Implications of Increasing Carpool Occupancy Requirements on the Katy Freeway High-Occupancy-Vehicle Lane in Houston, Texas

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The Texas State Department of Highways and Public Transportation and the Harris County Metropolitan Transit Authority are in the process of developing an extensive system of high-occupancy-vehicle (HOV) lanes on the freeways in Houston, Texas. Locally, these HOV lanes are referred to as transitways. Considerable attention is being given to developing appropriate techniques for operating these priority facilities. In October 1988, carpool occupancy requirements to use the lane were increased from two or more to three or more persons per vehicle between 6:45 and 8:15 a.m. in order to restore free-flow operation on the transitway. This change represented the first time in the United States that occupancy requirements to use an HOV facility had been increased. The action had its intended effect of restoring free flow to the transitway. Although in the short run total person volume for the facility declined slightly, the result was a significant increase in the value of time saved by transitway users. Increases both in bus patronage and in three-or-more-person carpool use were noted. This action was implemented with surprising ease and has worked effectively in the field. Much of the success is directly related to the design and enforcement policy used in developing and operating the Houston transitways. This approach may now be used on a routine basis as needed to effectively operate the Houston transitway facilities.

The Texas State Department of Highways and Public Transportation and the Metropolitan Transit Authority of Harris County are in the process of developing an extensive system of high-occupancy-vehicle (HOV) lanes on the freeways in Houston, Texas. Locally, these HOV lanes are referred to as transitways. Today, over 36 mi of these facilities are in operation on four separate freeways. Ultimately, nearly 96 mi of transitways will be developed at a cost approaching $700 million. These lanes are generally located in the median of the freeway, are 20 ft wide, are reversible, and are separated from the mixed-flow traffic lanes by concrete median barriers. A more complete description of this transitway system was given by Christiansen and Morris (*1*).

Because the Houston commitment to developing transitways is somewhat unique and extensive, considerable effort is being given to identifying appropriate procedures for operating the transitways. The Katy (I-10) transitway, Phase 1 of which opened in October 1984, was the first of the transitways to be completed in final form. Consequently, in many respects it has been used as a laboratory in which different operating procedures could be tested.

One of the major operational issues affecting the transitways is the decision regarding what vehicle groups will be allowed to use the transitway. In effect, a balancing act is required. On one hand, it is desirable to have a reasonably large volume of vehicles using the transitway so that it appears to be sufficiently used. On the other hand, for the transitways to be successful they need to offer a high travel speed and a reliable travel time. As a result, it is essential that volumes in the transitway be kept below capacity so that significant delay and congestion do not develop on the high-speed priority lane.

This balancing act is further complicated by two other factors. First, experience with HOV lanes in southwestern and western cities has shown that the two-or-more-person carpool volume can be substantial; the three-or-more-person carpool volume is generally quite small. However, using a three-or-more-person rather than a two-or-more-person carpool designation can reduce carpool volume by 75 percent. Second, transitway facilities have exceedingly high peaking characteristics. Generally, the hourly vehicle volume on either side of the peak hour is about half of the peak-hour volume. Thus, the need may exist to manage the peak-hour volume without adversely affecting the volumes on either side of that peak hour.

ELIGIBLE KATY TRANSITWAY USER GROUPS

Definition of which vehicle types are allowed to use the Katy transitway has changed on several occasions between its opening (in October 1984) and October 1988. When the transitway opened in October 1984, because of previous experience in Houston on the North Freeway (I-45) contraflow lane, only buses and vanpools formally authorized by the Harris County Metropolitan Transit Authority (Metro) were allowed to use the Katy transitway. Authorization involved many factors, including insurance requirements, driver training, and vehicle inspections. Drivers were issued licenses allowing them to operate in the priority lane, and vehicles using the lane displayed permits. With this approach, shortly after it opened approximately 50 vehicles used the transitway in the peak hour. Surveys (*2*) of motorists in the freeway main lanes found

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that 97 percent of those individuals felt that the transitway was being underused.

In April 1985, a decision was made to allow authorized four-or-more-person carpools to begin using the transitway to increase its use. It was found that few four-or-more-person carpools existed in the Houston traffic stream and that a carpool of that size was relatively unstable on a day-to-day basis (because of at least one person not traveling to the place of work that day). As a result, the effects of this action were minimal; only about 10 vehicles per hour (vph) were added to the peak-hour volume.

