Evaluation of Minnesota I-394 High-Occupancy-Vehicle Transportation System

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Construction of the major elements of the I-394 transportation system was completed in fall 1992. This system includes high-occupancy-vehicle (HOV) reversible lanes, concurrent HOV lanes, three car pool parking garages in downtown Minneapolis, five transit stations, seven park-and-ride lots, improved transit service, an extensive automated traffic management system, and a number of other HOV-related services, including enforcement and marketing. The Minnesota Department of Transportation began a three-phase evaluation of the I-394 system in 1985, when an interim HOV lane was constructed. The first phase of evaluation addressed the effectiveness of the interim HOV lane before major construction. The second phase looked at HOV use and operation during construction. The third phase has been underway since the facility was completed in late 1992. This evaluation effort includes data collection related to bus ridership, vehicle occupancy, traffic volumes, occupancy compliance, park-and-ride use, garage use, and travel times. The results of the I-394 evaluation will be used to develop incentive programs to encourage further car pooling and bus ridership in the I-394 corridor, to fine tune operational elements of the system to provide safer and more efficient traffic flow, and to provide guidance for the development of other HOV facilities in the Twin Cities metropolitan area.

I-394 was the first Interstate project in the United States to fully integrate the funding and construction of highways with the construction of high-occupancy-vehicle (HOV) lanes, transit facilities, parking garages, and elevated and enclosed walkways called skyways. These physical features are supported proactively by a myriad of programs including transit and ride-share services, traffic management systems, enforcement programs, parking incentives, and public information and marketing activities. The intent of the I-394 transportation system, as this unique combination of physical facilities and programs has come to be known, is to maximize the number of people carried by aggressively encouraging car pooling and bus ridership in a heavily congested highway corridor.

The Minnesota Department of Transportation (Mn/DOT) completed construction of I-394 in fall 1992. I-394 is an 11-mi facility that fully integrates transit and highway systems and is designed to maximize incentives for HOVs, including buses, car pools, and van pools. HOVs are defined as vehicles with two or more people. The key components of the I-394 transportation system are illustrated in Figure 1 and include the following:

- Three miles of reversible HOV lanes.
- Eight miles of concurrent-flow HOV lanes.
- An automated traffic management system.
- Eight HOV meter bypass lanes.
- Three parking garages in downtown Minneapolis that have direct access to/from I-394, reduced parking fees for car poolers, and transit stations.
- Elevated and enclosed walkways called skyways connecting the downtown Minneapolis parking garages to each other and to the downtown Minneapolis skyway system.
- Three additional transit transfer stations.
- Seven park-and-ride lots.
- Expanded express and timed-transfer local bus service.
- Ride-share matching.
- Enforcement activities.
- An extensive marketing program to increase car pooling and transit ridership.

U.S. Highway 12 between Wayzata and downtown Minneapolis was designated initially to be upgraded to Interstate standards in 1968. It was a politically and publicly controversial project that encountered several stumbling blocks and milestones before construction began in 1984.

I-394 INTERIM HIGH-OCCUPANCY-VEHICLE LANE

On November 19, 1985, the Minnesota Department of Transportation opened the I-394 interim HOV lane. Initially, the HOV lane was a physically separated, single reversible lane in the median of Trunk Highway (TH) 12, a four-lane, signalized highway. It evolved through several combinations of the separated HOV lane and concurrent HOV lanes over the following 7 years of construction, transitioning ultimately into the permanent I-394 transportation system.

The interim HOV lane was built in 1985 to (*a*) introduce the concept of an HOV lane in advance of the permanent HOV lanes, (*b*) generate public support for car pooling and bus ridership, and (*c*) provide additional people-carrying capacity during the reconstruction of Highway 12 into I-394.

Because of the uncertainty surrounding public acceptance and use of the HOV lane, Mn/DOT and its I-394 Policy Committee and Corridor Management Team made a decision to review periodically the use and operation of the I-394 system. Four distinct time periods were established for evaluation:

1. First year: first year of operation of the interim HOV lane (1986).
2. Construction: period during which the interim HOV lane was affected by the construction of TH 12/I-394 (1987–1992).
3. Start up: first 18 months after completion of construction (1993–1994).

