A Review of HOV Lane Performance and Policy Options in the United States

FINAL REPORT

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The report provides an assessment of performance of existing HOV lane facilities in the United States, and explores policy alternatives and effects related to conversion of existing HOV lanes to HOT lane operations. The report includes sketch planning tools for exploring policy alternatives, and is intended for an audience of transportation professionals responsible for planning, designing, funding, operating, enforcing, monitoring, and managing HOV and HOT lanes, and other stakeholders in policy decisions for improving HOV lane and highway mainline operations through conversion to HOT lanes.</td></tr>
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EXECUTIVE SUMMARY

High-Occupancy Vehicle (HOV) lanes are common throughout the United States. There is a growing body of evidence suggesting that efficient and effective management of existing HOV lanes is both achievable and sustainable through applications including managed lanes and electronic toll collection. However, development and implementation of effective HOV strategy and policy has involved challenges that include planning and design issues, stakeholder concerns, and less than optimal performance. There is a need to obtain a better understanding of the experience and factors that contribute to successful HOV lane performance.

HOV owners nationwide were contacted to discuss the performance of existing HOV lanes, if and why owners are considering policy changes, and what are the future expectations. Based on respondents representing 10 states and over 70 HOV facilities, the primary objectives of HOV lanes are to maximize person throughput, manage congestion, and provide an option for travel time savings and reliability. Over 80 percent of respondents actively monitor system performance. Most respondents indicate that HOV lanes are currently meeting performance objectives. For HOV lanes that are not performing adequately, the primary concerns are overcrowding, low speeds, lack of a continuous system, and enforcement issues.

The next study task involved assessing the impacts of pricing and other policy shifts on the operational performance of the nation's HOV lanes. A sketch planning tool was developed to evaluate the effects of policy on operational performance and measures of financial feasibility. The tool involves conducting the following steps – 1) Assess existing HOV facility operations, 2) Define opportunities for HOV policy changes, 3) Evaluate potential impacts, and 4) Compare impacts relative to specified objectives. The sketch planning tool provided a quantifiable, useful approach to measuring the impacts of HOV policy changes on facility performance.

Many HOV facility owners are interested in policy changes, often influenced by performance, political interest, and public opinion. Changing commute and congestion levels dictate the need to consider such policy changes on an ongoing basis. A policy options evaluation tool was developed to help HOV owners consider a range of potential policies, including changing occupancy requirements and managed lane pricing. How the performance objectives are defined greatly influences the optimal policy changes that should be considered. Every HOV lane is unique in its demand and operations, and the locally-specific context must be carefully taken into account.

SECTION 1: INTRODUCTION

High-occupancy vehicle (HOV) lanes are reserved for vehicles with a driver and one or more passengers. In some cases, other vehicles are also exempted (permitted in the HOV lanes). Examples include motorcycles, transit and charter buses, emergency and law enforcement vehicles, low emission vehicles, hybrid or alternative fuel vehicles, and/or single-occupancy vehicles (SOVs) with a toll. These lanes, which usually run parallel to general-use highway lanes, have been implemented in over 30 US metro areas since they first appeared in the late 1960s and early 1970s. HOV lanes were originally conceived as a means to encourage carpooling and therefore increase person throughput in the transportation system, among other potential benefits like providing reliable transit trip times and increasing roadway capacity while benefiting air quality. The restrictions in these lanes limit traffic demand, which can provide travel time savings along a corridor when compared to adjacent general-use lanes. This travel time advantage is an incentive to drivers to form carpools in order to bypass congestion. Today, there are nearly 350 HOV facilities operating or planned across 20 states.

Unfortunately, HOV lanes do not always provide the expected advantages. Situations frequently arise in which the facility operates with too many (or too few) vehicles during lane operation periods, leading to a number of potential problems. Empty-lane syndrome, the popular term for a condition in which HOV lanes are underutilized, is one common concern. Peak-hour congestion in HOV lanes is another. Striking the proper utilization balance is a challenge for all HOV operators. Add to that the issues that stem from peak directional flows, and the efficient operation of HOV facilities becomes even more complicated. Agencies seeking to avoid or mitigate these lane performances problems will often consider and implement HOV lane policy change as a solution. .

Not all policy changes are motivated by operational difficulties, however. Other motivations for such change include maximizing system throughput, revenue generation (in the case of high occupancy toll (HOT) lanes), and legislative mandate. Opportunities for getting more vehicles through a particular corridor almost always exist, and changes to HOV policies can help to realize throughput gains. Implementation of tolling on HOV lanes can also provide revenue for lane maintenance or expansion, transit improvements, or other purposes in the region. Legislation can also drive policy change. HOV operators are currently required to consider policy changes if average speeds in the HOV lanes drop below 45 mph for 90 percent of the time over a consecutive 180-day period during the weekday peak periods (23 USC. 166 (d)(2)(B). And some operators have had to adjust their policies based on laws that allow hybrid vehicles to use the lanes without charges. Finally, Federal initiatives, such as the Value Pricing Pilot Program and the Urban Partnership Agreement, encourage pricing experimentation and have in some cases included policy changes to existing HOV lanes to serve as tests leading to wider implementation.

This study examined the performance of HOV lanes with regard to the goals and objectives under which existing HOV lane facilities were deployed. Also addressed are factors that can best contribute to the success of HOV lanes, through targeted and focused outreach to HOV operators. Identification and improved understanding of these factors can contribute to effective policy change decisions that improve performance of existing and future HOV facilities.

The study consisted of the following four tasks:

- **Task 1: Prepare a Detailed Work Plan.** This task involved conducting a project kick-off meeting and preparing a detailed work plan that articulates the approach and strategies employed to achieve the study's goals and objectives. The work plan outlined key topic areas and described an overall approach to assembling the information critical to understanding the relationship between operations, policy, and performance.
- **Task 2: Assemble Available Data and Perform Analysis of the Performance of Existing HOV Lanes in the United States.** The purpose of this task was to develop an understanding of HOV lane success factors and what forces will raise expectations of HOV lanes in the future. This task consisted of the following subtasks: Conduct Inventory of HOV Programs and Operations; Develop Screening Criteria for Identification of Critical Partners; Assess the Performance of HOV Investments; and Prepare Task Documentation.
- **Task 3: Assemble Available Performance Data and Analyze the Impacts of Increasing Occupancy Requirements.** The purpose of this task was to develop a policy options evaluation tool in order to quantify the effects of HOV policy changes on operational performance and measures of financial feasibility. This task included the following subtasks: Organize and Consolidate Critical Success Factors; Develop Policy Drivers and Performance Targets; Develop Policy Options Evaluation Tool; Use the Policy Options Evaluation Tool to Quantify the Impacts to Operational Performance and Financial Impacts; Establish Relationships between HOV Lane Operating Performance and Policy Drivers; and Prepare Technical Documentation.
- **Task 4: Final Documentation.** This task involved packaging the main study outcomes into a Draft Final Report for FHWA review, then a Final Report that incorporates comments received.

The remainder of this report is organized according to the following sections:

- **Section 2: Operational Description of the Nation's HOV Lanes.** Contains summary information from the HOV Lane Compendium, prepared as a deliverable for Task 2, documenting the basic characteristics of current and proposed High-Occupancy Vehicle (HOV) lanes throughout the United States. This includes information on the number of facilities, date opened and status, operating characteristics, and operating performance.
- **Section 3: HOV Lane Operator Survey Results.** Provides findings from an online survey of HOV lane operators and in-depth interviews with a subset of HOV facility critical partners to discuss their experiences, challenges, and success factors. This includes information on system goals and objectives, performance monitoring, HOV system performance, plans to revisit goals, HOV lane operational policies and policy changes, policy change motivations, and policy implementation success factors.
- **Section 4: Policy Options Evaluation Tool.** Describes the Policy Options Evaluation Tool for Managed Lanes (POET-ML), developed to help HOV owners consider a range of potential HOV lane policies including changing occupancy requirements and managed lane pricing. This includes information on the tool's purpose, framework, user inputs, and evaluation of potential impacts.
- **Section 5: Conclusions.** Provides the characteristics and lessons learned that increase the chances for successful implementation of HOV lane policy changes.

SECTION 2: OPERATIONAL DESCRIPTION OF THE NATION'S HOV LANES

The intent of the HOV Lane Compendium deliverable was to document the basic characteristics of current and proposed High-Occupancy Vehicle (HOV) lanes throughout the United States. Data sources used were the HOV Facility Inventory (a database maintained by the FHWA HOV Pooled Fund Study, last updated in March 2007) and discussions with select HOV facility critical partners.

Summary information from this compendium is provided next. This information is grouped into the following subsections: Number of Facilities; Date Opened and Status; Operating Characteristics; and Operating Performance. The HOV Lane Compendium itself is provided as a separate deliverable.

Number of Facilities

By State. A total of 345 HOV facilities are contained in this inventory. California is the state with the most HOV facilities, at 88. This is followed by Minnesota with 83 facilities, Washington State with 41, Texas with 35, and Virginia with 21.

By Region. The region with the most HOV facilities in the inventory is the Twin Cities (Minneapolis-St. Paul) with 83. This is followed by the San Francisco Bay Area with 47, the Puget Sound (Seattle-Tacoma) with 40, Los Angeles with 23, and Houston with 21.

By Responsible Agency. The agencies responsible for the most HOV facilities in the inventory are the California Department of Transportation (Caltrans) and the Minneapolis DOT, both with 83. This is followed by the Washington State DOT with 38, the Metropolitan Transit Authority of Harris County in Texas with 21, and the Virginia DOT with 19.

Date Opened and Status

Date Opened. The I-395 HOV lanes in Virginia between Washington DC and the Capital Beltway are listed as the oldest HOV facilities, having opened in 1969. Several more HOV facilities opened in the 1970s. The majority of HOV facilities in the inventory began operation within the past 25 years (from the early 1980s to present).

Status. Of the 345 HOV facilities in the inventory, 301 (87 percent) are open and in operation. Ten facilities (3 percent) are being planned, 15 (4 percent) are in the design or environmental review phase, 14 (4 percent) are under construction, and the remaining five (1 percent) were constructed but are currently inactive.

Operating Characteristics

Number of HOV Lanes. The vast majority of HOV facilities have one HOV lane in each direction. The only active facility with two HOV lanes in each direction is I-110 between Adams Blvd and SR 91 in Los Angeles, California. Seven other facilities with two HOV lanes in each direction are being planned, under construction, or operating – One in Florida: I-95 between downtown and the Golden Glades interchange in Miami; three in Texas: SR 183 between I-35W and Loop 12 in Dallas, Hempstead Highway between SH 99 and I-610 in Houston, and SR 288 between SH 518 and US 59 in Houston; one in Utah: I-15 between Provo and I-215 in Salt Lake City; and two in Virginia: the I-495 Capital Beltway in the Washington DC region and the I-95/I-395 between Fredericksburg and Arlington.

Length. The longest active HOV facilities are I-95 between SR 112 and Gateway Blvd in Miami, Florida (116.0 lane-miles, 58.0 route miles) and I-405 in Los Angeles County, California (105.2 lane-miles, 52.6 route miles). Two other HOV facilities are being planned or constructed that will exceed these in length on a lane-mile basis: the I-495 Capital Beltway in the Washington DC region in Virginia (224.0 lane-miles, 56.0 route miles), and I-15 between Provo and I-215 in Salt Lake City, Utah (128.0 lane-miles, 32.0 route miles).

Type. The most common type of HOV facility is Concurrent (Median), with 187 facilities (54 percent) falling into that category. Only four HOV facilities are Concurrent (Right Side): the I-95 approach to the George Washington Bridge toll plaza in New Jersey and three SR 520 facilities in Washington State which will be converted to the inside lane when the SR 520 bridge is replaced.

In the Twin Cities, Minnesota, 77 of the 83 HOV facilities in the region are bus-only shoulder lanes. In Houston, Texas, 13 of the 21 HOV facilities in the region are concurrent lanes on one-way urban arterials.

There are 37 reversible or contra flow HOV facilities nationwide. There are 15 HOV facilities that are separate roadways. The remaining HOV facilities are curb lanes, bus only lanes, other or unspecified.

Separation. The most common separation used for HOV facilities is Painted Stripe, with 118 (34 percent) falling into that category. There are 60 HOV facilities (17 percent) that use buffers. There are 45 HOV facilities (13 percent) that use barriers. Of those that use barriers, six are moveable barriers to facilitate reversible HOV lanes (H-1 in Honolulu, Hawaii; I-93 between Boston and Quincy in Massachusetts; I-278 between the Verrazano Bridge and Battery Tunnel in New York; I-495 between Maurice Ave and QM Tunnel in New York; and two I-30 facilities in Dallas, Texas – one that is open and another that is under construction).

In the Twin Cities, Minnesota, the 77 bus-only shoulder lanes are separated by a traveled lane edge line with signage. In Houston, Texas, the 13 concurrent lane facilities on one-way urban arterials are separated by a dashed line with “broken diamond” pavement markings. Standard dash lines are used for 9 facilities, which are all arterials.

Cones or pylons are used for two facilities in Honolulu, Hawaii (Kalanianaole Highway and Nimitz Highway), one facility in Union City, New Jersey (I-495 contra flow bus only lane), and one facility in Weehawken, New Jersey (local approach ramp to the Turnpike toll plaza). The remaining HOV facilities do not have the separation method specified.