In September 1985, three-or-more-person authorized carpools were allowed onto the Katy transitway, which increased peak-hour volume to about 100 vph, but the transitway still appeared underused.

In April 1986, two-or-more-person carpools were allowed to use the transitway and all occupancy requirements were dropped. The peak-hour volume immediately increased to about 1,200 vph, and for 2 years this approach worked relatively well. The volume both of persons and vehicles using the transitway was significant and relatively high travel speeds continued to exist in the transitway.

KATY TRANSITWAY VOLUME AND CAPACITY RELATIONSHIPS

In September 1988, with the economy in the Houston area beginning to rebound, volumes using both the freeway main lanes and the transitway began to increase noticeably. Peak-hour volumes on the transitway frequently would approach or exceed 1,500 vph. Several site-specific geometric and operational constraints limit the capacity of the Katy transitway. Given these constraints, traffic analysis (*3*) showed that delays would begin to occur on the transitway as volumes exceeded about 1,200 vph, and that 1,500 vph effectively was the upper volume level that could be served with reasonably reliable travel speeds. Speeds during the peak of the peak hour were below 55 mph at these volumes. Because the eastern terminus of the transitway is temporarily located at a traffic signal, delay problems on the transitway itself occurred only during a.m. operation.

As demands began to approach and exceed 1,500 vph, the purpose of the transitway to provide travel time advantages began to be lost. Considerable delays occurred on the transitway during the a.m. peak hour, and bus passengers began complaining to the transit authority.

In response to this problem, studies (*3*) of alternatives for managing demand were undertaken. Consideration was given to (a) doing nothing, (b) requiring authorization for two-person carpools desiring to use the transitway in the peak hour, (c) metering access to the transitway, and (d) increasing carpool occupancy requirements. All of the alternatives considered had problems; there was no obvious best alternative. A policy-level decision was made to increase carpool occupancy requirements from two or more to three or more persons per vehicle for the period from 6:45 to 8:15 a.m., but the two-or-more-person policy would remain in effect during all other operating hours. The decision was implemented on 3 days' notice with relatively little marketing and became effective October 17, 1988.

This decision represented an innovative approach for operating transitway facilities. It was the first time a carpool occupancy requirement had been increased on a HOV facility, and it also was the first time that HOV requirements were varied by time of day (some HOV facilities do revert from HOV lanes to regular mixed-flow freeway lanes during off-peak periods).

IMPACTS OF THE INCREASE IN OCCUPANCY REQUIREMENTS

The increase in carpool occupancy requirements between 6:45 and 8:15 a.m. was implemented with surprisingly little difficulty. The relatively unique design (barrier-separated transitways with a limited number of access and egress locations) and regular routine enforcement associated with the transitways greatly enhanced the feasibility of this demand management approach. Data are available through March 1989 to permit evaluation of at least the short-term impacts of this action. Data relevant to the analysis are presented in Table 1.

Morning Transitway Operations

7:00 to 8:00 a.m. Transitway Travel

Between 7 and 8 a.m., the total peak-hour vehicle volume on the transitway immediately decreased by about 64 percent, from 1,400 to 510 (Table 1). Travel time delays that had been experienced on the transitway before the occupancy change were immediately eliminated (Figure 1). To that end, the change in occupancy requirements achieved its desired effect.

Since the initial decrease of about 33 percent in person-volume on the transitway between 7 and 8 a.m., demand has been increasing. For March, the person-volume increased to 3,445, 19 percent less than the volume before the change but 18 percent greater than the November–December volume.

Because the decline in vehicle-volume was greater than the decline in person-volume, average vehicle occupancy on the transitway increased from 3.1 to 4.7 persons per vehicle. The data in Table 1 also indicate that a significant volume of two-person carpools are on the transitway between 7 and 8 a.m. Some of these are clearly violators; however, most appear to have legally entered the transitway before 6:45 a.m. at its western terminus and were still in the transitway at 7:00 a.m. when counted at the eastern terminus.

6:00 to 9:30 a.m. Transitway Travel

During the a.m. peak period, person-volume immediately dropped by 17 percent; however, it has been increasing and in March was 10 percent less than what it was before changing the occupancy requirement (Figure 2).