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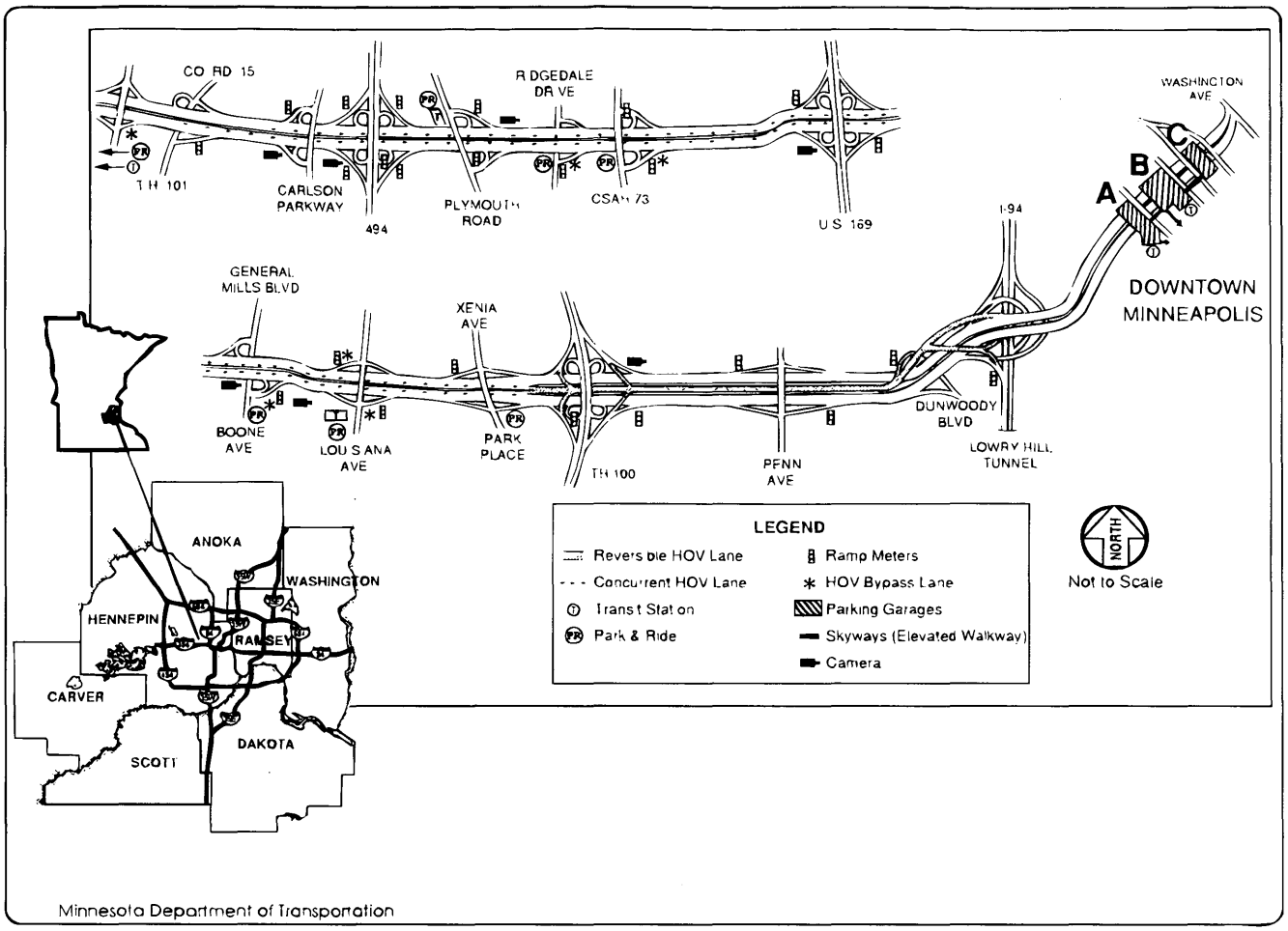

FIGURE 1 I-394 HOV transportation system.

4. Stable operation: ongoing operation of permanent system to initial forecast year (1995–2000).

I-394 CASE STUDY EVALUATION

I-394 was one of the first HOV facilities in Minnesota and included some unique features, particularly the downtown car pool parking garages. Therefore, it has been the subject of a case study evaluation since 1984, when base line information was collected on old TH 12 and parallel roadways before construction. The case study evaluation involved three of the previously described time periods:

Phase I, which was completed in October 1987, analyzed the effectiveness of the interim HOV lane during its first year of operation. The results of the Phase I evaluation were documented in the Phase I report published in October 1987.

Phase II was conducted midway through the construction of I-394. It focused on the effectiveness of the interim HOV lane during the construction period and the problems associated with keeping the HOV lane operational during roadway construction. A Phase II report was published in July 1990.

Phase III was completed in late 1994. Its purpose was to examine the operation and use of the roadway with all of the system elements in place, to identify any operational problems, and to recommend changes and fine tuning to improve the operation of the roadway and the effectiveness of the HOV facilities and programs.

PERFORMANCE OBJECTIVES

Several performance objectives were established in 1984 as part of the original I-394 transportation system management plan. These initial objectives for I-394 were to:

- Increase the peak-hour car pool/van pool modal split for the I-394 corridor.
- Increase the peak-hour transit modal split for the I-394 corridor.
- Improve the level of service for car pools and van pools on I-394.
- Improve the provision of transit service in the I-394 corridor.
- Maintain or improve the existing level of service for mixed traffic on I-394.
- Decrease the accident rate along I-394.
- Achieve and maintain high-occupancy compliance in the I-394 HOV lanes.
- Construct a cost-effective HOV facility on I-394.

