the eastbound traffic during 4 p.m. and 6 p.m. where the toll remained for HOV3+ vehicles, the average hourly traffic counts for HOV3+ decreased from 348 vehicles per hour to 337 vehicles per hour after the change. The toll reduction encouraged use of the Express Lanes by HOV3+s and pushed a few into the afternoon shoulder periods.

From examining traffic patterns on SR-91X lanes it is clear that HOV3+s are sensitive to the toll and shift lanes and time of travel based on the toll. However, mode shifts due to the toll rate changes are less well known. The 1998 tolling of HOV3+s found approximately the same number of additional HOV3+s in the GPLs as left the ELs. Likely indicating minimal mode shifts.

I-15 Express Lanes in San Diego

The I-15 Express Lanes near San Diego have undergone multiple, significant, changes since they began in 1996. This report will focus on the early years of the project – when the lanes were an eight-mile, two-lane, reversible facility in the median of I-15, extending from SR 163 to SR 56/Ted Williams Parkway. The Phase I ExpressPass program ran from December 1996 through March 1998. During this phase, a limited number of solo drivers paid a flat fee ($50 until February 1997 and $70 thereafter) for unlimited use of the I-15 Express Lanes. HOV2+ vehicles could travel toll free as they had before the ExpressPass program. In late March 1998, the program began Phase II I-15 FasTrak, which allowed solo drivers to pay a per-trip fee to use the lanes. The fees were adjusted dynamically on the basis of traffic levels in the I-15 Express Lanes as well as time of day. HOVs continued to use the lanes toll free. Additional changes occurred in 2008 extending and widening the lanes. Since the focus of this paper is the conversion from HOV to HOT we focus on the changes that happened in the late 1990s.

An attitudinal panel survey conducted in September and October 1997 (Golob et al., 1998) provides insight into mode shifts of early users of the ELs. This survey was conducted during the Phase I ExpressPass period. A total of 1,513 telephone surveys were completed. Respondents represented four commuter segments: current ExpressPass users (users during the survey), former ExpressPass users, other I-15 users (i.e., non-ExpressPass), and I-8 users representing the control corridor. Of ExpressPass users who had driven on I-15 before the ExpressPass program, approximately 95 percent previously drove alone while approximately 4 percent reported that they had previously carpooled. This result indicates that very few carpools broke up as a result of the ExpressPass program. This result was collaborated with traffic volume data from 1997 (see Table 1). However, 1998 and 1999 traffic volumes show a much different impact.

Table 1. HOV Volumes on I-15 (source: Supernak, 2001)

Time of Day	Year	I-15 Main Lanes	I-15 Express Lanes	Total HOVs on I-15 Corridor
Morning Peak Period (6:00 a.m. to 9:00 a.m.)	**1996**	3,817	3,014	6,831
	1997	3,579	3,732	7,311
	1998	2,535	3,675	6,210
	1999	1,268	2,937	4,206
Afternoon Peak Period (3:00 p.m. to 7:00 p.m.)	**1996**	3,346	4,795	8,141
	1997	3,150	5,547	8,697
	1998	3,345	5,136	8,481
	1999	2,496	5,486	7,982

The I-15 corridor experienced a large increase in SOV volume and a corresponding decrease in HOV volume during the a.m. peak period from 1997 to 1999 (see Table 1). This decline in HOV volume in I-15 was in contrast to the increasing HOV volume in control corridor I-8. This suggests that corridor specific

factors, possibly I-15 pricing project, are responsible for these differences (Supernak, 2001). During the p.m. peak period the total number of HOVs changed little from 1996 to 1999 (see Table 1). There was a substantial shift of the HOVs to the Express Lanes during the p.m. peak period.

The changes in HOV volumes in the a.m. peak period did not occur uniformly over the three year period. From 1996 to 1997 there was a large increasing in HOVs in both the a.m. and p.m. peak periods. Thus, the results from the 1997 attitudinal survey indicating little conversion from HOV to SOV seems reasonable. Starting in 1998, and continuing in 1999, there was a sizable drop in HOV traffic in the a.m. peak and a smaller drop in the p.m. peak. This corresponds to the ending of the ExpressPass program and the beginning of allowing travelers to pay for the Express Lanes on a per use basis. All other HOT lanes in the country currently use a pay per trip tolling model. Therefore, the decrease in HOVs on I-15 once SOVs had to start paying per trip was a potential issue for all HOT lanes around the county. Note that total traffic on I-15 (see Table 2) remained relatively stable through these four years. Also note that the total number of HOVs on the HOT lane increased from 1996 to 1999, but HOVs on the GPLs decreased by even more, so the net result was a loss in HOVs. Because the loss in HOVs was on the GPLs it is possible that the loss in HOVs was, at least in part, due to factors other than the change of the HOV lanes to Express Lanes, such as the economic boom of the time. Without surveying the travelers it is difficult to know the reason behind these changes.

Table 2: Total Traffic Volume on I-15 (source: Supernak, 2001)

Time of Day	Year	I-15 Main Lanes	I-15 Express Lanes	Total I-15 Corridor Traffic
Morning Peak Period (6:00 a.m. to 9:00 a.m.)	**1996**	30,397	3,650	34,048
	1997	29,905	4,373	34,278
	1998	31,765	5,185	36,950
	1999	30,666	5,583	36,248
Afternoon Peak Period (3:00 p.m. to 7:00 p.m.)	**1996**	36,214	5,476	41,690
	1997	35,055	6,113	41,168
	1998	36,537	6,766	43,303
	1999	35,850	7,904	43,754

I-394 Express Lanes in Minnesota

The I-394 HOV lanes were converted to HOT lanes (called MnPASS Express Lanes in Minnesota) in May of 2005. The I-394 MnPASS Express Lanes stretch 11 miles from downtown Minneapolis to the western suburbs. Dynamic pricing is used to ensure free flow speeds (50 to 55 mph) in the Express Lanes. The I-394 Express Lanes include two different types of design. There is a 3 mile barrier-separated reversible section with two lanes located directly to the west of downtown Minneapolis (from highway 100 to I-94). There is also an 8 mile long portion that has one lane in each direction called the diamond lane section. In the 3-mile section SOVs are always charged a fee. In the diamond lane section, SOVs are only

charged in rush hours. The tolls range from 25 cents to $8 and are typically $1 to $4 during rush hours (Cambridge Systematics Inc., 2006).

Three waves of MnPASS Evaluation Panel Surveys were conducted by NuStats under subcontract to the State and Local Policy Program at the Humphrey Institute of Public Affairs at the University of Minnesota for the Minnesota Department of Transportation. The first wave of the Attitudinal Panel Survey was conducted in November/December 2004 before I-394 MnPASS Express lane implementation. The second wave was conducted about 6 months after MnPASS implementation in November/December 2005. Finally, the third wave was conducted in May/June 2006 (Zmud, 2006).

