The State of the Practice in HOV System Performance Monitoring

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ABSTRACT

Performance monitoring has been an integral element of HOV system development since the first HOV facilities were opened in the late 1960's. Much of the current HOV guidance has evolved from the lessons learned from performance reporting during these initial projects, and performance monitoring remains is the only effective way to determine whether a particular facility or system has accomplished desired goals and achieves benefits.

The state of the practice in HOV system performance monitoring in the United States reveals that generally all areas conduct some form of performance monitoring, although the range of goals and objectives, performance measures and analysis methodologies varies widely between areas. Often there is a disconnect between HOV goals and performance monitoring resulting in monitoring programs that do not focus on appropriate expectations for the HOV system making it inherently difficult to adequately address the legitimacy of the HOV system through performance or to appropriately respond to changing performance conditions.

Disparities in HOV performance monitoring programs need to be addressed to establish an analogous range of goals, data collection techniques and performance measures. Appropriate goals and performance measures can then be articulated for each region as the basis for ongoing monitoring. Current experience demonstrates that meaningful HOV system performance can be accomplished for relatively limited resources when goals and performance measures are focused, data collection is automated, and data analysis sampling is applied. Recognizing the need to demonstrate the benefits of HOV facilities to address public expectations, monitoring agencies call for a commitment to advance data collection technologies and to provide the necessary resources to sustain and enhance the state of the practice in HOV system performance monitoring.

INTRODUCTION

High Occupancy Vehicle (HOV) system performance monitoring has been an integral component of HOV system development in the United States since the first HOV facilities were opened more than 30 years ago. Much of the HOV guidance developed was the result of lessons learned from monitoring and performance reporting from these initial projects.

Performance monitoring is the only way to determine whether a particular HOV facility or system has accomplished defined goals and objectives, and achieves desired operational thresholds. Performance monitoring provides a mechanism to accomplish the following:

- To quantify benefits and impacts for an HOV facility or system.
- To ascertain the degree to which the cumulative benefits of HOV facilities are accomplishing desired results.
- To determine needed design and operational changes in facility or system performance.
- To plan and prioritize future HOV facility investments.

Performance monitoring results afford policy makers and the public, alike, the necessary information to make informed decisions regarding the operations of, and future investments in HOV facilities.

The purpose of this paper is to assess the state of the practice in HOV system performance monitoring, specifically related to freeway HOV lane systems within the United States. In order to evaluate the state of the practice in system performance monitoring, this paper initially addresses the legislative requirements for performance monitoring and the range of HOV goals and objectives against which HOV systems are typically evaluated. Having established the context for HOV system performance monitoring, the paper discusses the results of a survey of transportation agencies responsible for HOV system development and operations nationwide to determine the current state of the practice leading to the identification of appropriate directions for future HOV system performance monitoring and reporting.

BACKGROUND

HOV Goals and Objectives

In the most fundamental sense, the goal of HOV lanes is to move more people in fewer vehicles. This increase in the total number of people being moved through a congested corridor is accomplished by offering two types of travel incentives: a substantial travel time savings, along with a reliable and predictable travel time*(1)*. By providing incentives that encourage people to utilize transit services, carpool or vanpool, HOV lanes are able to move significantly more people during periods of congestion, even though the number of vehicles using an HOV lane may be fewer that adjacent general-purpose lanes

This basic goal of HOV lanes is reflected in all published statements of HOV goals and objectives. The *HOV Systems Manual* states that "HOV facilities are intended to help maximize the person-carrying capacity of the roadway…by altering the design and/or operation of the facility in order to provide priority treatment for high-occupancy vehicles*(2)*." By providing dedicated facilities, high occupancy vehicles are afforded the opportunity to effectively bypass congested traffic thus realizing more predictable travel times and travel time savings.

Regional derivations of HOV goals and objectives typically expand beyond the fundamental goal of moving more people in fewer vehicles to reflect local transportation priorities and a response to local transportation issues and needs. Six specific HOV objectives that are often replicated, in part, in regional HOV goals and objectives are*(3)*:

1. Induce mode shift from driving alone to higher occupancy modes.
2. Increase the person-carrying capacity of highway corridors.
3. Reduce total travel time.
4. Reduce or defer the need to increase highway vehicle-carrying capacity.
5. Improve efficiency and economy of public transit operations.
6. Reduce fuel consumption.

Many States and metropolitan areas with HOV lanes have stated goals and objectives relating to their HOV investments. Table 1 provides a summary of issues addressed in HOV Goals and Objectives for select areas. Clearly moving more people in fewer vehicles or increasing people-moving capacity is a common theme in HOV goals and objectives. However, the expanded range of goals and objectives varies considerably between areas, based on local priorities, and transportation issues and needs. This range in goals and objectives is reflected in disparate HOV performance monitoring and associated measures of effectiveness between areas.

