

Role of High-Occupancy-Vehicle Lanes in Highway Construction Management

ALLAN E. PINT, CHARLEEN A. ZIMMER, AND FRANCIS E. LOETTERLE

The Minnesota Department of Transportation (Mn/DOT) is constructing I-394 along the portion of US-12 that extends from downtown Minneapolis to the suburb of Wayzata. When completed, I-394 will have high-occupancy-vehicle (HOV) lanes. Mn/DOT built a temporary HOV lane along US-12 before constructing I-394 to introduce the HOV lane concept to commuters and to improve capacity during construction. Mn/DOT and the FHWA have been conducting an evaluation of this temporary HOV lane. Phase I evaluated operation in an arterial highway environment before construction. Phase II evaluated operation and use of the HOV lane during highway construction. Five key issues were addressed in the Phase II evaluation: (a) what can be learned about the design and operation of HOV lanes, (b) who uses HOV lanes and what factors cause people to choose carpooling or the bus over driving alone, (c) how has construction affected use of the HOV lane, (d) what was the role of the HOV lane in construction traffic management, and (e) how has the HOV lane affected highway construction? Key findings are summarized regarding these questions and advantageous circumstances under which the use of HOV lanes during construction are identified.

In 1985, the Minnesota Department of Transportation (Mn/DOT) began construction of I-394 in Minneapolis, Minnesota. As part of this project, Mn/DOT constructed a temporary high-occupancy-vehicle (HOV) lane on US-12 to link the western suburbs of the Twin Cities to downtown Minneapolis (see Figure 1). The interim HOV lane was built for the purposes of introducing the HOV lane concept to commuters before construction of permanent HOV lanes and providing added capacity during construction.

Mn/DOT and FHWA have funded an ongoing evaluation of the I-394 HOV lane to track its progress before, during, and after construction. Phase I reported on the first year of operation in a before-construction condition. The current phase, Phase II, evaluates the operation of the interim HOV lane during construction but before major segments of the highway have been completed. The final phase of the evaluation will focus on the operation of the HOV lane after completion of major segments of I-394.

Five primary questions are being asked in the current phase of the evaluation:

1. What can be learned about the design and operation of HOV lanes on arterial highways and during construction?
2. Who uses the HOV lane and what factors caused people to choose carpooling or the bus over driving alone?

3. How has construction affected use of the HOV lane?
4. What was the role of the HOV lane in traffic management during construction?
5. How has the HOV lane affected the highway construction project?

FUTURE I-394 TRANSPORTATION SYSTEM

When completed, I-394 will have two mixed traffic lanes in each direction and two lanes for high-occupancy vehicles (3 mi of separated reversible lanes and 8 mi of concurrent flow diamond lanes). I-394 is being built along the alignment of existing US-12, from downtown Minneapolis to the third-ring suburban municipality of Wayzata, 11 mi to the west. US-12 has a 3-mi freeway section on the east end (two lanes in each direction plus auxiliary lanes) and an 8-mi signalized suburban arterial section (two lanes in each direction) on the western end.

Mn/DOT and FHWA are working together to provide more than concrete and bridges on I-394. Programs and facilities are being provided to integrate regular route transit and carpooling into the highway facility and to encourage increased use of these forms of transit. The intent of the I-394 transportation system, as this combination of facilities and programs has come to be known, is to maximize the number of people carried by encouraging carpooling and bus ridership. Key design features are shown in Figure 2 and include two bus transfer stations, seven park-and-ride lots, ramp metering with HOV bypass lanes, three parking garages in downtown Minneapolis with preferential carpool parking, skyway connections between the garages and downtown Minneapolis, and a sophisticated traffic management and surveillance system. These facilities will be supported by expanded timed-transfer bus service, carpool matching services, aggressive HOV enforcement, and an extensive public information program.

The estimated total cost of construction is \$420 million. Construction began in 1985 and is scheduled for completion in 1993. Interstate completion funds provided 90 percent of the funding for the project with state funds used for the matching 10 percent.

INTERIM HOV LANE

The I-394 interim HOV lane combines concurrent flow diamond lanes and a single reversible lane. Diamond lanes are lanes that are marked with a diamond symbol and reserved for HOVs, but are not physically separated from the regular traffic lanes. The single reversible lane is physically separated

A. Pint, Minnesota Department of Transportation, 2055 North Lilac Drive, Golden Valley, Minn. 55422. C. Zimmer and F. Loetterle, Stgar-Roscoe-Fausch, Inc., One Carlson Parkway North, Minneapolis, Minn. 55447.

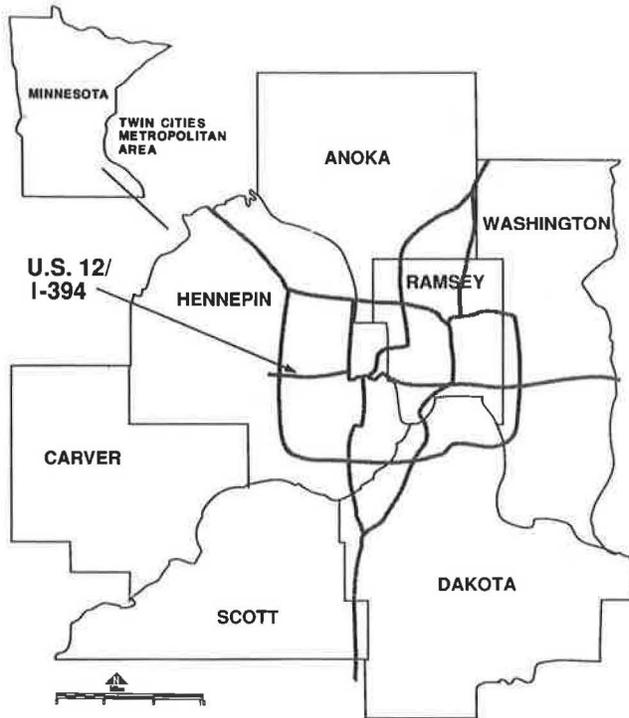


FIGURE 1 Regional location of I-394.

from the regular traffic lanes by a jersey barrier and is located in the median of US-12. During construction, the initial design of the interim HOV lane has been and will continue to be modified as different portions of the highway undergo reconstruction.

