# Current Practices in Evaluating Freeway HOV Facilities

KATHERINE F. TURNBULL, ROBERT W. STOKES, AND RUSSELL H. HENK

Evaluating the impact of high-occupancy vehicle (HOV) facilities has been a topic of considerable interest and discussion among transportation professionals in recent years. Project objectives, potential evaluation criteria, appropriate effectiveness measures, and data collection methodologies have been a major focus of sessions at national HOV conferences, as well as of numerous reports. A review of the major before-and-after evaluation studies that have been conducted on HOV facilities in the United States since the opening of the Shirley Highway (Northern Virginia) bus lane in 1969 is presented in this paper. The review includes a summary of the approaches used with the different evaluations and the identification of common elements. The results of this analysis advances understanding of the major components that should be considered in the design of HOV evaluation studies. The paper should prove beneficial to agencies in the process of designing before-and-after evaluation programs for new HOV facilities. In addition, it should be of help to transportation professionals in areas that have operating HOV facilities and may be interested in improving their current evaluation methods.

High-occupancy vehicle (HOV) facilities are being used in many metropolitan areas to address growing traffic congestion problems. Many areas are faced with significant increases in traffic congestion and projected travel demands beyond what can reasonably be served at current vehicle occupancy rates. Attempting to address these congestion and mobility problems in a time of limited financial resources and right-of-way availability has led many transportation professionals to consider a range of potential solutions. The use of HOV facilities, which focuses on increasing the person-movement capacity of the roadway facility, represents a viable alternative in many areas of the country.

As the use of HOV facilities increases, interest in the proper approaches and techniques to evaluate their effectiveness is continuing. Discussions of project objectives, potential evaluation criteria, appropriate effectiveness measures, and data collection methodologies have been a major focus of recent conferences, reports, and articles. To advance the discussion of these topics and assist in the establishment of a more uniform approach, this paper presents a review of the major before-and-after evaluation studies that have been conducted on HOV facilities during the past 20 years. The review includes a brief discussion of the development of HOV facilities and evaluation programs, a summary of the approaches used in the different evaluations, and the identification of common elements among the studies.

The results of this analysis should be of benefit in the design of before-and-after studies of new HOV facilities and to transportation professionals in areas with operating HOV facilities who may be interested in improving current evaluation procedures. Thus, this paper advances the state-of-the-art understanding of the major elements that should be addressed in evaluating HOV facilities.

Texas Transportation Institute, The Texas A & M University System, College Station, Tex. 77843.

## DEVELOPMENT OF HOV FACILITIES AND EVALUATION PROGRAMS

The first HOV lanes in the United States were implemented in the late 1960s and early 1970s. The initial section of the Shirley Highway exclusive bus lanes opened in 1969 in Northern Virginia. This was followed in 1971 by the exclusive bus lane approach to the Lincoln Tunnel on I-495 in New Jersey and the first phase of the Los Angeles–San Bernardino Freeway Busway in 1973. Since the late 1970s, the use of HOV lanes has expanded greatly. As of April 1990, there were approximately 40 HOV facilities in operation on either freeways or in separate rights-of-way in 20 metropolitan areas in North America (*1*).

Although these facilities often differ in design and operation, all have similar purposes. In general, HOV facilities are intended to help maximize the person-carrying capacity of the roadway. This is done by altering the facility's design, operation, or both and provides priority treatment for HOVs, which are defined as buses, vanpools, and carpools.

A primary concept behind these priority facilities is to provide HOVs with both travel time savings and more reliable travel times. These two benefits serve as incentives for individuals to choose a higher occupancy mode. This, in turn, can increase the person-movement efficiency of the roadway by carrying more people in fewer vehicles. In some areas, additional incentives such as reduced parking charges or preferential parking for carpools and vanpools have been used to further encourage individuals to change their commuting habits. Thus, the intent is to provide a cost-effective travel alternative that a significant number of commuters will find attractive.

The reasons for implementing HOV facilities and the approaches used vary greatly. Many HOV applications have been attempts to develop relatively low-cost methods for increasing the capacity of congested freeways. This is especially true with some of the early facilities, many of which were implemented as part of transportation system management (TSM) programs. Approaches used in these cases include restriping to add an HOV lane to an existing facility, using the shoulder for an HOV lane, and other relatively low-cost treatments. Other HOV facilities represent permanent long-

term improvements. These include the construction of high-cost projects, such as bus-only facilities on separate rights-of-way and exclusive HOV facilities on freeways.

Evaluation methods and approaches have also varied greatly among projects. Because of limited resources, adequate before-and-after data have not always been collected. In some cases, an initial evaluation may have been completed shortly after implementation, with little or no ongoing data collection or evaluation activities. Thus, evaluating the effectiveness of many facilities has been difficult. In addition, the purpose or goal of the HOV facility has not always been well defined. Furthermore, the evaluation measures, along with the data collection techniques and evaluation criteria, have differed among areas. Thus, no standard approach or set of evaluation measures, criteria, and data collection techniques exist for evaluating HOV projects.

It should be noted that the lack of common evaluation measures and extensive before-and-after studies is not unique to HOV projects. Many transportation improvements, both roadway and transit, have been implemented without a clear statement of the goals for the project and a definition of the evaluation measures that will be used to determine their effectiveness. Good before-and-after studies are not all that common with highway or transit projects. However, these shortcomings do not dismiss the need for accurate evaluations of the effectiveness of HOV facilities. Because they require spending public funds, HOV lanes need to be evaluated to ensure that these investments are providing the desired benefits.