HOV Eligibility. 185 of the HOV facilities in the inventory (54 percent) are purely 2+. There are 14 facilities (4 percent) that are purely 3+. There are two facilities that are 3+ during certain times of the day and 2+ during other times of the day – the I-10 El Monte HOV facility in Los Angeles, California and the Nimitz Highway in Honolulu, Hawaii.

There are six facilities that are open to 2+ HOV vehicles with no toll and to single-occupancy vehicles (SOVs) with a toll (i.e., 2+ high-occupancy toll (HOT) lanes): SR 91 between Riverside County and Orange County in Los Angeles, California; I-15 between SR 163 and SR 56 in San Diego, California; two in Denver, Colorado (I-25 between downtown and US 36, US 36 between Pecos St); and two in Salt Lake City (I-15 between 600 North and 14600 South, I-15 between 14600 South and University Parkway). Three additional 2+ HOT facilities are being planned: two facilities on I-680 in the San Francisco Bay Area, California and one on I-15 between 600 North and University Parkway in Salt Lake City, Utah.

There are two facilities that are open to 3+ HOV vehicles with no toll and to 2+ HOVs and SOVs with a toll (i.e., 3+ HOT lanes), both in the New York City region: I-495 between Maurice Ave and QM Tunnel and I-278 between Verrazano Bridge and Battery Tunnel. Four additional 3+ HOT facilities are in the planning or construction phase: I-40 between Durham and Raleigh in North Carolina; SR 183 between I-35W and

Loop 12 in Dallas, Texas; I-95/I-395 between Fredericksburg and Arlington in Virginia; and the I-495 Capital Beltway in northern Virginia.

Two facilities operate as 2+ HOT at certain times and 3+ HOT at other times, both in Houston, Texas: US 290 between I-10 and SH 6 and I-10 WB (SH 99 to I-610 & Studemont to CBD).

Five toll plazas in the San Francisco Bay Area, California are free to either 2+ or 3+ HOVs during weekday peak periods: the I-80 WB Bay Bridge (3+), the I-880 NB Bridge (3+), the I-80 EB Carquinez Bridge (3+), the SR 84 WB Dumbarton Bridge (2+), and the SR 92 WB San Mateo Bridge (2+). Three toll plazas in New Jersey are free to 3+ HOVs during weekday AM peak periods: I-95 approach to the George Washington Bridge in Ft. Lee, 12th St approach to the Holland Tunnel in Jersey City, and local approach ramp to the Turnpike toll plaza in Weehawken.

In the Twin Cities, Minnesota, the 77 bus-only shoulder lanes are restricted to buses only. There are 7 other bus only facilities in other states. The remaining HOV facilities in the inventory do not have occupancy requirements specified.

Special Fuel Eligibility. Several states allow hybrid or alternative fuel vehicles to use HOV facilities. In Arizona, owners of select hybrid vehicles may apply for special license plates that allow them to use HOV lanes. In California, owners of select hybrid vehicles were allowed to apply for license plate decals that allow them to use HOV lanes until 2011, capped at 85,000 decals (all 85,000 decals have been assigned). In Colorado, owners of select alternative fuel and hybrid vehicles may apply for license plate decals and transponders that allow them to use HOT lanes with no fee, capped at 2,000 (the cap has not yet been reached). In Florida, owners of select hybrid vehicles may apply for license plate decals that allow them to use HOV lanes. In New Jersey, drivers of select hybrid vehicles are allowed to use the Turnpike's HOV lanes. In New York, owners of select hybrid vehicles may apply for license plate stickers that allow them to use the Long Island Expressway's HOV lanes. In Tennessee, owners of select hybrid vehicles will be able to apply for license plate decals that allow them to use HOV lanes starting in January 2009. In Utah, owners of select hybrid vehicles may apply for special license plates that allow them to use HOV lanes until December 2010. In Virginia, owners of select hybrid vehicles may apply for special license plates that allow them to use most HOV lanes in the state (except I-95/I-395 during weekday peak periods).

Similar hybrid vehicle HOV legislation is currently being considered or has recently been considered in Connecticut, Georgia, Hawaii, Massachusetts, Michigan, Minnesota, Texas, and Washington State.

Hours of Operation. 140 of the HOV facilities in the inventory (41 percent) operate 24 hours a day, seven days a week. This includes the 77 bus-only shoulder lane facilities in the Twin Cities, Minnesota. 156 facilities (45 percent) operate on weekdays only during the AM peak, the PM peak, or both. The remaining HOV facilities do not have hours of operation specified.

Intermediate Access. 41 of the HOV facilities in the inventory (12 percent) allow continuous access, primarily in Northern California, Houston Texas, and Washington State. 180 facilities (52 percent) allow some intermediate access. 26 facilities (8 percent) allow no intermediate access, including select facilities in Arizona, Southern California, Connecticut, Hawaii, Massachusetts, New York, and Dallas Texas. The remaining HOV facilities do not have intermediate access specified.

Operating Performance

Utilization. Most of the HOV facilities in the inventory do not provide utilization data, so it is difficult to make definitive statements. Of the HOV facilities with utilization data provided, the one with the highest number of peak hour persons in the HOV lanes is the Route 495 Lincoln Tunnel Bus Lane in New Jersey, with 23,500 vehicles in the AM peak. The facility with the highest number of peak hour vehicles in the HOV lanes is I-5 NB between Northgate and S Everett in the Seattle Puget Sound region in Washington State, with 5,280 vehicles in the PM peak.

Peak Hour Violation Rate. Most of the HOV facilities in the inventory do not provide peak hour violation rate data, so it is difficult to make definitive statements. Of the 86 HOV facilities with data provided, the range is from 1 percent to 43 percent. The highest reported peak hour violation rates are I-15 between SR 163 and SR 56 in San Diego, California (43 percent), I-35W SB between 66th St and Burnsville Pkwy in the Twin Cities, Minnesota (37 percent), SR 54 EB between I-805 and SR 125 in San Diego, California (28 percent), and seven facilities in the Washington DC region, either in Maryland or Virginia (ranging from 17 to 28 percent). The other 76 HOV facilities with data provided reported peak hour violation rates of 15 percent or less.

Peak Hour Travel Time Savings. Most of the HOV facilities in the inventory do not provide peak hour travel time savings data, so it is difficult to make definitive statements. Of the 91 HOV facilities with data provided, the range is from 0.4 minutes to 37 minutes. The highest reported peak hour travel time savings are SR 85 NB in the San Francisco Bay Area, California (37 minutes), I-95 NB between Rte 234 and I-495 in the Washington DC region, Virginia (35 minutes), I-880 SB between Marina Blvd and Mission Blvd in the San Francisco Bay Area, California (31 minutes), US 101 SB between San Mateo Co and Cochrane Rd in the San Francisco Bay Area, California (30 minutes), and the I-10 El Monte HOV facility in Los Angeles, California (28 minutes). Seven other facilities report travel time savings of 20 minutes or more – I-110 in Los Angeles, California; I-210 in Los Angeles, California; I-405 in Los Angeles, California; SR 85 SB in San Francisco, California; Rte 495 in New Jersey, I-66 EB in Virginia; and I-395 SB in Virginia.

SECTION 3: HOV OPERATOR SURVEY AND INTERVIEW RESULTS

To understand the performance of HOV lane systems across the country, an initial survey of HOV lane operators was conducted in order to understand their goals, objectives, and current HOV lane performance based on monitoring efforts. The survey also explored policy changes that have been implemented or are planned to be implemented on HOV systems, as well as the reasons for making these changes and their impacts on lane performance. An online survey was developed and distributed to 74 HOV contacts across the country utilizing the Federal Highway Administration (FHWA) HOV Pooled Fund Study Database and other HOV resources including the Transportation Research Board (TRB) Committee on HOV Lanes and the Texas Transportation Institute, as well as networks of HOV professionals. The survey generated 28 responses representing 10 states and approximately 73 HOV facilities. The survey was supplemented with a review of existing data and follow-up conversations with additional HOV professionals and representatives of HOV operators.

Following the initial survey and literature review, in-depth one-on-one interviews were held with a subset of HOV operators who have experience in implementing various policy changes to discuss their experiences, challenges, and success factors. The objective was to understand how actual policy changes have impacted lane performance and under what conditions policy changes might be implemented in other areas to improve system performance. These discussions included representatives from Denver, Colorado; Houston, Texas; Minneapolis, Minnesota; Northern Virginia; San Diego, California; and the Puget Sound Region of Washington State.

Main findings from the survey and follow-up interviews are provided next. These findings are grouped into the following subsections: System Goals and Objectives; Performance Monitoring; HOV System Performance; Plans to Revisit Goals; HOV Lane Operational Policies and Policy Changes; Policy Change Motivations; and Policy Implementation Success Factors. The survey instrument and more detailed survey/interview comments are provided in a separate deliverable.

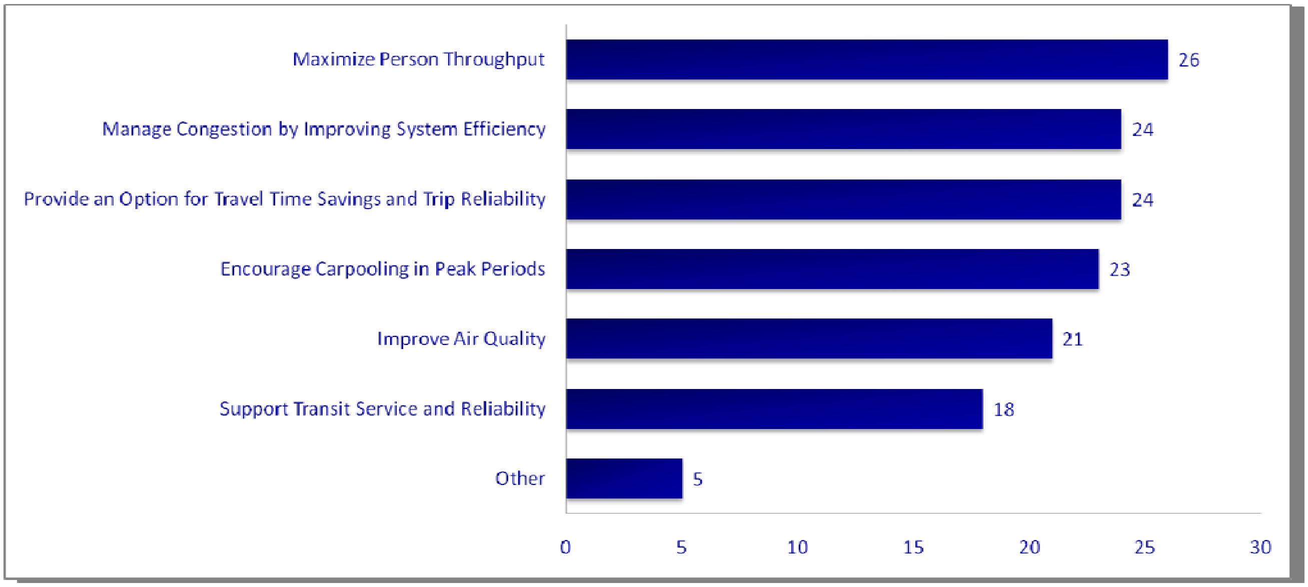
System Goals and Objectives

Respondents have indicated that while many HOV systems do not have officially adopted goals and objectives, most have goals and policies understood by operating and partner agencies and the urban areas of which they are part. Considerable similarity was found from one region to the next, incorporating six common objectives:

- Maximizing person throughput;
- Managing congestion by improving system efficiency;
- Providing options for travel time savings and trip reliability;
- Encouraging carpooling in peak periods;
- Improving air quality; and
- Supporting transit service and transit reliability.

Figure 3-1 summarizes survey responses relative to the goals and the intent of HOV systems. Some areas also note that the addition of HOV lanes was a means to add system capacity to accommodate regional growth under circumstances that will not permit the addition or expansion of general-use capacity. Others identify energy savings as an additional goal for their HOV systems.

Figure 3-1: Why did you add HOV lanes in your region? What are your HOV system goals?



Performance Monitoring

Eighty-two percent (82%) of survey respondents report that they monitor the performance of their HOV lanes. In most cases, the HOV lane operating agency is responsible for monitoring efforts. In some cases, partnerships with university research centers and third-party contractors or consultants are responsible for monitoring efforts. Performance criteria for HOV lanes most frequently include throughput (vehicular and/or person), travel time savings, and speed in the HOV lanes versus speed in the general-use lanes. Level of service is monitored almost as frequently. Other responses indicate the collection and analysis of data regarding accident rates, enforcement, transit performance and ridership trends, lane usage trends, and public opinion.

Performance measures and criteria generally relate to system goals and objectives. Therefore, systems identifying transit service as a priority, and/or are managed by a transit agency, may focus significant resources on monitoring transit-specific measures, while those who lack this focus do not. A measure such as public opinion has become increasingly important on systems where a pricing component (HOT lanes) has been implemented on a previously free HOV lane. Although most HOV systems do not specifically track public opinion, the monitoring of performance measures that clearly demonstrate a marked difference between the number of persons and vehicles in the HOV lanes versus the general-use lanes in an urban area, and the travel times and speeds in the HOV lanes versus the general-use lanes, have helped to generate public buy-in and support for lane operations in some urban areas. Effective communication of these measures can also be used to demonstrate that a policy change may be necessary to better utilize HOV assets in locations where they are not performing effectively.