Requirements for HOV Performance Monitoring

The *Intermodal Surface Transportation Efficiency Act of 1991* (ISTEA) represented a new direction for surface transportation development in the United States. ISTEA provided state and local governments with the tools of enhanced transportation planning and management systems to guide the development of innovative solutions to growing transportation problems. ISTEA required that the planning process in Transportation Management Areas (TMAs) include the development of a Congestion Management System (CMS) that provides for the management of transportation facilities through the use of travel demand reduction, travel management, and traffic operations strategies*(1)*.

On December 19, 1996, the USDOT published the *Management and Monitoring Systems; Final Rule*. §500.109 of the Final Rule (23 CFR) advises that "an effective CMS is a systematic process for managing congestion that provides information on transportation system performance and on alternative strategies for alleviating congestion and enhancing the mobility of persons and goods." Specifically, "consideration needs to be given to strategies that reduce SOV (single occupant vehicle) travel and improve existing transportation system efficiency*(4)*."

The Final Rule required that all TMA's develop "methods to monitor and evaluate the performance of the multimodal transportation system", and in particular, the "establishment of a program for data collection and system performance monitoring*(4)*." While not explicitly requiring the consideration of HOV facilities as an element of the CMS, HOV facilities clearly represent appropriate strategies to reduce SOV travel, and therefore the requirements of the Final Rule imply that, where applicable, HOV facilities should be monitored to evaluate performance and the effectiveness of these facilities to enhance mobility.

The Final Rule encourages the use of Intelligent Transportation System (ITS) technologies as a means to collect system performance data as part of the performance monitoring program. The 1998 *Transportation Equity Act for the 21st Century* (TEA21)

reaffirmed the CMS and ITS requirements of ISTEA. TEA21 also incorporated additional provisions requiring the establishment of regional ITS architecture and standards to "accelerate the rate at which ITS is incorporated into the national surface transportation network*(5)*." With the availability of additional funding through TEA21 and the development of a coordinated ITS architecture, these systems represent a potentially valuable resource for the continued expansion and refinement of HOV (and CMS) monitoring activities.

Formal requirements for HOV monitoring and evaluation tend to be limited and varied in specificity at a state or local level. In Massachusetts, state legislation requires the ongoing evaluation of Boston area HOV facilities to ensure they accomplish a specific operational performance threshold. However, despite federal CMS monitoring requirements, this type of prescriptive requirement at a state level is not the norm. Instead, the genesis of HOV monitoring programs tends the be a practical need or desire at either the State Department of Transportation (DOT) or regional Metropolitan Planning Organization (MPO) level to understand the performance of the system and to respond to scrutiny of HOV facilities. HOV monitoring programs generally appear to evolve as an extension of other highway monitoring programs to specifically address questions relating to HOV facility performance. In some areas, adopted DOT or MPO policies provide limited guidance with regard to HOV system monitoring and evaluation activities.

Guidance for HOV Performance Monitoring

In August 1990, the Texas Transportation Institute (TTI), in cooperation with the USDOT, published *Suggested Procedures for Evaluating the Effectiveness of Freeway HOV Facilities(6)*. This document provided a review of the state of the practice in HOV evaluation practices at the time, and outlined suggested procedures for conducting HOV system evaluations and monitoring. The suggested procedures represented the first comprehensive model suitable for application to all types of freeway HOV projects. It outlined seven steps considered necessary for completing an effective evaluation of HOV facilities. The report focused on the completion of before and after HOV facility evaluations—based on the number of emerging projects at that time—while also offering steps for ongoing HOV monitoring programs. These seven steps include*(6)*:

1. Clear articulation of goals and objectives.
2. Identification of measures of effectiveness and operational threshold ranges.
3. Identification of the information needed to complete the evaluation.
4. Development of the study design.
5. Conduct "before" data collection.
6. Conduct "after" data collection and evaluation.
7. Ongoing monitoring and evaluation.

The TTI report presented seven general objectives for consideration as part of the initial evaluation step. The report also discussed each objective to define appropriate measures of effectiveness and threshold ranges.

The 1998 NCHRP HOV Systems Manual restated the recommendations of the earlier TTI report while expanding the objectives to be considered during the evaluation of HOV facilities. The matrix of suggested objectives and measures of effectiveness for HOV monitoring summarized in the NCHRP report are replicated in Table 2. For each objective, the HOV

Systems Manual outlines the measures of effectiveness, general threshold ranges and data needs to accomplish an appropriate level of detail for evaluation. The report also details data collection techniques and evaluation methods, including the recommended frequencies for data collection activities to ensure appropriate sampling.