A comparison of these stated performance objectives and actual performance to date is provided in Table 1. In general, the use of the

TABLE 1 Performance of I-394 HOV Transportation System

Objectives[1]	Performance Measures[1]	Actual in 1984[1]	Objectives for Start Up Period (1993-1994)[1]	Actual in April 1994[2]	Forecast Conditions (2000)[3]
Increase Peak Hour Car pool/Van pool Usage	Car pools/Van pools	535	1,075	1,596	1,585
	Car pools as Percent of Autos	19%	25%	22%	29%
	Auto Occupancy Rate	1.15	1.30	1.29	1.6
Increase Peak Hour Bus Usage	Buses	21	42	70	57
	Bus Ridership	1,000	2,000	2,256	2,700
Improve the Level of Service for Car pools/Van pools	Average Peak Hour Speed	47 km/hr	69 km/hr	89 km/hr	89 km/hr
	Travel Time from TH 101 to Downtown[4]	23 min	12 min	11.8 min	12 min
Improve Provision of Bus Service in I-394 Corridor	Average Express Bus Speed	47 km/hr	81 km/hr	89 km/hr	81 km/hr
	Travel Time from TH 101 to Downtown[4]	25 min	13 min	11.8 min	13 min
Maintain Improve the Level of Service for Mixed Traffic on I-394	Average Peak Hour Speed	47 km/hr	63 km/hr	80 km/hr	63 km/hr
	Travel Time from TH 101 to Downtown[4]	23 min	17 min	13.5 min	17 min
Decrease Accidents along I-394	Accident Rate per Million km	2.7	1.1 or less	0.59[5]	0.81 or less
Maintain High Compliance with Occupancy Requirements	Compliance Rate	Not applicable	More than 90%	87% 96%	More than 90%

[1] Source I-394 Transportation System Management Plan, 1986
[2] Source Surveys and Counts conducted in spring, 1994
[3] Source Year 2000 forecasts from Mn/DOT TA-M307, 1984
[4] Does not include delays at ramp meters
[5] As of September 6, 1993
Conversion Factor is 1 km = 1.61 miles

HOV lane has been higher than projected and the level of service in the HOV lane has been excellent. Although the use of the mixed traffic lanes has been higher than projected, higher-than-expected average speeds have been maintained. HOV use continues to climb during the peak hours, whereas mixed lane use appears to have peaked related to available capacity.

VEHICLE VOLUMES

Peak-hour volumes for the peak direction are presented in Table 2. Both the daily traffic and peak-hour traffic along the I-394 corridor have increased significantly since before construction began. The morning peak hour has demonstrated the largest percentage increase, whereas the increase during the afternoon peak is similar to the daily increase. There was a dramatic increase in both daily and peak-hour traffic volumes immediately after completion of the new highway.

The following are general observations regarding changes in vehicle volumes from 1984 to 1994:

- Daily traffic volumes on I-394 have risen substantially. At Penn Avenue, the peak-load point of the roadway, daily volumes have increased from 86,000 vehicles per day to 143,000 vehicles per day, a gain of 66 percent. At the western end, there has been an increase of 9,000 vehicles per day, a 35 percent gain.
- Morning peak-hour inbound volumes at Penn Avenue have risen by 68 percent (from 4,000 vehicles to 6,700 vehicles); at Xenia/Park Place the volumes have risen by 124 percent (from 2,500 vehicles to 5,600 vehicles).
- Afternoon peak-hour westbound volumes at Penn Avenue have risen by 75 percent (from 3,600 vehicles to 6,300 vehicles); at Xenia/Park Place the volumes have risen by 115 percent (from 2,600 vehicles to 5,600 vehicles).

TABLE 2 Peak Hour Vehicle Volumes on T.H. 12/I-394

	April 1984	Nov 1992	April 1993	Sept 1993	April 1994	% Change 1984-1994
A.M. Peak Hour (7:00 - 8:00 a.m.) (Inbound)						
Penn Avenue	4,000	4,700	6,300	6,200	6,700	68%
Xenia/Park Place	2,500	1,700[1]	5,100	5,100	5,600	124%
Plymouth Road	2,500		4,500		--	80%
I-494	--	4,500	4,800	5,000	4,500	-
P.M. Peak Hour. (4:45 - 5:45 p.m.) (Outbound)						
Penn Avenue	3,600	4,200	6,000	6,300	6,300	75%
Xenia/Park Place	2,600	4,700	4,600	5,400	5,600	115%
Plymouth Road	3,000		3,800			27%
I-494		4,600	4,700	4,900	4,200	--

[1] Significant congestion levels during count period resulting in low peak hour volumes

HIGH-OCCUPANCY-VEHICLE LANE VEHICLE VOLUMES

Mn/DOT has collected daily and monthly data on vehicle volumes in the HOV lane since the interim HOV lane opened in late 1985. Before the opening of the reversible section between TH 100 and downtown, this data was collected between Turner's Crossroads (near Xenia/Park Place) and Florida Avenue (the peak-load point for the interim reversible HOV lane that ended just east of TH 100). Since the reversible HOV lane opened, data has been collected at Penn Avenue (the peak-load point for the permanent HOV lane). Figure 2 indicates historic traffic volumes in the HOV lane during the morning peak hour and peak period.