To identify past and current practices used to evaluate HOV facilities, an extensive literature review was conducted. Several reports and articles were examined from many sources. These included documents from federal agencies, such as the Federal Highway Administration and the Urban Mass Transportation Administration, state departments of transportation, local transit agencies, metropolitan planning organizations, consulting firms, university transportation research organizations, and other groups. These reports cover a wide range of topics including general guidelines for HOV project planning and development, project specific case studies, and overviews of HOV projects around the country.

Reports dealing with before-and-after project evaluations were examined in detail. In addition, telephone conversations were held with representatives from agencies responsible for different aspects of the evaluations to obtain further information. The results of this review are summarized in the next two sections. An overview of selected evaluation studies is then provided. This is followed by a summary of the common elements among the different studies and general conclusions resulting from the review (*2*).

## REVIEW OF SELECTED HOV EVALUATION STUDIES

This section examines some extensive before-and-after evaluation studies that have been conducted on freeway HOV facilities and the approaches that have been used in the different metropolitan areas where the facilities are located. Evaluation studies from the following areas are included: Washington, D.C.-Northern Virginia, Los Angeles, Houston, Seattle, and Minneapolis and Orange and Santa Clara counties in California. Although this review does not include all the evaluation studies conducted of HOV facilities, it does provide a sample of the types of studies, level of detail, and approaches that have been used with different freeway HOV facilities.

The analysis is on available evaluation reports and additional telephone conversations with representatives from agencies in the different areas. A brief description is provided of the project, evaluation process, project objectives, evaluation measures and criteria, data collection techniques, and any unique features of the study.

### Shirley Highway HOV Lanes, Northern Virginia

As noted previously, the Shirley Highway HOV lanes were the first major HOV facility in North America. A 5-mi bus-only lane opened in 1969 and additional segments of the facility were opened in 1970 and 1971, with the 11-mi, 2-lane, reversible, barrier-separated HOV facility completed in 1975. Buses were the only vehicles allowed to use the facility during the initial stages; vanpools and carpools were permitted later.

Several evaluation studies have been conducted on the Shirley Highway HOV lanes during the past 20 years. The first of these was conducted on the Express-Bus-On-Freeway Demonstration Project from 1971 to 1975. This demonstration project, which was the largest bus and highway project ever sponsored by the U.S. Department of Transportation, had three major components. These were the 11 mi of HOV lanes, the use of new feature buses in express service, and the use of new park-and-ride lots coordinated with the express bus service. The primary and secondary goals of the project, related objectives, evaluation measures, and data for the project are shown in Figure 1 (*3*).

Specific thresholds or performance standards were not set for each of the objectives or measures upon which the project's success would be evaluated. Rather, such general terms as "improve," "increase," and "reduce" were used to describe the desired results.

Extensive data collection and analysis were conducted to evaluate the demonstration program. These included traffic counts, surveys, and the use of analytical procedures to estimate some impacts. The major data collection and analysis efforts and their use are described in the following.

- *Vehicular volumes and person-trip counts.* Periodic counts were made of peak-period vehicular volumes and person-trips (bus and automobile) crossing an 8-station screenline that intercepted the main radial arterials in the corridor. This information helped determine overall changes in travel within the corridor, and specifically on the Shirley Highway facility. It was used to analyze changes in the person-movement efficiency of the corridor, as measured by changes in total person-trips, bus person-trips, bus market share, and automobile occupancy rates.
- *Monitoring bus schedule adherence.* Surveys of bus schedule adherence, as measured by comparing the actual arrival time of buses at the first downtown stop with the time listed in the printed schedule, were conducted before the opening of the entire busway and at seven times throughout the demonstration.

*Primary Goal:* Demonstrate that express bus-on-freeway operations can improve the quality of bus service and lead to an increase in the people moving capability of peak period transportation facilities for the entire urban corridor.

*Objectives:*
- o Increase reliability of bus service
- o Reduce travel time for transit and auto commuters
- o Increase coverage by bus routes
- o Increase bus passenger convenience and comfort
- o Increase bus's share of corridor commuters

*Measures:*
- o Operating speed
- o Door-to-door travel times
- o Reliability of service
- o Coverage area of bus service
- o Passenger comfort and convenience features (seat availability, fewer transfers, etc.)
- o Increase in bus patronage and market share
- o Increase in carpooling and reduction in single occupant automobiles
- o Growth in person volumes (bus and auto) per lane on the Shirley Highway and resultant changes in the quality of service encountered by both bus and auto commuters.

*Secondary Goal:* Demonstrate that the technology can have a favorable impact on the transportation-related environmental and social conditions within a corridor and on the economic condition of the transit operator.

*Objectives:*
- o Reduce peak period auto pollutant emissions
- o Reduce peak period gasoline consumption
- o Increase mobility of the transportation disadvantaged
- o Increase productivity of the bus operator

*Measures:* To determine changes in the social and economic objectives, the following changes were measured:

- o Economic Impact - operating costs and capital expenditure, and savings from increased productivity for the bus operator
- o Environmental Impact - gasoline consumption and automobile pollutant emissions
- o Social Impact - use of bus service by transit dependent households

**FIGURE 1 Shirley Highway Express-Bus-on-Freeway Demonstration: goals, objectives, and measures.**

• *Monthly bus data.* The bus operator provided monthly information on passenger levels, aggregate system costs, revenues, and operating statistics. These were used to evaluate the impact on the transit operator.