In Table 3, the usual modes of travel for the three I-394 waves are compared. It could be seen that the differences in modes used by travelers between the three waves are very small (Zmud, 2006). The survey also found that I-394 travelers were almost equally likely to switch from SOV to carpool (7%) as they were to switch from carpool to SOV (8%). Therefore, the results from the surveys show that there was not a noticeable shift from HOVs to SOVs after MnPASS Express lane implementation (Zmud, 2006).

Table 3. Usual Travel Mode for Survey Respondents (source: Zmud, 2006)

I-394	**Wave 1 Results (2004 – Before)**		**Wave 2 Results (2005 – Just After Implementation)**		**Wave 3 Results (2006 - After)**	
	FREQUENCY	**PERCENT**	**FREQUENCY**	**PERCENT**	**FREQUENCY**	**PERCENT**
Drive alone	212	80%	177	76%	214	81%
Carpool	52	19%	54	23%	50	19%
Ride bus	2	1%	3	1%	1	0%
Total	**266**	**100%**	**234**	**100%**	**265**	**100%**

Vehicle occupancy counts were also conducted before and after MnPASS implementation to examine the impacts of MnPASS on carpooling (see Table 4). Vehicle occupancy was counted over a 2-day period in May and June 2004 for before data. After data was collected in two different periods during October 6-11, 2005 and May 9-10, 2006. Carpooling on I-394 decreased substantially after MnPASS implementation. However, results from occupancy counts in the control corridor, I-35W, also showed a substantial decrease. Northbound carpooling decreased by 14% and southbound decreased by 20% on I-35W. Although the decrease in carpooling on I-394 seems to be larger than the decrease on I-35W, due to the small number of HOVs in both the before and after periods and the fact that occupancy counts were conducted manually, it cannot be statistically concluded that the decrease in carpooling on I-394 was greater than the decrease on I-35W (Cambridge Systematics Inc., 2006).

Table 4. Comparison of SOV and HOV Vehicle Volume on I-394 (2004 to 2006) (source: Cambridge Systematics Inc., 2006)

I-394 @ Penn Eastbound - a.m. peak (6:00 a.m. to 9:00 a.m.)		2004	Share	2006	Share	# Change	%Change
MnPass Lanes	HOV Volume	3,322	96%	2,635	62%	-687	-21%
	SOV Volume	141	4%	1,599	38%	1,458	1034%
	Total Volume	3,463		4,234		771	22%
General Purpose Lanes	HOV Volume	335	2%	375	3%	40	12%
	SOV Volume	14,742	98%	14,107	97%	-635	-4%
	Total Volume	15,077		14,482		-595	-4%
Total All Lanes	HOV Volume	3,657	20%	3,010	16%	-647	-18%
	SOV Volume	14,883	80%	15,706	84%	823	6%
	Total Volume	18,540		18,716		176	1%
I-394 @ Penn Westbound - p.m. peak (3:00 a.m. to 6:00 p.m.)		**2004**	**Share**	**2006**	**Share**	**# Change**	**%Change**
MnPass Lanes	HOV Volume	3,446	88%	2,578	63%	-868	-25%
	SOV Volume	226	6%	1,516	37%	1,290	571%
	Total Volume	3,898		4,094		196	5%
General Purpose Lanes	HOV Volume	1,864	13%	884	6%	-980	-53%
	SOV Volume	12,782	87%	15,124	94%	2,342	18%
	Total Volume	14,646		16,008		1,362	9%
Total All Lanes	HOV Volume	5,310	29%	3,462	17%	-1,848	-35%
	SOV Volume	13,008	71%	16,640	83%	3,632	28%
	Total Volume	18,318		20,102		1,784	10%
I-394 @ Louisiana Eastbound - a.m. peak (6:00 a.m. to 9:00 a.m.)		**2004**	**Share**	**2006**	**Share**	**# Change**	**%Change**
MnPass Lanes	HOV Volume	2,054	89%	1,511	58%	-543	-26%
	SOV Volume	254	11%	1,083	42%	829	326%
	Total Volume	2,308		2,594		286	12%
General Purpose Lanes	HOV Volume	369	3%	499	5%	130	35%
	SOV Volume	11,322	97%	10,574	95%	-748	-7%
	Total Volume	11,691		11,073		-618	-5%
Total All Lanes	HOV Volume	2,423	17%	2,010	15%	-413	-17%
	SOV Volume	11,576	83%	11,657	85%	81	1%
	Total Volume	13,999		13,667		-332	-2%
I-394 @ Louisiana Westbound- p.m. peak (3:00 p.m. to 6:00 p.m.)		**2004**	**Share**	**2006**	**Share**	**# Change**	**%Change**
MnPass Lanes	HOV Volume	2,376	76%	1,308	60%	-1,068	-45%
	SOV Volume	751	24%	870	40%	119	16%
	Total Volume	3,127		2,178		-949	-30%
General	HOV Volume	414	5%	1,029	7%	615	149%

Purpose Lanes	SOV Volume	7,805	95%	13,903	93%	6,098	78%
	Total Volume	8,219		14,932		6,713	82%
Total All Lanes	HOV Volume	2,790	25%	2,337	14%	-453	-16%
	SOV Volume	8,556	75%	14,773	86%	6,217	73%
	Total Volume	11,346		17,110		5,764	51%

SR 167 HOT Lanes

SR 167 HOT lanes began operating in May 2008. They extend about nine miles (11 miles in the northbound direction and 8 miles in the southbound direction) from Renton to Auburn near Seattle. There is a single HOT lane along with two general purpose lanes in each direction of travel. Two-person carpools, vanpools, transit and motorcycles can use the HOT lanes for free. When extra space is available in the HOT lane, SOVs are allowed to use HOT lane by paying a toll using a transponder. Dynamic tolling is used to ensure a free flow condition on the HOT lanes; toll rates are between 50 cents and $9. There are six northbound and four southbound access zones for the HOT lane. Toll rates are posted at each access point and drivers are only charged once (with the toll that is displayed when the vehicle enters the lane) (http://www.wsdot.wa.gov).

From 2007 to 2008, bus ridership increased by 17% in the corridor and by 23% in the region; this increase in bus ridership was probably due to a rapid increase in the gas prices (American Public Transportation Association, 2011). Ridership then decreased in 2009 which was attributed to a reduction in the price of gas, recession and regional job loss. On the other hand, average daily tolled trips on the HOT lanes increased by 46% in May through November 2009 as compared to May through November 2008 (Goel and Burris, 2012).