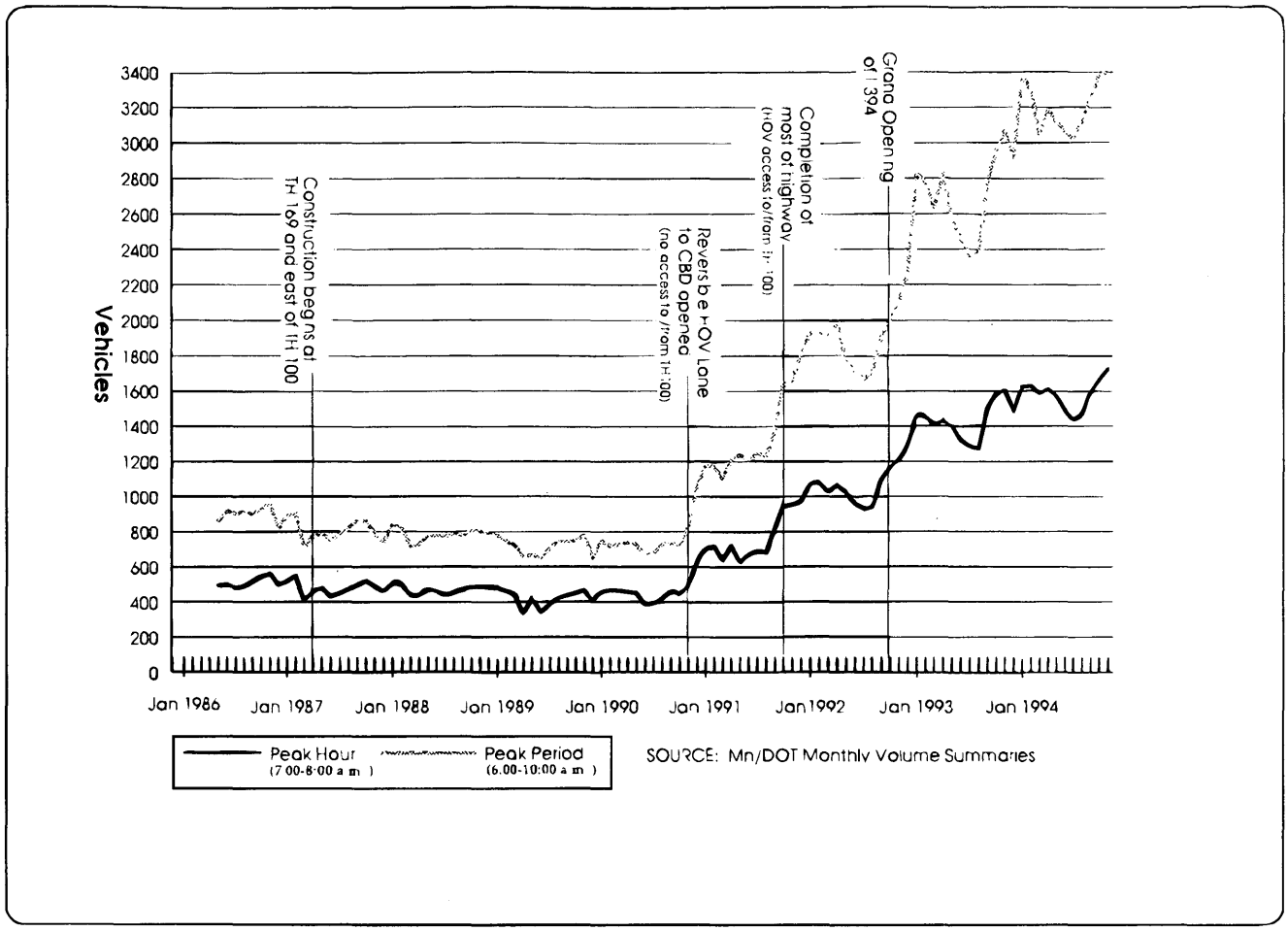

FIGURE 2 I-394 HOV lane traffic volume. At the peak load point—a.m. eastbound.

The following observations are based on an analysis of these historic HOV traffic volumes:

- In April 1994, 22,800 people used the HOV lanes on an average weekday. The HOV lanes are open eastbound from 6:00 to 10:00 a.m. and westbound from 2:00 to 8:30 p.m.
- Sharp increases in HOV lane volumes have coincided with the completion of major portions of the HOV lanes. The sharpest increase in HOV use to date occurred immediately after the I-394 grand opening in October 1992.
- The volume in the reversible lane at Penn Avenue during the morning peak hour (1,596 vehicles) was 19 percent higher than during the afternoon peak hour (1,343 vehicles) in April 1994.
- At Penn Avenue, during the morning peak hour, HOV lane volume increased from 1,139 vehicles to 1,596 vehicles, constituting a 40 percent increase from November 1992 to April 1994. The regular lanes at this location exhibited a 42 percent increase in total traffic volume for morning peak hour inbound, rising from 4,700 vehicles to 6,700 vehicles.
- The afternoon peak-hour volume at Penn Avenue in the HOV lane increased from 795 vehicles to 1,343 vehicles, a 69 percent increase from November 1992 to April 1994. The outbound total volume (regular and HOV lanes) during the same time period increased from 4,200 vehicles to 6,300 vehicles, or 50 percent.