Data collection methods vary from facility to facility and include both manual and automatic detection methods. Vehicle throughput (determined by traffic volume counts) and speed are typically collected through automatic detection devices such as traffic sensors and loop detectors. Person throughput and occupancy rates are determined through manual counts and visual survey. Enforcement data and violation rates are typically provided by the police or enforcement entity responsible for the HOV system. Travel time data collection frequently utilizes floating vehicle methods of collection by placing a transponder or GPS unit in cars or buses utilizing the HOV system. Other information, such as the number of hybrid vehicles that utilize an HOV system where this is permitted, may be collected from enforcement data, manual counts, or hybrid registrations (where applicable) to track their utilization of the system. This type of specialized information may not be regularly tracked, depending on available resources, but may be collected if there is a reason for the operating agency to investigate a particular type of system use that could impact a proposed policy change. Frequency of data collection is somewhat dependent on the method of collection and how often the operating agency queries automatic collection systems. Automatic measurement methods may be ongoing, while manual counts take place once or twice a year. Some agencies issue publicly available annual reports on system performance, while others have data available upon request.

On HOT systems emerging throughout the country, a greater emphasis has been placed on performance monitoring as resources, infrastructure, and technology that can be used for lane monitoring programs are considered in initial system design, and the advent of pricing raises the importance of accountability to the public regarding lane performance.

HOV System Performance

Seventy-five percent (75%) of survey respondents indicate that their HOV systems are achieving current performance objectives. Those who indicate otherwise cite issues resulting from congested lanes, such as too much demand during the peak period and resulting overcrowding issues, and low speed differential between HOV and general-use lanes. Other performance issues include lack of a continuous system, “end of the line” issues such as bottlenecks where HOV lanes reconnect with general-use lanes, high violation rates, and low usage during enforcement periods.

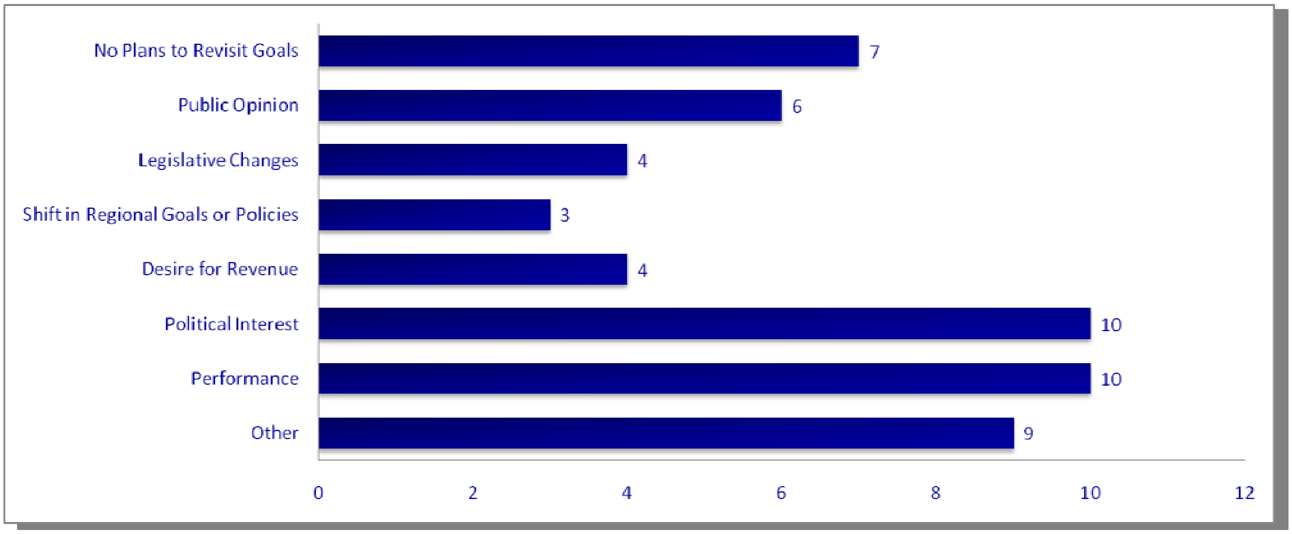
Underutilization, or “empty-lane syndrome,” is another common performance issue nationwide that has led to policy changes on HOV systems. Inadequate speed differential is also noted in some areas as it relates to geometric design, where a buffer separation results in lane friction between the HOV lane and the slower moving general-use lanes and impacts the HOV lane driver’s tendency to drive at free-flow speeds.

Plans to Revisit Goals

Of the 28 respondents, 21 have revisited or plan to revisit system goals based on changes since the initial implementation of their HOV system (see Figure 3-2). The two most frequent reasons for a policy change were cited as political interest and performance. Public opinion was the next most frequent motivation for revisiting goals, with other motivating factors including legislative changes, a desire for revenue, or a shift in regional goals or policies. Some facilities have changed goals based on a shift to HOT lanes, or due to a regional examination of pricing options. One respondent indicated that the goals were revisited due to the deterioration of transit speed and reliability.

High violation rates have also emerged in discussions with some HOV operators as necessitating the need for a policy shift that could enable better enforcement. One school of thought is that pricing may help to curb violation rates, as violators could buy in to the lane, generating a revenue stream and supporting increased infrastructure that in turn supports better enforcement activities. Infrastructure improvements could include improved lane configuration, implementation of enforcement technology, and increased presence of law enforcement.

Figure 3-2: Do you have plans to revisit / have you revisited the goals of your HOV system based on any of the following reasons?



HOV Lane Operational Policies and Policy Changes

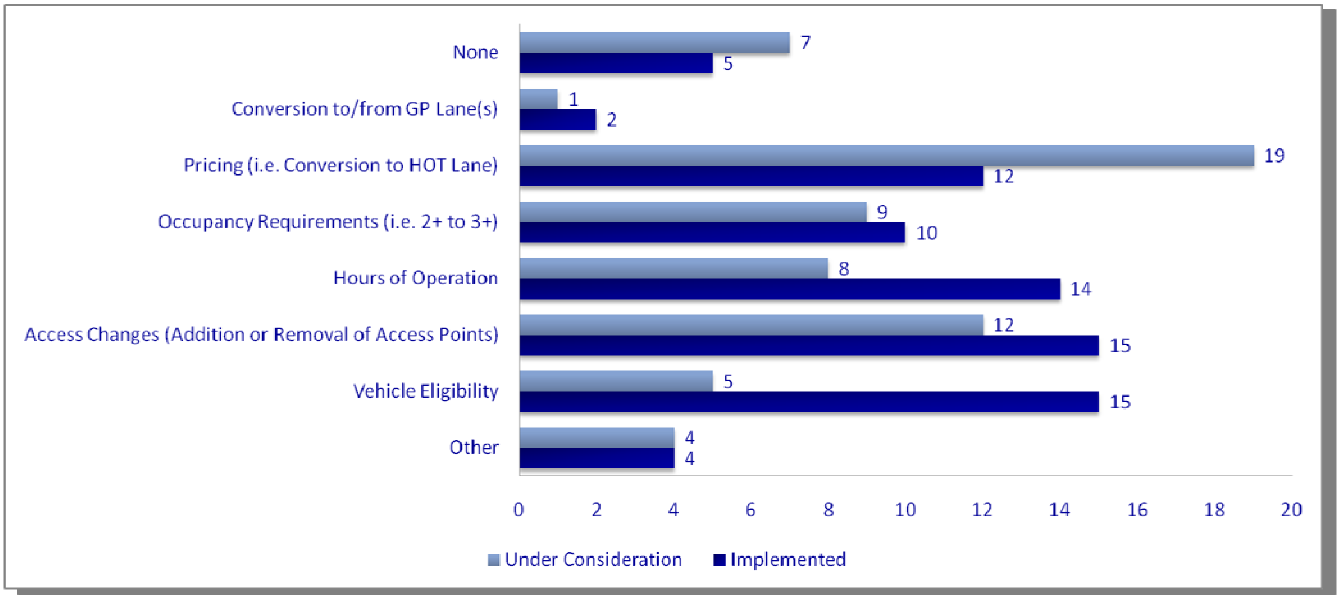
There is wide variation in HOV lane operational policies across the country, which is largely dependent on system design and usage trends related to system goals, local politics (e.g., acceptance of toll lanes, carpool formation rates, air quality conformity, public support, transit ridership, legislative mandates), and the relationship of HOV lanes to the commute patterns of the traveling public. HOV operational limitations and performance issues have often been addressed by policy changes including occupancy requirements and hours of operation. The concept of managed lanes has further evolved to include vehicle eligibility, pricing, and access control as a viable means to impact overall lane performance and system efficiency.

Policy changes impacting hours of operation and occupancy requirements have been implemented and explored in many locations experiencing empty-lane syndrome as a means to improve utilization of the HOV system. Hours of operation have been reduced from 24-7 operations to weekday peak periods or daytime hours in some urban areas. This is typically due to political and public pressure for use of the lanes. In most cases, occupancy requirements have been decreased (e.g.., from 3+ to 2+ or from 4+ to 3+) to relax carpool requirements and improve lane utilization. Increases in occupancy requirements have also been considered as a means to address lane overcrowding, and this has been successful in some areas such as Houston. At the same time, studies in other urban areas indicate that increases in occupancy requirements have resulted in sharp drops in lane usage and additional congestion in the general-use lanes. For this reason, many areas now view pricing as a better option to manage lane congestion.

Conversion to or from general-purpose lanes has frequently been part of the HOV conversation. Many regions report constant public and political pressure to convert HOV capacity to general use, despite results indicating positive HOV performance. In Vancouver, Washington, design issues including a lack of connections to other HOV facilities and connections to park and ride resulted in conversion of HOV lanes to general-purpose lanes after a pilot project even with performance results indicating positive lane performance. "Take away" of a general-use lane for conversion to a managed lane is not a politically popular concept. Nevertheless, many departments of transportation (DOTs) across the country are including this option as part of the discussion. In concert with pricing, managed lanes may help to address current or future transportation funding shortfalls for urban areas.

Access changes have been common on existing systems over the years. Access and/or egress locations may be added or shifted due to public support, safety concerns, or in response to changing congestion levels that may impact lane performance. Access changes have typically been implemented in design situations where striping or moveable barriers can easily be shifted.

Figure 3-3: Have any of the following policy changes been applied / are you considering any of the following changes to your original HOV System?



Survey results indicate that pricing is currently explored most frequently among respondents as a potential policy change (see Figure 3-3 above). Pricing is viewed as a potential solution for a spectrum of issues—potentially addressing unused HOV capacity in the peak period and the need for better lane management in congested conditions and providing needed revenue. Systems with a transit-oriented focus believe pricing can help directly impact transit trip times that are potentially degraded on congested HOV lanes. Pricing also offers a better performance management option for some regions because of the impacts that solutions such as an occupancy requirement change alone may have on the general-purpose lanes. Pricing is packaged with at least one additional policy change—most frequently, vehicle eligibility to allow SOVs into the lane. Pricing also has benefits that could potentially address HOV enforcement concerns in areas with extremely high violation rates that impact lane performance.

Vehicle eligibility was also identified as a frequently implemented policy change. HOV lane eligibility has most frequently been expanded to allow motorcycles and hybrid vehicles into the lanes. In some areas, lanes initially designated as bus-only or transit-only have been expanded to include HOVs. The issue of hybrid and alternative fuel vehicle eligibility varies by state and has been handled in a variety of ways. Many systems permitting these vehicles did so prior to the mass market availability of hybrids. Given hybrid availability and rising fuel prices, allowing these vehicles has had a significant impact on HOV lane conditions in recent years, particularly in locations where lanes are already congested in peak periods. Hybrids may also have a significant impact on revenue on systems that have converted or are considering a conversion to HOT. Pressure from politicians in some states impedes lane operators from excluding hybrid vehicles from managed lanes, even in congested situations. The compromise has been to cap the numbers of hybrid vehicles eligible for lane usage through vehicle registration or permitting programs. For HOT lane systems, operators have issued a limited number of transponders to hybrid users through a lottery or registration process. HOV systems attempting to cap hybrid usage, such as in

Virginia, initiated a date cutoff tied to vehicle registration and issue a special license plate to permitted hybrid users.

Policy Change Motivations

Follow-up interviews with survey respondents revealed motivations for previously implemented policy changes on HOV lanes. These previous policy changes ranged from occupancy restrictions and hours of operation to the implementation of tolling for otherwise ineligible vehicles (e.g., SOVs). The original motivation for past policy changes varied, but a few common themes emerged from the interviews. Empty-lane syndrome was the single most frequent motivation for conversion of HOV lanes to HOT lanes. In these cases, the HOV lanes were underutilized, and public desire was for HOV lanes to be returned to general-use lanes. To retain benefits for carpoolers, while addressing the perception of underutilized HOV lanes, the agencies proposed pricing as a means to increase vehicle throughput in both HOV and general-use lanes. Pricing of SOVs provides a more flexible option for managing lane volume. By varying the SOV (“buy-in”) toll rates in the HOT lanes, an agency can attract enough vehicles to fill the lanes while still avoiding congestion from too much demand. A parallel motivation for shifting HOV to HOT is the desire for new revenue.