• *Bus and automobile travel times.* These were measured directly by travel time and speed surveys, and indirectly by questions on the mail-out and passenger surveys.

• *General and specific commuter surveys.* Several surveys were used to identify changes in commuter behavior, the reasons for these changes, and commuters' general perceptions of the significance of these changes. In-depth, mail-back surveys of automobile and bus commuters in the corridor were conducted in the initial and final stages of the demonstration. Surveys of park-and-ride lot users and bus users were conducted.

• *Analytical procedures.* Specific analytical procedures were developed to estimate bus market share, commuter travel time savings resulting from HOV lanes, bus operating costs, and reductions in automobile volumes, gasoline consumption, and air pollutant emissions.

As the first evaluation of an HOV facility, the Shirley Highway provides a good example of an in-depth evaluation. The evaluation process for the Shirley Highway Express-Bus-On Freeway Demonstration did not include any surveys focused on nonusers of the HOV lane. This was a noted weakness of the evaluation in the final report, and it was suggested that such a survey be part of future evaluations. In addition, the report recommended the development of a better procedure to identify and analyze improvements in vehicle and driver productivity attributable to the higher speeds on the HOV facility.

### San Bernardino Freeway Busway, Los Angeles

The 11-mi San Bernardino Freeway Busway was opened in 1973. The two-lane, two-direction facility was initially re-

stricted to buses. Carpools and vanpools were allowed to use the facility starting in 1976. An initial evaluation of the busway was conducted over the first 5 years of operation, from 1973 to 1978. According to the final report (*4*), the goals and measures of effectiveness identified in Table 1 were used in the cost-effectiveness analysis. The relative importance of these different goals was identified by the Busway Evaluation Committee and the corresponding values were used in the analysis.

The data collection and analysis were conducted over the 5 years and included the following major elements:

- *Travel time studies.* Caltrans conducted before-and-after tachography (time and speed) runs on the busway, freeway, and on several major parallel roadways.
- *Vehicular volume and occupancy counts.* Caltrans also conducted before-and-after vehicle and occupancy counts. This included electronic counts at four locations along the San Bernardino Freeway and one location on the Santa Ana Freeway. Mechanical volumes counts were taken at several locations along the busway, at ramps along the Santa Ana Freeway, and on five parallel surface streets. Occupancy counts were taken at one location on the freeway and two on the busway.
- *Violation rates.* Caltrans monitored the number of violators (vehicles using the lane not meeting the occupancy requirements) during the 5 years and the California Highway Patrol provided records of enforcement activities.
- *Bus ridership and travel times.* Southern California Regional Transit District provided weekly ridership counts until 1977, after which they were done monthly.
- *Safety.* The California Highway Patrol collected continuous accident data for the busway.
- *User and nonuser surveys.* Several surveys evaluated user and nonuser perceptions of the facility and specific reasons for mode selection and mode shift. These included an onboard survey of bus riders, a handout–mail-back survey of carpoolers, and a follow-up telephone survey, a handout–mail-back survey of freeway mainlane users, and an interview survey of bus drivers.

It is interesting to note that the San Bernardino Freeway Busway evaluation contained three elements not included in the Shirley Highway HOV facility evaluation. These are the inclusion of safety and accident data, violation and enforcement data, and surveys of nonusers of the busway facility.

### Houston Transitways

The first HOV facility in Houston was the I-45 North Contraflow Lane (CFL) demonstration project, which was implemented in 1979. The successful implementation of this project led to developing additional HOV facilities, called transitways, on other freeway corridors. Currently 47 mi of a planned 96-mi system of transitways are in operation on four

TABLE 1 SAN BERNARDINO FREEWAY BUSWAY EVALUATION PROCESS

| Goal | Effectiveness Measures | Relative Importance |
|---|---|---|
| Provide added corridor capacity | Increased carrying capacity of the corridor (persons per peak-hour or period) | 20% |
| Reduce environmental impacts of corridor travel | Reduced emissions of air pollutants (tons per year) | 10% |
| | energy savings (BTU-equivalent gallons of gasoline | 10% |
| Improve the level of service | Travel time savings (minutes per person trip) and the value of such savings, in dollars | 20% |
| Reduce the cost of personal travel | User cost savings, (cents per person trip, including parking cost savings) | 20% |
| Improve the safety of corridor travel | Number of accidents avoided and the associated dollar savings to society | 15% |
| Provide for future contingencies (e.g., a rail line, future growth, etc.) | Adaptability of the busway for such situations, plus their likelihood and timing | 5% |

freeways in Houston. These are all one-lane, reversible, barrier-separated facilities located in the freeway median.

The evaluation procedures, measures of effectiveness, and data collection to evaluate the effectiveness of the Houston transitways have evolved over the past 11 years. The process used with the initial evaluation of the I-45 North CFL demonstration project is reviewed first, followed by a review of current practices. Listed in Figure 2 are the objectives and evaluation measures used in this project (*5*).