WHO USES THE HOV LANE?

Data have been collected on the I-394 HOV lane since it opened in November 1985. Volume, occupancy, bus ridership, and travel time data were collected in April 1989. Questionnaires were also distributed to people using the regular lanes, using the HOV lane, and riding on buses that used the HOV lane. Survey response rates were 37 percent for regular lane drivers, 29 percent for carpoolers in the HOV lane, and 50 percent for bus riders. The following information was derived from this survey.

Demographics

The typical carpooler on the I-394 interim HOV lane is 31 to 45 years old, lives in a 2- to 4-person household, owns two automobiles, and has a household income of over \$50,000. These characteristics are also typical of the regular lane driver. However, the typical bus rider is younger, has fewer family

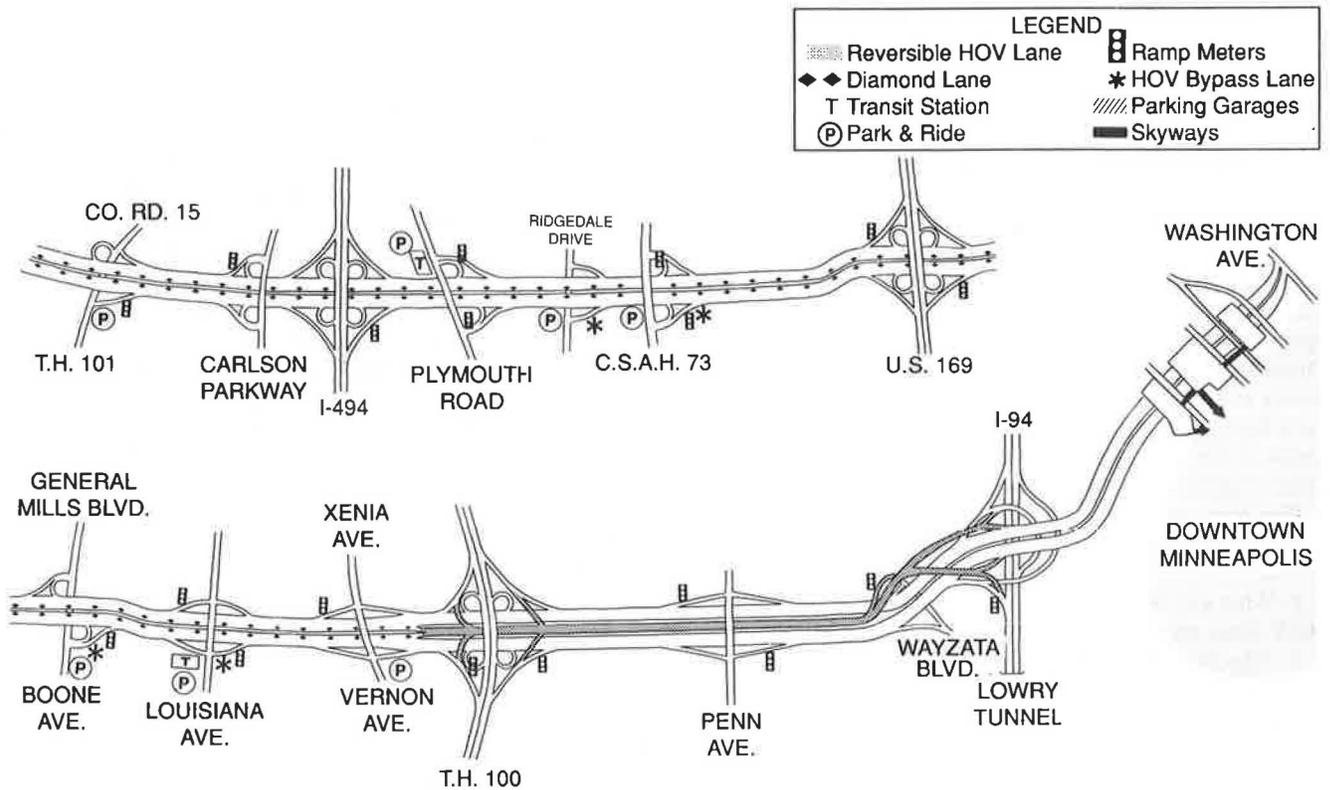


FIGURE 2 I-394 transportation system.

members, owns fewer automobiles, and has a lower household income.

Trip Purpose

The majority of respondents (86 percent of regular lane drivers, 83 percent of HOV lane respondents, and 98 percent of bus riders) were traveling to or from work, which is consistent with findings before construction activity.

Trip Frequency

Approximately 62 percent of carpoolers use the HOV lane 5 days per week. Eleven percent use the HOV lane four days per week, 11 percent three days, 8 percent two days, and 9 percent one day a week. Carpoolers in the morning tend to use the HOV lane more regularly than carpoolers in the afternoon. These patterns are similar to those found before construction activity.

Trip Destination

The survey results show a strong correlation between mode and downtown destination. Ninety-one percent of bus riders, 71 percent of carpoolers in the HOV lane, and 29 percent of regular lane drivers who use US-12 eastbound in the morning were going to downtown Minneapolis.