Components of the change in person volumes Before the change in occupancy requirements, approximately 5,090 persons used the transitway in two-person carpools between 6 and 9:30 a.m. (Table 1). This figure decreased to 2,490 in the

TABLE 1 MORNING TRAVEL VOLUMES BEFORE AND AFTER CHANGE IN OCCUPANCY REQUIREMENTS, KATY FREEWAY CORRIDOR

Travel Volumes	"Representative" Pre-Occupancy Change Value[1]	Value After Occupancy Change			
		11/88 and 12/88		3/89	
		Value[2]	% Change[3]	Value	% Change[3]
Daily Transitway Person Volume	18,880	16,595	- 12%	17,831	- 6%
A.M. Peak-Period (6-9:30) Person Volume, Total	8,780	7,265	- 17%	7,945	- 10%
2 Person Carpools	5,090	2,490	- 51%	2,800	- 45%
3+ Person Carpools	935	1,835	+ 96%	1,905	+ 104%
Total, Carpool Riders	6,025	4,325	- 28%	4,705	- 22%
Patrons	2,450	2,670	+ 9%	2,885	+ 18%
Vanpool Riders	305	270	- 11%	355	+ 16%
7-8 A.M., Total Person Volume	4,320	2,915	- 33%	3,445	- 19%
Carpools	2,885	1,315	- 54%	1,750	- 39%
2 Person Carpools	2,410	230	- 90%	480	- 80%
Bus Patrons	1,310	1,500	+ 15%	1,490	+ 14%
Vanpoolers	125	100	- 20%	205	+ 64%
A.M. Peak Period Vehicle Volume, Total	2,900	1,950	- 33%	2,120	- 27%
Carpools	2,780	1,820	- 34%	1,990	- 28%
7-8 A.M., Total Vehicle Volume	1,400	510	- 64%	730	- 48%
2+ Carpool Vehicles	1,365	455	- 67%	660	- 52%
2 Person Carpools	1,205	115	- 90%	240	- 80%
3+ Carpools	160	340	+112%	420	+ 162%
Carpool Volume (6-7 and 8:15-9:30)	1,230	1,170	- 5%	1,295	+ 5%
Freeway Mainlane Volumes, 6-9:30 a.m.					
Vehicles	15,300	15,900	+ 4%	16,805	+ 10%
Total Persons	16,455	17,230	+ 5%	18,675	+ 13%
Average Vehicle Occupancy	1.075	1.084	+ 1%	1.111	+ 3%

[1]This is the value representative of the trend line that existed prior to changing the occupancy requirement. It does not reflect the values for any particular month.

[2]These are representative of the average of the November and December data.

[3]The percent change in comparison to the representative pre-occupancy change value.

Source: Texas Transportation Institute data collection.

November–December period and was 2,800 in March. Thus, if all the individuals in those two-person carpools had ceased to use the transitway, the apparent loss in transitway ridership in the November–December period would have been 2,600 persons, and in March, 2,290 persons. Actual declines in peak-period transitway ridership were 1,515 and 835 for those periods, respectively. It is apparent that some changes have occurred in transitway travel patterns as a result of the changed occupancy requirement.

Table 2 presents the changes that have occurred in peak-period transitway ridership since the change in occupancy requirements. They indicate that a significant volume of individuals has changed to a higher-occupancy mode (either three-or-more-person carpool or bus) to be able to keep using the transitway.

Through March, a 104 percent increase in three-or-more-person carpool person-volumes had been realized, which occurred almost immediately (Figure 3). It is also significant that bus ridership in the a.m. peak period had increased by nearly 20 percent through March. Apparently, there is some modal overlap because some individuals, if necessary, will choose a higher-occupancy mode of travel.