Many DOTs cannot afford to adequately maintain, improve, or expand their current systems without additional revenue or without help from private sector resources. Public-private partnership initiatives have emerged as a new funding mechanism for managed-lanes projects and are based upon the premise that there will be a return on investment for the private sector. Revenue generated from priced lanes makes this type of funding mechanism possible. In some states, priced lanes are currently viewed as the only mechanism for future freeway capacity expansion, given limited resources and regional transportation goals and policies.

Some responding agencies have also made changes to occupancy restrictions, eligibility restrictions, and hours of operation. Conversion from an occupancy policy of 2+ to that of 3+ (or even 4+) is typically in response to peak period congestion. Some agencies apply this increased restriction for the entire period of HOV operation, while others just apply the change in the peak hour, with the original occupancy restriction in the off-peak. Examples also exist where the responsible agency originally made the occupancy requirement too restrictive. There are instances where 3+ or 4+ policies have been changed to 2+ or 3+ due to lack of use. Indeed, there are even a couple of examples of HOV 2+ lanes being converted back to general use for the same reason. Vehicle eligibility is another change category that HOV operators have leveraged. In the last several years, there has been particular interest in allowing low-emission and/or hybrid vehicles in HOV lanes, regardless of the number of persons inside. Federal law (SAFETEA-LU) currently allows this, and some states have taken steps to implement this policy change. HOV operators have also changed the hours of operation of their facilities. For those facilities that are not restricted all 24 hours of the day, operating hours can be changed to best serve the travel market. For example, peak spreading could lead to congestion in the corridor at times when the HOV lane is open to all traffic. By expanding the hours of operation, the advantage of increased travel speeds can be preserved for carpoolers.

Table 3-1 summarizes the anticipated performance impacts of potential policy changes based on the operating conditions in an HOV lane.

Table 3-1: HOV Conditions and Potential Policy Changes

HOV Lane Condition	Policy Change	Anticipated Result
Underutilized	Occupancy policy decrease	Increased volumes in the HOV lane and shift from general-use lanes due to relaxed restrictions.
	Hours of operation change	Increased daily volumes in the HOV lane and shift from general-use lanes due to relaxed restrictions.
	Vehicle eligibility □ Hybrid □ Transit □ Motorcycle	Increased volumes in the HOV lane and shift from general-use lanes due to relaxed restrictions.
	Pricing	Increased volumes in the HOV lane and shift from general-use lanes, particularly during peak periods when SOV drivers can pay for a guaranteed travel time. Revenue stream generated from paying SOV drivers. Positive impact on general-use lanes due to volume shift during peak period.
	Conversion to GP lane	Increased lane volume due to the removal of lane restrictions. Decreased person and vehicular throughput, and degraded transit trip times can be anticipated for the corridor due to lack of demand management and lack of travel time incentives to carpoolers and transit users.
	Access changes	Increased volumes in the HOV lane and shift from the general-use lanes if access/egress better reflects peak period commute patterns or is easier for the public to understand and utilize.
Congested	Occupancy policy increase	Decreased volumes in the HOV lane and shift to the general-use lanes due to increased restrictions. Potential for negative impact on general-use lanes if there is a sharp decrease in carpools meeting new requirements.
	Vehicle eligibility □ Hybrid □ Transit □ Motorcycle	Decreased volumes in the HOV lane and shift to the general-use lanes due to increased restrictions. Increased restrictions on hybrid vehicles are most likely to impact lane performance but can be controlled through registration caps and permitting.
	Pricing	Free-flow volumes maintained in the lane during hours of operation due to active lane management, particularly during peak periods. Revenue stream generated from paying SOV drivers. Guaranteed travel times on priced lanes during peak periods also provides benefits to carpoolers and transit users.

HOV Lane Condition	Policy Change	Anticipated Result
	Add or convert a lane	Increased person and vehicular throughput and improved travel times due to an extra lane of managed capacity. Potential for negative impact on general-use lanes if there is a lane takeaway.
High violation rate / Incorrect utilization	Pricing	Improved monitoring on the HOV lanes due to enhanced infrastructure. Revenue stream generated from paying SOV drivers can help to support monitoring efforts.
	Access changes	More restrictive access will curb tendencies for ineligible drivers to enter the lane. Access changes can include separation changes (i.e., stripe vs. buffer vs. pylon) or ingress/egress location changes
Degraded transit trip times	Pricing	Free-flow volumes maintained in the lane during hours of operation due to active lane management, particularly during peak periods, supports transit trip reliability. Revenue stream generated from paying SOV drivers can support transit operations. Guaranteed travel times on priced lanes during peak periods provide benefits to transit users and could increase transit ridership.
	Vehicle eligibility □ Hybrid □ Motorcycle	Decreased volumes in the HOV lane and shift to the general-use lanes due to increased restrictions. Increased restrictions on hybrid vehicles are most likely to impact lane performance but can be controlled through registration caps and permitting.
	Add or convert a lane	Improved transit travel times due to an extra lane of managed capacity. Additional lane could be reserved for transit-only usage or transit and carpool usage for additional travel-time reliability. Potential for negative impact on general use lanes if there is a lane takeaway.

Policy Implementation Success Factors

While lane performance is a central factor in the decision for HOV policy change and the key to understanding the system impacts of one policy over another, there are many other factors that influence the successful implementation of a policy change. Changes such as hours of operation, vehicle eligibility, and occupancy may in some circumstances be policy changes within the authority of the facility operator, or they may require legislative action, depending on the institutional arrangements and laws in a particular location. Authorized policy changes are of course a quicker path to implementation, as they do not require the formal actions of elected legislators. Some agencies acknowledged preferences for not opening up legislative issues, but rather to work with factors within their control. Opening up legislation can lead to unexpected outcomes and slow response to the operating issues faced. Some HOV operators have appointed boards designated to make policy decisions regarding HOV systems. This institutional arrangement can facilitate the HOV policy decision-making process, particularly when multiple partnering agencies are involved. Along these same lines, many operators comment that specific Federal rules related to HOV policy changes and lane performance actually facilitate implementation at the local level.

Some states still require enabling legislation for HOV policy changes. There are many examples of policy changes that have been made due to the political will of legislators or other local leaders, and there are at least as many that have failed due to the lack of a political champion. In particular, all HOT lane operators across the country indicate that political support and a political champion was a key in overcoming potential implementation hurdles for HOT lanes. It typically has taken years of education and persuasion to cultivate political leaders and agency partners to implement HOT pricing on existing HOV lanes. Effective interagency coordination and clear ownership of designated roles and responsibilities is another commonality across systems that have successfully implemented HOT lanes. Research studies and data that validate the need for this type of policy change are also critical tools to support these decisions.

Transportation agencies exploring pricing have also learned that not all HOV lanes are good candidates to be HOT lanes. Many lanes that meet the performance “rules of thumb” for conversion are constrained corridors with no space for tolling systems without costly design overhauls and acquisition of additional rights-of-way. The HOT facilities currently in operation are regarded as “low hanging fruit” relative to other facilities under study for conversion.

Recent experience has been promising. Operating agencies have made progress with the support of US DOT grant programs such as the Urban Partnership Agreement (UPA) and the Value Pricing Pilot Program (VPPP). Corridors have been carefully selected for implementation considering factors that promote a high likelihood for success.

Typical success factors include favorable geometrics and access locations, reasonable potential for public acceptance, a political champion, clear roles and responsibilities between agencies, and strong interest from the transit operator. In general, agencies proposing candidate facilities for conversion experience 20 percent or more of unused capacity in the peak period, and have the staff and financial resources to plan, design, implement, and operate the HOT facility. The lack of some of these factors[1] is a principle reason given for abandoned efforts in the past.

Federal assistance in rule-setting would be helpful in some areas, such as in rules and guidance for setting minimum occupancy and eligibility policies. For example, in conditions where occupancy policy must increase to 3+ to address congestion, but hybrid vehicles are still allowed in the lanes, this seems counterintuitive to many in the HOV/HOT community.

[1] Or the need for too many design exceptions and compromises to overcome right-of-way limitations and other geometric design problems

SECTION 4: POLICY OPTIONS EVALUATION TOOL

Purpose

Every HOV lane is unique in its demand composition and operational characteristics. These characteristics are often difficult to quantify, so it is challenging for HOV operators to know exactly how well their HOV lanes are operating. Likewise, the impacts of any policy changes to their HOV facilities are also difficult to quantify, and would create additional uncertainty concerning future HOV performance. So before making any changes, it is critical to understand: (1) the current operating conditions of the existing HOV facility; (2) what impacts on the operational performance of the HOV facility can be expected with policy shifts; and (3) whether policy shifts will help the operator meet the goals and objectives established in the study region.

Travel demand modeling is one approach commonly used to evaluate current and future conditions in transportation systems. These models can be used to estimate the potential impacts of policy shifts, including changes in HOV lane policies. However, the traditional modeling process tends to be complex and requires extensive time and budget to implement, rendering it ineffective for quick-response analysis.

The Policy Options Evaluation Tool for Managed Lanes (POET-ML) was developed as one feasible alternative to travel demand modeling. The tool makes it possible for HOV operators to complete a current HOV system condition assessment, quantify the impacts of HOV lane policy shifts on operational performance and financial feasibility, and ultimately prioritize the most appropriate HOV policy changes, or combination of HOV policy changes, to best align with their system goals and performance objectives. This will all be accomplished through a simple user interface that does not require extensive modeling know-how. Users equipped with even limited input data will be able to apply what they know to get sketch-level planning output and suggestions for HOV policy modification.

Specifically, POET-ML has been structured to help HOV operators answer the following questions:

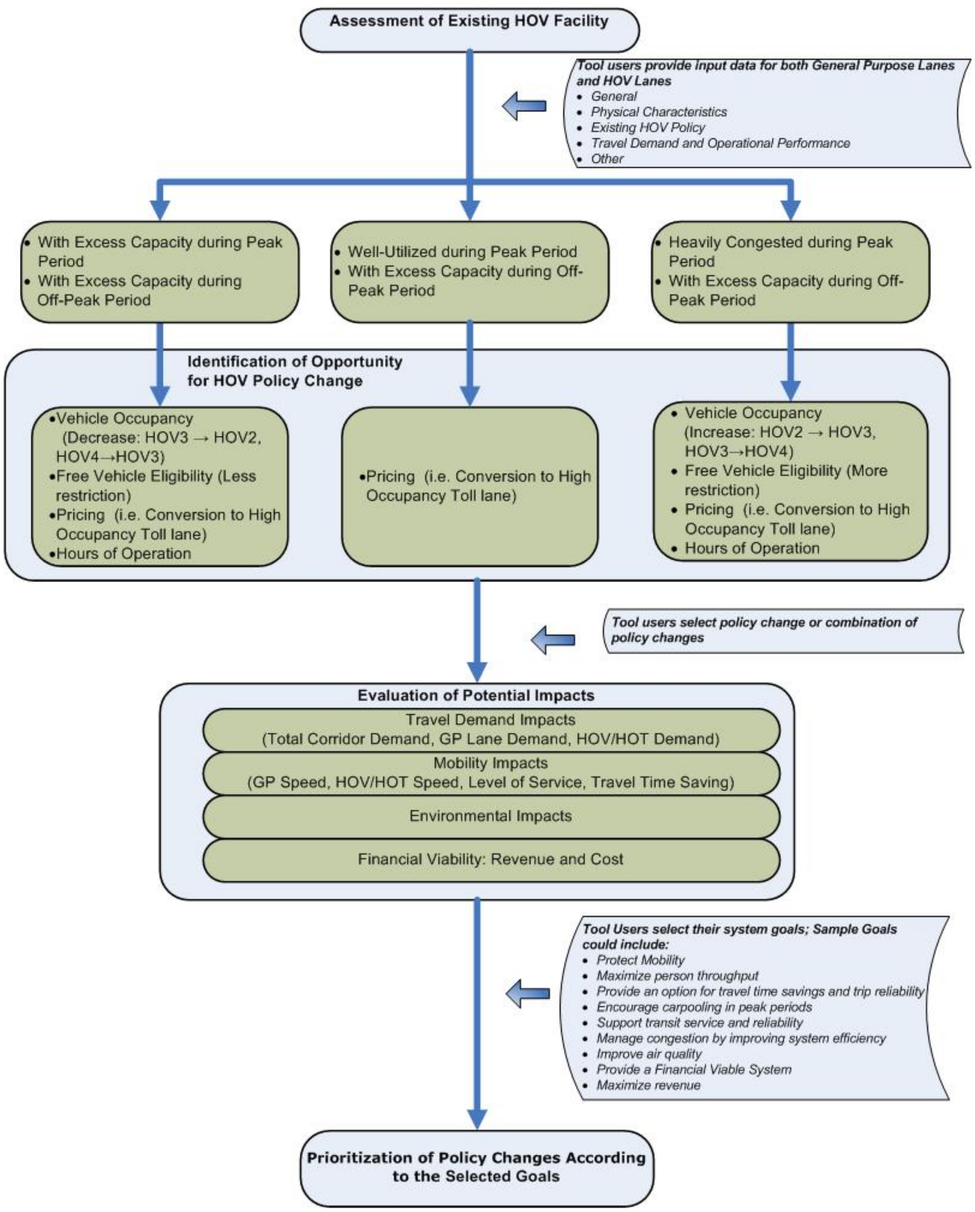
- How effective are HOV facilities in my region? How well are these lanes utilized?
- What HOV policy changes are **necessary** to address locations where my HOV facility appears to be underutilized, or where excess capacity on the HOV facility exists during the peak period and off-peak period? What HOV policy changes are **optional** to address these concerns?
- What HOV policy changes are **necessary** to address locations where my HOV facility is congested during the peak period? What HOV policy changes are **optional** to address these concerns?
- What are the advantages or disadvantages associated with each HOV policy change?
- How is HOV system performance impacted as a result of each policy change or combination of policy changes?
- Will the changes in HOV policy meet the system goals and performance objectives? Which policy changes are recommended to meet those goals and performance objectives?