Tuesday through Thursday HOT lane usage from May 2008 through April 2009 and monthly average gas prices in Seattle are compared in Figure 1. It could be seen that carpool usage on the HOT lanes and gas prices followed similar trends. Conversely, tolled vehicles generally increased as the gas price decreased. This strongly suggests that the reduction in the gas price resulted in reduced carpooling and reduced the bus ridership (Goel and Burris, 2012). Therefore, exogenous factors like gas price are likely to have a significant impact on HOV travel – further complicating the analysis of HOV travelers on HOV lanes that transition to a HOT lane.

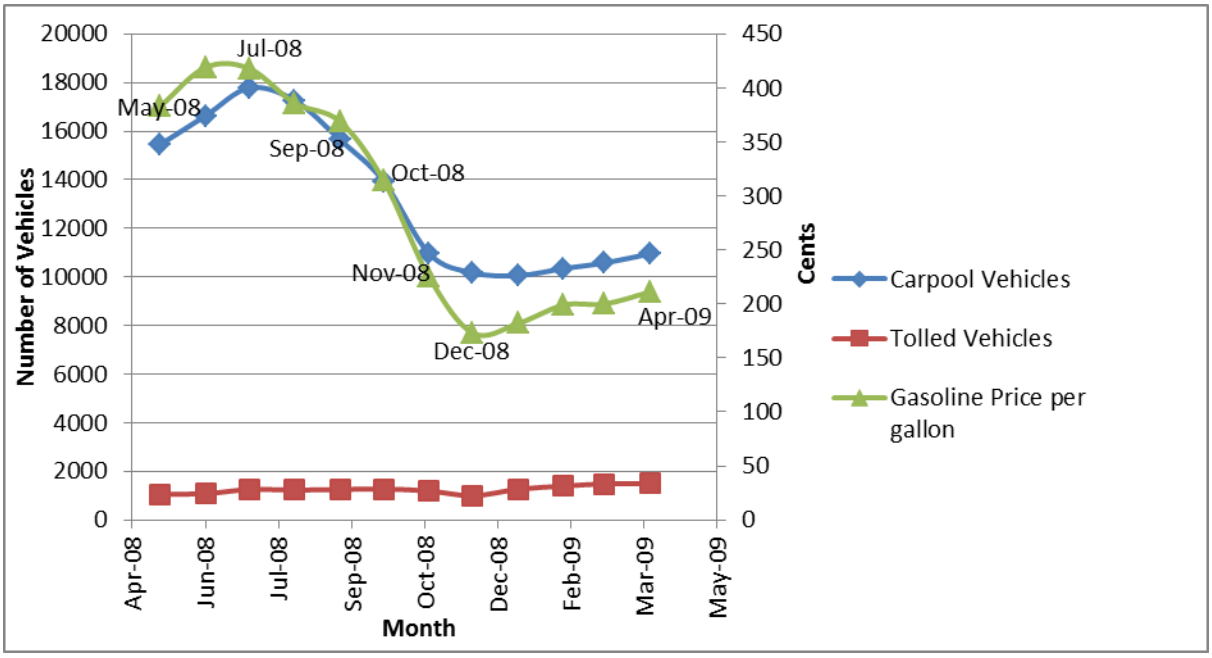

Figure 1. Usage of HOT lanes by HOV Vehicles and Tolled Vehicles and Gas Prices for May 2008 Through April 2009 (source: Goel and Burris, 2012)

I-95 Express Lanes

In December 2008, one single northbound HOV lane along I-95 from SR-112 to the Golden Glades Interchange (GGI) near Miami, Florida, was converted to two express lanes (phase 1A of the I-95 Express Lane Project). These ELs can be accessed only at the two ends of the lanes. In addition, EL operation also included changing the carpool eligibility from HOV2+ to registered HOV3+. Travelers who register with Florida DOT as a HOV3+, hybrid vehicle or motorcycle can use the lanes for free. All other travelers use a transponder to pay a toll that varies with the level of congestion. The toll is varied to ensure a speed of at least 45-mph in the ELs. In January 2010, southbound ELs from GGI to SR 836 opened. Then the northbound extension to I-395 opened in March 2010 (phase 1B). In phase 2 the facility will extend from GGI to I-595. Phase 2 is expected to open in Mid-2014 (http://www.95express.com/pages/project-overview/project-schedule).

Table 5 shows how person throughput changed for different vehicle types after converting the northbound HOV lane to ELs. In this table, SOVs recorded in 2008 were violators. The total person throughput in ELs increased 42% from 2008 to 2010, which is likely due to the additional lane (Pessaro, 2011). From 2008 to 2009, a substantial shift from HOV3 in the ELs to HOV3 in the GPLs and a reduction in HOV2s in both the ELs and the GPLs occurred. From 2009 to 2010, the number of HOV2s in both the ELs and the GPLs increased. At the same time, there was a dramatic reduction in the number of HOV3s in the GPLs which likely indicates some shifting from HOV3 to HOV2.

Table 5. Person Throughput by Vehicle Type (northbound p.m. peak) (source: Pessaro, 2011)

	Vehicle Type	2008	2009	2010	% Change 2008-2010
Express Lanes	SOV	1,061	3,778	3,686	274%
	HOV 2	3,040	1,899	2,566	-16%
	HOV 3	477	171	308	-35%
	Transit	810	821	1,099	36%
	Total	5,388	6,669	7,659	42%
General Purpose Lanes	SOV	8,080	8,428	9,300	15%
	HOV 2	7,397	6,282	8,602	16%
	HOV 3	1,858	2,387	108	-94%
	Transit	-	-	-	-
	Total	17,335	17,097	18,010	4%
Facility	SOV	9,141	12,206	12,986	42%
	HOV 2	10,437	8,181	11,168	7%
	HOV 3	2,335	2,558	416	-82%
	Transit	810	821	1,099	36%
	Total	22,723	23,766	25,669	13%

The p.m. peak period is from 4:00 p.m. to 7:00 p.m.

A May 2009 survey found that only 33 percent of HOV3+ in the ELs were registered carpools and the rest paid the same toll as SOV and HOV2 vehicles. These data combined with the substantial decrease in HOV3+s in the ELs, indicate that the strict registration requirement for free carpool use of the ELs was likely a factor behind the mode shift away from HOV3. Table 6 contains responses from those who indicated they used the ELs (Goel and Burris, 2012).

Table 6. Mode Shifts on I-95 by EL Users (source: Goel and Burris, 2012)

		Usual Mode of Travel (Number of respondents)		
		SOV (n=2558)	**HOV2 (n=158)**	**HOV3+ (n=120)**
Current Mode used to Access Express Lanes	**Toll Paying (SOV/HOV2/Unregistered HOV3+)**	94%	92%	61%
	Registered HOV3+	0%	3%	33%
	Hybrid	5%	6%	1%
	Vanpool	0%	0%	16%
Prior Mode on I-95	**Carpool in HOV**	6%	71%	81%
	Hybrid in HOV	4%	4%	2%
	Not Carpool lanes	86%	24%	18%

Note: The percentages for current mode do not total 100 percent since the respondents could select more than one mode if they frequently used different modes to access the ELs.