DESIGN AND OPERATION OF HOV LANES ON ARTERIAL HIGHWAYS AND DURING CONSTRUCTION

The I-394 temporary HOV lane is unusual in two respects. First, this lane uses a reversible HOV lane on a signalized arterial highway. Second, both concurrent-flow diamond lanes and reversible HOV lanes are used during construction. One of the purposes of the I-394 case study was to evaluate the design and operational characteristics of the HOV lane. Observations were made regarding

- Occupancy requirements,
- Hours of operation,
- Use during special events,
- Considerations in combining diamond lanes and reversible lanes,
- Left exits and entrances,
- Intersection operations,
- Problems with lane gates, and
- Snow removal.

Occupancy Requirements

One of the principal research concerns of the I-394 case study was the evaluation of a carpool occupancy requirement of only two people. This occupancy requirement was established because there were so few carpools with three or more people

when the HOV lane was first opened. Surveys in 1986 and 1989 indicate that 80 percent of carpools in the HOV lane have two people, 14 percent have three, and 6 percent have four or more people. These proportions have remained consistent before and during construction. In the April 1989 survey, 76 percent of carpoolers said they would not have started carpooling in the HOV lane if the occupancy requirement had been three or more.

Hours of Operation

The HOV lane is open to traffic eastbound from 6 to 10 a.m. in the morning and westbound from 2 to 7 p.m. in the afternoon with hours sometimes shortened because of construction activities. Mn/DOT research indicates that it may be cost-effective to operate the lane for longer hours in the afternoon but not in the morning. The HOV lane is opened and closed manually by Mn/DOT personnel. An active reminder system and a back-up plan have been necessary to ensure that the lane opens on time consistently.

Use During Special Events

Since late 1986, the HOV lane has been opened during special events, particularly for Minnesota Vikings and Minnesota Twins games. An April 1989 survey of regular lane drivers on US-12 indicated that 74 percent of people driving alone in the mixed traffic lanes have used the HOV lane at least during a special event.

Combination of Reversible HOV Lanes and Diamond Lanes

Use of both a single reversible HOV lane and two concurrent-flow diamond lanes has provided much needed flexibility during construction. However, care must be taken to provide adequate signing and transition areas to limit driver confusion and maintain safety. An early concern was that short diamond lane segments might result in people weaving in and out of the mixed traffic lanes to jump queues. Although it occurs, lane switching is much less common than initially anticipated.

Left Entrances and Exits

Entrances to and from the reversible HOV lane are from the left lane. The I-394 experience indicates that such a design can work safely if an adequate merging section can be provided. However, locations exist where HOVs experience delays in entering or exiting the HOV lane because of congestion in the regular lanes.

Intersection Operations

The HOV lane runs through several signalized intersections. Because of operational and safety concerns, no turns are permitted to or from the HOV lane at these intersections. Illegal

turning at the intersections was a problem initially but additional signing, good enforcement, and time have significantly reduced this problem. Signal timing, which is critical for ensuring maximum time savings for HOVs, is set to facilitate the progression of drivers in the HOV lane.

Gates

Entrance gates have been an ongoing maintenance problem because of weight, wind damage, and poor night visibility. The majority of accidents related to the HOV lane involved vehicles hitting the gates at night.

Snow Removal

No special procedures have been needed to provide adequate snow removal. Maintenance activities are managed as part of Mn/DOT's standard highway maintenance program.

WHAT INCENTIVES AFFECTED MODE CHOICE?

In the April 1989 surveys, people using HOV lanes were asked what the greatest benefits of the HOV lane were. Time savings were the most important benefit to carpoolers, whereas cost savings were the most important benefit to bus riders.

People using the regular traffic lanes were asked what incentives would encourage them to use the HOV lane. Incentives that appealed most to people driving alone were time savings (18 percent), help finding a partner (10 percent), operating cost savings (5 percent), and parking cost savings (4 percent). Forty-eight percent of regular lane drivers indicated they could be encouraged to use the HOV lane, whereas 52 percent indicated that nothing would encourage them to use the HOV lane.

Time Savings

Carpoolers note time savings as the most significant benefit of the HOV lane and perceive an average time savings of 10 min per trip. This finding is consistent with results of surveys prior to construction on US-12. Measured time savings in the morning peak hour are still between 8 and 10 min but less than 5 min during other hours. Both perceived and measured time savings are less in the afternoon than in the morning. Carpoolers also often note that the HOV lane is more reliable than the regular traffic lanes. Most bus riders perceive no time savings.

Parking Cost Savings

In the April 1989 surveys, 19 percent of carpoolers and 63 percent of bus riders say they save money on parking. This percentage may have changed significantly since the first I-394 parking garage was opened in August 1989. Carpoolers from I-394 who park in these garages pay \$10 per month compared to the regular rate of \$80 per month.

Operating Cost Savings

Thirty-six percent of carpoolers and 56 percent of bus riders say they save money on fuel. Twenty-one percent of carpoolers and 35 percent of bus riders say they save money on vehicle operating costs.

Work Hours

Fifty-three percent of carpoolers and 63 percent of bus riders reported fixed working schedules compared with only 34 percent of regular lane drivers. Regular lane drivers most frequently cite job-related reasons such as job schedule or need car for work as reasons they do not use the HOV lane. However, 19 percent said they had no one to carpool with and 6 percent said they had an irregular carpool partner.

HOW HAS CONSTRUCTION AFFECTED USE OF THE HOV LANE?

One of the primary purposes of the I-394 HOV lane was to provide additional traffic capacity during construction, which was easily accomplished initially because an additional lane was added to an already congested facility. However, highway construction typically causes considerable traffic diversion, which affects the travel times on the interim HOV lane as well as regular traffic lanes. The I-394 Case Study—Phase II is comparing the use of the HOV lane before and during construction to determine the impacts of construction on HOV use.