The POET-ML framework, methodology, and illustrative results from four typical scenarios (Scenario 1: HOV & GP Lanes Both Under Capacity; Scenario 2: HOV Lane Under Capacity & GP Lanes Congested; and Scenario 3: HOV Lane & GP Lanes Over Capacity [Increased Restrictions]; and Scenario 4: HOV Lane & GP Lanes Over Capacity [Additional Capacity]) are provided next. The POET-ML tool itself is provided as a separate deliverable.

Framework, Methodology, and Illustrative Results

Figure 4-1 illustrates the analytical process used in POET-ML.

Figure 4-1: POET-ML Framework



Step 1: Operational Assessment of Existing HOV Facility

The initial step in the model process is an assessment of the operational effectiveness of the existing HOV facility. This assessment considers both physical and operational characteristics including number of lanes, length, separation, eligibility, and demand, among others.

In this step, the user can select a specific HOV facility from the FHWA Highway HOV Facility Inventory database that includes information on HOV policy details and physical characteristics. The user is then required to enter the number of HOV lanes and GP lanes in each direction during peak hour operations as well as the corresponding volumes in these lanes (records highlighted in red). Other information, such as public transportation vehicles (no. of buses per hour); percentage of motorcycles; percentage of taxi and percentage of low emission and/or energy efficient vehicles, is optional. Once valid values are entered for these items, the user can continue with the analysis. It is also possible to store a specific profile for future use by modifying the text for one or more of the input data field records.

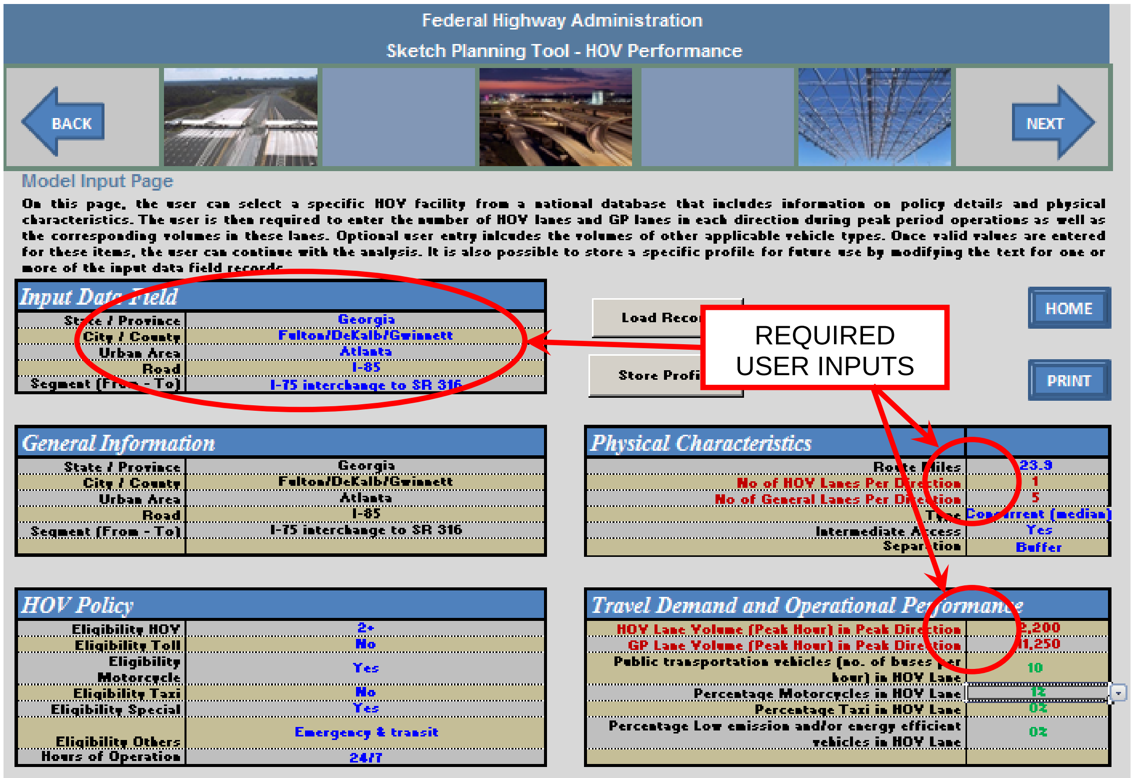
Table 4-1 outlines the set of information to be populated either from the FHWA Highway HOV Facility Inventory database or by the user. The data was grouped into four major categories. General information, physical characteristics, and HOV policies should be readily available to nearly any user familiar with the HOV system under consideration. However, travel demand and operational performance could be more difficult to obtain.

Table 4-1: User Inputs

Data Category	Data Requirement	Data Sources	Requirement
General Information	• State / Province	FHWA Highway HOV Facility Inventory	Required
	• City / County		Required
	• Urban Area		Required
	• Road name		Required
	• Segment (from/to)		Required
Physical Characteristics	• Route Miles	FHWA Highway HOV Facility Inventory	Required
	• No of HOV Lanes Per Direction	User Input	Required
	• No of General Purpose Lanes Per Direction	User Input	Required
	• Type	FHWA Highway HOV Facility Inventory	Optional
	• Intermediate Access		Optional
	• Separation		Optional
HOV Policies	• Eligibility HOV	FHWA Highway HOV Facility Inventory	Required
	• Eligibility Toll		Optional
	• Eligibility Motorcycle		Optional
	• Eligibility Taxi		Optional
	• Eligibility Special Fuel		Optional
	• Eligibility Others		Optional
	• Hours of Operation		Optional
Travel Demand and Operational Performance	• HOV Lane Volume (Peak Hour) in Peak Direction*	User Input	Required
	• GP Lane Volume (Peak Hour) in Peak Direction*		Required
	• Public transportation vehicles (no. of buses per hour)		Optional
	• Percentage Motorcycles		Optional
	• Percentage Taxi		Optional
	• Percentage Low emission and/or energy efficient vehicles		Optional

* Volumes represent demand for the corridor by lane type.

Figure 4-2: Model Input Page



User input, to be input to the model using the interface shown in Figure 4-2, will supply the information necessary to assign the HOV facility to one of two categories based on the established performance thresholds, such as volume-to-capacity ratios or service flow rate (pc/h/ln). These categories describe the general performance of the facility in terms of utilization. During step 2 of this process, the user will be presented with a set of policy adjustments based on the specific category to which the facility is assigned. Table 4-2 outlines the two categories and corresponding performance thresholds by default.

Table 4-2: HOV Facility Performance Thresholds

Categories	Volume-to-Capacity Ratios	Service Flow Rate (pc/h/ln)
• HOV facility that has excess capacity during both peak and off-peak periods;	Peak Hour V/C Ratio <0.75	Peak Hour Service Flow Rate < 1650 pc/h/ln
• HOV facility that is congested during the peak period and has excess capacity during the off-peak period.	Peak Hour V/C Ratio >=0.75	Peak Hour Service Flow Rate >= 1650 pc/h/ln

It is important to note that the default threshold values of V/C ratio (0.75) and service flow rate (1650 pc/h/ln) were established based on aggregated national survey results, and they are consistent with the assumptions in FHWA's Spreadsheet Model for Induced Travel Estimation - Managed Lanes (SMITE-ML). The default values of V/C ratio and service flow rate are stored in the POET-ML parameters page and remain interactive and transparent to the user. Users are allowed to adjust these values to reflect the unique characteristics of facilities in their region. To review and/or modify the default model parameters navigate to the Potential Impacts page and select "Adjust Parameters".

The precision of the analysis will depend on the availability of data from the user, and the quality of the final model output depends entirely on the user's ability to supply as much needed information as possible.

Example:

The example corridor is I-85 in Atlanta, GA from I-75 north to SR316. This 24 mile facility has a single HOV lane in each direction with HOV2+ occupancy policy. Key information was loaded from the HOV data base. User input included:

No. of HOV Lanes Per Direction	**= 1**
No. of General Lanes Per Direction	**= 5**
HOV Lane Volume (Peak Hour) in Peak Direction	**= 2,200**
GP Lane Volume (Peak Hour) in Peak Direction	**= 11,250**

Step 2: Identification of the required and/or optional HOV policy changes

A set of applicable policy adjustments are introduced in step 2 of the model process, based on the assessment from step 1. If it is determined that the HOV facility has excess capacity in both the peak and off-peak periods, the user will be shown a number of policy change options related to vehicle occupancy, vehicle eligibility, and pricing. In order to fill unused HOV capacity, and avoid empty lane syndrome, the user could choose to lower the occupancy restrictions (e.g. from HOV3+ to HOV2+) or to allow additional free vehicles (e.g. public transportation vehicles, taxis, motorcycles, hybrid vehicles, etc.). Additionally, the user could convert the lanes from HOV to high-occupancy toll (HOT) lanes, and sell excess capacity to users not permitted in the lanes but who would be willing to pay for the travel time savings these lanes provide. These policy changes could also be bundled together in some combination that both achieves the utilization targets and meets the goals of the region. Table 4-3 shows the options to be presented to the user.

The same set of policy change options applies for HOV facilities determined to be congested during peak periods. However, the potential adjustments will be more restrictive, rather than less restrictive, as was the case for the excess-capacity scenario. For example, one option to address congested HOV lanes is to increase the occupancy requirements (e.g. from HOV2+ to HOV3+). Likewise, non-carpools that are currently eligible to use the HOV lanes could be prohibited (e.g. disallow motorcycles, transit vehicles, etc.). Pricing of non-eligible vehicles can also be implemented on congested HOV lanes, but it must be bundled with some other policy shift. Once demand in these lanes is brought down below capacity through more restrictive policies, any remaining capacity could be sold to ineligible vehicles (i.e. those not meeting the current occupancy/eligibility policy) that are willing to pay for access. In addition to policy change options related to vehicle occupancy, vehicle eligibility, and pricing, the user can also explore the impacts of adding an additional managed lane. This option is only available for HOV facilities that are congested during peak period. This could either be an additional lane in each direction, or an additional reversible lane, depending on the facility. By adding additional capacity, it provides increased flexibility for HOV operators and eliminates the need for immediate occupancy policy changes. Table 4-4 shows the options for the congested peak period condition.

If HOV demand is deemed to be on target during peak periods (i.e. neither underutilized nor congested), there are still opportunities for policy adjustment. Future demand may eventually lead to congestion in lanes that are operating well today, and proactive steps could ensure efficient operation for years to come. Pricing is always an option that provides flexibility for HOV operators to manage demand in these lanes in order to achieve more efficient use. Occupancy and eligibility policy changes alone, offer only discrete solutions that may tip the utilization balance too far in one direction.

Example:

Based on the volumes in the corridor, both the HOV and general purpose lanes operate at undesirable levels, LOS E and F for the HOV and GP lanes respectively.

Mobility Impacts in HOV Lanes and General Purpose Lanes During Peak Hours

Mobility Impacts	**With Existing HOV Policy**	
	HOV Lane	**GP Lane**
Peak Hour V/C	**1.00**	**1.02**
Peak Hour Speed (mph)	**34.2**	**33.1**
Level of Service	**E**	**F**
Corridor Travel Time (minutes) - Congested Condition	**41.9**	**43.3**
Total Vehicle Travel Delays (hours)	**728**	**3,983**
Total Vehicle Delay * VOT of $/hr	**18,200**	**99,575**

Mobility Impacts in HOV Lanes and General Purpose Lanes Daily

Mobility Impacts	**With Existing HOV Policy**	
	HOV Lane	**GP Lane**
Daily V/C	**0.75**	**0.77**
Daily Speed (mph)	**47.2**	**46.0**
Daily Level of Service	**C**	**D**
Corridor Travel Time (minutes) - Congested Condition	**30.4**	**31.2**
Total Vehicle Travel Delays (hours)	**3,614**	**20,520**
Total Vehicle Delay * VOT of $/hr	**90,350**	**513,000**
Travel Efficiency (Speed * Volume)	**1,235,939**	**6,209,440**

Potential policy adjustments include:

1. Increase vehicle occupancy from HOV2+ to HOV3+ or HOV 4+
2. Further restrict vehicle eligibility such as transit, motorcycles, taxis or low emission vehicles. In this example, motorcycles and transit vehicles are the only vehicle types with eligibility.
3. Allow pricing of non-eligible vehicles (this requires an initial policy shift to free-up capacity to sell, increased occupancy or additional capacity for example).
4. Add an additional managed lane in each direction.