Changes in Time of Use of the Transitway It would be expected that carpool volumes between 6:30 and 7:00 a.m. might have increased as a result of the change in occupancy requirements. Overall, carpool volumes now peak earlier than they did before the occupancy change, but the absolute volume of carpools using the transitway between 6:00 and 7:00

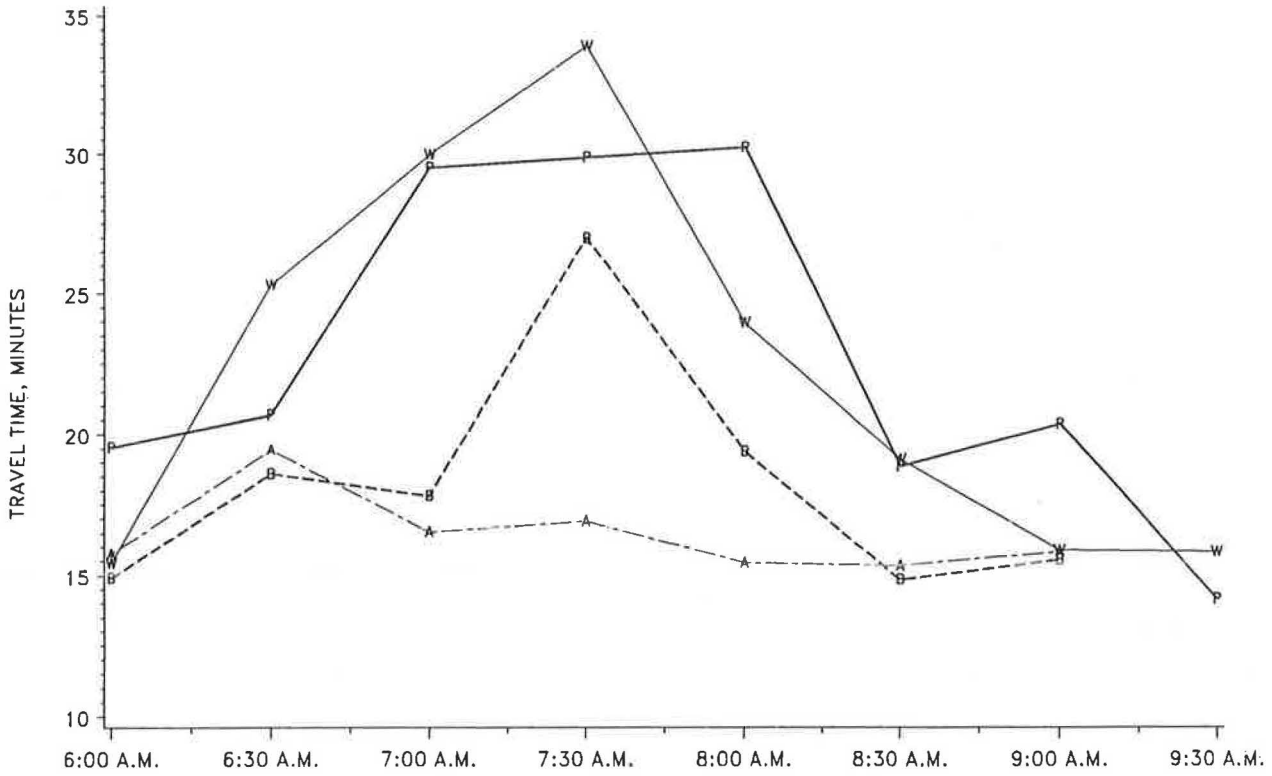


FIGURE 1 Katy Freeway main lanes and transitway, a.m. travel times.