Various data were collected and analyzed to support the evaluation, including traffic and CFL vehicle-volume data. Several surveys of commuters in the corridor were conducted; bus passengers, van drivers, van passengers, peak direction automobile drivers and passengers, and off-peak direction drivers were surveyed. The use of surveys to measure the attitudes and reactions of both users and nonusers was the most extensive use of surveys to date in evaluating HOV facilities.

As other transitway facilities were planned and implemented, a standardized evaluation program and corresponding monitoring and data collection program began to emerge. The Texas State Department of Highways and Public Transportation and the Metropolitan Transit Authority of Harris County have sponsored this effort, which has been conducted by the Texas Transportation Institute (TTI). The major elements of this process focus on data collection efforts needed to evaluate the following objectives (*6*).

- Effective person-movement capacity of the freeway should be increased;
- Transitway implementation should not unduly impact freeway mainlane operation;
- Transitways should be cost-effective;
- Development of the transitways should have public support; and
- Transitways should have favorable impacts on air quality and energy consumption.

To evaluate the transitways on the basis of these general objectives various information is regularly collected by TTI. The following list provides a summary of the major elements of the monitoring process.

- *Vehicle and occupancy counts.* Vehicle and occupancy counts are taken on the transitways and the general-purpose freeway lanes. The same counts are taken on two freeways that do not currently have transitways. These facilities act as a control group. In addition, vehicle and occupancy counts are taken on eight arterial streets that serve as alternative routes to the freeway facilities. These counts are taken quarterly.
- *Park-and-ride lot counts.* Vehicle counts are conducted at the park-and-ride lots associated with the transitways and the two control freeway corridors.
- *Travel Time Runs.* Travel time runs are conducted quarterly on the four transitways and the two control freeways.
- *User and nonuser surveys.* Surveys of bus users, carpoolers, and vanpoolers using the transitways and single-occupant vehicles in the general-purpose lanes are conducted annually. These surveys gather information on user and nonuser perceptions of transitway use, reasons for mode choice selection, and general attitudes toward the impact of the transitways.
- *Accident data.* Accident data are collected by the Houston Police Department for the freeway mainlanes and by Metro for the transitways.
- *Violation rates.* Metro Transit Police monitor the violation rates on the transitways. The vehicle and occupancy counts also provide a check on violation rates.

The Houston transitway evaluation program is the most extensive and comprehensive monitoring and evaluation program currently being conducted on HOV facilities. As such, it represents one of the better models.

### I-5 HOV Lanes, Seattle

Six miles of concurrent flow HOV lanes were opened on I-5 in Seattle in 1983. Three-month and 20-month evaluations of

*Project Objectives:*

- Decrease (or slow the growth of) corridor vehicle miles of travel (VMT) and associated fuel consumption and vehicle emissions
- Increase vehicle occupancy in the corridor
- Reduce congestion and, thus, decrease travel time
- Encourage acceptance and usage of public transportation

*Evaluation Measures:*

- Person and vehicle utilization
- Characteristics of both contraflow lane users and non-priority travellers
- Impact on non-priority users of the freeway
- Influence in promoting bus and vanpool use relative to other corridor improvements
- Associated safety and enforcement issues
- Public acceptance
- Impacts on corridor VMT, fuel consumption and vehicle emissions
- Associated costs

**FIGURE 2 I-45 North Freeway Contraflow Lane Demonstration: objectives and evaluation measures.**

the facility were conducted by the Washington State Department of Transportation (*7,8*). Six general measures of effectiveness were used to evaluate the impact of the HOV lanes:

1. Number of vehicles traveling in the lanes;
2. Number of people served by the lanes;
3. Extent to which people are obeying the laws governing the HOV lanes;
4. Time savings for freeway commuters;
5. Effect on accident rates; and
6. Public reaction.

No specific thresholds were identified for these measures. It appears that only a limited amount of data was collected for the before-and-after analysis of I-5. Vehicle and occupancy counts were taken in the HOV lane after 2 weeks, 3 months, and 20 months of operation. Freeway mainlane volumes were measured by the average daily traffic for the same time period. Violation studies were conducted during the second and third month of operation, and after the implementation of the HERO program (a telephone hotline program on which HOV lane occupancy violators can be reported), which was initiated in February 1984. Travel time savings were measured as part of the annual metropolitan travel time study. Accident information was not available for the 3-month study and is not mentioned in the 20-month study. Public reaction was measured by the number of letters and telephone calls received by the department.

The I-5 HOV project and other HOV facilities in Seattle are monitored continuously as part of the FLOW System. FLOW is the name given to TSM techniques in the Central Puget Sound area. Evaluations of the system components, including ramp metering, HOV lanes, freeway mainlanes, bus service, and accidents, are being conducted by the Washington State Department of Transportation on a regular basis (*9*).

### I-394 Minneapolis

An interim HOV lane is currently in operation in the Highway 12, I-394 corridor. The interim facility includes 3 mi of a reversible, barrier-separated HOV lane located in the median of the highway and additional segments of concurrent flow lanes. The final design of I-394, which is scheduled to open in 1993, includes 3 mi of 2-lane, reversible, barrier-separated HOV lanes and 8 mi of concurrent flow lanes. The interim HOV lane was opened in November 1985.