Changes in HOV Lane Volumes

The highest volumes in the HOV lane were reached 1 year after the HOV lane opened, just a few months before mainline construction started on US-12 (see Table 1). Overall, volumes in the HOV lane have decreased since construction began but

TABLE 1 HISTORICAL TRAFFIC VOLUMES ON US-12 WEST OF TURNER'S CROSSROAD

	AM Peak Hour		AM Peak Period	
	HOV	Regular	HOV	Regular
May 1984	--	1,890	--	4,940
November 1985	410	1,750	740	4,660
May 1986	495	1,610	860	4,570
November 1986	560	1,650	960	4,840
May 1987	480	1,900	790	4,950
November 1987	490	1,840	790	4,700
May 1988	470	1,990	770	5,150
November 1988	480	1,650	780	5,010
May 1989	420	1,940	670	4,830
November 1989	470	1,940	780	5,060

are still higher than they were when the HOV lane first opened. Volumes in the regular lanes also decreased when construction began but have increased to levels that equal or exceed pre-HOV lane volumes. Typically, volumes both in the HOV lane and in the regular traffic lanes drop in April when construction starts but then gradually rebound to previous volumes by November when construction ends. In November 1989, 1,550 people in 470 vehicles were using the HOV lane during the a.m. peak hour, compared with approximately 1,300 people in 950 vehicles in each regular traffic lane.

Changes in Carpool Volumes

Since 1984, before construction began, eastbound a.m. peak-hour traffic has increased by 9 percent. Carpooling in both the HOV lane and the regular traffic lanes has increased by 117 percent during the same time period.

Changes in Automobile Occupancy

Automobile occupancy during the a.m. peak hour increased from 1.17 to 1.25 persons when the HOV lane opened and continued to increase to 1.29 during the first year of operation (see Figure 3). Since construction began, automobile occupancy during the a.m. peak hour has declined slightly to 1.28 persons. Automobile occupancy on similar highways in the Twin Cities metropolitan region has been declining and was about 1.12 persons per vehicle in the peak hours in 1989.

Changes in Bus Ridership

Bus ridership has remained fairly stable since 1984. Shortly after the HOV lane opened in November 1985, an express

route was added to the existing local bus service on US-12. Total weekday ridership of these two routes in October 1989 was about 2,400. Over the 5-year period, this ridership level has fluctuated between 2,300 and 2,900. This variation seems to be more directly related to the changing seasons than to any long-term trend, although ridership on the local route, which does not use the HOV lane, has been affected by the elimination of some roadside transit stops because of construction.

Approximately half of the bus riders on US-12 drive alone to a park-and-ride lot to ride the bus. Another 10 percent are dropped off at a bus stop. Thirty-nine percent walked or bicycled and 4 percent rode another bus. Over half of the bus respondents (56 percent) have ridden the bus more than 2 years, whereas another 15 percent have ridden the bus for at least 1 year. Eighty-seven percent plan to continue riding the bus after I-394 is completed. Twenty-five percent of bus riders receive some assistance from their employer to pay transit fares.

Changes in Prior Mode

Twenty-eight percent of carpoolers in the HOV lane drove alone on US-12 before they started using the HOV lane. Another 11 percent drove alone on other routes. One year after opening of the HOV lane, 26 percent said they drove alone on US-12 previously and 12 percent said they drove alone on other routes. The largest change in previous mode was a dramatic decrease in the number of people who previously carpooled on other routes (see Figure 4). The most significant impact of construction on HOV lane use was the redirection of carpoolers from other routes back to their previous routes. This diversion may have been a direct result of the elimination of access between the HOV lane and T.H. 169 because of construction bypasses.

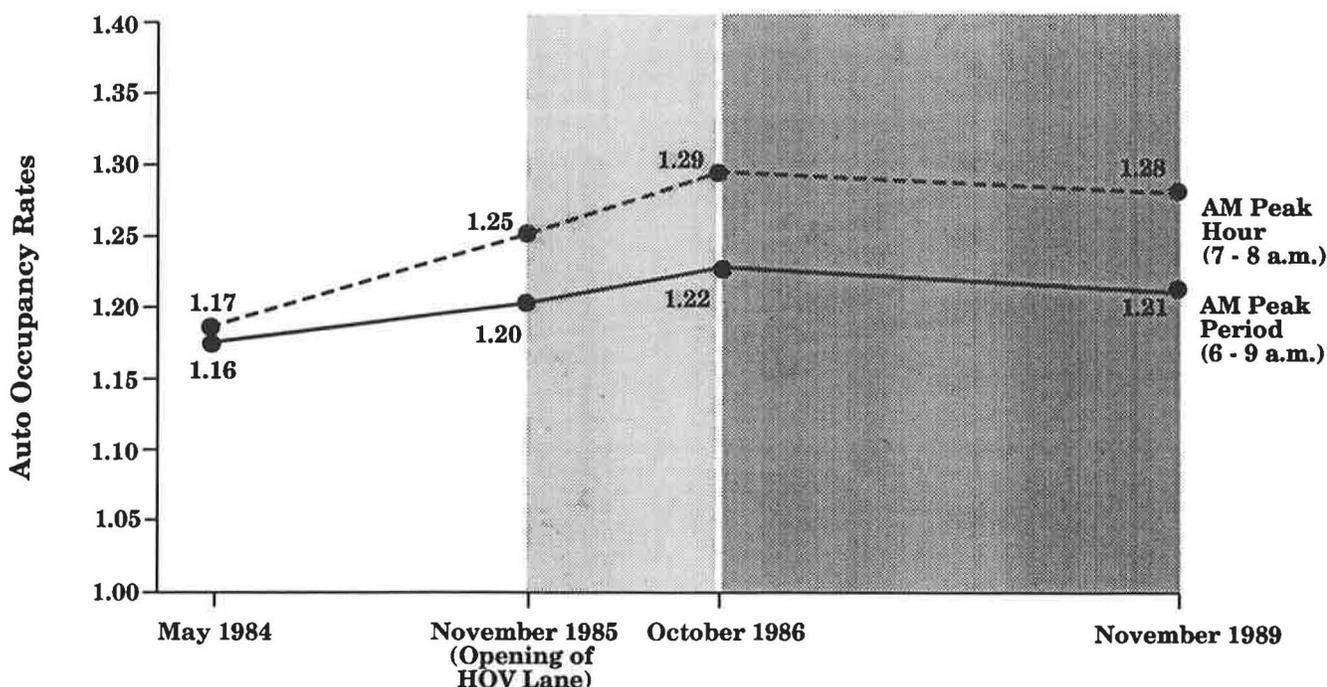


FIGURE 3 Automobile occupancy rates.