VEHICLE OCCUPANCY RATES

One of the primary objectives of the I-394 transportation system is to increase vehicle occupancy in the I-394 corridor through the provision of incentives for car pooling. Vehicle occupancy rates have been collected at various locations at different times to measure progress in achieving this objective. Only one location is directly comparable throughout the entire project, and that is the segment of roadway east of TH 100. Table 3 shows the change in vehicle occupancy at this location from 1984 to 1994. Vehicle occupancy at the peak-load point of the roadway increased between 1984 and 1994 for both the morning and afternoon peak hours. In 1984, the morning peak-hour occupancy was 1.15, and by April 1994 it was 1.29.

TRANSIT USE

Since 1984, there has been a 126 percent increase in transit ridership on I-394 during the morning peak hour, in part because transit service has been increased and some buses have been rerouted to use the I-394 HOV lane (see Table 4).

The bus routes diverted from other roadways include Route 91 before the fall 1992 data collection and Route 53E after the fall 1992 data collection. These routes operate 10 buses during the peak

TABLE 3 Vehicle Occupancy Rate East of TH 100

	A.M. Peak Hour (Inbound)	P.M. Peak Hour (Outbound)
April 1984	1.15	1.12
May 1986	1.16	1.13
April 1989	1.16	1.13
November 1992	1.27	1.26
April 1993	1.25	1.28
September 1993	1.31	1.29
April 1994	1.29	1.27

period and eight buses during the peak hour. Additional bus service was also diverted from other corridors in spring 1994.

The use of express routes serving the I-394 park-and-ride lots was also evaluated. Reserve capacity on express buses to downtown is available at all lots during both the morning peak hour and peak period. Currently, the most heavily used routes are those providing direct service from the park-and-ride lots to downtown without intervening stops. The last bus trip departing from individual lots scheduled to arrive downtown before 8:00 a.m. is the best used of the buses departing from that lot.

Although there has been a substantial increase in both transit service and transit ridership since the beginning of I-394 construction, the transit service levels envisioned for the corridor upon completion of the roadway have not yet been achieved.

The Metropolitan Transit Commission is moving toward the implementation of a full timed-transfer system using the I-394 transit services and facilities plan as a guide, and will continue to improve service incrementally as resources permit.

TABLE 4 Transit Ridership on TH 12/I-394 During the a.m. Peak Hour East of TH 100

	Ridership	% Change From 1984	Buses	% Change From 1984
April 1984	1,000		27	
May 1986	1,160	16%	35	30%
November 1992	1,492	49%	50	85%
April 1993	1,633	63%	53	96%
September 1993	1,717	72%	49	81%
April 1994	2,256	126%	70	159%

PERSON TRIPS

The number of automobile person trips is added to the number of transit riders to determine total person trips using the corridor. In April 1994, there were an estimated 10,403 person trips in 6,679 vehicles (automobiles, buses, trucks, and motorcycles) at Penn Avenue during the morning peak hour. Fifty percent of all person trips were in the HOV lane.

From 1986 to 1994, vehicle trips east of TH 100 during this time period increased by 57 percent, from 4,250 vehicles to 6,679 vehicles, whereas person trips increased by 72 percent. The increase in person trips predominantly occurred in the HOV lane. From 1992 to 1994, person trips at Penn Avenue during the morning peak hour inbound increased 41 percent, from 7,376 to 10,403.

In the morning peak hour, the HOV lane at Penn Avenue has the ability to carry many more persons, whereas the mixed lanes at the same location have already reached their vehicle trip capacity. In order for there to be an increase in person trips at Penn Avenue, there must be an increase in people using buses or car pools.

PARK-AND-RIDE LOTS

Table 5 indicates the initial capacity of park-and-ride lots along TH 12, along with the current capacity and use of I-394 lots. Seventy-five percent of the 301 spaces available in the corridor were being used in March 1986, or approximately 225 cars. In April 1994, there were 677 vehicles parked in I-394 park-and-ride lots, an increase of 200 percent. Sixty-six percent of the 1,021 available park-and-ride lots spaces are now being used.

TRAVEL TIMES

In terms of travel time, the construction of I-394 had two goals: (*a*) to reduce travel time for everyone using the roadway, and (*b*) to provide a travel-time incentive for people to car pool and ride the bus.