An extensive before-and-after study of the interim and final HOV lanes was initiated before the opening of the interim facility. Under the guidance of the Minnesota Department of Transportation, a set of project goals and objectives was identified by the I-394 project management team for both the interim and completed facilities. These formed the basis to develop the evaluation program (*10*).

The evaluation program was developed before the interim facility was opened in 1985. Three different periods were identified for the project evaluation. These were the construction period, when the interim facility would be in operation; the start-up period for the completed facility; and the stable operating period. The following objectives were identified for the HOV facility. Although these objectives were to apply in general to all three evaluation periods, the evaluation program noted that the degree to which they are achieved will vary for each period (*10*). The objectives were as follows:

- Increase the peak hour carpool-vanpool 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 carpools and vanpools on I-394;
- Maintain or improve the existing level of service for mixed traffic on I-394;
- Maintain or improve the accident rate along I-394;
- Achieve and maintain a low violation rate of the HOV lanes on I-394; and
- Construct a cost-effective HOV facility on I-394.

For each of these objectives, specific performance measures were identified and a corresponding performance threshold was established for each period. The thresholds were established by an analysis of the existing conditions and the forecasted use for the different periods. The performance measures and thresholds identified for the objective relating to increasing the peak hour mode split are shown in Table 2. This provides an example of the approach and level of detail involved in the I-394 before-and-after evaluation.

The I-394 evaluation program is supported by continuous data collection. This program includes many elements similar to those described for other studies. These include regular vehicle and occupancy counts on the HOV lane, mainlanes, and parallel facilities; travel time runs; accident data; violation rates; surveys of users and nonusers; and evaluation of the different marketing and public information programs. Like the Houston program, the I-394 evaluation program is one of the more extensive and comprehensive evaluation programs currently being conducted.

### Route 55 Commuter Lane, Orange County, California

In 1985, 11 mi of concurrent flow HOV lanes were opened on Route 55 in Orange County. Called commuter lanes, they were the first exclusive carpool facilities in Orange County. The lanes were initially opened as part of a 90-day demonstration program sponsored by the Orange County Transportation Commission and Caltrans. An evaluation program for this demonstration was developed by the Route 55 Advisory Committee. The key evaluation issues used in the 90-day evaluation are outlined in Table 3 (*11*).

The data collection activities needed to support the evaluation were also identified, as were the initial thresholds the project should meet to be considered successful. Data that were to be examined included vehicle and occupancy counts, travel time and speed runs, accident reports, buffer and vehicle occupancy violations, and monitoring the letters and telephone calls received. Two aspects of the data collection activities are of interest. First, videotaping vehicles at selected locations was used as one method of monitoring vehicle and occupancy counts. Second, no surveys were conducted of users and nonusers during the initial demonstration or the first few years of operation. However, in 1987 an extensive Route 55

TABLE 2 I-394 EVALUATION OBJECTIVE AND PERFORMANCE MEASURES: EXAMPLE

| Objective | Performance Measure | Existing Conditions 1984 | Construction Period 1985-1990 | Start-Up Period 1991-1992 | Stable Operation 1993-2000 |
|---|---|---|---|---|---|
| Increase the Auto Peak Hour Modal Split | Number of Carpools/Vanpools | 625 | 700 | 1,075 | 1,585 |
| | Carpool/Vanpool/ Occupants | 1,380 | 1,540 | 2,515 | 4,900 |
| | Carpools as % of Autos | 19% | 21% | 25% | 29% |
| | Carpool Occupants as % of Auto Occupants | 34% | 36% | 42% | 56% |
| | Auto Occupancy Rate | 1.23 | 1.25 | 1.3 | 1.6 |

travel behavior study was conducted that included extensive surveys of both users and nonusers of the HOV facility (*12*).

Using the same general approach, evaluation studies were conducted on Route 55 after 9 months, 12 months, and 18 months of operation. In addition to the travel behavior inventory, additional special studies were conducted on safety issues (*13*). These studies focused specifically on changes in traffic safety resulting from the HOV lanes.

Two elements of the Route 55 evaluation process are worth stressing. First, the Route 55 process appears to be one of the first to use video cameras extensively to obtain vehicle, occupancy, and violation information. Second, and probably more important, the concern over and emphasis placed on safety and accident information provides an element for consideration in other evaluations.

### Santa Clara County Commuter Lanes

HOV lanes, called commuter lanes, are currently in operation on three expressways and one freeway in Santa Clara County. These facilities were opened between 1982 and 1988 and represent the first phases of a larger system of HOV lanes that had been planned. In 1988, the Santa Clara County Transportation Agency sponsored a detailed assessment of the county's existing commuter lane network (*14*). The purpose of the study was to compile and summarize available data on commuter lane use, travel time savings, safety, and enforcement. This information was then used to evaluate the effectiveness of the four existing projects.

The final report on the evaluation does not identify any specific goals or objectives the commuter lanes were designed to meet. The evaluation relied primarily on historical data available from Santa Clara County, Caltrans, and other public agencies. The report presents a summary of available data on each facility and identified data deficiencies. The following information was examined in the evaluation:

- Vehicle volume counts for both the commuter lanes and the mixed-traffic lanes;
- Occupancy counts for both the commuter lanes and the general-purpose lanes, which were used to compute the violation rates and rideshare percentages;
- Travel time data documenting speed and travel time for vehicles in the commuter lanes and general-purpose lanes;
- Enforcement statistics on the number of citations issued for illegal use of the HOV lanes;
- Accident data documenting the number of accidents in the HOV and general-purpose lanes; and
- Surveys of drivers on routes with commuter lanes.