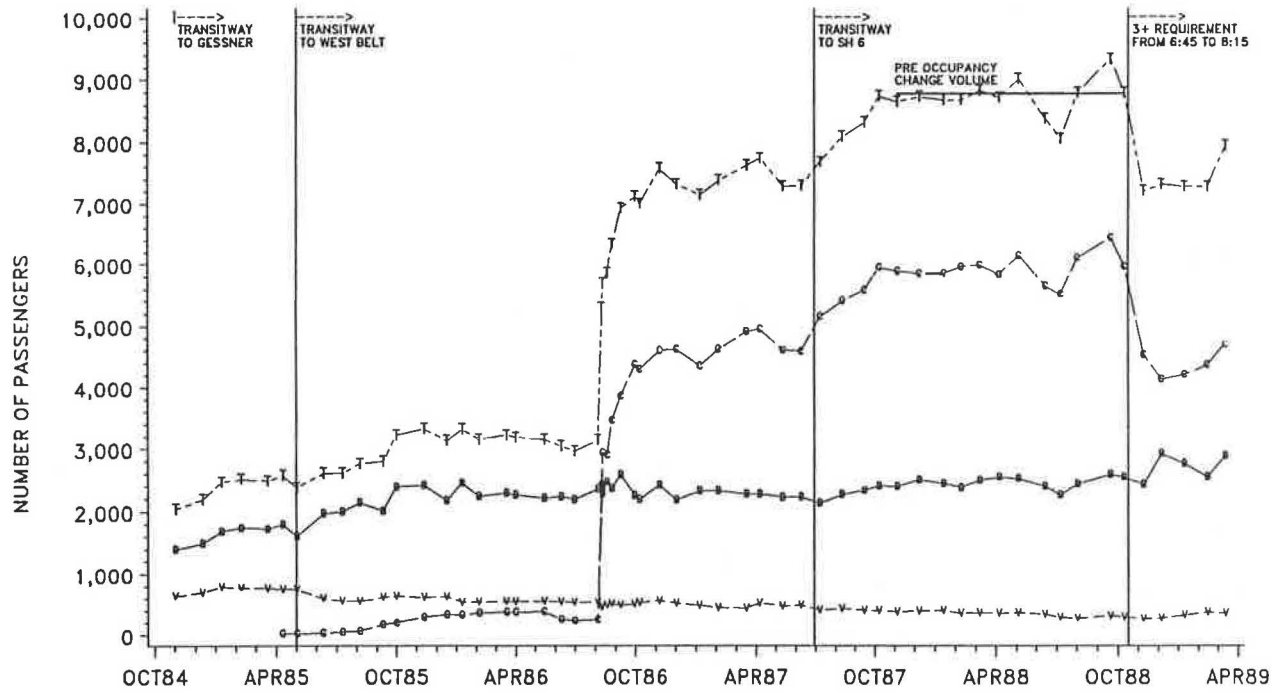
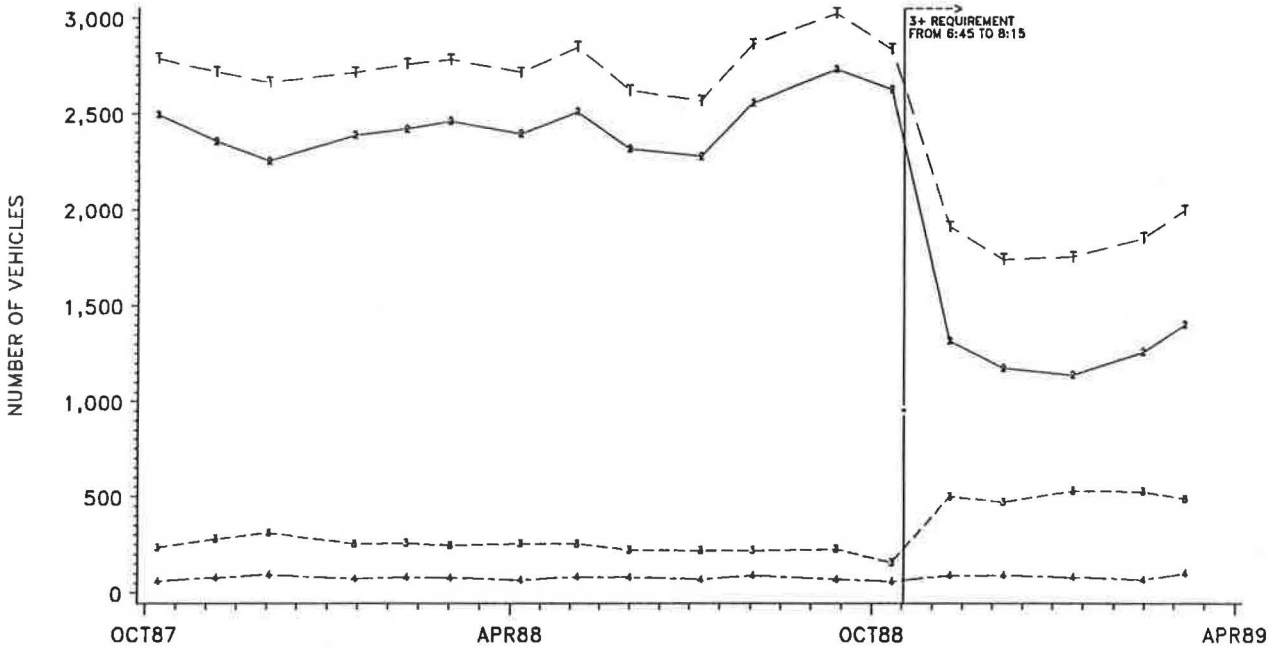


FIGURE 2 Katy Freeway transitway, a.m. peak-period person movement.