CURRENT STATE OF THE PRACTICE

To assess the state of the practice in HOV system performance monitoring, representatives of jurisdictional agencies responsible for the operation of a majority of HOV facilities in the US were interviewed. Information derived from these interviews was supplemented by information contained in study reports and other publications to provide an understanding of the extent and complexity of HOV systems monitoring nationwide. The HOV systems represented in the interview sample include:

- Boston, Massachusetts
- Dallas, Texas
- Denver, Colorado
- Houston, Texas
- Los Angeles County, California
- Minneapolis, Minnesota
- San Diego, California
- San Francisco Bay Area, California
- Seattle, Washington
- Suffolk and Nassau Counties, New York
- Vancouver, Washington

Ongoing HOV Performance Monitoring Efforts

Consistent with the performance monitoring requirements of the Management and Monitoring Systems; Final Rule, monitoring of the HOV system was an ongoing activity in all eleven of the areas reviewed, although the degree and complexity of the monitoring activities varied greatly. In the simplest form, ongoing monitoring of the HOV system involves the collection and tabulation of lane volume data for archiving, as was the case in Denver. Although the data collected in Denver are not specifically reported for distribution, it represents a resource available for analysis on an as-needed basis. In the most complex form, ongoing monitoring efforts include the collection, tabulation, analysis and reporting of performance data for a combination of measures that may include lane volumes, travel times, average vehicle occupancy, violation rates, incidents, transit utilization, park-and-ride utilization, and public opinion. Data may be published as frequently as quarterly for public distribution. HOV systems in California, Texas and Washington were typically subjected to the most comprehensive ongoing performance monitoring programs, reflecting the substantial investments in HOV facilities in these states.

Goals and Objectives

Despite the guidance of the HOV Systems Manual, the identification of clear goals and objectives as the basis for performance monitoring is mixed. Most of the area representatives indicated that their respective areas had general goals and objectives for HOV facility and system performance, including moving more people in the HOV lanes, increasing the number of carpools and transit riders, providing HOV time savings, reducing congestion and improving air

quality. However, it was acknowledged that performance monitoring efforts were not necessarily structured to address a particular set of goals and objectives, but rather, were structured in consideration of resource limitations and immediate institutional need. While current HOV monitoring efforts tended to be generally consistent with national and regional area HOV goals, overall there did not appear to be an apparent direct relationship between defined goals and objectives and monitoring efforts in many locales.

Two notable exceptions to this general observation were Boston and New York, where monitoring efforts are specifically tied to stated objectives. In Boston, travel time savings and air quality impacts are HOV objectives prescribed by state statutes. HOV monitoring efforts in the Boston area have focused primarily on these two objectives with a one-time evaluation of the air quality impacts and ongoing monitoring of the travel time savings. Similarly, the New York Department of Transportation (NYDOT) has a stated policy objective for minimum HOV lane utilization, which is the primary focus of the Long Island Expressway HOV lane performance monitoring.

In California, State law declares that HOV lanes are intended "to stimulate and encourage the development of ways and means of relieving traffic congestion on California highways and, at the same time, to encourage individual citizens to pool their vehicular resources and thereby conserve fuel and lessen emission of air pollutants*(7)*." While the California State law represents laudable transportation goals, current monitoring efforts in California generally do not demonstrate HOV benefits in terms of relieving congestion and improving air quality. Despite documentation through ongoing monitoring of the relatively successful performance of HOV lanes in California in terms of lane utilization, person trips, violation rates, time savings and public acceptance, the legitimacy of HOV lanes in California continues to be challenged periodically on the basis the lanes do not reduce congestion or improve air quality in accordance with State law. The difficulty in adequately responding to these periodic challenges using available performance monitoring results demonstrates the need to clearly define goals as a basis for performance monitoring and to structure performance monitoring to specifically address defined goals.

Performance Measures

Table 3 provides a matrix overview of the performance measures addressed as part of the ongoing HOV system monitoring efforts. The matrix indicates the topical measures that are subject to data collection and evaluation in the respective areas sampled. Vehicle volume was the single performance measure that was common to all eleven areas sampled. Average vehicle occupancy was the next most prevalent measure being evaluated.

Vehicle volumes, and the volume/occupancy derivative person trips, for the purpose of demonstrating lane utilization were cited equally as the most important performance measure by the areas interviewed. Quantification of lane utilization was typically considered important for one of three reasons:

1. To illustrate the productivity or efficiency of HOV lanes in terms of the lanes ability to move more people in fewer vehicles than adjacent general-purpose lanes – it comes down to how many people are using the lanes
2. To demonstrate the lanes are sufficiently utilized to address the perception of "empty lanes" – the vehicles are what people see;

3. To ensure optimal operational performance is maintained in areas where HOV lanes are approaching capacity and congestion in the HOV lanes is becoming problematic, or where lanes are not sufficiently utilized making capacity potentially available for other user groups.

In two of the three areas where occupancy data was not collected, resource limitations and labor intensive occupancy data collection techniques were identified as constraints to collecting and analyzing these data. Several area representatives noted a desire for the development of automated occupancy data collection technology to enhance their data collection programs.