This information was used in the evaluation for a general summary of the operating trends on the facilities. The results were not measured against any benchmark; the evaluation is descriptive and provides an overall summary of the historical trends.

### Summary of Common Elements

The preceding studies represent some of the better examples of before-and-after evaluations of HOV facilities. Note that the facilities covered in these evaluations constitute a relatively small percentage of the approximately 40 HOV projects currently in operation. Formal evaluations have not been conducted on many HOV facilities and in some areas the data needed for such evaluations has not been, and is not now being, collected. General conclusions that appear to be appropriate concerning the current state-of-the-art in HOV project evaluations follow.

Formal evaluations of major HOV facilities and those with significant federal funding have been more extensive and comprehensive than lower-cost TSM-type HOV facilities. Most of the HOV projects reviewed in this paper involved significant investment in major facilities. Many of these also included federal funding not only for the facility, but also for the evaluations and data collection activities. The limited number of evaluations on other facilities appears to have partially resulted from the nature of these facilities, many of which were implemented as TSM activities that limited funding for evaluation.

Although formal evaluations were often conducted during the initial demonstration stages of some projects, such as the

TABLE 3 SUGGESTED OBJECTIVES, MEASURES OF EFFECTIVENESS, AND THRESHOLD RANGES

| Objective | Measures of Effectiveness |
|---|---|
| o The HOV facility should improve the capability of a congested freeway corridor to move more people by increasing the number of persons per vehicle | o Acutal and percent increase in the person movement efficiency<br>o Actual and percent increase in average vehicle occupancy rate<br>o Actual and percent increase in carpools and vanpools<br>o Actual and percent increase in bus riders |
| o The HOV facility should increase the operating efficiency of bus service in the freeway corridor | o Improvement in vehicle productivity (operating cost per vehicle-mile, operating cost per passenger, operating cost per passenger mile)<br>o Improved bus schedule adherance (on-time performance)<br>o Improved bus safety (accidents rates) |
| o The HOV facility should provide travel time savings and a more reliable trip time to HOVs utilizing the HOV facility | o The peak-period, peak-direction travel time in the HOV lane(s) should be less than the travel time in adjacent freeway lanes<br>o Increase in travel time reliability for vehicles using HOV lane(s) |
| o The HOV facility should have favorable impacts on air quality and energy consumption. | o Reduction in emissions<br>o Reduction in total fuel consumption<br>o Reduction in the growth of vehicle miles of travel (VMT) and vehicle hours of travel |
| o The HOV facility should increase the per lane efficiency of the total freeway facility. | o Improvement in the peak-hour per lane efficiency of the total facility |
| o The HOV facility should not unduly impact the operation of the freeway mainlanes | o The level of service in the freeway mainlanes should not decline |
| o The HOV facility should be safe and should not unduly impact the safety of the freeway general-purpose mainlanes | o Number and severity of accidents for HOV and freeway lanes<br>o Accident rate per million vehicle miles of travel<br>o Accident rate per million passenger miles of travel |
| o The HOV facility should have public support. | o Support for the facility among users, non-users, general public, and policy makers<br>o Violation rates (percent of vehicles not meeting the occupancy requirement) |
| o The HOV facility should be a cost-effective transportation improvement. | o Benefit-cost ratio |

Shirley Highway HOV lanes and the San Bernardino Freeway Busway, ongoing evaluations have not always been conducted. The data collection and evaluation process used on the Houston transitways appears to represent the most extensive and comprehensive effort currently being conducted.

Many HOV facilities have been implemented without clearly defined goals on the purpose and objective of the project. This lack of a clear understanding of the purpose and goals of the project make evaluating the effectiveness difficult. There is no way of knowing if the goal has been reached when the goal has not been defined. Compounding this problem in some cases is the use of objectives that either cannot be measured or are inappropriate for the desired goal.

Many evaluations have been conducted using very general evaluation criteria. These measures may be as simple as a statement that the HOV lane should reduce travel times for bus and automobile commuters, without identifying the level of time savings that should occur. Thus, no benchmark or specific threshold is identified against which the project will be measured. If the HOV facility leads to any improvement in the general evaluation measure, the project is considered successful. For example, the Shirley Highway Busway evaluation did not set specific improvement levels, but rather used terms like improve and increase. The I-394 and Route 55 evaluation programs represent two of the better examples of the use of specific thresholds.

There does not appear to be a consensus among transportation professionals on the appropriate criteria or measures to evaluate HOV facilities. Various measures have been used with different facilities. Although common elements exist, many different approaches are currently being used. Further, a consensus does not appear to exist regarding what levels of improvement or change are of sufficient magnitude to conclude that project has been effective. These appear to be greatly influenced by local conditions and perceptions.

Some evaluation studies have focused just on the HOV lane, without considering the full range of impacts, such as the effect on nonusers in the general purpose lanes and the operation of the total system. Most of the evaluation studies examined in this paper accounted for some or most aspects of the non-HOV lanes and the operation of the total facility. This appears to be an issue that needs to be evaluated, but because of costs is not always examined as extensively as might be desired.