TABLE 2 SUMMARY OF CHANGES IN a.m. PEAK-PERIOD PERSON TRAVEL ON THE KATY TRANSITWAY

Component of Change from Base Ridership	November-December Time Period	March Time Period
Base Ridership (Pre-Occupancy Change)	8,780	8,780
Change Due to Vanpooling	- 35	+ 50
Change in 2-Person Carpool Volume	-2,600	-2,290
Change in 3+ Person Carpool Volume	+ 900	+ 970
Change in Bus Patronage	+ 220	+ 435
Resulting Peak Period Ridership	7,265	7,945



KATY TRANSITWAY PHASE 1, POST OAK TO GESSNER (4.7 MI.), OPENED OCTOBER 29, 1984
TRANSITWAY EXTENSION FROM GESSNER TO WEST BELT (1.7 MI.) OPENED MAY 2, 1985
TRANSITWAY EXTENSION FROM WEST BELT TO SH 6 (5.0 MI.) OPENED JUNE 29, 1987
4+ AUTHORIZED CARPOOL OPERATION BEGAN APRIL 1, 1985
3+ AUTHORIZED CARPOOL OPERATION BEGAN SEPTEMBER 1985
OFF-PEAK, UNAUTHORIZED & 2+ CARPOOL OPERATION BEGAN AUGUST 11, 1986
3+ REQUIREMENT FROM 6:45 T 8:15 A.M. IMPLEMENTED OCTOBER 17, 1988
SOURCE : TEXAS TRANSPORTATION INSTITUTE

LEGEND : T = TOTAL CARPOOLS
2 = TOTAL 2 PERSON CARPOOLS
3 = TOTAL 3 PERSON CARPOOLS
4 = TOTAL 4 PERSON CARPOOLS

FIGURE 3 Katy Freeway transitway, a.m. peak-period carpool use.