HOV lane average travel speed, travel time and/or travel time savings were measured in two thirds of the areas sampled. Travel time savings was cited as the most important performance measure for the one area that did not indicate volume or person trips as the most important measure, although several other area representatives did acknowledge travel time as an important measure. Where travel time savings was cited as the most important performance measure, the need to quantify and demonstrate reliable and consistent time savings was the principle consideration. In Houston, where travel time savings had previously been measured, but are not quantified as part of the current HOV system monitoring program, resources constraints were cited as the prohibitive limitation on travel time data collection.

The balance of the measures identified address the particular needs and interests of the respective areas, and more importantly, the availability of sufficient resources to collect and analyze appropriate data. Financial and labor resource limitations were cited exclusively as the reason for not collecting and analyzing a particular performance measure. In some cases, technological improvement in data collection was identified as an appropriate mechanism to partially overcome labor resource limitations.

Chapter 13 of the HOV Systems Manual outlines a range of performance thresholds for each of the measures of effectiveness discussed. In most cases, these threshold ranges are applied by the areas represented to assess their respective area HOV system performance. However, the experience of some areas has indicated the need to further review and refine select performance thresholds. In particular, HOV minimum and maximum lane volume thresholds, and travel time savings have been identified as candidates for further threshold refinement. Additionally, performance measures such as safety and air quality have presented a challenge for assessment as part of an HOV monitoring program. Traditional methodologies for recording safety data and evaluating the air quality impact of transportation facilities are not sufficiently detailed to distinguish benefits at the HOV facility level. Further refinements in evaluation methodologies are necessary to ensure HOV facilities can be definitively evaluated using these performance measures.

The measurement of the duration of congestion and the measurement of lane density were two unique performance measures identified by area representatives as those they would like to pursue should technology and resources allow in the future. The measurement of the duration of congestion was cited as a mechanism to better evaluate the effectiveness of carpool lanes to affect the magnitude of congestion in adjacent general-purpose lanes. Lane density was identified as a measure to help determine the optimal operating capacity of carpool lanes.

Frequency of Data Collection, Analysis and Reporting

As could be expected, the frequency of data collection, analysis and reporting varied by area, although all areas met the HOV Systems Manual guidance for data collection frequency for the measures they were addressing. In most cases, data collection frequencies were consistent with the desirable frequency identified in the NCHRP report.

The increasing availability of automatic vehicle counters has made the continuous collection of volume data possible in most of the sample areas. The ability to collect volume data automatically maximizes limited resources and as a result, volume data forms the basis of all HOV monitoring programs. These volume data are typically supplemented with other more labor intensive data to collect such as occupancy, travel time, public opinion and violations, which are collected at more infrequent sample intervals.

The use of technology to further automate data collection was cited by many area representatives as a priority for improving HOV system monitoring and reducing effort and cost. Specifically, the automation of travel time and vehicle occupancy data collection was identified as a means for reducing resource demands for HOV performance monitoring. The availability of automated data collection technology provides for data to be collected at more regular intervals thereby increasing data sample frequency so they can be more representative of actual conditions. More regular data samples in terms of frequency and number of samples also provides the opportunity to more easily calculate measures such as HOV VMT, reliability and duration of congestion.

Data analysis is most often completed on an as needed, quarterly or biannual basis. The interval for data analysis tends to be driven by one of two factors; the interval for collection of supplemental data necessary to support the analysis, or an institutional need to review data and analysis results.

Data are archived by all area areas interviewed using a combination of electronic database, spreadsheet and hard copy formats. Archiving summary data in spreadsheet format is the most common method for archiving data. The use of electronic database applications is exclusively used to archive the large amounts of volume data that is collected using automated vehicle counting equipment. Most areas indicate they have archived data available from the inception of their area programs, although changing technologies and data archive formatting was noted as a limitation to the availability of some older archived data.

Reporting of data for the majority of the sample areas is equally divided between quarterly and annually. In the two areas with the most basic monitoring programs, Denver and San Diego (I-15 HOT lanes), analysis results are not reported but are reviewed and archived for institutional use.

Published HOV systems monitoring reports typically consist of a consolidated set of tables and charts illustrating the data analysis results. In the simplest form, HOV monitoring reports are presented as summary fact sheets for areas with limited facilities and performance measures. More extensive monitoring reports generally provide detailed results for each HOV facility and each performance measure evaluated as part of a regional system, and include limited interpretive text.

With the evolution of the internet, several areas now publish their HOV analysis results online. Table 4 details the Uniform Resource Locator (URL) for websites presenting HOV analysis results. In many areas where analysis results are currently not available online, efforts were underway to make information available in the near future.

Cost, Funding and Staffing

The variations in the complexity and extents of HOV systems monitoring is similarly reflected in the estimated annual cost of the program. Generally the cost of volume data collection is absorbed by regional freeway volume data collection and traffic monitoring programs conducted by area transportation departments. The cost of supplemental data collection, data analysis and reporting activities are typically those costs associated with HOV monitoring programs.

The approximate annual cost of the HOV system monitoring programs sampled range from $10,000 to $450,000, with an average of $160,000 and a median of $88,000. As could be expected, the costs of the most basic programs were the least expensive, with cost generally increasing as the programs become more comprehensive and complex.