For travel from I–494 to Penn Avenue, the travel time in the mixed lanes during the a.m. peak hour has dropped from 17.4 min

TABLE 5 Park-and-Ride Spaces in I-394 Corridor

	Initial Capacity	Current Capacity	Current Use	Percent Utilized
Xenia/Park Place	--	60	31	52%
Louisiana Avenue	--	173	127	73%
General Mills Boulevard	--	112	34	30%
CSAH 73 (north and south)	182	467	317	68%
Ridgedale Mall	30	--	--	--
Plymouth Road	--	111	97	87%
Wayzata	89	98	71	72%
Total	301	1,021	677	66%

in 1984 to 8 min in April 1994, a savings of 9.4 min or a 54 percent improvement (see Table 6). These times do not include delays at ramp meters. For those now using the HOV lane, travel time in the a.m. peak hour has dropped from 17.4 min to 7.3 min in April 1994, a savings of 10.1 min. This represents a 58 percent improvement.

In the spring of 1994, there was a 1.7-min time savings in the HOV lane over the mixed traffic lanes during the morning peak hour from TH 101 to downtown Minneapolis (see Table 6). Travel times in the HOV lanes are very consistent, whereas travel times can vary considerably in the mixed lanes, depending on driving conditions and incidents. In addition, vehicles using the mixed traffic lanes have additional delays at the metered ramps.

The mixed-lane travel times in spring 1994 were exceptionally fast, and the use of a relatively small sample taken under ideal (i.e., no incidents) conditions does not best represent the observed travel time differences. The variability in speeds in the mixed traffic lanes versus the speeds in the HOV lanes is indicated in Figure 3. This figure depicts the range of expected speeds along the facility based on several years of sample data. Clearly, the overall speeds in the HOV lanes are higher than those in the mixed lanes, and at the same time have significantly less variation.

Since the opening of I-394, Mn/DOT has been adapting its traffic management system for the corridor to alleviate or minimize operational problems. As part of this effort, entrance ramp-metering rates are adjusted constantly on the basis of downstream flow rates. This in effect allows the mainline to operate relatively smoothly in periods of good weather and when incidents are not present. As a result, traffic destined to the mixed lanes is spending more time at the ramp meters, whereas HOVs are given either meter bypass lanes or direct ramps to avoid the queue. The typical delay at the TH 100 ramp meter for mixed traffic is 6 to 8 min during the morning peak hour. Therefore, the total travel time difference between HOVs and mixed traffic, incorporating both ramp delay and mainline speed differences, is 7 to 9 min.

TABLE 6 Travel Time in Minutes on TH 12/I-394 a.m. Peak Hour

	Mixed Lanes	HOV Lanes	Travel Time Savings In HOV Lanes
I-494 to Penn Avenue			
• April 1984	17.4	--	--
• May 1986	14.9	9.7	5.2
• November 1992	10.9	6.7	4.2
• April 1993	9.9	6.6	3.3
• September 1993	11.8	7.6	4.2
• April 1994	8.0	7.3	0.7
TH 101 to Third/Fourth Street			
• November 1992	17.4	13.4	4.0
• April 1993	16.4	13.0	3.4
• September 1993	16.7	11.6	5.1
• April 1994	13.5	11.8	1.7

COMPLIANCE WITH OCCUPANCY REQUIREMENTS

The occupancy requirement for the I-394 HOV lane is two or more persons per vehicle. In addition, motorcycles are permitted to use the HOV lane and HOV meter bypass lanes. Enforcement of occupancy requirements is very important to protect the integrity of the HOV lane, both to maintain high operating speeds and to maintain an incentive for ride sharing. The compliance rate is the percentage of vehicles in the HOV lane that meet the automobile occupancy requirement of two or more people. Violation rate refers to the percentage of vehicles that do not meet the occupancy requirement.

Reversible High-Occupancy-Vehicle Lane

Compliance in the reversible HOV lane (both interim and permanent) has ranged between 93 and 98 percent during the eastbound morning peak hour since 1986 (see Table 7), and between 92 and 97 percent during the afternoon westbound peak hour at the peak-load point. For the period between November 1992 and April 1994, compliance in the reversible section during the morning and afternoon peak hours has been stable.

Concurrent High-Occupancy-Vehicle Lanes

Compliance rates are slightly lower in the concurrent HOV lane segments (87 to 97 percent) at Louisiana Avenue, but even lower at the western end of the corridor, during both the morning and the afternoon peak hours (see Table 7). However, compliance rates in the concurrent-flow HOV lanes are consistent with or higher than concurrent-flow HOV lanes facilities in other cities.

CAR POOL PARKING IN DOWNTOWN MINNEAPOLIS

Three garages with a total capacity of 5,923 parking spaces have been constructed over the eastern end of I-394 near downtown Minneapolis (see Figure 1). These garages have direct access to/from I-394. Approximately 90 percent of capacity (5,302 parking spaces) is available for monthly contract parking. Car pools from I-394 are eligible for a reduced contract parking fee of $25 per month. Car pools not from I-394 and all single-occupant vehicles pay a monthly fee of $90.