Many evaluations are performed on data that may preclude statistical analysis of the significance of any changes. In many cases, "before" data is scarce or nonexistent. This, combined with limited samples of "after" data and little ongoing data collection, has often lead to the inability to make statistically meaningful comparisons.

The evaluation methodology, definition of terms, and data collection methods often differ among projects making comparisons between them difficult. A close examination of the data collection methods and definition of terms used in the preceding evaluations identified many such differences. For example, the definition of the length of the peak period often varies, as does the exact time of the peak hour.

There does not appear to be consensus among researchers on the appropriate way to deal with outside changes that may affect the results of the HOV project. In addition, some localities use a control facility to monitor overall changes, while others do not. The Houston evaluation process, which monitors not only the four transitways, but also two control freeways, provides one of the better approaches for identifying potential outside influences.

The forgoing examination of the evaluation processes in the seven metropolitan areas and a review of other relevant literature identified a number of common goals or objectives and corresponding measures of effectiveness that appear to be most appropriately used with HOV facilities. These are presented in Figure 3. An indication of the types of data needed to support the evaluation are provided in Table 4.

In addition, the following steps are important elements in the development and implementation of a comprehensive ongoing evaluation program for HOV facilities. These steps are not new—they reflect the major activities that should be undertaken as part of any evaluation program.

- Clear articulation of project goals and objectives. The goals and objectives the HOV project are intended to accomplish need to be clearly defined. This is a critical step, because the remainder of the program will be designed to obtain and

*What is the effect of the Commuter Lane on overall freeway operations?*
- o Is the Commuter Lane being utilized effectively?
- o What is the effect of the demonstration project on overall freeway utilization?

*What effect has the Commuter Lane had on travel times and congestion levels in the general use lanes?*

*How do the Commuter Lanes affect overall freeway safety and violations?*
- o Are the Commuter Lanes safe to use?
- o To what extent are freeway users violating the painted buffer and entering and exiting the lanes?
- o To what extent are the lanes being used by non-carpoolers?

*Has the Commuter Lane had an effect on traffic volumes on the parallel arterials and/or freeways?*

*What is the public's attitude toward the project?*

*Are there any special factors or circumstances that should be reported and considered?*

**FIGURE 3 Route 55 commuter lane evaluation elements.**

TABLE 4 SUGGESTED OBJECTIVES, DATA COLLECTION EFFORTS, AND MEASURES OF EFFECTIVENESS FOR EVALUATING HOV FACILITIES

| Objective | Data Collection Efforts: Vehicle and Occupancy Counts | | Travel Time Runs | | Surveys[1] | | | Corresponding Measures of Effectiveness (MOE's)[3] |
|---|---|---|---|---|---|---|---|---|
| | Freeway[2] | HOV Lane | Freeway[2] | HOV Lane | Freeway | HOV Lane | Other | |
| Increase vehicle occupancy | * | * | | | ** | ** | **[4] | Actual and percent increase in peak-hour, peak-direction person volume; increase in average vehicle occupancy; and modal shift |
| Bus operating efficiency | | | * | * | | | *[5] | Improved vehicle productivity; improved bus schedule adherance; and improved bus safety |
| Travel time savings | | | * | * | ** | ** | **[6] | Amount of travel time saving by HOV users; reliability of trip time for HOV users |
| Energy and air | * | * | * | * | ** | ** | **[7] | Reduction in emissions; reduction in energy consumption |
| Per lane efficiency | * | * | * | * | | | | Increase in peak-hour per lane efficiency of total freeway facility |
| Freeway operations | * | | * | | ** | | | Maintain or improve level of service on freeway mainlanes |
| Safety | ** | ** | | | | | *[8] | Number and severity of accidents; accident rate per million vehicle miles of travel and per million passenger miles of travel |
| Public support | | ** | | | * | * | **[9] | Percent of users, non-users, and general public who approve of HOV facility; violation rates |
| Cost effective | ** | * | * | * | | | | Benefit-cost ratio |

* Indicates the top priority data collection efforts needed to evaluate the objectives.

** Indicates data collection efforts which should ideally be conducted, but are not absolutely necessary to evaluate the objectives.

1 Involves periodic use of surveys of HOV users (bus riders, carpoolers, and vanpoolers), non-HOV users in the general traffic lanes, and in some cases, the general public.

2 It is strongly suggested that this data be collected for both the freeway lanes adjacent to the HOV facility and the control freeway.

3 Some, but not necessarily all, of the suggested MOEs associated with gauging the attainment of the objectives are shown.

4 Vehicle and occupancy counts on alternate arterial routes to identify any changes in throughput for the corridor, counts at park-and-ride lots, and vehicle and occupancy counts on a "control" freeway.

5 Before-and-after bus service levels, vehicle productivity, schedule adherence, number and severity of bus accidents, vehicle operating costs, and changes in labor, fuel, and other costs.

6 Monitoring bus on time performance and schedule adherence before-and-after implementation of the HOV lane(s).

7 Monitoring air quality levels along the corridor and use of simulation models to estimate impact.

8 Monitoring freeway accident rates and types before-and-after implementation of the HOV lane(s), as well as obtaining accident rates on the HOV facility.

9 Identifying violation rates for the HOV lane (i.e., those vehicles not meeting the minimum occupancy requirement). Monitor complaints, media, and policy actions.

evaluate information that will be used to determine if these objectives have been met. The development of measurable objectives is not an easy task, but time spent on this effort will help ensure a focused evaluation.