The most notable exception to the cost/complexity relationship is the Houston HOV monitoring program, where a relatively comprehensive program is accomplished for approximately $60,000 per year. The ability to conduct the Houston program at a relatively low cost is reflective of the use of automated data collection and automated database analysis techniques. For the Houston program, an automated Statistical Analysis Software (SAS) application has been used since the inception of the program in the early 1980's.

In addition to automated data collection, sharing data collected for other purposes, analyzing data for a representative sample of locations and identifying a targeted range of appropriate performance measures have been successfully applied to simplify HOV performance monitoring efforts and minimize costs. Recent efforts in Southern California have demonstrated that the effective use of data sampling and the analysis of targeted key measures can be sufficient to successfully demonstrate HOV system performance where limited resources are available. In many cases, expanded data coverage and the analysis of excessive performance measures translates into more difficulty in identifying, interpreting and communicating system performance results.

Funding for HOV system monitoring is almost exclusively from State Department of Transportation funding categories or programs. Exceptions to the use of state funding sources include the use of MPO or local transit sales tax revenues, and toll revenues. The limited availability of additional funding resources is most often cited as a constraint to the expansion of HOV system monitoring programs.

Staffing for HOV systems monitoring is divided between agency staff and contracted staff at a ratio of seven to four for the areas represented. State Department of Transportation and MPO staff are responsible for conducting HOV system monitoring efforts in all areas except those in the Texas and Washington. Contractor services are utilized in both Texas and Washington, with three of the four areas using respective State University research group staff services.

Supplemental HOV Performance Monitoring Efforts

In addition to ongoing HOV system monitoring efforts, three areas have recently completed supplemental HOV monitoring efforts. Two areas, Boston and Denver, have recently completed one-time evaluation efforts to assess specific performance measures in addition to those evaluated on an ongoing basis. In the case of Boston, an evaluation of the air quality impacts of HOV lanes was completed in accordance with state legislative requirements. In Denver, an evaluation of travel time savings and air quality impacts was completed to assess the suitability of converting existing HOV lanes to HOT lanes.

The most notable recent supplemental evaluation effort was the Los Angeles County HOV Performance Program. The Los Angeles County Metropolitan Transportation Authority (LACMTA) HOV Performance Program expanded on the ongoing Caltrans HOV system monitoring program to complete a detailed, comprehensive evaluation of the nation's most extensive HOV system. In addition to the volume, occupancy, travel time and violation information evaluated as part of the Caltrans program, the LACMTA program also included consideration of transit utilization, air quality impacts, accidents, benefit-cost, and public opinion. The HOV Performance Program addressed each of the HOV objectives described in the HOV Systems Manual, while also addressing State legislated and MPO adopted HOV goals and objectives.

The LACMTA study involved the evaluation of a variety of operational performance measures primarily using spreadsheet calculation supplemented with a database application for data management. The study also included a detailed market research component to assess public opinion using a range of survey techniques. The findings of the HOV Performance Program along with the ongoing Caltrans monitoring efforts will be used as a basis for ongoing performance monitoring, planning future HOV system investments and changing HOV operating policies in Los Angeles County.

Data limitations, particularly the lack of historical trend data and inconsistent data sets, were cited as concerns during the conduct of the HOV Performance Program. Limitations in the existing automated data collection, data archiving and data reporting systems for Los Angeles County were the primary constraint to the program evaluation. These data limitations highlight the need for future improvements in automated data collection and archiving technology.

EFFECTIVENESS, LIMITATIONS AND UNIFYING THEMES OF HOV MONITORING AND EVALUATION

Effectiveness of Monitoring to Address HOV Goals and Objectives

The HOV Systems Manual outlines the "clear articulation" of HOV goals and objectives as the first step in the development of a monitoring and evaluation program. The definition of goals and objectives is critical, as the monitoring program should be designed to obtain and evaluate information that will be used to determine if the objectives have been achieved*(2)*. In a sense, the definition of appropriate goals and objectives can help to focus the subsequent monitoring efforts.

While many areas have defined HOV goals and objectives, these have typically been developed during the planning and policy development phases of the HOV facility project, and

have not been developed with the specific purpose of guiding the monitoring of system performance. Furthermore, there generally seems to be an institutional oversight or reluctance to revisit and change HOV goals and objectives to respond to changing performance needs as HOV systems expand and mature over time. The review of ongoing monitoring efforts has revealed that there is often disconnect between the defined HOV goals and objectives, and performance monitoring. This situation leads to the development of a monitoring program that does not focus on appropriate expectations for the HOV facility, but is instead structured in consideration of resource limitations and institutional need. The result is an inherent difficulty in adequately addressing issues and concerns regarding the performance of the HOV system, highlighting the need for clearly articulated goals and objectives.