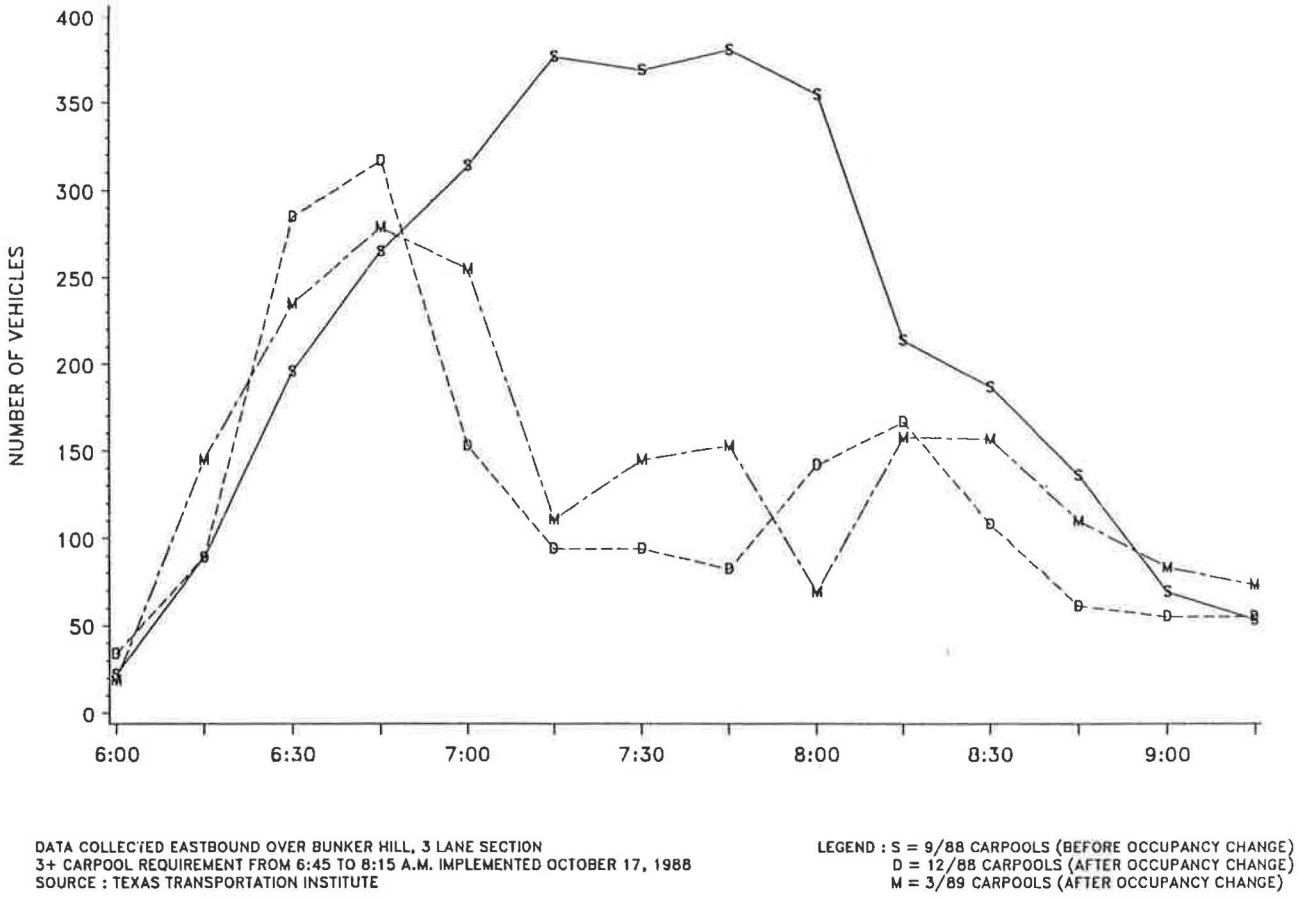


FIGURE 4 Katy Freeway transitway, a.m. peak-period carpool peaking characteristics.

a.m. is not that much different than it was before the occupancy change (Figure 4).

Where Did the Remaining Volume Go? Although the decrease in overall transitway use was not as great as it might have been had not a meaningful number of commuters switched to a higher-occupancy mode, nevertheless, fewer people used the transitway during the peak period. Compared with conditions that existed before the occupancy change, in the November–December period the person-volume was 1,515, whereas in March it was 835.

It had been speculated that some portion of this volume may have been diverted to the northwest (US-290) transitway, a new transitway partially in the same corridor as the Katy transitway and still open to two-or-more-person carpools during all operating hours. However, an analysis of trends in use on the northwest transitway suggests that no significant diversion to that transitway took place.

It seems that most of the volume no longer using the Katy transitway has diverted back to either using the Katy Freeway main lanes or using other streets in the corridor. Indeed, freeway volumes have increased (Table 1) although it is not possible to clearly identify the components of that increase. Small increases in freeway vehicle occupancy have also occurred, suggesting that additional carpools are now in the freeway main lanes.

However, surveys (2) have clearly indicated that about half the carpools using the Katy transitway were formed since that transitway opened and because of it. If those vehicles are forced back to using freeway main lanes, it is probable that at least some of those carpooling may choose to go back to driving alone.

Evening Transitway Operations

During the p.m. peak period (3 to 6:30 p.m.), the transitway is still open for use by two-or-more-person vehicles. As a result, it would be expected that meaningful changes in person-volume should not occur; however, a decline in vehicle volume would be expected because there are more bus riders and more three-or-more-person carpoolers caused by the actions taken in the a.m. peak period. In general, this has been the case (Table 3). By March, the increasing trend in p.m. person-volume was back in evidence and compared with preoccupancy change conditions, peak-period person volume was up 4 percent with vehicle-volume being down 4 percent.