As of July 1994, 3,115 contract spaces in the three garages had been sold. This is 59 percent of the 5,302 spaces available for monthly contract parkers (10 percent of spaces are held for hourly parkers). Sixty percent of these are I-394 HOVs. The remainder are HOVs from other routes or single-occupant vehicles (SOVs). Garage A is 52 percent full whereas Garage B is 90 percent occupied. Garage C, which currently has a utilization rate of 38 percent, was opened in November 1992.

PERFORMANCE OF HIGH-OCCUPANCY-VEHICLE SYSTEM

Overall, the HOV system has performed beyond initial expectations:

- Use of the HOV lane has exceeded the start up objectives and continues to grow.

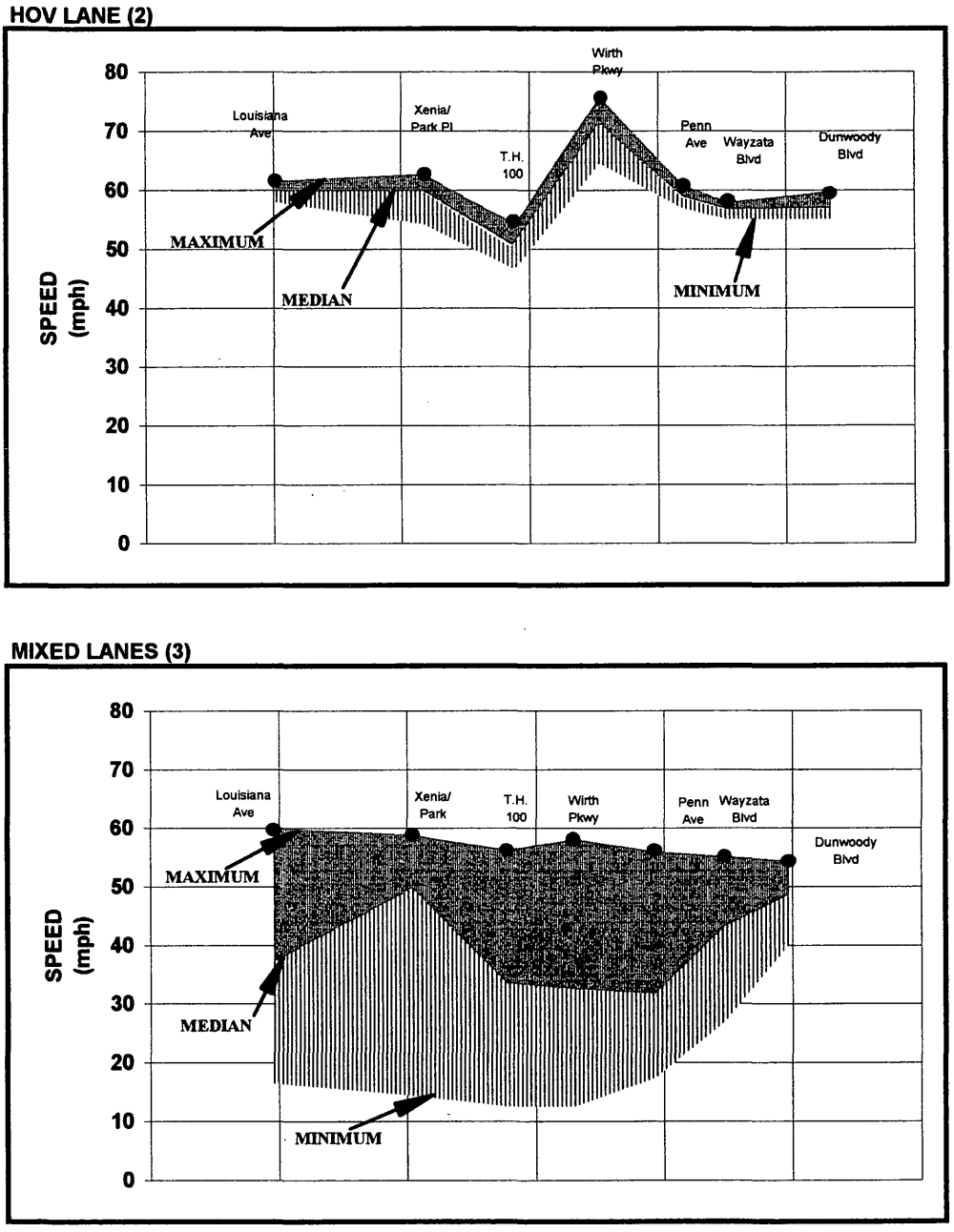

FIGURE 3 Peak hour a.m. speeds on eastbound I-394. Louisiana Ave. to Dunwoody Blvd. 1) Plotted speeds represent averages for the segment defined by the points shown, i.e., the speed for Penn Ave. is that for the segment between Wirth Parkway and Penn Ave. 2) Speeds computed using runs from Fall 1992, Spring 1993, Fall 1993, and Spring 1994. 3) Speeds computed using runs performed in Fall 1994.