Limitations

The limitations for HOV performance monitoring and evaluation most often fall in the category of resource limitations. Although many areas now utilize automated counting equipment to collect volume data, limited financial and labor resources constrain many areas' ability to gather more labor intensive supplemental data. Several of the areas cited labor intensive data collection as the primary constraint to HOV system monitoring. In particular, the collection of occupancy data using visual observation, and the collection of travel time data using "floating vehicle" travel time runs are identified as the most labor intensive and costly elements of data collection programs, highlighting the need to automate these collection methods as technology permits.

The ability to access limited funding resources was identified as a challenge for several area representatives. While many area programs rely on state gasoline tax revenues to support ongoing monitoring efforts, several areas noted shifts in their respective funding sources as competition for gasoline tax revenues increases. Several areas already utilize alternative funding sources such as local sales tax revenues and toll revenues to support HOV monitoring and evaluation, along with other operational needs such as enforcement. It has been suggested that the USDOT consider expanding the use of federal funding to support ongoing HOV lane monitoring, evaluation and enforcement, which are all integral to successful facility operations.

The evolution of electronic technologies has provided significant improvements in the ability to collect certain data automatically, but has also created limitations as a result of differing software and hardware formats, and the need to check, archive and evaluate large quantities of data. The ability to access historical data and the reliability of data samples was questioned by several area representatives. With the authorization of TEA21, and in particular the National ITS Architecture requirements, the USDOT has recognized the need to coordinate and standardize technologies and procedures for ITS. It will be necessary to ensure that the ITS architecture considerations extend to monitoring and reporting activities to ensure reliable and compatible data is collected, synthesized and archived in support of ongoing performance evaluation efforts.

All of the areas conducted HOV system monitoring, typically including a comparison of current and recent performance trends for HOV lanes and general-purpose lanes and freeway corridors within their region. However, none of the areas represented addressed comparative findings with other areas to validate local area performance. This situation is reflective of the disparity in performance monitoring and evaluation between areas and the inconsistencies in data collection techniques, performance measures and analysis methodologies. To provide for a

better comparison of HOV system performance between areas, consideration needs to be given to a consistent range of data and performance measures. With the implementation of ITS Architecture principles to coordinate and standardize data collection techniques, performance measures and evaluation methodologies, an HOV system monitoring "clearinghouse" could be established to provide a resource to facilitate the sharing of information and comparison of HOV system performance between areas.

For some areas, regulatory requirements devised by non-transportation entities have lead to redundant monitoring efforts or the inability to attain unrealistic HOV goals and objectives. The need to respond to inappropriate or misguided legislated requirements has detracted from the ability of some areas to address appropriate goals and objectives, and results in a strain on limited system monitoring resources. In some cases, HOV system monitoring is limited from generating the best information due to the need to respond to legislative and institutional requirements.

HOV Systems Operational Changes

In many cases, HOV system monitoring has lead to changes in systems planning and operations. Observed HOV lane volumes are used extensively as a basis for future facility planning decisions, including the calibration of regional models used to evaluate future HOV facilities. Evaluation results are also applied to contemplate the implication of operational policy changes, such as minimum occupancy and hours of operation.

Information derived from the monitoring of HOV lane volumes has lead to changes in hours of operation, minimum vehicle occupancy requirements, and ingress/egress point or termini locations on many facilities to ensure lanes operate at maximum efficiency. In San Diego, HOV lane volume information is also used to determine the appropriate toll for non-HOV users of the I-15 HOT lanes in order to regulate lane demand. The application of HOV system monitoring findings to maximize lane efficiency represents the most immediate benefit of a comprehensive monitoring and evaluation program.

HOV system monitoring information has also been used by many areas to defend current operation policies, and to refute common misconceptions regarding public support and perceived utilization of the lanes. Attitudinal survey results from the LACMTA HOV Performance Program revealed overwhelming public support for the provision of HOV lanes, despite the apparent vocal opposition to these facilities by select interest groups and elected officials. Furthermore, monitoring results from many areas have affirmed the universal HOV goal of moving more people in fewer vehicles, with HOV lanes successfully accommodating more person trips than adjacent general-purpose lanes in the same freeway corridor.

Unifying Themes

Having considered the state of the practice in HOV system performance monitoring, it is evident that there are several unifying themes that apply to the areas sampled. At the most fundamental level, all areas conduct some form of HOV system performance monitoring, most often considering measures such as lane volume, average vehicle occupancy and travel time to assess HOV facility performance. However, despite the broad application of HOV system performance monitoring, there is often disconnect between HOV system goals and the performance measures being evaluated. There is a need for many areas to revisit HOV system goals and objectives to

achieve consensus on realistic goals and objectives as the basis for performance monitoring. Equally important is the need to periodically revise HOV system goals and objectives to reflect changing HOV system performance characteristics and needs, particularly as systems expand and mature.