Next the change in travel due to the opening of the southbound lane was examined (see Table 7). There was a substantial decrease in the number of HOV3s in both the ELs and the GPLs. The number of HOV2s remained almost constant in the facility; however HOV2s decreased in the ELs and increased in the GPLs. This shows that HOV2s shifted from the ELs to the GPLs.

Table 7. Person Throughput by Vehicle Type (southbound a.m. peak) (source: Pessaro, 2011)

	Vehicle Type	2008	2010	% Change 2008-2010
Express Lanes	SOV	573	4,827	742%
	HOV 2	3,624	1,702	-53%
	HOV 3	294	49	-83%
	Transit	1,026	1,259	23%
	Total	5,517	7,837	42%
General Purpose Lanes	SOV	7,599	10,982	45%
	HOV 2	2,156	4,215	96%
	HOV 3	358	155	-57%
	Transit	-	-	-
	Total	10,113	15,352	52%
Facility	SOV	8,172	15,809	94%
	HOV 2	5,780	5,917	2%
	HOV 3	652	204	-69%
	Transit	1,026	1,259	23%
	Total	15,630	23,189	48%

The a.m. peak period is from 7:00 a.m. to 9:00 a.m.

Next the average vehicle occupancy (AVO) was examined (see table 8). The AVOs include transit but do not include vanpools since vanpool data was not available. AVO decreased in both directions for the facility as a whole and the ELs. The decrease in AVO for the whole facility indicates some shifting from carpooling to driving alone.

Table 8. Average Vehicle Occupancy 2008 to 2010 (source: Pessaro, 2011)

		2008	2009	2010
Express Lanes	A.M. Southbound	2.2	-	1.36
	P.M. Northbound	1.95	1.39	1.5
General Purpose Lanes	A.M. Southbound	1.15	-	1.17
	P.M. Northbound	1.4	1.39	1.32
Facility	A.M. Southbound	1.38	-	1.23
	P.M. Northbound	1.5	1.39	1.37

Houston HOT Lanes

Katy Freeway Managed Lanes

The Houston, Texas metropolitan area has developed an extensive HOV system over the past 30 years. This system began with a single contraflow lane on Interstate 45 and has evolved to over 100 miles of HOV lanes (mostly barrier-separated) on six corridors. The length of each HOV lane ranges from 12 to 20 miles. HOV support facilities include more than 30 park and ride lots, 19 transit centers, and approximately 20 miles of additional non-barrier separated diamond lanes.

In 2003 the Harris County Toll Road Authority (HCTRA), Metropolitan Transit Authority of Harris County (METRO), and Texas Department of Transportation (TxDOT) cooperatively developed the Interstate 10 Katy Freeway Managed Lanes (KML) project, a four-lane tolled facility (two permanent lanes in each direction) that allowed HOV's and buses to ride for free during the peak periods. The Katy Managed Lanes project coincided with the planned reconstruction of the Katy Freeway, completed in 2009. The reconstruction project added capacity to the GPLs, added the managed lanes, and upgraded the entire facility to current design standards.

The KML is a four-lane facility, 12 miles long, and is separated from the GPLs by flexible pylons and a 22 foot buffer. The KML has four entrances and exits in each direction at approximately four mile spacing along with three toll plazas in each direction. HOV2+ and motorcycles are allowed free travel in both directions during the weekday peak periods: 5 to 11 a.m. and 2 to 8 p.m. This is consistent with prior HOV access policy (as a single-lane reversible HOV lane, there had previously been a 3+ occupancy requirement during each of the a.m. and p.m. peak hours). At each toll plaza there are declaration lanes. The inside lane is for HOV vehicles who do not pay a toll in the peak periods while the lane closer to the GPLs is for SOVs who must pay a toll at all times. The facility is open in both directions, 24 hours, 7 days a week, and 365 days per year through use of electronic tolling for SOV customers. Tolls vary by time of day and currently range from $0.30 to $7.00 depending on time of day and length of trip. Maximum toll rates for the entire length started at $4.00 in 2009, were increased in 2012 to $5.00, and as of September 2013 they are $7.00, with the increase intended to reduce demand and ease capacity issues on the facility. The Katy Freeway and Managed Lanes serve the area known as the Energy Corridor, which has seen substantial growth in the western portion of the area.

The Houston HOV system has been extensively studied over the past 25 years. Manual volume and classification counts have been conducted before and after implementation of various projects and the results are presented in the charts below. Note that these data are from manual counts collected on one day each quarter. Therefore, the data is potentially subject to the exact day of the count being far from a typical day.

Figures 2 and 3 depict the one-day count volumes along the Katy Managed Lanes by toll payment and number of vehicle occupants. Note that when the ML facility first opened there were a significant number of toll-paying HOVs. This meant many HOVs were driving in the lane that was for SOVs and all vehicles had to pay a toll in that lane. This was likely due to confusion over which lane to use. This quickly changed to where very few HOVs used the toll lane and paid a toll (they select the HOV lane).

However, in March 2012 there was a jump in HOV2s that paid a toll (HOV2 Toll Lane) – likely due to some incident on the lanes but this was not recorded in the data collection.

There appears to be little change in HOV2 volume with the opening of the MLs. Immediately after SOV tolled travel was allowed (early 2009) the number of HOV2s was similar to the prior year. Since that time there appears to be a general upwards trend – as there is with most traffic along this corridor (see Figure 2 and Table 9). However, there does appear to be a decrease in HOV3+ travel once the MLs became operational. HOV3+ dropped from around 300 in the a.m. and 400 in the p.m. to less than 100 in the a.m. and p.m. Note that there are almost no HOV3s that pay a toll and thus the decrease in toll free HOV3+ travel on the HOV lane represents the total change in HOV3+ travel on the MLs. These vehicles may have shifted to the GPLs, but since the MLs were free for them and had a higher travel speed that would be unlikely.