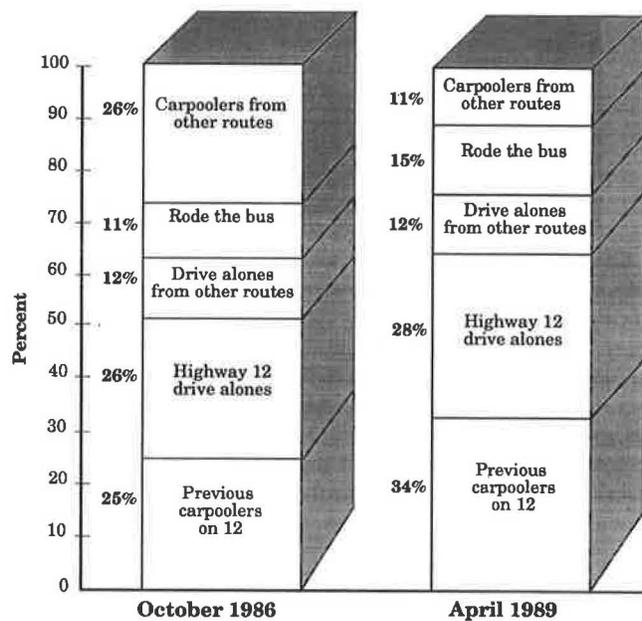


FIGURE 4 Previous travel mode of a.m. peak-hour I-394 HOV lane users.

Traffic Diversion

Twelve percent of regular lane drivers said they avoided US-12 during construction in 1988 and 8 percent said they would avoid the route during the 1989 construction season. By comparison, 20 percent of carpoolers said they avoided US-12 during construction in 1988 and 17 percent said they would do the same during the 1989 construction season. Of the bus riders, 87 percent rode the bus during the 1988 construction season, whereas 95 percent of bus riders planned to continue riding the bus during the 1989 construction season.

Satisfaction

Fifty-two percent of HOV lane carpoolers are very satisfied with the facility and 44 percent are somewhat satisfied. Fifty-two percent of bus riders are very satisfied with bus service and 45 percent are somewhat satisfied.

ROLE OF HOV LANE IN TRAFFIC MANAGEMENT DURING CONSTRUCTION

The interim HOV lane is an integral part of an overall strategy for effective management of traffic during construction. Most important, the HOV lane provided added traffic capacity during the construction period along a corridor with high traffic congestion. Key strategies for managing traffic during the I-394 construction project included

- Maintenance of people-carrying capacity,
- Encouragement of carpooling,
- Maintenance of access,
- Signing, and
- Public information.

Maintenance of People-Carrying Capacity

Two regular lanes are kept open in each direction at least during peak hours, which had to be accomplished without taking more right-of-way than what is required for the completed roadway. Contractors cannot restrict lanes between 6 and 9 a.m. or between 3 and 6 p.m. Contractors may be fined if this condition is not met. Signal timing is coordinated where possible and maximum green times are allocated to US-12 traffic.

Encouragement of Carpooling

Because two regular lanes have been kept open, the HOV lane is a bonus lane for commuters. The hours of operation for the HOV lane have been maintained during the construction periods.

Since 1985, Mn/DOT has also maintained surface parking lots near downtown Minneapolis for free carpool parking. The lots have changed location and size as a result of construction activities, but have been actively used on a regular basis. In August 1989, Mn/DOT opened the 5th Street garage with 1,600 spaces with priority access and reduced-rate contracts for I-394 carpoolers. This facility is the first of three parking garages with carpool preference being built as part of the I-394 transportation system. In the first week of December 1989, there were 456 I-394 HOV parkers with monthly contracts in the 5th Street garage out of a total of 1,245 parkers per day.

Existing park-and-ride lots and major bus stops have been maintained along the corridor. However, the size and location of park-and-ride lots have varied and many local bus stops have been eliminated on US-12. Mn/DOT has worked closely with the Metropolitan Transit Commission (MTC) to coordinate bus service and maintain service to existing transit passengers to the greatest extent possible.

Maintenance of Access

An important goal of traffic management on the I-394 project has been to maintain reasonable access to all businesses and residential areas. Mn/DOT has worked with local municipalities to develop a business area signing program for directional signing from US-12. The signs are made and installed by the city with businesses bearing the cost. Mn/DOT has also allowed special signing for individual businesses in unique situations where access is significantly changed. This program has been effective in satisfying business concerns. Many illegal signs are also present on the project but are allowed to remain if they do not block construction signage or cause a safety problem.

Special attention is paid to access to Ridgedale Regional Shopping Center, especially during the busy holiday season. The Ridgedale Drive interchange was reconstructed in 1989, removing a key access route to the Ridgedale Regional Shopping Center. During ramp construction, the HOV lane between Ridgedale Drive and Plymouth Road operated only eastbound from 6 to 9 a.m. weekdays. Part of the HOV lane served as a westbound ramp to Ridgedale at all other hours.

This change was permitted temporarily because travel time savings for westbound HOVs were nonexistent because of construction bypass design in the westbound direction.

Changeable Message Signs

Changeable message signs are used extensively to communicate traffic changes to the motorist. Through the I-394 contract, Mn/DOT has acquired four of these signs, which have been effective in communicating traffic changes to motorists.