Table 4-3: Potential Policy Adjustments for Facilities with Excess Capacity Condition (Empty Lane Syndrome)

Operating Element	Direction of Change	Details	Policy Change Options	
Vehicle Occupancy (HOV)	Decrease	By relaxing the vehicle occupancy restrictions, more vehicles could gain access to HOV lanes, filling unused capacity in the currently underutilized lanes.	Vehicle Occupancy (HOV)	2+
Free Vehicle Eligibility	Less Restriction	By allowing vehicles that don't meet the existing vehicle eligibility policy (e.g. low emission and energy-efficient vehicles) to use the HOV lanes, more vehicles could gain access to these lanes, filling unused capacity.	Public transportation vehicles (no. of buses per hour)	50
			Motorcycles	1%
			Taxi	2%
			Low emission and/or energy efficient vehicles	4%
Pricing	Allow Paying Vehicles	For the existing HOV lanes which are underutilized, allowing vehicles that don't meet passenger occupancy or vehicle eligibility requirements to gain access to HOV lanes by paying a toll provides the opportunity to fill unused capacity and also provides transportation choice for those willing to pay. By pricing those previously ineligible vehicles, new revenue is generated that could, if authorized, be utilized for transportation improvements.	Paying vehicles	Allow

Table 4-4: Potential Policy Adjustments for Facilities with Congested Peak Period Conditions

Operating Element	Direction of Change	Details	Policy Change Options	
Vehicle Occupancy (HOV)	Increase	By increasing the vehicle occupancy requirement, some currently eligible HOVs are diverted from the lanes, providing additional capacity in currently overutilized HOV lanes.	Vehicle Occupancy (HOV)	**2+**
Free Vehicle Eligibility	More Restrictions	By disallowing some currently eligible vehicles, additional capacity is freed up in the overutilized HOV lanes.	Public transportation vehicles (no. of buses per hour)	**0**
			Motorcycles	**0%**
			Taxi	**0%**
			Low emission and/or energy efficient vehicles	**0%**
Pricing	Allow Paying Vehicles	Pricing needs to be bundled with a vehicle occupancy change, (free) vehicle eligibility change, and/or capacity change for the facility that is overutilized. By pricing those previously ineligible vehicles, new revenue is generated that, if authorized, could be utilized for transportation improvements.	Paying vehicles	**Allow**
Additional Capacity	Add a Managed Lane	Building additional capacity provides increased flexibility for HOV operators facing peak period congestion. Additional capacity eliminates the need for immediate policy changes.	Capacity	**Disallow**

Step 3: Evaluation of Potential Impacts

The third step in the process is to assess the impacts of the HOV lane policy change or combination of policy changes that were selected in step 2. The tool will track four key measures of effectiveness: travel demand impacts, mobility impacts, environmental impacts, and financial feasibility.

Travel Demand Impacts

Both vehicle and person travel demand will be examined over daily and peak hour periods in the HOV/HOT and general-purpose (GP) lanes. Travel will be broken down into carpools, transit, motorcycles, special fuel vehicles, taxis, and paying vehicles. At a minimum, the user will be required to supply information on peak hour vehicle trips for each vehicle type under the current HOV policies. Relationships coded into the tool will be used to calculate peak hour person trips and daily vehicle and person trips.

Travel demand impact calculations will depend heavily on which of the two conditions (excess capacity or congested) applies to the facility under evaluation. If pricing is selected as a policy change, the level of travel demand in priced lanes will be maintained at Level of Service C during the peak hour, by default, i.e., about 75% of absolute capacity. Paying vehicle volumes in priced lanes during the peak hour are estimated to be equal to the spare vehicle capacity that would be available on the lanes at a Level of Service C. The balance of the volume is occupied by non-paying vehicles.

A number of combinations exist between existing conditions and subsequent policy adjustments. The algorithms in place to determine final volumes for both HOV/HOT lanes and general purpose (GP) lanes are different based on the combination under consideration. Following are four potential scenarios, meant to outline the different calculation processes executed by POET-ML. Each scenario description includes a table with example output data and a figure showing general travel conditions in the corridor. Following these scenarios is a detailed description of the calculations for mobility and environmental impacts, along with financial feasibility.

Scenario 1: HOV & GP Lanes Both Under Capacity

Many corridors with HOV lanes are uncongested in peak periods. Under these conditions, no changes are required to bring HOV operating speeds back to acceptable levels. However, the HOV operator may be interested in seeing the impact of implementing pricing, or of allowing additional vehicles into the HOV lanes through occupancy or eligibility changes. Figure 4-3 illustrates the potential impact of allowing priced vehicles into the HOV lanes. The colored arrows represent the flow conditions for each lane in the corridor. Table 4-5 shows an example calculation for this scenario.

Of the 1,100 peak hour HOV trips in the existing condition, 1,004 of them are carpools. The rest are other eligible vehicles. These other vehicles generally make up a small proportion of total HOV demand, and therefore changes to eligibility restrictions could have little direct impact on HOV and GP lane performance.

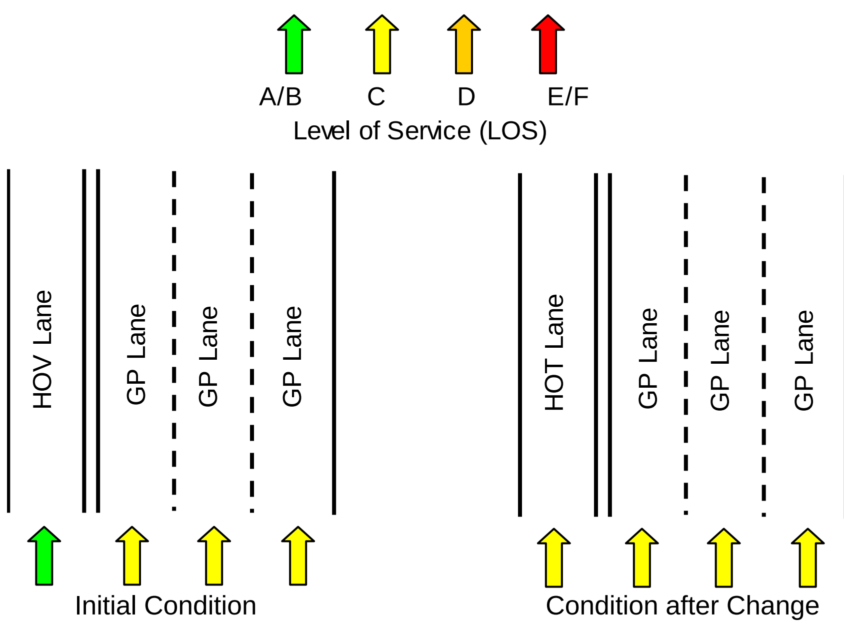
Initially, this uncongested corridor experiences LOS C conditions in the GP lanes and LOS A/B conditions in the HOV lane. Allowing priced vehicles in the HOV lane will attract additional users because of the time savings relative to the GP lanes. POET-ML pulls these users from two different places: the GP lanes and parallel facilities. The percent split from these sources depends on the conditions in the GP lanes. As the V/C ratio in the GP lanes rises, the contribution of vehicles from these lanes to the HOV/HOT lane also rises. When GP conditions are near LOS A/B, a larger portion of vehicles are diverted from parallel facilities to the HOV/HOT lane. The final volumes in the HOT lane under this condition are no higher than the maximum LOS C volume defined in the Tool. Nor are they larger than ¼ the total corridor volume (¼ because the facility has 4 total lanes, with one HOV lane). This is to ensure that HOT operating speeds do not fall below GP speeds, which is a possible, but unlikely scenario. For these reasons, revenue is likely to be minimal under this condition. Obviously, few motorists would be willing to pay a toll to use the HOT lane when only minimal time savings can be realized.

Indeed, Table 4-5 shows just 300 paying vehicles after the policy change, bringing the peak hour total in the HOV/HOT lane to 1,400. Volumes decrease from a total of 4,500 on the GP lanes to 4,380. With a per lane capacity of 2,200 vehicles per hour, the GP lanes have a similar V/C ratio to that of the HOV/HOT lane, which is the reason for the low demand from paying vehicles in that lane.

Table 4-5: Scenario 1 Lane Condition Data

Travel Demand Impacts – Scenario 1	Existing HOV Policy		With Policy Changes	
	HOV (1) Lane	GP (3) Lane	HOV (1) Lane	GP (3) Lane
Total Peak Hour Vehicle Trips (with PCE factor)	1,100	4,500	1,400	4,380
Peak Hour Carpools (Free)	1,004	N/A	1,004	N/A
Peak Hour Others (Transit)	10	N/A	10	N/A
Peak Hour Motorcycle	17	N/A	17	N/A
Peak Hour Taxi	17	N/A	17	N/A
Peak Hour Special Fuel	33	N/A	33	N/A
Peak Hour Tolling	0	N/A	300	N/A

Figure 4-3: Scenario 1 Lane Condition Diagrams



Scenario 2: HOV Lane Under Capacity & GP Lanes Congested

Another common scenario involves congested GP lanes adjacent to an HOV facility that operates well below capacity. Again, the operator is not required to make policy changes in order to maintain an acceptable LOS in the HOV lane, but there may be interest in achieving greater utilization in this lane. Options for increasing HOV volumes include relaxing occupancy and eligibility restrictions in the lanes, as well as allowing previously ineligible vehicles (e.g. single-occupant vehicles) to pay a toll in order to use the lane. These options would have different impacts on lane volume, however, and caution needs to be observed to avoid creating congested HOV conditions. For example, lowering the occupancy restriction from 3+ to 2+, if applicable, could potentially allow too many vehicles into the HOV lane, degrading performance below acceptable levels.

In this example, a congested corridor has an underutilized HOV lane. This condition is commonly referred to as “empty lane syndrome”, and is one key motivator for HOV policy change. Allowing priced vehicles access to the HOV lane can lead to improvements in the GP lanes and better use of the HOV lane. One likely outcome of this change can be seen in Figure 4-4. Here, LOS improves from ‘E/F’ to ‘D’ on the GP lanes, while LOS degrades slightly on the HOV/HOT lane from ‘A/B’ to ’C’. In POET-ML, most of the priced vehicles in the HOT lanes come from the GP lanes under these conditions, with a small contribution from parallel facilities. As a result, total corridor throughput increases slightly under this scenario. As noted previously, vehicle contribution from these two sources is determined based on a sliding scale with a 70/30 split between parallel facilities and GP lanes when the GP lanes operate at LOS A. This split changes to 60/40 under LOS B, 50/50 under LOS C, 40/60 under LOS D, and 30/70 under LOS E/F conditions. This distribution is included in the parameters page, and can be modified by the user.

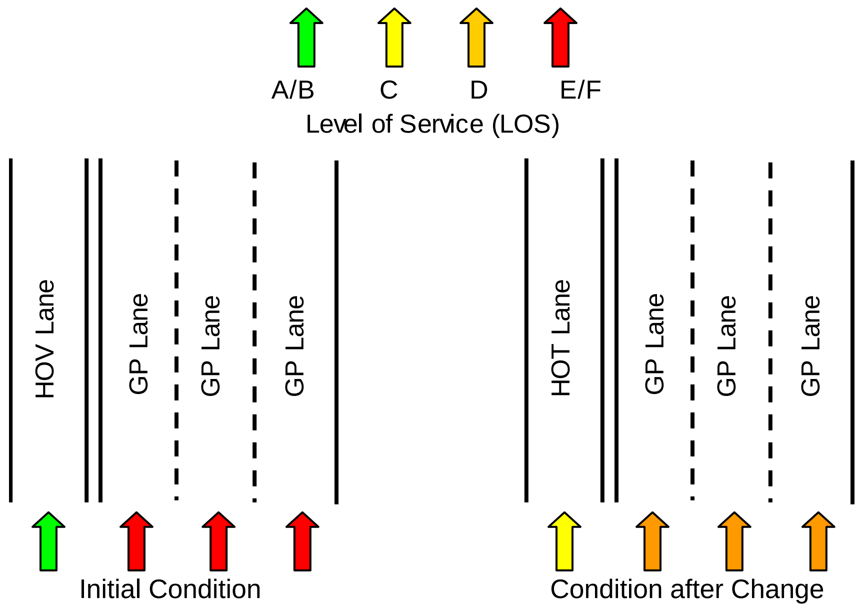
HOT lane volumes are capped at the LOS C capacity, which is accomplished in practice through demand-responsive, variable tolling. If pricing is not a viable alternative, an HOV operator could still achieve greater corridor throughput by increasing the types of eligible vehicles in the HOV lane. Allowing hybrids or special fuel vehicles, taxis, or additional transit vehicles can provide a degree of relief to the GP lanes while increasing utilization of the HOV lane. However, as discussed previously, relaxing eligibility restrictions may not impact many vehicles, and therefore conditions may not change much in the corridor.

Table 4-6 shows example output from this scenario. Here, HOV volume is brought to capacity after pricing is allowed, and GP lane conditions improve with decreases of more than 100 vehicles per lane. Again, total corridor throughput increases over the existing case. Pricing allows for more efficient movement in these 4 lanes.