Information derived from HOV performance monitoring programs is used widely to respond to scrutiny of HOV facilities reiterating the importance of structuring performance monitoring activities to specifically address HOV system goals. Additionally, performance monitoring information is used as a basis to adjust operational policy and facility design to maximize performance. Hours of operation, minimum occupancy requirements, and facility termini, ingress and egress locations have been adjusted in many areas on the basis of HOV system performance monitoring information.

Resource limitations have been cited uniformly as a challenge to ongoing HOV system performance monitoring. Where appropriate, automated data collection, data sharing and data sampling can be applied to maximize limited resources. HOV performance measures should be targeted and monitoring programs simplified to specifically address system goals. The use of superfluous performance measures or overly complicated evaluation methodologies simply leads to more difficulty in identifying, interpreting and communicating system performance results.

CONCLUSIONS AND RECOMMENDATIONS

Existing HOV Performance Monitoring and Evaluation

Monitoring of the HOV system was an ongoing activity in all of the areas sampled, although the degree and complexity of the monitoring activities varied greatly. In the simplest form, HOV system monitoring involves the collection, review and archiving of lane volume data. In the most complex form, ongoing monitoring efforts include the collection, tabulation, analysis and reporting of performance data for a variety of measures including lane volumes, travel times, average vehicle occupancy, violation rates, incidents, transit utilization, park-and-ride utilization, and public opinion.

While all of the areas sampled conducted HOV system monitoring for within their respective jurisdiction, none of the areas compared their findings with those of other areas to validate local area system performance. This situation reflects the inconsistencies in data collection techniques, performance measures and analysis methodologies between areas. To provide for the comparison of HOV system performance between areas, an analogous range of data collection techniques and performance measures needs to be considered. Furthermore, an HOV system monitoring “clearinghouse” could be established to provide a centralized resource to facilitate the exchange of HOV system performance data between areas.

Appropriate Goals and Objectives

Despite the guidance of the HOV Systems Manual and other HOV literature, the clear articulation of goals and objectives as the basis for performance monitoring is deficient in many areas. While most areas have defined HOV planning and policy development goals and objectives, there does not appear to be a direct relationship between these defined goals and objectives and monitoring efforts. For most areas, performance monitoring efforts are structured by resource limitations and political or institutional need.

Example HOV performance objectives have been defined in a number of literary sources, including the HOV System Manual. The most commonly defined objectives are as follows:

1. Move more people by increasing the average vehicle occupancy.
2. Provide reliable travel times and travel time savings for HOV lane users.
3. Do not unduly impact the operation of the freeway corridor.
4. Defer the need to increase freeway capacity by increasing the per lane efficiency of the freeway corridor.
5. Increase the operating efficiency and economy of transit services.
6. Provide favorable air quality and fuel consumption impacts.
7. Be safe and not unduly impact the safety of the freeway corridor.
8. Provide a cost-effective transportation improvement.
9. Have public support.

Although each of the proceeding objectives offers credible expectations for the performance of an HOV facility, not all objectives necessarily apply to each area. In addition, regional transportation goals sometimes justify the inclusion of differing objectives for a local HOV facility. In either case, it is critically important for each area to assess their current HOV performance goals and objectives to ensure that an appropriate set of goals and objectives are clearly articulated as the basis for ongoing monitoring and evaluation. Goals and objectives need to be realistic to the intent of the HOV investment made and must not be overreaching in expectations.

Appropriate Performance Measures and Thresholds

With the adoption of appropriate HOV performance goals and objectives, and the development of a consistent range of HOV performance measures, it will be possible for individual areas to apply appropriate performance measures and thresholds to determine the effectiveness of their system performance. The use of consistent performance measures and thresholds will also provide for the assessment of regional HOV facilities in the context of systems nationwide.

Chapter 13 of the HOV Systems Manual prescribes a variety of performance measures of effectiveness and threshold ranges for the nine most commonly defined HOV performance objectives. These performance measure and threshold ranges have typically been applied as part of HOV system monitoring efforts. As appropriate, these performance measures and threshold ranges should continue to be applied to evaluate the effectiveness of HOV system. The threshold ranges should be reviewed and refined in consideration of the experiences of previous monitoring efforts. The refinement of HOV performance measure and threshold ranges is necessary to ensure that appropriate evaluation methods and thresholds are being used to assess HOV system performance.

Future Resource Needs

Clearly the availability of sufficient financial and labor resources to support ongoing HOV system monitoring activities is the most immediate future need. Increased competition for limited state gasoline tax revenues has resulted in reduced priority for HOV system monitoring, leading to the application of alternative funding sources to support monitoring efforts. The use of alternative funding sources, such as local transit sales tax revenues and toll revenues, should continue to be investigated as an option to state gasoline tax revenues. In addition, USDOT

should consider expanding the use of federal funding programs to support ongoing HOV lane monitoring, evaluation and enforcement, which are all integral to performance of these facilities.