Public Information

Extensive and early public information has been essential in minimizing the complaints received in the field. Public meetings are held in early spring and late fall at each major intersection to provide information to businesses and residents about seasonal construction activities. These meetings have been coordinated through the local chamber of commerce. Day-to-day changes are communicated with a hand-delivered construction bulletin. A semiannual newsletter is mailed to all households and businesses in the corridor. Mn/DOT also works closely with the media to provide information on construction bypasses and delays through press releases, interviews, and announcements by the corridor manager. Information on carpooling and bus services, including information on the HOV lane, is provided at all meetings and in all printed materials.

Newspaper articles, highway signs, and the newsletter are the most frequently cited sources of information on I-394 for bus riders, carpoolers, and regular lane drivers. Other sources of information include billboards, newspaper advertisements, brochures, and the local transit provider. Recognition of the newsletter as a source of information has increased steadily since its first publication. Bus riders, carpoolers, and regular lane drivers all want more timely information on construction activities. Carpoolers also expressed a strong interest in more information on carpool parking.

HOV LANE EFFECTS ON CONSTRUCTION

In general, the highway segments that include the interim HOV lane are the most difficult to construct. Difficulties arise because, while a six-lane freeway and its associated frontage roads are being constructed, five or six lanes of traffic are being maintained within the right-of-way of the final freeway and frontage road system. In many cases, maintaining this level of access requires the construction of temporary roadways that add to the cost of construction and the time required to complete a segment. For example, the construction project near the US-169 interchange and the General Mills Boulevard interchange included 1.5 mi of roadway and two interchanges at a cost of \$45 million. Twenty percent of this cost was attributed to activities and temporary construction related to maintaining traffic.

The greatest design challenge of the interim HOV lane has been to incorporate the lane into the construction bypass and staging plans for the project. Both the design and the location

of the HOV lane have been required to change periodically during construction in order to meet this challenge. Figure 5 shows the overall construction staging of the project and the associated changes in the HOV lane. The primary objectives of these plans have been to ensure that the HOV lane remains open continuously, is safe to use, provides head-of-the-line preference to HOVs at congestion points, and can be tied into permanent HOV sections as they are completed.

Recognizing the impacts of the HOV lane on construction costs and schedules, Mn/DOT has aggressively used a number of contract management tools to ensure timely completion of project stages. These tools include the coordination of construction staging and related transit projects, contract fast-tracking, contract incentive and disincentive clauses, field modifications, and management by a corridor manager.

Construction Staging

The I-394 project is divided into eight major construction segments. Each of these projects was advanced through the design process separately and let to construction when ready. Initially, construction staging was designed to be compatible between adjoining segments; however, staging generally changes during construction. As a result, the plans are modified in the field after consultation with the designers and traffic engineers.

Coordination With Construction of Transit Facilities

Mn/DOT is also constructing two transit stations and five park-and-ride lots as part of the I-394 project. These projects are staged to open at the same time the interchange serving the facility is opened. Although separate site amenity contracts including buildings, signing, and landscaping will be awarded, construction will be coordinated with the site development work.

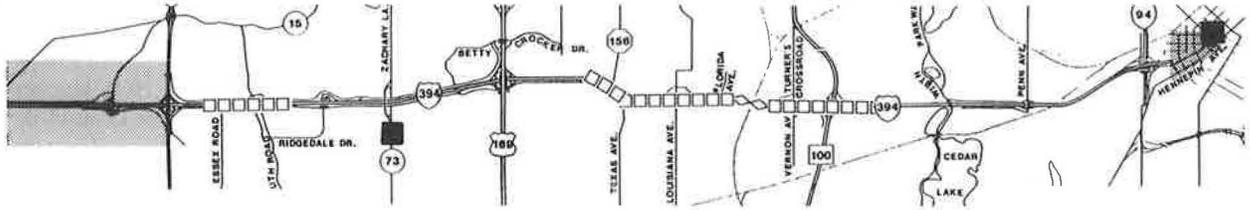
Contract Fast-Tracking

Fast-tracking is used extensively to keep contractors on a tight time schedule. Mn/DOT engineers determine completion dates of the various stages. Contractors are expected to meet these completion dates even if it requires additional personnel and equipment or extended working hours including overtime and weekend work. Contractors are also required to stage work so that bridges and walls can be built during the winter months. Bar charts and other progress schedule requirements are included in all contracts to monitor contractor performance and schedule.

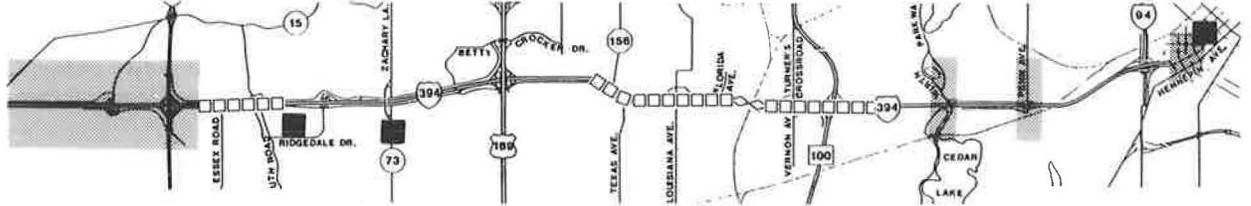
Incentive and Disincentive Clauses

All contracts include liquidated damages if work is completed late. Damages are generally \$5,000 per day for work beyond the completion dates. All Mn/DOT contracts also include a value engineering clause. Although large incentive and disincentive clauses have only been used in isolated cases, the