Table 9. Traffic Counts on Katy Freeway MLs

	A.M. Peak Period (6:00 a.m.to 9:30 a.m.)				P.M. Peak Period (3:30 p.m.to 7:00 p.m.)			
	Free Lane			Toll Lane	Free Lane			Toll Lane
Date	SOV	HOV 2	HOV3+	All Traffic	SOV	HOV 2	HOV3+	All Traffic
6/1/2013	106	3153	101	4472	149	2663	20	5496
3/1/2013	230	3473	81	5697	110	2757	183	4418
12/1/2012	197	3397	69	4127	168	3021	49	4301
9/1/2012	24	2905	91	6359	184	1886	38	4027
6/1/2012	77	2875	53	3674	338	2707	52	5101
3/1/2012	53	3331	87	5095	129	2830	53	4363
12/1/2011	111	3186	85	4413	38	2415	85	3980
9/1/2011	55	2915	106	4472	86	2618	74	3615
6/1/2011	43	2373	217	3034	69	2743	140	4003
3/1/2011	73	3085	87	4665	74	2642	64	3813
12/1/2010	64	3032	59	4399	73	2619	86	3896
9/1/2010	146	2815	235	4313	61	2367	220	3158
6/1/2010	225	2095	432	3097	99	2079	170	2388
3/1/2010	114	2789	67	3666	72	2110	185	2559
12/1/2009	378	2088	132	2950	280	1997	85	2091
9/1/2009	210	2406	105	2767	280	1997	85	2091
6/1/2009	309	2024	100	2283	308	1879	133	1427
3/1/2009	192	2830	396		516	2457	89	
12/1/2008	146	2820	256		261	2401	165	
9/1/2008	343	2143	297		462	2448	549	
6/1/2008	343	2143	297		462	2448	549	
3/1/2008	467	3294	297		323	2936	442	

12/1/2007	254	3239	353		190	2809	633	
9/1/2007	384	3149	402		351	3114	163	
6/1/2007	212	3033	242		325	2612	406	
3/1/2007	432	2412	746		254	2701	445	
12/1/2006	213	3015	275		117	2988	387	
9/1/2006	172	2955	354		167	2901	453	
6/1/2006	227	2334	467		130	2263	538	
3/1/2006	317	2317	371		363	2657	662	