- Vehicle occupancy objectives for the start up period have been met. However, the overall auto occupancy rate declined when the automated traffic management system became functional as a result of an increase in the peak-hour capacity of the mixed traffic lanes.
- Bus ridership has increased 126 percent, fulfilling the objective for the start up period. However, substantial route changes have occurred to take advantage of the time savings in the HOV lane. Total service area ridership changes are not presently known.
- Travel speeds are higher than expected in both the HOV and the mixed traffic lanes. Peak-hour speeds in the mixed traffic lanes increased significantly when the automated traffic management sys-

TABLE 7 HOV Lane Compliance Rates

		Reversible HOV Lane (1)		Concurrent HOV Lanes (2)	
		A.M. Peak Hour	P.M. Peak Hour	A.M. Peak Hour	P.M. Peak Hour
May	1986	95%	97%	--	--
April	1989	98%	--	--	--
November	1992	95%	94%	96%	89%
April	1993	96%	92%	97%	90%
September	1993	93%	96%	96%	89%
April	1994	98%	93%	95%	87%

(1) *At peak load point.*
(2) *At Louisiana Avenue.*

tem became fully functional, thus reducing the speed differential between the HOV lane and the mixed traffic lanes.

- Travel time savings in both the HOV lane and the mixed traffic lanes are greater than expected when compared to the "before" condition. However, travel time differences between the HOV lane and the mixed traffic lanes are less than expected, even though volumes in the mixed traffic lanes are higher than projected.
- Although travel time savings between the HOV lane and the mixed traffic lanes declined significantly when the automated traffic management system became fully functional, the time savings at the HOV bypass lanes on the metered ramps increased significantly. However, there are no HOV bypass lanes at the I-494 and TH 169 interchanges, which have long ramp queues and delays.
- Travel times in the HOV lanes are very consistent, whereas travel times in the mixed traffic lanes may vary dramatically from day to day. This factor may also contribute to perceived average travel time savings, which are higher than measured average travel time savings.

CHANGES IN DATA COLLECTION AND INTERPRETATION

Based on the findings of the I-394 evaluation to date, the following changes are recommended in the collection and interpretation of traffic data related to HOV systems, particularly those operated in a managed freeway environment.

- Increases in peak-hour car pooling are a complex mix of mode shift, route changes, time-of-travel changes, and changes in car pool participants. Field traffic data reflect all of these factors. It is not possible to determine the exact level of mode shift from field traffic data. Modal shifts can be better determined through surveys.
- Auto occupancy rates are influenced more quickly by vehicle volume changes in the mixed traffic lanes than in the HOV lane. Because the volume and speed of traffic in the mixed traffic lanes are influenced significantly by the automated traffic management system, small changes in vehicle occupancy rates should not be interpreted as changes in car pooling. Long-term trends in the volume of activity in the HOV lane itself are a more accurate representation of changes in car pooling in the corridor.
- Because of circulation bus route changes that appear to improve overall bus travel time savings, changes in ridership should be evaluated on a service area basis rather than a linear corridor basis. In addition, bus travel time savings should include the savings associated with circulation route changes, as well as the mainline travel time savings.
- It is important to collect and report travel time variability in the mixed traffic lanes as a measure of the predictability and reliability of the HOV lane. This has been identified as an important factor in mode choice in recent focus groups.
- In a managed freeway environment, travel time savings at the HOV bypass lanes on metered ramps are a significant portion of overall travel time savings. It is important that travel time data collection is designed to include these time savings, as well as mainline time savings.
- Enforcement of occupancy requirements in the I-394 parking garages has been very difficult, in part because drop-offs are allowed before entering the garages. An automated method for verifying vehicle occupancy and travel on the I-394 HOV lanes is needed to address this problem.

OPERATION OF HIGH-OCCUPANCY-VEHICLE FACILITY WITHIN CONTEXT OF MANAGED FREEWAY

The most difficult issue associated with evaluating the operation of the I-394 HOV lane is related not only to the change of the highway from a signalized arterial to a limited access freeway, but also to the change from an unmanaged highway to a fully automated, managed system. The ability to control the flow and, therefore, the speed and volume of traffic in the mixed traffic lanes has a direct impact on the performance of the system as a whole and the differences in performance between the HOV lane and the mixed traffic lanes. Typically, HOV lanes operating in the context of an automated, managed freeway system will have the following characteristics:

- There may be a lower mainline speed differential between the HOV lane and the mixed traffic lanes because of the ability to control mainline speed in the mixed traffic lanes.
- HOV bypass lanes at metered ramps are very important because the time savings for HOVs may be more significant on the bypass lanes than on the mainline.
- The overall vehicle occupancy rate and the percentage of car pools in the total traffic mix may be lower because the peak-hour capacity of the mixed traffic lanes can be increased by the traffic management system.

These potential impacts need to be addressed in a well-defined philosophy for traffic management in an HOV system corridor, and specifically for the management of traffic on I-394. These factors also need to be reflected adequately in the interpretation of traffic data relative to system performance.

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