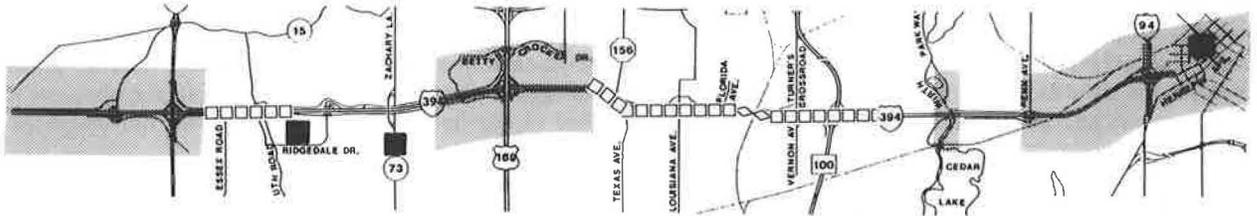
1985 CONSTRUCTION SEASON



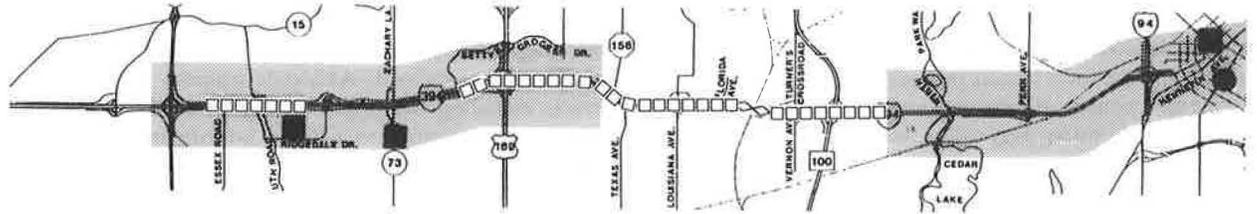
1986 CONSTRUCTION SEASON



1987 CONSTRUCTION SEASON



1988 CONSTRUCTION SEASON



1989 CONSTRUCTION SEASON

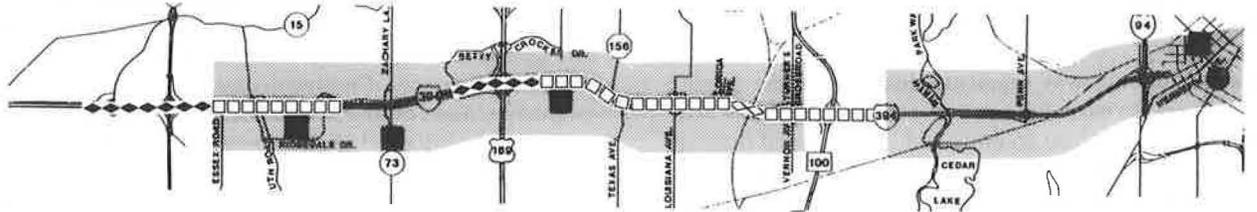


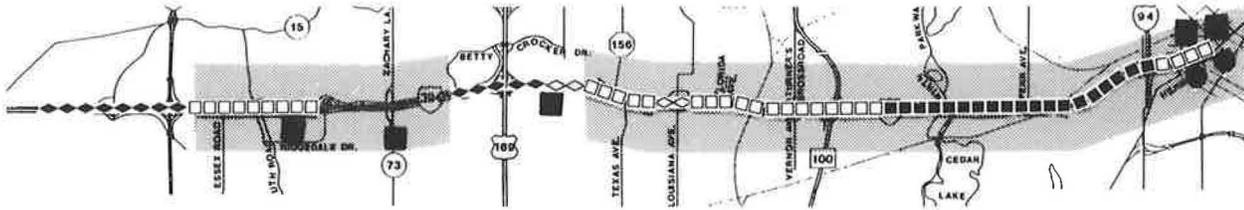
FIGURE 5 I-394 construction staging schedule. (continued on next page)

last major construction contract on the I-394 project will include a bonus of up to \$1,000,000 for early completion. The bonus and penalty clause is \$5,000 per day for either early completion or late completion. Early completion of this segment, which includes an interchange between T.H. 100 and I-394, is desirable because the segment has the highest volume interchange along the project.

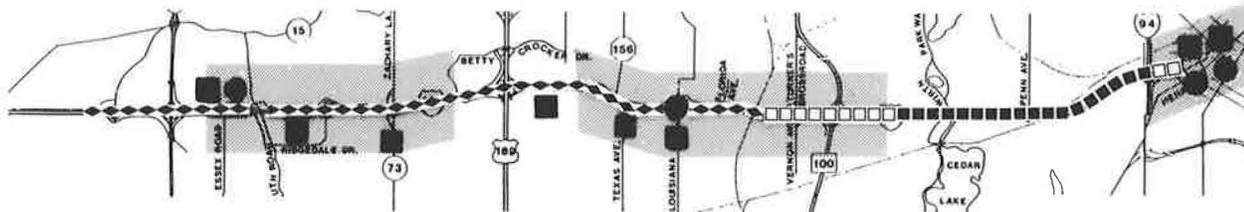
Field Modifications

Because the I-394 project was fast-tracked through design as well as construction, field modifications and changes are often required. In order to facilitate these changes expeditiously, a member of the design team is assigned to the construction administration team, which has worked well to resolve prob-