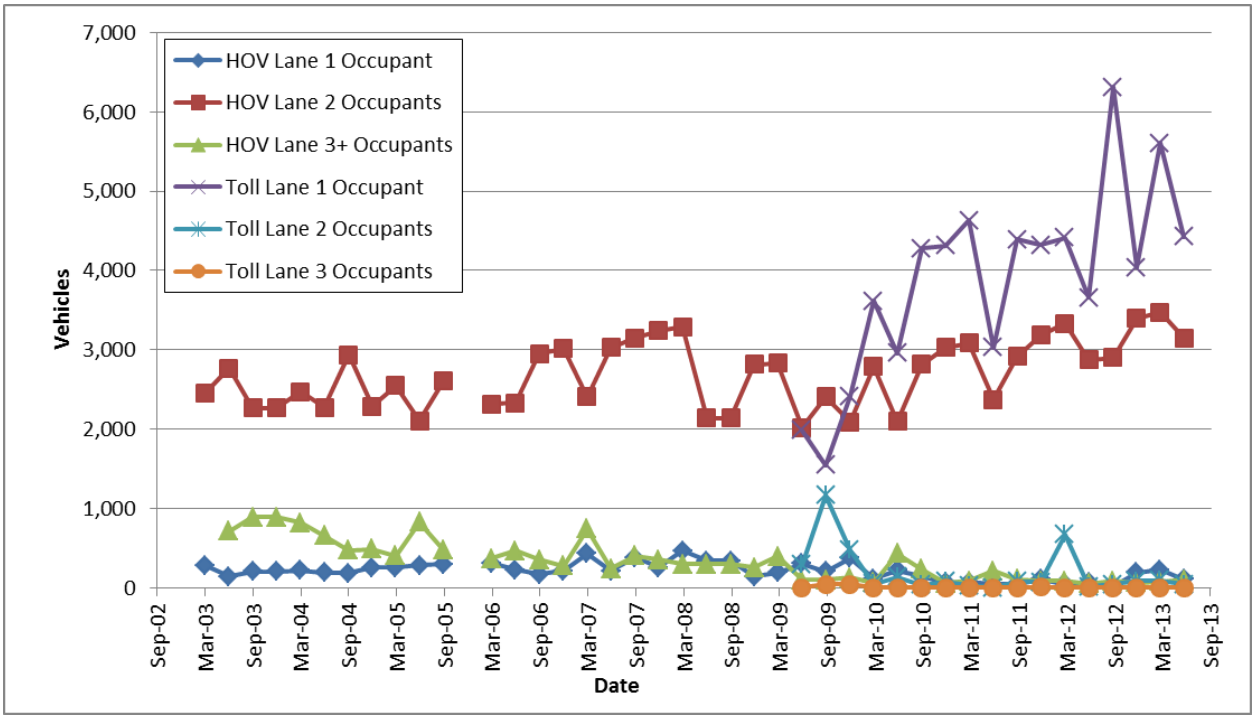

Figure 2. Katy Managed Lanes Morning Peak Period Eastbound Vehicle Trips

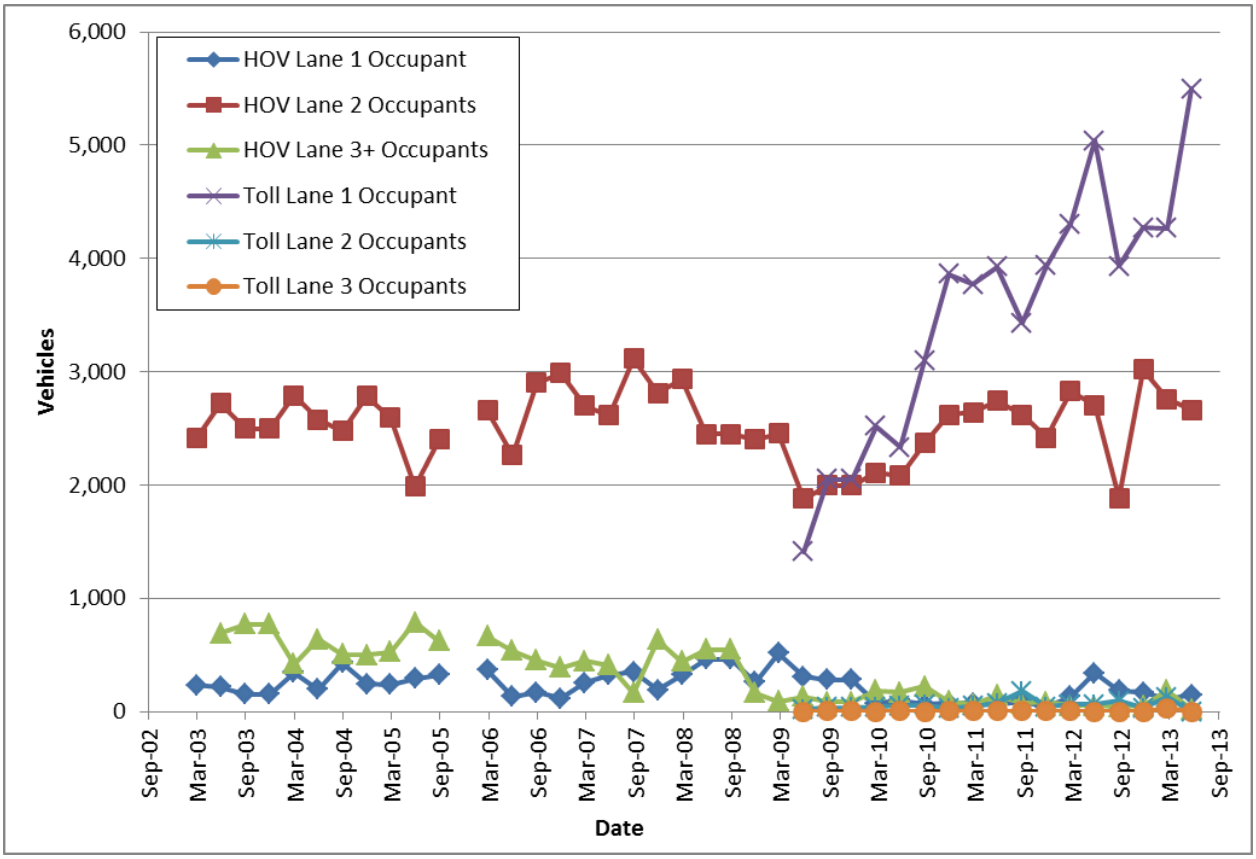

Figure 3. Katy Managed Lanes Afternoon Peak Period Westbound Vehicle Trips

IH 45 Gulf Freeway HOT Lanes

In 2011, Houston METRO began to implement HOT lanes on five existing HOV facilities (IH 45 North, IH 45 Gulf, US 59 Southwest, US 59 Eastex, and US 290 Northwest), with a new corridor planned to open every four to six months. The HOT lane capability was retrofitted into the existing HOV lanes by including declaration lanes at several locations to allow for multiple tolled declaration and access points along each corridor. HOV 2+ travel continues to be toll-free on all facilities except from 6:45 a.m. to 8:00 a.m. on US 290, which has a HOV 3+ requirement for toll-free passage.

The HOT system allows SOV travelers to use the lanes for a toll except during the peak hour on each lane when only HOVs can use the lane to protect operational speeds due to capacity constraints. Variable tolls are charged by time of day and currently range from $1.00 to $5.00 per trip. The HOT lanes are closed from 11:00 a.m. to 1:00 p.m. to reverse the direction of the lane. Currently, most HOT lanes are also closed at night and on weekends, with some seasonal exceptions on the IH 45 Gulf Freeway facility (open outbound on Saturdays and inbound on Sundays during the summer).

The IH 45 Gulf Freeway HOT lane was the first facility converted to HOT operation in February of 2012. Therefore, it has over one-years' worth of HOT lane data to examine. Plus, it is the only HOT lane where the location of manual occupancy counts did not change. Therefore, this is the only one of the five conversions examined in this research. There was little change in HOV volumes after the lanes started

allowing SOVs (see Figures 5 and 6). There was a large increase in the SOV (toll) traffic – which would be expected since SOV traffic prior to February 2012 were violators and were subject to large fines if caught. Caution should be used when reviewing the results due to the high year to year variability in the data the dip in June of 2012 is assumed to be the seasonal summer traffic pattern fluctuation.