Table 4-6: Scenario 2 Lane Condition Data

Travel Demand Impacts – Scenario 2	Existing HOV Policy		With Policy Changes	
	HOV (1) Lane	GP (3) Lane	HOV (1) Lane	GP (3) Lane
Total Peak Hour Vehicle Trips (with PCE factor)	1,100	6,700	1,650	6,315
Peak Hour Carpools (Free)	1,004	N/A	1,004	N/A
Peak Hour Others (Transit)	10	N/A	10	N/A
Peak Hour Motorcycle	17	N/A	17	N/A
Peak Hour Taxi	17	N/A	17	N/A
Peak Hour Special Fuel	33	N/A	33	N/A
Peak Hour Tolling	0	N/A	550	N/A

Figure 4-4: Scenario 2 Lane Condition Diagrams



Scenario 3: HOV Lane & GP Lanes Over Capacity (Increased Restrictions)

Some HOV facilities are congested during peak periods and require policy adjustment in order to maintain federally mandated performance standards. Low cost strategies for decreasing HOV lane volume include increasing occupancy restrictions and implementing more exclusive eligibility criteria. However, efforts to divert vehicles from the HOV lanes can lead to increased congestion on GP lanes. And if HOV lane rules are made too restrictive, traffic could fall well below LOS C conditions, leading to empty lane syndrome. For example, in many urban areas, the vast majority of HOVs have just 2 occupants, with only a small percentage of 3+ occupant vehicles. If the HOV operator increases the occupancy restriction from 2+ to 3+, many of the vehicles in the lane will no longer be eligible, and will be diverted to the GP lanes or parallel facilities.

POET-ML takes into account the overcapacity scenario described above. Once it is determined that the HOV lane is congested in peak periods, the user is presented with a list of potential policy changes designed to achieve improved HOV operating conditions. The greatest impact usually comes from increased occupancy restrictions. Figure 4-5 shows an example of the impact of first increasing this restriction from 2+ to 3+, followed by allowing priced vehicles in the lane.

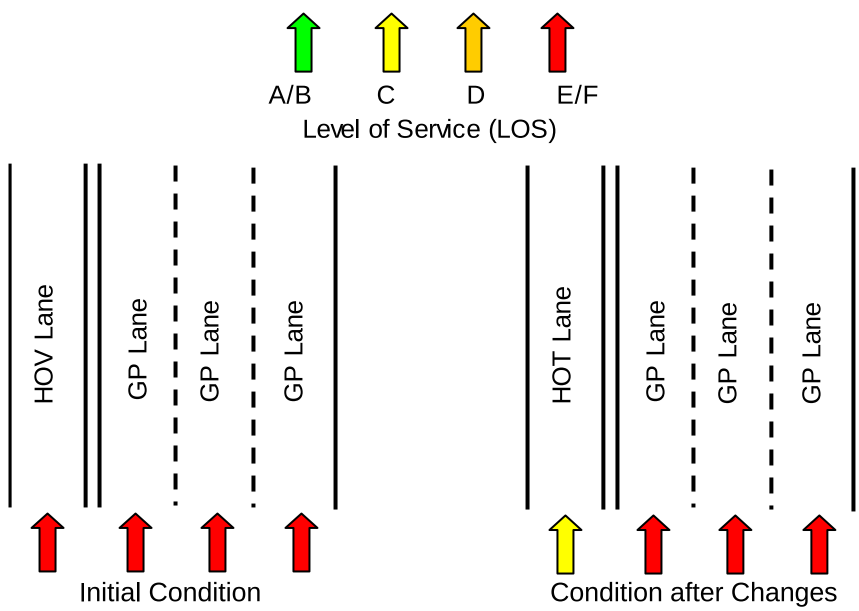
The first selection shifts a large number of vehicles from the HOV lane to the GP lanes. Of course, the number of vehicles diverted will vary by facility, according to the regionally-specific HOV mix (i.e. the relative number of HOV2, HOV3, HOV 4+, etc.). This split is coded as a parameter in the Tool, and it can be updated by the user as desired. If the user changes only the occupancy restriction, total corridor volume will remain constant, and GP lane conditions will likely become even more congested. In addition, it is possible that the HOV lane may exhibit LOS A/B conditions, which is suboptimal utilization. If the user follows this selection by allowing pricing in the HOV lane, however, vehicles return to the lane and fill the unused capacity. POET-ML pulls most of the priced vehicles from the GP lanes, and a smaller portion from parallel facilities. This split is also coded as a parameter in the Tool, and if the user desires to vary the source of priced vehicles, he or she has that flexibility. Once both decisions are executed, conditions are likely to appear as they do on the right of Figure 4-5.

Table 4-7 shows the extent to which the GP lanes become more congested in this scenario. Of course, the HOV lane is maintained at the LOS C capacity, and most of these vehicles are tolled. HOV3+ vehicles, along with other eligible free vehicles, comprise the balance of the lane volume. The HOV2 vehicles, which were pushed to the GP lanes in response to the occupancy policy change, are responsible for the increased GP lane congestion.

Table 4-7: Scenario 3 Lane Condition Data

Travel Demand Impacts – Scenario 3	Existing HOV Policy		With Policy Changes	
	HOV (1) Lane	GP (3) Lane	HOV (1) Lane	GP (3) Lane
Total Peak Hour Vehicle Trips (with PCE factor)	2,200	6,700	1,650	7,621
Peak Hour Carpools (Free)	2,104	N/A	316	N/A
Peak Hour Others (Transit)	10	N/A	10	N/A
Peak Hour Motorcycle	17	N/A	17	N/A
Peak Hour Taxi	17	N/A	17	N/A
Peak Hour Special Fuel	33	N/A	33	N/A
Peak Hour Tolling	0	N/A	1,238	N/A

Figure 4-5: Scenario 3 Lane Condition Diagrams



Scenario 4: HOV Lane & GP Lanes Over Capacity (Additional Capacity)

Another option for addressing a corridor with congested HOV and GP lanes is to add HOV/HOT capacity. In locations where available right of way affords such an investment, this option can provide a high degree of flexibility for HOV operators. Additional HOV capacity allows greater opportunities for efficient corridor flow and can eliminate the need for occupancy and/or eligibility policy change. In the scenario highlighted in Figure 4-5, the user has opted to add HOV capacity and implement tolling in these lanes. In doing so, corridor conditions are improved for both the managed and GP lanes. In addition, total corridor volume increased, which means the facility can serve more vehicles, more efficiently than before. And all of this is possible while maintaining occupancy restrictions of 2+. This last point is important, because raising occupancy restrictions can be controversial. Those that have formed 2 person carpools to use the HOV lanes will likely object to any change in policy that forces them out of the lanes. Additional capacity can help avoid this situation.

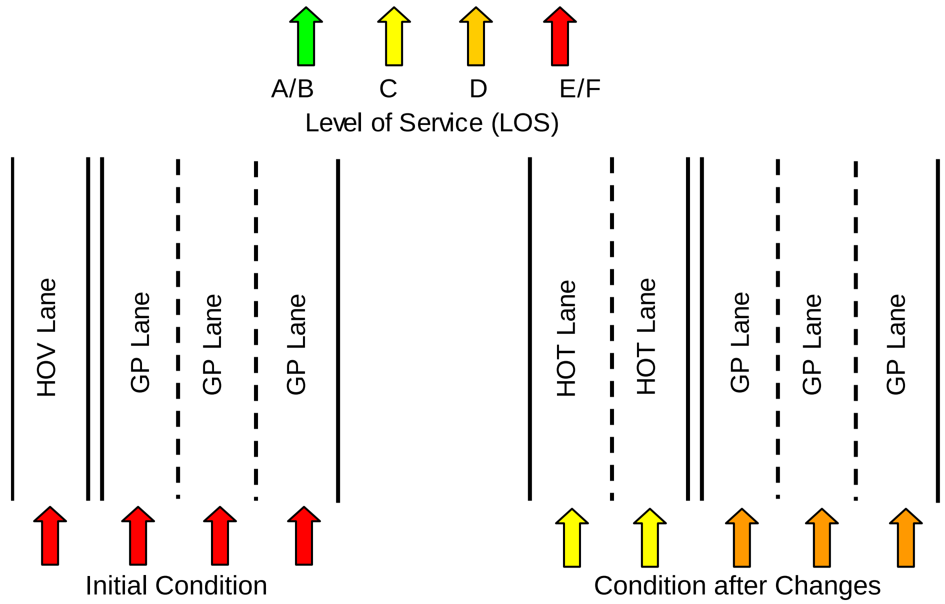
In the scenario highlighted in Figure 4-6, the user has chosen to address corridor congestion by maintaining the existing HOV policy, adding a lane of HOV/HOT capacity, and implementing pricing on both lanes. POET-ML is equipped to respond to each of these decisions and to calculate the final conditions on the managed and GP lanes. The additional HOV lane doubles the capacity for qualifying vehicles. These vehicles are spread evenly over the two lanes, which likely eliminates peak period congestion. Allowing priced vehicles fills unused capacity in these lanes while helping to improve conditions in the GP lanes. Again, the majority of paying vehicles are taken from the GP lanes, with a smaller percentage diverted from parallel facilities.

The number of free vehicles in the HOV lanes remains the same both before and after the capacity addition, as shown in Table 4-8. This allows for a 1,100 paying vehicles to enter the HOV/HOT lanes, bringing both lanes to their LOS C capacity. Since many of those paying vehicles come from the GP lanes, total GP volume decreases from 6,700 to 5,930, resulting in improved LOS on these lanes as well.

Table 4-8: Scenario 4 Lane Condition Data

Travel Demand Impacts – Scenario 4	Existing HOV Policy		With Policy Changes	
	HOV (1) Lane	GP (3) Lane	HOV (2) Lanes	GP (3) Lane
Total Peak Hour Vehicle Trips (with PCE factor)	2,200	6,700	3,300	5,930
Peak Hour Carpools (Free)	2,104	N/A	2,104	N/A
Peak Hour Others (Transit)	10	N/A	10	N/A
Peak Hour Motorcycle	17	N/A	17	N/A
Peak Hour Taxi	17	N/A	17	N/A
Peak Hour Special Fuel	33	N/A	33	N/A
Peak Hour Tolling	0	N/A	1,100	N/A

Figure 4-6: Scenario 4 Lane Condition Diagrams



Additionally, POET-ML analyzes the peak hour person trips based on occupancy rate for different vehicle types. It also analyzes the total daily vehicle trips and total daily person trips based on Peak Hour vehicle/person trips and daily to Peak Hour Conversion factor. Table 4-9 outlines those travel demand impacts and its corresponding calculation methodology. Table 4-10 fills in these formulas, under the existing conditions, with values from the example cited earlier.

Table 4-9: Daily Conversion Formulas

Travel Demand Impacts	With Existing HOV Policy		With Selected Policy Changes	
	HOV Lane	GP Lane	HOV Lane	GP Lane
Total Peak Hour Person Trips	**HOV Lane:** *Peak Hour (Carpools (Free) + Buses + Motocycles + Taxi + Special Fuel + Paying Vehicles) Persons* **GP Lane:** *Peak Hour GP Lane Vehicle Trips * Average Auto Occupancy Rate*			
Peak Hour Carpool Persons (Free)	*Peak Hour Carpools (Free) Vehicles Trips * Carpool Occupancy Rate*			
Peak Hour Others (Transit)	*Peak Hour Bus Vehicles Trips * Bus Occupancy Rate*			
Peak Hour Motorcycle	*Peak Hour Motocycle Trips * Average Auto Occupancy Rate*			
Peak Hour Taxi	*Peak Hour Taxi Trips * Average Auto Occupancy Rate*			
Peak Hour Special Fuel	*Peak Hour Special Fuel Vehicle Trips * Average Auto Occupancy Rate*			

Peak Hour Tolling	*Peak Hour Tolling Trips * Average Auto Occupancy Rate*
Daily	
Total Daily Vehicle Trips	**HOV Lane:** *Daily (Carpools (Free) + Buses + Others + Paying Vehicles)* **GP Lane:** *Peak Hour GP Lane Vehicle Trips * Daily to Peak Hour Conversion Factor*
Daily Carpools (Free) in HOV Lane*	*Peak Hour Carpools(Free)* Daily to Peak Hour Conversion Factor*
Daily Buses in HOV Lane*	*Peak Hour Buses * Daily to Peak Hour Conversion Factor*
Daily Others in HOV Lane*	*Peak Hour (Motocycles + Taxi + Special Fuel Vehicles) * Daily to Peak Hour Conversion Factor*
Daily Paying Vehicles in HOV Lane*	*Peak Hour Paying Vehicles (Free) * Daily to Peak Hour Conversion Factor*
Total Daily Person Trips	**HOV Lane:** *Daily (Carpools (Free) + Buses + Others + Paying Vehicles)* **GP Lane:** *Peak Hour GP Lane Vehicle Trips * Daily to Peak Hour Conversion Factor*
Daily Carpool Persons (Free) in HOV Lane*	*Daily Carpools Persons (Free) * Daily to Peak Hour Conversion Factor*
Daily Bus Passengers in HOV Lane*	*Daily Buses Passengers * Daily to Peak Hour Conversion Factor*
Daily Other Persons in HOV Lane*	*Peak Hour (Motocycles Persons + Taxi Persons + Special Fuel Persons) Daily to Peak Hour Conversion Factor*
Daily Paying Persons in HOV Lane*	*Peak Hour Paying Persons (Free) * Daily to Peak Hour Conversion Factor*

*Only applies to HOV Lane.