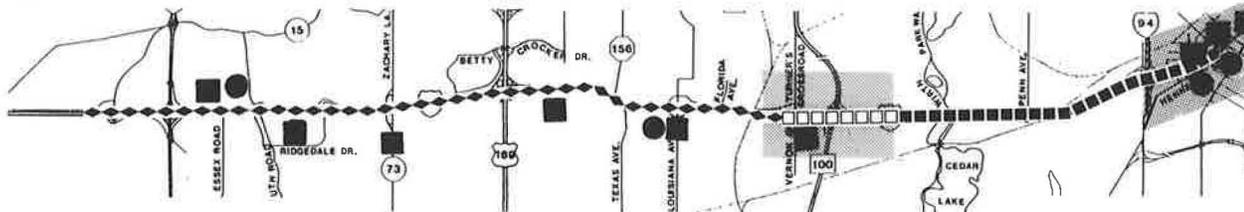
1990 CONSTRUCTION SEASON



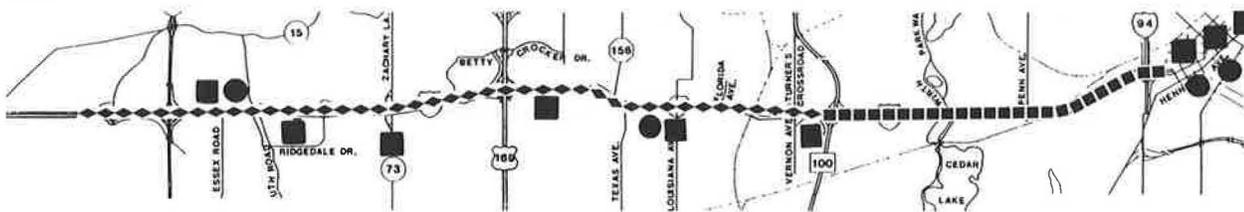
1991 CONSTRUCTION SEASON



1992 CONSTRUCTION SEASON



1993



LEGEND

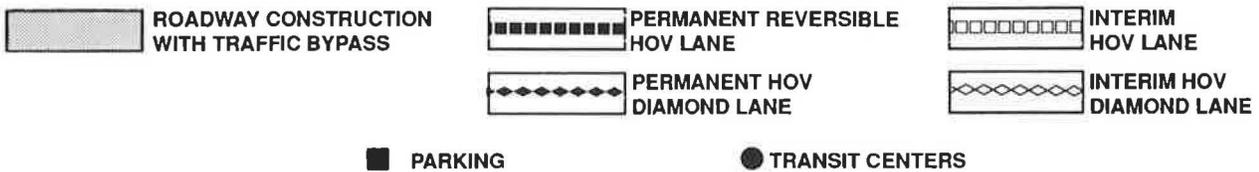


FIGURE 5 (continued from previous page)

lems as they occur, and to make minor redesigns in the field. Mn/DOT generally attempts to settle all contractor claims in the field.

In several situations, the bypass plans have had to be modified in the field to either narrow general traffic lanes or shorten the HOV lane to safely accommodate the HOV lane and its entrances or exits. Generally, the decision to shorten

the HOV lane has been based on sight distance for safe merges and on the length of anticipated queues.

Corridor Manager

Use of a corridor manager for the project as well as one construction engineer responsible for all major construction

contracts has been an effective management tool. The corridor manager is the chief spokesperson for and coordinates all aspects of the I-394 project. The corridor manager is also the manager and chief advocate of the HOV lane and all other transit elements of the project.

CONCLUSION

Although construction is not yet complete on I-394 and the permanent HOV lanes are not yet open, the project has provided valuable information on the design, operation, and use of HOV lanes on an arterial highway and during a major highway construction project. Key conclusions from the research to date are as follows.

Design and Operation of HOV Lanes

- A reversible HOV lane in combination with concurrent flow diamond lanes on a signalized arterial highway can operate successfully and safely, even during construction;
- The carpool occupancy requirement of two persons was a significant factor in mode change; and
- Opening the HOV lane during special events exposed a high percentage of commuters on US-12 to the benefits and use of the HOV lane.

Incentives for Carpooling

- Time savings is the most important incentive for a mode shift to carpooling,
- Cost savings is the most important incentive for bus riders, and
- Job-related issues are the most frequent deterrent to carpooling.

Impacts of Construction on HOV Lane Use

- Construction causes traffic diversion of HOV lane users as well as people using the regular traffic lane, although the majority of users diverted by construction were carpoolers who had been initially attracted from other routes when the HOV lane was first opened and before construction was initiated;
- HOV lane use decreased when construction first began, but traffic volumes tend to return to similar levels in the fall when construction ends;
- When diversion to the HOV lane from other routes has been discounted, growth in the number of carpoolers previ-

ously driving alone on US-12 has been observed, even during construction;

- Even though measured time savings have declined during construction, carpoolers perceive that they are saving as much time using the HOV lane as before construction; and
- HOV lane users feel that the HOV lane is safe even during construction.

Impact of the HOV Lane on Construction Activities

- The HOV lane reduces overall congestion in the corridor, making traffic flow smoother through the construction zones, which makes it easier for the contractor to move workers and equipment on the job.
- Provision of a HOV lane during construction complicates construction staging and traffic switches. Construction costs are increased and construction time may be extended.
- The following three conditions would improve the benefits of using a HOV lane as a construction management strategy:
 - A permanent HOV lane is part of the construction project. The I-394 HOV lane has been effective as an advance version of the permanent HOV lane, allowing Mn/DOT the opportunity to market and promote the advantages of carpooling before the permanent facility is completed.
 - No nearby parallel routes are available for traffic diversion. Travel time savings of the HOV lane and many HOV lane users were lost during construction because there were parallel routes available nearby for traffic diversion. This diversion resulted in improved traffic flow and travel times in the regular lanes. Impacts of a HOV lane during construction would be significantly greater on a roadway with no parallel routes.
 - Regular lane traffic capacity cannot be maintained on the highway under construction. Two lanes of traffic in each direction have been maintained on the I-394 project, which is equivalent to the capacity available before construction. As a result, good traffic flow has been maintained during construction but has reduced the impact of the HOV lane. HOV lanes would have a greater impact on facilities on which regular lane traffic capacity is reduced by construction.

ACKNOWLEDGMENT

This research was funded by FHWA and the Minnesota Department of Transportation.

Publication of this paper sponsored by Committee on High-Occupancy Vehicle Systems.