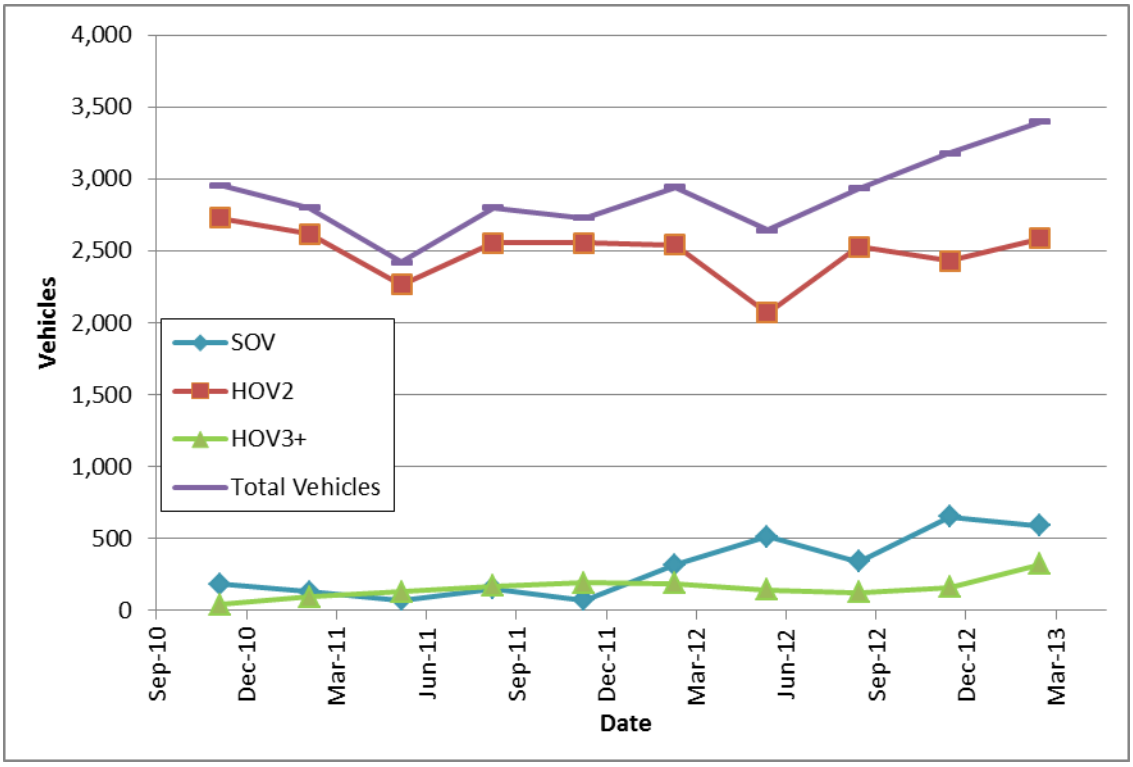

Figure 5. Gulf Freeway HOV Lane Vehicle Count - Morning Period

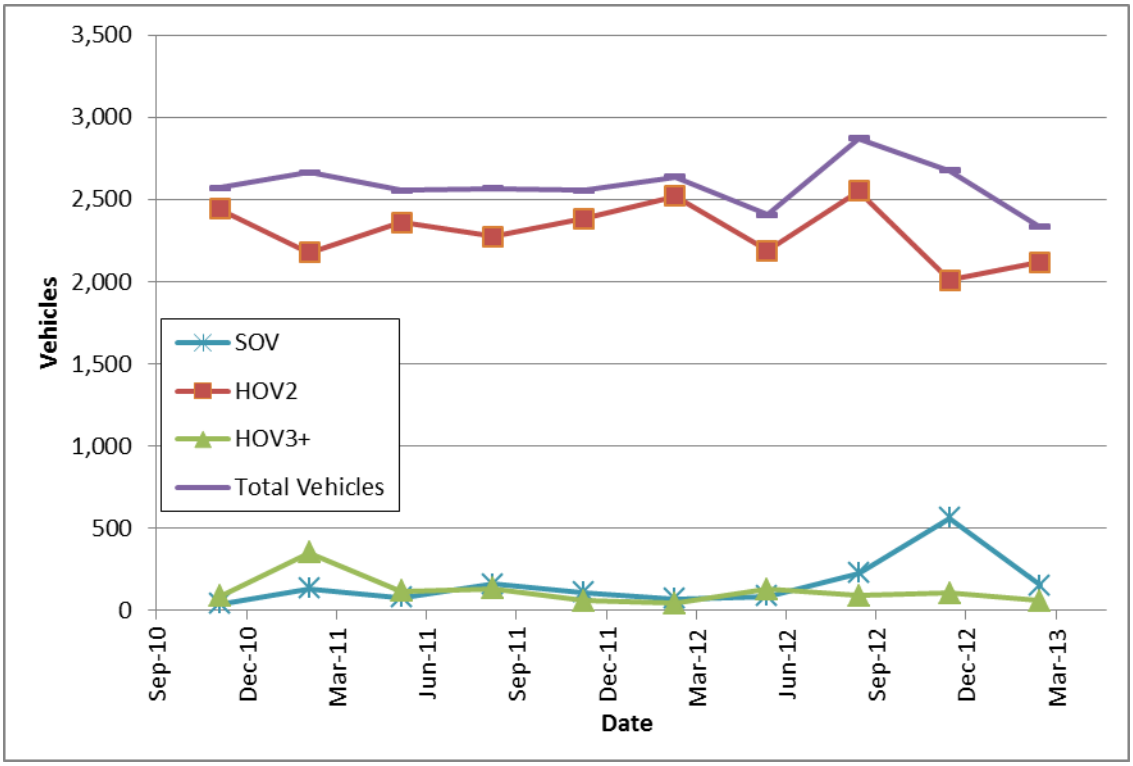

Figure 6. Gulf Freeway HOV Lane Vehicle Count - Afternoon Period

I-85 Express Lanes in Atlanta

Approximately 16 miles of existing HOV lanes on I-85 in Atlanta, Georgia were converted to dynamically-priced HOT lanes in October 2011. The HOT lanes were officially branded as the I-85 Express Lanes. The project was the first HOV-to-HOT lane conversion that simultaneously introduced tolling while increasing the occupancy requirement (from HOV2+ to HOV3+), but did not add additional lanes. At the same time there was greatly expanded express bus service in the corridor along with limited outreach and education to employers to encourage alternative commuting, including carpooling.

The Express Lanes use the existing footprint of the former HOV lane and kept most of the intermediate access points where vehicles can enter and exit the lane. The toll segments that existed between each access point ranged from 1.5 – 3.5 miles in length, creating five distinct tolling segments in both the northbound and southbound directions. A double-white striped buffer separates the HOV lane from the general purpose lanes. An automated enforcement system monitors where vehicles illegally crossed the buffer by using a network of toll gantries installed at roughly 1/2-mile intervals along the corridor.

The toll rates change dynamically throughout both the morning (6-10 am) and afternoon (3-7 pm) weekday peak periods, based on the toll segment with the highest demand. Rates outside of peak periods during the midday period, at night, and on weekends are adjusted to be $0.01 per mile. All other toll segments are charged the same per mile rate as the segment with the highest demand, but

rates differ between the northbound and southbound directions. HOVs and other toll exempt vehicles (including motorcycles and alternatively-fueled vehicles) are required to register for a transponder under the operating guidelines for the Express Lanes. Transponders were not needed to enter the former HOV lane.

The number of vehicles traveling as HOV2+ in the Express Lane decreased after the conversion, from 3,966 to 613 average weekday travelers during the am peak period and from 3,941 to 697 travelers during the pm peak period. In contrast, the number of HOV2+ carpoolers in the general purpose lanes grew from 1,666 to 3,548 travelers during the am peak period and from 2,702 to 4,853 travelers during the pm peak period (see Table 10). In total, for both the a.m. and p.m. peak periods and for all lanes of the facility, there was a loss of 2,564 carpools based on these Georgia Department of Transportation (GDOT) data analyzed by the Texas A&M Transportation Institute (as part of a USDOT National Evaluation of UPA/CRD Programs) (Goodin et al., 2013). These data were based on vehicle occupancy counts and traffic volumes collected by the GDOT during the one year before operation (as the former HOV lane) and one year after tolling began. The average vehicle occupancy fell from 1.17 to 1.14 for the corridor and from 2.03 to 1.22 on the EL.

Table 10. Average Weekday Vehicle Throughput by Occupancy Mode (Excluding Transit), Before and After Opening of I-85 Express Lanes (Source: Goodin et al., 2013**)**

Lane Type	Time Period	Vehicle Throughput by Occupancy				Total Carpools
		1	2	3	4+	
Southbound Morning Peak Period (7:00 – 9:00 a.m.)						
HOV/Express Lanes	Before	317	3730	133	103	3966
	After	3555	504	38	71	613
GP Lanes	Before	32341	1564	68	34	1666
	After	29308	3351	131	66	3548
Northbound Afternoon Peak Period (4:30 – 6:30 p.m.)						
HOV/Express Lanes	Before	343	3585	223	133	3941
	After	3476	563	42	92	697
GP Lanes	Before	34788	2477	150	75	2702
	After	31093	4457	252	144	4853
TOTALS	*Northbound & Southbound, GPL & EL, Peak Periods*					
All Lanes	Before	67789	11356	574	345	12275
	After	67432	8875	463	373	9711

Source: Texas A&M Transportation Institute based on GDOT data. Table does not consider person throughput from transit vehicles.

A survey of carpools registered with the Clean Air Campaign done by the State Road and Tollway Authority (SRTA) of Georgia had shown a similar shift in two-person carpools. The survey helped gauge

the response of carpoolers to the HOV-to-HOT lane conversion. Some of the findings of the survey were as follows:

- 9% stayed in the HOT lane as a two-person carpool
- 12% were originally HOV3+ carpools and continued as HOV3+
- 6% added a third period to their carpool to use the lane toll-free
- 4% switched to transit
- 39% switched to the general purpose lanes
- 30% switched to driving alone

Part of the reason for the retention of two-person carpools may be attributed to the HOV2+ lane that still exists just to the south of the I-85 Express Lane corridor, extending to Downtown (Goodin et al., 2013).