- Identification of measures of effectiveness and the threshold level of change. For each objective, the appropriate measure or measures of effectiveness should be identified, along with the desired level of change to be used to determine if the facility has met the objective. It is important that this activity focus on identifying the key measures that most accurately relate to the objectives, and that realistic threshold levels be established.
- Identification of the information needed to complete the evaluation. This step identifies the information needs of the evaluation process. For each measure of effectiveness, the data needed to determine if the objective has been realized must be identified. The appropriate methods to obtain and evaluate the information should also be identified.
- Development of the study design. The previous three activities should be brought together in the development of the comprehensive study design. This should include the listing of objectives, measures of effectiveness, and data collection and analysis needs and procedures. It is important that the scope of this effort corresponds to the funding and staffing limitations of the agencies involved.
- Conduct "before" data collection. In this step, data are collected before the implementation of the HOV project. This step is critical. If no "before" data are collected, it is virtually impossible to determine the impact of the HOV facility.
- Conduct "after" data collection and evaluation. In this step, the "after" data are collected. Usually a number of different evaluation points are identified, such as after 1 year, 2 years, and on an continuing basis. The before-and-after data are then evaluated, and the project effectiveness is examined.
- Ongoing monitoring and evaluation. After the initial evaluation, an ongoing monitoring and evaluation process should be maintained. Because different areas will have different resources available for this, the program should be designed to ensure that the key information is collected and analyzed within the resources available.

## CONCLUSION

A review of current practices used to conduct evaluation studies of operating HOV facilities has been presented in this paper. It has included a review of examples of seven evaluation programs conducted on HOV projects and a discussion of the common elements of these studies. The results of this analysis should be beneficial for areas in the process of designing before-and-after evaluation programs for new HOV projects and for areas with operating HOV facilities that may wish to improve current evaluation methods.

It is important to note that differences will probably continue to exist in the evaluation processes used by different metropolitan areas. This is appropriate because of the need to focus evaluations on the issues that are of local concern. However, in the long run, all areas could benefit from a more standardized and focused approach to evaluating HOV facilities.

## ACKNOWLEDGMENT

The work described in this paper was undertaken by TTI, a part of The Texas A & M University System. The examination of current before-and-after evaluation studies of freeway HOV facilities was one element conducted as part of a larger study, *The Assessment of Freeway High-Occupancy Vehicle Lane Projects*. This assessment is funded by the Urban Mass Transportation Administration through the Texas State Department of Highways and Public Transportation.

## REFERENCES

1. K. F. Turnbull and J. W. Hanks, Jr. *A Description of High-Occupancy Vehicle Facilities in North America*. Texas Transportation Institute, College Station, Tex., 1990.
2. K. F. Turnbull, R. H. Henk, and D. L. Christiansen. *Suggested Procedures for Evaluating the Effectiveness of Freeway HOV Facilities*. Draft. Texas Transportation Institute, College Station, Tex., 1990.
3. J. T. McQueen, D. M. Levinsohn, R. Waksman, and G. K. Miller. *Evaluation of the Shirley Highway Express-Bus-On-Freeway Demonstration Project—Final Report*. U.S. Department of Commerce, 1975.
4. Crain and Associates. *San Bernardino Freeway Busway Evaluation of Mixed-Mode Operations*. Southern California Association of Governments, Los Angeles, 1978.
5. T. J. Atherton and E. S. Eder. *Houston North Freeway Contraflow Lane Demonstration*. Cambridge Systematics, Inc.; U.S. Department of Transportation, Austin, Tex., 1982.
6. D. L. Christiansen and D. E. Morris. *The Status of the Effectiveness of the Houston Transitway System, 1989*. Texas Transportation Institute, College Station, Tex.; Texas State Department of Highways and Public Transportation, Austin, Tex., 1990.
7. S. M. Betts, L. N. Jacobson, and T. D. Rickman. *I-5 HOV Lanes: Three Month Report*. Washington State Department of Transportation, Seattle, Wash., 1983.
8. *I-5 HOV Lanes: A Twenty Month Report*. Washington State Department of Transportation, Seattle, Wash., 1985.
9. K. C. Henry and M. Mehyar. *Six-Year FLOW Evaluation*. Washington State Department of Transportation, Seattle, Wash., 1989.
10. Strgar-Roscoe, Inc. *I-394 Transportation System Management Plan Objectives*. Minnesota Department of Transportation, St. Paul, Minn., 1984.
11. *Route 55 Commuter Lane Demonstration Project: 90 Day Evaluation Report*. Orange County Transportation Commission; California Department of Transportation, 1986.
12. S. Green and J. Capelle. Route 55 Travel Behavior Study, Orange County, California. Presented at the 68th Annual Meeting of the Transportation Research Board, Washington, D.C., Jan., 1989.
13. *An Analysis of Traffic Safety Relative to the Commuter Lane Projects on SR-55 and SR-91 in Orange and Los Angeles County*. Technical Memoranda 1 and 2. Institute of Transportation Studies, University of California, Irvine, 1987.
14. *Commuter Lane Performance Evaluation*. SYSTAN, Inc.; Santa Clara County Transportation Agency, San Jose, 1989.

*The opinions expressed in this paper are those of the authors, not UMTA or SDHPT.*

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