Daily Transitway Travel Volumes

As would be expected, reducing the types of vehicles that can use the transitway during a portion of the a.m. peak would,

TABLE 3 EVENING PEAK-PERIOD (3 TO 6:30 p.m.) TRANSITWAY TRAVEL VOLUMES BEFORE AND AFTER CHANGE IN OCCUPANCY

Travel Volume	"Representative" Pre-Occupancy Change Value[1]	Value After Occupancy Change			
		11/88 and 12/88		3/89	
		Value[2]	%Change	Value	%Change[3]
Peak Period Person Volume	8,325	8,180	-2%	8,682	+4%
Peak Period Vehicle Volume	2,825	2,665	-6%	2,714	-4%

[1]This is the value of the trend line that existed prior to changing the occupancy requirement. It does not reflect the values for any particular month.

[2]These are representative of the average of November and December data.

[3]The percent change in comparison to the representative pre-occupancy change value.

Source: Texas Transportation Institute.

at least in the short run, reduce total transitway use. Compared with the conditions that existed before changing the occupancy requirement, the November–December period experienced a 12 percent decrease in daily travel. However, demand has been increasing, and in March 1989 the daily person-volume on the transitway was 6 percent less than what it was before changing the occupancy requirement (Table 1).

Value of Transitway Travel Time Saved

Although person-volumes on the transitway declined, the increase in travel time saved was substantial. This finding is partly the result of eliminating delay on the transitway and partly the result of increased congestion on freeway main lanes (Figure 1). In March 1989, travel time savings for users of the transitway were greater than they were before initiating the occupancy change requirement (Table 4). Most of the 32 percent increase in person-time saved during the a.m. peak period can be attributed to the occupancy change.

CONCLUSIONS

In order to restore high speeds and reliable travel times on the Katy transitway, occupancy requirements for carpools were increased from two or more to three or more persons between 6:45 and 8:15 a.m. in October 1988. This increase had its intended effect of immediately eliminating congestion on the transitway.

This change represented the first time carpool occupancy requirements had been increased on a HOV facility. Although considerable concern existed over whether this could be done, the change was actually accomplished with relative ease. Given the design and enforcement associated with the Houston transitways, it has been possible to enforce this restriction. The change in occupancy requirements became insignificant within several days of being implemented. Although this action directly affected over 2,000 peak-hour commuters, fewer than 36 calls were received by the operating agencies complaining about or commenting on the measures taken. Apparently, those persons using the transitway realized that the value of that facility was being greatly reduced by the high vehicle volumes.

The action resulted in many individuals choosing to use a higher-occupancy travel mode. By March 1989, peak-period bus ridership, compared with conditions before the occupancy change, had increased by 435 riders or 18 percent. Three-or-more-person carpool person-volume in the peak period increased by 970 persons, or 104 percent.

By March, daily person usage of the transitway had increased to within 6 percent of the volume that existed before the change. However, although person-volume decreased, at least in the short run, the value of time saved by users of the transitway increased substantially because of the elimination of congestion on the transitway and the increase in congestion on the freeway main lanes. The result was a 90 percent increase in the value of time saved daily by users of the transitway. During the a.m. peak period, person-hours of time saved by users of the transitway on nonincident days increased from 833 to 1,100 hr, an increase of 32 percent. Much of this increase is because of the change of occupancy requirements.

The Houston transitways are intended to move a design-year volume of 7,000 to 10,000 persons in the peak hour. This volume simply cannot be realistically attained with a two-or-more-person occupancy requirement. As a result, it was recognized that at some point in time peak-hour occupancy requirements would have to be increased. That action has now been taken successfully. This successful experiment has shown that, given the design and enforcement procedures associated with the Houston transitways, an effective operating tool can be used to help manage transitway demand to ensure that those facilities function as planned. In the future, this approach may be used on a routine basis as needed to effectively operate other Houston transitways.

TABLE 4 DAILY PERSON-HOURS OF TIME SAVED BY USERS OF THE KATY TRANSITWAY

Time Period	Hours of Time Saved		
	Representative Pre-Occupancy Change Value[1]	Value after Occupancy Change	
		Value[2]	% Change[3]
A.M. Peak Period	833	1,100	+ 32%
P.M. Peak Period	202	858	+325%
Total	1,035	1,958	+ 89%

[1]This is the average of travel time data collected in 12/87, 3/88 and 6/88. Travel time saved due to incidents is not included.

[2]This is the average of travel time data collected in 12/88 and 3/89. Travel time saved due to incidents is not included.

[3]The percent change in comparison to the 9/88 value pre-occupancy change value.

Source: Texas Transportation Institute.

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