Alternatively, financial and labor resource needs can be offset by the increase automation of labor intensive data collection and the simplification of data analysis activities. The USDOT should continue to coordinate with state and local agencies to accelerate the development and implementation of new technologies to support systems monitoring. The National ITS Architecture prescribed in TEA21 has established a framework for coordinating the development of compatible ITS technologies. The provisions of the National ITS Architecture should be expanded to explicitly reference the development and application of automated data collection and management technologies for HOV and other system monitoring efforts.

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REFERENCES

1. Web Page
   Federal Highway Administration, *Federal-Aid Highway Program Guidance on High Occupancy Vehicle (HOV) Lanes*, United States Department of Transportation, Washington, D.C., March 26, 2002.
   http://www.fhwa.dot.gov/operations/hovguide01.htm. Accessed June 12, 2002.
2. Book
   National Cooperative Highway Research Program, *HOV Systems Manual, Report 414*, Transportation Research Board, National Research Council, Washington, D.C., February 1998.
3. Book
   Fuhs, Charles A., *High-Occupancy Vehicle Facilities – A Planning, Design and Operation Manual*, William Barclay Parsons Fellowship, Parsons Brinckerhoff Quade and Douglas, Inc., December 1990.
4. Government Report
   United States Department of Transportation, *Management and Monitoring Systems; Final Rule*, Part III, 23 CFR Part 450, et al., 40 CFR Parts 613 and 614, Federal Register, Volume 61, Number 245, National Archives and Records Administration, Washington, D.C., December 1996.
5. Government Report
   United States Department of Transportation, *Intelligent Transportation System Architecture and Standards; Final Rule*, Part IV, 23 CFR Part 655 and 940, Federal Register, Volume 66, Number 5, National Archives and Records Administration, Washington, D.C., January 2001.
6. Book
   Texas Transportation Institute, *Suggested Procedures for Evaluating the Effectiveness of Freeway HOV Facilities*, Texas Transportation Institute, College Station, Texas, August 1990.
7. Government Report
   Legislative Analyst Office, *HOV Lanes in California: Are They Achieving Their Goals?*, Sacramento, California, January 2000.
8. Book
   Stockton, W. R., G. Daniels, D. A. Skowronek and D. W. Fenno, *ABC's of HOV - The Texas Experience*, Texas Transportation Institute, College Station, Texas, September 1999.
9. Government Report
   Metropolitan Washington Council of Governments National Capital Region Transportation Planning Board, *1998 Performance of Regional High-Occupancy Vehicle Facilities on Interstate Highways in the Washington Region – An Analysis of Person and Vehicle Volumes*, Metropolitan Washington Council of Governments, Washington, D.C., April 21, 1999.

LIST OF TABLES

TABLE 1 HOV Goals and Objectives

Area Scope	HOV Goals and Objectives

National *(1)* (FHWA)	• Move more people in fewer vehicles
	  • Provide travel time savings
	  • Provide reliable and predictable travel times

State of California *(7)*	• Increase people-moving capacity • Reduce congestion • Provide travel time and cost savings • Increase system efficiency • Improve Air Quality
Minneapolis, Minnesota *(3)*	• Maximize people-moving capacity • Provide support for bus services and rideshare programs
State of Texas *(8)*	• Increase people per vehicle • Preserve person-movement capacity • Enhance bus operations
State of Washington *(3)*	• Maximize people-moving capacity • Mitigate transportation related pollution • Reduce fuel consumption
Washington, D.C. *(9)*	• Increase people per vehicle • Preserve person-movement capacity • Enhance bus transit operations • Support air quality improvements • Provide predictable travel times

TABLE 2 Suggested Objectives and Measures of Effectiveness*(2)*

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

TABLE 3 HOV System Monitoring Area Performance Measures

Area	Volume	Speed/Time	Classification	Occupancy	Transit	Park and Ride	Reliability	Incidents	Violations	Public Opinion
Boston	X	X	X						X	
Dallas	X	X		X	X	X				
Denver	X									
Houston	X		X	X		X				
Los Angeles County	X	X	X	X					X	
Minneapolis	X			X	X					
San Diego[a]	X									
San Francisco Bay	X	X		X					X	
Seattle	X	X		X	X		X			
Suffolk/Nassau Counties	X	X	X	X						
Vancouver	X	X		X				X	X	X

[a] San Diego measures for I-15 HOT lanes only.

TABLE 4 HOV System Monitoring Results Websites

Area	Uniform Resource Locator[a]
Denver[b]	http://www.valuelanes.com
Los Angeles County	http://www.dot.ca.gov/dist07/aboutdist7/hov_info.shtml
San Francisco Bay	http://www.dot.ca.gov/dist4/d4hwops/01HOVReport/01HOV_intro.htm
Seattle	http://depts.washington.edu/trac/reports/reports.html
Suffolk and Nassau Counties	http://www.dot.state.ny.us/reg/r10/hov10.html
Vancouver	http://www.rtc.wa.gov/hov/evaluation.htm

[a] URLs current as of October 31, 2002
[b] Denver online analysis results for HOT lane study.