Note that transit ridership in the I-85 Express Lanes increased by 249 riders (21 percent) in the morning peak period and 215 riders (17 percent) in the afternoon peak period. Most of the growth came from the new Express Bus routes that were created as part of the project. Some of the growth could have been from previous carpoolers as noted in the bullets above.

Conclusions

This research examined what happened to carpooling immediately after a HOV lane was converted to a HOT lane. In theory, the added choice of traveling as a SOV on the HOV lane may result in some carpools breaking up. The focus was to examine the change in carpools in the year following the conversion to a HOT lane, but some data cover more than one year after the conversion.

The data were imperfect as there are some locations where counts were not taken. When counts are undertaken, much of the data is from short term, even one-day counts of vehicles classified by number of occupants. There is considerable fluctuation in these values from day to day and it is difficult to accurately count the number of occupants in a vehicle – especially ones moving at freeway speeds during periods of poor lighting. In addition, exactly what happened to carpools and why travelers may have shifted modes is usually unknown. It is likely that some carpools changed for reasons other than the HOT lane. For example, gas prices and employment likely have a significant impact on carpooling. Despite these caveats, there is a general trend in the data from HOT lanes around the country as shown in Table 11.

Overall, we see a pattern of substantial decreases in carpools on many of the HOT lanes. There are exceptions to this, including the three locations with added capacity: SR-91X (entirely new capacity), I-95 (added a lane), I-10 (added a lane) and one location without new capacity: I-45. There also may be unaccounted external/exogenous factors. There is a particularly strong case for this on I-394 (control corridor also lost carpools) and SR-167 (gas price fluctuations). So, the evidence does not provide a clear result, but it would appear HOT lanes have a negative impact on carpools, particularly HOT3+ lanes.

Table 11. Summary of Impacts of HOT lanes on HOVs

Location (plus year if multiple changes to the facility)	Type of Conversion	Impacts on Carpools
SR-91X	Construction of new capacity. Started as HOV3+, had a period where HOV3+ paid half-price toll, now HOV3+ are free most of the week.	The new capacity and toll free status of HOV3+ caused an increase in HOV3+ on the corridor. Future changes in policy shifted the lanes used by carpools but not their amount.
I-15 San Diego (initial opening in the late 1990's)	HOV2+ to a HOT lane where SOVs pay a toll. The toll was monthly to begin with (ExpressPass Phase) and then varied dynamically per trip.	ExpressPass Phase – little impact on carpools. Dynamic Pricing Phase – large decrease in total HOVs in the corridor, mostly in the morning period where carpools dropped by nearly one-third.
I-394	HOV2+ to a HOT lane where SOVs pay a toll.	Manual counts indicated a decrease in carpools of 28% westbound and 17% eastbound on the corridor (all lanes). However, a nearby control corridor also showed a nearly as large decrease in carpools.
SR-167	HOV2+ to a HOT lane where SOVs pay a toll.	Carpooling on the Express Lanes dropped by approximately 41%. However, the decrease tracks the rapid change in gas prices at that time, so the contribution of the HOT lane versus gas prices is unclear.
I-95	Single HOV2+ lane converted to two HOT3+ lanes with restrictions on what constitutes a carpool	Corridor wide, there was a 7% gain in HOV2s, and an 82% loss of HOV3+. Including all modes (transit and SOV as well), AVO dropped by about 10% on the corridor.
Katy Freeway (IH 10) Managed Lanes (2009)	HOV2+ (HOV3+ in the peak periods) to a HOT lane where SOVs pay a toll.	Little change in HOV2s on the HOT lane. HOV3+ have decreased but it is unknown if they broke up the carpool or use the GPLs.
Gulf Freeway (IH 45)	HOV2+ to a HOT lane where SOVs pay a toll.	Little change in carpools.
I-85	HOV2+ to HOT3+ where SOVs and HOV2s pay a toll.	Carpools dropped 21% on the corridor, primarily HOV2s.

Acknowledgements

The authors are grateful to the many researchers who collected the data used in this paper. We also thank Phil Winters, Angela Jacobs and Carol Zimmerman for their helpful comments on an earlier version of this paper. However, the views expressed in this paper are solely those of the authors and do not represent the opinions of TTI, Texas A&M, or any other agency or organization.

References

American Public Transportation Association, (2011). Potential Impact of Gasoline Price Increases on U.S. Public Transportation Ridership. Washington, D.C. < http://www.apta.com/resources/reportsandpublications/Documents/APTA_Effect_of_Gas_Price_Increase_2011.pdf> accessed on January 20, 2014.

Cambridge Systematics, Inc. (2006): *I-394 MnPASS Technical Evaluation: Final Report*. Minnesota Department of Transportation.

Goel, R. and M.W. Burris (2012): 'Hot Lane Policies and their Implications'. *Transportation,* 39, 1019-1033.

Golob, J.M, J. Supernak, T.F. Golob, and K. Kawada (1998): 'An Evaluation of a High Occupancy Toll (HOT) Lane Demonstration Project In San Diego'. *Proceeding of Seminar C held at the European Transport Conference, Loughborough University*: 225-270. PTRC, London.

Goodin, G., E. Schreffler, N. Wood, and C. Zimmerman. "White Paper: Impact of HOV-to-HOT Conversions on Carpooling." Federal Highway Administration, Office of Operations. Washington, D.C. Draft Version, October 2013.

~~Li, Jianling. (2007) "Potential Users' Perspective on Managed Lanes: Insights from a Focus Group Study," in the *Journal of Public Works Management and Policy*, Vol. 12, No. 2, pp. 416-430.~~

Pisarski, A. (2006). "COMMUTING IN AMERICA III - The Third National Report on Commuting Patterns and Trends." NCHRP REPORT 55O, National Cooperative Highway Research Program, TCRP REPORT 11O, Transit Cooperative Research Program, National Academy of Science, Washington, D.C. < http://onlinepubs.trb.org/onlinepubs/nchrp/CIAIII.pdf> accessed May 2013.

Pessaro, B. and C.V. Nostrand (2011): *Miami Urban Partnership Agreement (UPA) Project: Phase 1 Transit Evaluation Report Final*, FL-26-7110-02, U.S. Department of Transportation Federal Transit Administration, Washington, DC.

Sullivan, E. (1998): *Evaluating the Impacts of the SR91 Variable Toll Express Lane Facility: Final Report*, California Department of Transportation, Sacramento.

Sullivan, E. (2000): *Continuation Study to Evaluate the Impacts of the SR91 Value-Prices Express Lanes: Final Report*, California Department of Transportation, Sacramento.

Supernak, J. (2001): *I-15 Congestion Pricing Project Monitoring and Evaluation Services: Task 1*, San Diego Association of Governments, San Diego.

Zmud, J. (2006): *MnPASS Evaluation Attitudinal Panel Survey Wave 3: Final Report*. University of Minnesota, Minneapolis.