Table 4-10: Daily Conversion Calculations

Travel Demand Impacts	With Existing HOV Policy		With Selected Policy Changes	
	HOV Lane	GP Lane	HOV Lane	GP Lane
Total Peak Hour Person Trips	**HOV Lane:** =4,665 + 200 + 0 + 36 + 36 + 0 = 4,938 **GP Lane:** =11,250 * 1.1 = 12,375			
Peak Hour Carpool Persons (Free)	=2,121 * 2.2 = 4,665			
Peak Hour Others (Transit)	=10 * 20 = 200			
Peak Hour Motorcycle	=0 * 1.1 = 0			
Peak Hour Taxi	=17 * 2.1 = 36			
Peak Hour Special Fuel	=33 * 1.1 = 36			
Peak Hour Tolling	=0			
Daily				
Total Daily Vehicle Trips	**HOV Lane:** =25,452 + 120 + 600 + 0 = 26,172 **GP Lane:** =11,250 * 12 = 135,000			
Daily Carpools (Free) in HOV Lane*	=2,121 * 12 = 25,452			
Daily Buses in HOV Lane*	=10 * 12 = 120			
Daily Others in HOV Lane*	=(0 + 17 + 33) * 12 = 600			
Daily Paying Vehicles in HOV Lane*	=0			
Total Daily Person Trips	**HOV Lane:** =55,980 + 2,400 + 864 + 0 = 59,244 **GP Lane:** =12,375 * 12 = 148,500			
Daily Carpool Persons (Free) in HOV Lane*	=4,665 * 12 = 55,980			
Daily Bus Passengers in HOV Lane*	=200 * 12 = 2,400			
Daily Other Persons in HOV Lane*	=(0 + 36 + 36) * 12 = 864			
Daily Paying Persons in HOV Lane*	=0			

Mobility Impacts

The travel demand impacts will then be used to determine the facility operating conditions, including the volume-to-capacity ratio, operating speed, level of service, facility travel time, total vehicle travel delay, etc. Again, these impacts will be examined over daily and peak hour periods for both the HOV and GP lanes.

To calculate each of the mobility impacts, a number of assumptions are embedded into the calculations of these impacts. Examples of values the user may wish to update include Hourly Freeway Capacity per Lane (vph), Free Flow Speed (mph), the values for "alpha" and "beta" used in the Bureau of Public Roads equation for computing congested Peak Hour and Daily Travel Speeds, V/C thresholds for Level of Service, etc. All these assumptions are stored in the POET-ML Parameters Page. The user will have explicit access to change these assumptions if desired to better fit the characteristics of specific facilities and areas.

The calculations for mobility impacts are built with flexibility in mind, allowing the user to customize the assumptions to a specific region, if the data supports it, and if there is a desire for greater precision in the results. If not, the user can work with the set of assumptions that emerged out of the model calibration effort, which will be based on nationwide averages.

Table 4-11 outlines the information to be included for these mobility impacts and the detailed calculation methodology of those mobility impacts. Table 4-12 fills in these formulas, under the existing conditions, with values from the example cited earlier.

Table 4-11: Matrix of Mobility Impacts

Mobility Impacts	With Existing HOV Policy		With Selected Policy Changes	
	HOV Lane	GP Lane	HOV Lane	GP Lane
Peak Hour				
Peak Hour V/C	$\frac{Total\ Peak\ Hour\ Vehicle\ Trips\ (With\ PCE)}{\#of\ Lanes * Hourly\ Freeway\ Capacity\ Per\ Lane\ (vph)}$			
Peak Hour Travel Speed (mph)	$\frac{Free\ Flow\ Speed}{1 + alpha\left(Peak\ Hour\ V/C\right)^{beta}}$			
Peak Hour Level of Service (LOS)	*Peak Hour V/C<=0.3, LOS = A* *0.3< Peak Hour V/C<=0.5, LOS = B* *0.5< Peak Hour V/C<=0.75, LOS = C* *0.75< Peak Hour V/C<=0.9, LOS = D* *0.9< Peak Hour V/C<=1.0, LOS = E* *Peak Hour V/C>1.0, LOS = F*			
Peak Hour Corridor Travel Time (minutes) - Congested Condition	$\frac{Route\ Miles * 60}{Peak\ Hour\ Speed(mph)}$			
Peak Hour Total Vehicle Travel Delays (hours)	$\left(\frac{Route\ Miles}{Peak\ Hour\ Speed(mph)} - \frac{Route\ Miles}{Free\ Flow\ Speed(mph)}\right) * Total\ Peak\ Hour\ Vehicle\ Trips$			

Peak Hour Total Vehicle Travel Delay * Cost of Vehicle Delay ($/hr)	$Peak\ Hour\ Total\ Vehicle\ Travel\ Delay * VOT\ (\$/Hr)$
Peak Hour Travel Efficiency (Speed * Volume)	$\text{Peak Hour Speed} * \text{Total Peak Hour Vehicle Trips}$
Daily	
Daily V/C	$\frac{Total\ Daily\ Vehicle\ Trips\ (With\ PCE)}{\#of\ Lanes * Daily\ Freeway\ Capacity\ Per\ Lane\ (vph)}$
Daily Travel Speed (mph)	$\frac{Free\ Flow\ Speed}{1 + alpha(Daily\ V/C)^{beta}}$
Daily Level of Service	*Daily V/C<=0.3, LOS = A* *0.3< Daily V/C <=0.5, LOS = B* *0.5< Daily V/C <=0.75, LOS = C* *0.75< Daily V/C <=0.9, LOS = D* *0.9< Daily V/C <=1.0, LOS = E* *Daily V/C >1.0, LOS = F*
Daily Corridor Travel Time (minutes) - Congested Condition	$\frac{Route\ Miles * 60}{Daily\ Speed(mph)}$
Daily Total Vehicle Travel Delays (hours)	$(\frac{Route\ Miles}{Daily\ Speed(mph)} - \frac{Route\ Miles}{Free\ Flow\ Speed(mph)})$ $* Total\ Daily\ Vehicle\ Trips$
Daily Total Vehicle Travel Delay * Cost of Vehicle Delay ($/hr)	$Total\ Daily\ Vehicle\ Travel\ Delay * VOT\ (\$/Hr)$
Daily Travel Efficiency (Speed * Volume)	$\text{Daily Travel Speed} * \text{Total Daily Vehicle Trips}$

Table 4-12: Mobility Impacts Calculations

Mobility Impacts	With Existing HOV Policy		With Selected Policy Changes	
	HOV Lane	GP Lane	HOV Lane	GP Lane
Peak Hour				
Peak Hour V/C	=2,200 / (1 * 2,200) = 1.0			
Peak Hour Travel Speed (mph)	=65 / (1+0.9 * (1)^3) = 34.2			
Peak Hour Level of Service (LOS)	0.9< Peak Hour V/C<=1.0, LOS = E			
Peak Hour Corridor Travel Time (minutes) - Congested Condition	=(23.9 * 60) / 34.2 = 41.9			
Peak Hour Total Vehicle Travel Delays (hours)	(23.9 / 34.2 – 23.9 / 65) * 2200 = 728			
Peak Hour Total Vehicle Travel Delay * Cost of Vehicle Delay ($/hr)	=728 * 25 = 18,200			
Peak Hour Travel Efficiency (Speed * Volume)	=34.2 * 2,200 = 75,240			
Daily				
Daily V/C	=26,160 / (1 * 35,000) = 0.75			
Daily Travel Speed (mph)	=65 / (1 + 0.9 * (0.75)^3) = 47.2			
Daily Level of Service	0.5< Daily V/C <=0.75, LOS = C			
Daily Corridor Travel Time (minutes) - Congested Condition	=(23.9 * 60) / 47.2 = 30.4			
Daily Total Vehicle Travel Delays (hours)	(23.9 / 47.2 – 23.9 / 65) * 26,160 = 3,614			
Daily Total Vehicle Travel Delay * Cost of Vehicle Delay ($/hr)	=3,614 * 25 = 90,350			
Daily Travel Efficiency (Speed * Volume)	=47.2 * 26,160 = 1,234,752			

Environmental Impacts

POET-ML will use the traffic volume estimates and mobility impact estimates to evaluate the environmental effects of the HOV facility under consideration. Two key environmental indicators will be examined, including air quality performance and carbon dioxide.

The quantity of gasoline conserved can directly relate to reduced vehicular emissions. Gasoline savings were based on numbers derived using Texas Transportation Institute assumptions of 0.68 gallons of fuel per hour of delay. The evaluation will consider changes in total vehicle delay as a result of the policy adjustment package selected by the user and estimate the fuel-based emissions based on gas savings and estimated vehicular emission rates per gallon. Due to the difficulty in determining advancement in emissions technology, the values used in POET-ML reflect modern day estimated emission rates, as illustrated in Table 4-13.

Table 4-13: Matrix of Environmental Impacts[2]

Air Quality - Pollutant	Passenger Car Average Emissions
CO (kg/gallon)	14.44
NOx (kg/gallon)	1.27
VOC (kg/gallon)	1.91
Carbon Dioxide (kg/gallon)	8.79

For example, if the model results predict a reduction in total vehicle travel delay as a result of a conversion form HOV lanes to HOT lanes, POET-ML will model changes in air quality and carbon dioxide emissions based the above average rates. The user will be able to see the impact of any delay reduction in environmental terms.

Table 4-14 outlines the information to be included for the environmental impacts and the calculation methodology of these two performance measures. Table 4-15 fills in these formulas, under the existing conditions, with values from the example cited earlier.

[2] Source: Environmental Protection Agency

Table 4-14: Environmental Impacts Formulas

Environmental Impacts	With Existing HOV Policy		With Selected Policy Changes	
	HOV Lane	GP Lane	HOV Lane	GP Lane
Peak Hour				
Air Quality (kg)	*Peak Hour Total Vehicle Travel Delay * Gallons of Fuel /Hour * Passenger Car Aversage Emssion of* $(CO + NO_X + VOC)$			
Carbon Dioxide (kg)	*Peak Hour Total Vehicle Travel Delay * Gallons of Fuel /Hour * Passenger Car Aversage Emssion of Carbon Dioxide*			
Daily				
Air Quality (kg)	*Daily Total Vehicle Travel Delay * Gallons of Fuel /Hour * Passenger Car Aversage Emssion of* $(CO + NO_X + VOC)$			
Carbon Dioxide (kg)	*Daily Total Vehicle Travel Delay * Gallons of Fuel /Hour * Passenger Car Aversage Emssion of Carbon Dioxide*			

Table 4-15: Environmental Impacts Calculations

Environmental Impacts	With Existing HOV Policy		With Selected Policy Changes	
	HOV Lane	GP Lane	HOV Lane	GP Lane
Peak Hour				
Air Quality (kg)	=728 * 0.68 * (14.44 + 1.27 + 1.91) = 8,723			
Carbon Dioxide (kg)	=728 * 0.68 * 8.79 = 4,351			
Daily				
Air Quality (kg)	=3,614 * 0.68 * (14.44 + 1.27 + 1.91) = 43,302			
Carbon Dioxide (kg)	=3,614 * 0.68 * 8.79 = 21,602			

Again, the user will have access to adjust all the estimated emission rates for CO (kg/gallon), NOx (kg/gallon), VOC (kg/gallon) and Carbon Dioxide (kg/gallon) in the POET-ML Parameter page if desired.

Financial Feasibility

The final measure of effectiveness is financial feasibility. The set of policy adjustments includes pricing of existing HOV lanes, and if pricing is selected, it will trigger additional analysis in the model. Again, the user will have access to assumptions behind these calculations, including value of time estimates, weekend/weekday revenue ratios, and per-transaction tolling operation costs. The model incorporates national averages for these inputs and uses the results from the mobility impact analysis to perform this financial evaluation.

Output for this step includes the number of tolled vehicles, daily and annual revenue, and annual toll operation costs. Also bundled with this output is a set of transportation benefits calculated in monetary terms. These are presented as travel time and fuel savings as well as daily user benefits resulting from policy changes implemented on the HOV facility. Specific measures of financial feasibility and its corresponding calculation methodology are listed in Table 4-16. Table 4-17 presents example calculations assuming that occupancy restrictions were changed from 2+ to 3+ in the example cited previously.

Table 4-16: Matrix of Financial Feasibility Output

Financial Feasibility	With Selected Policy Changes	
	HOV Lane	GP Lane
Toll Revenue and Toll O&M Cost (Only apply to Scenario with Policy Change of Pricing on Existing HOV Lanes)		
Number of vehicles paying a toll in peak hours	*Peak Hour Tolling Vehicle Trips* *(from Travel Demand Impacts)*	
Number of vehicles paying a toll in other Daily Periods	*Daily Tolling Vehicle Trips* *(from Travel Demand Impacts)*	
Total Daily Revenue	*(Total Peak Hour Tolling Vehicle Trips * HOT Peak Hour Travel Time Savings* *+ Total Daily Tolling Vehicle Trips * HOT Daily Travel Time Savings)* ** Minimum Value of Time / 60*	
Total Daily Revenue per Mile	*Total Daily Revenue / Route Mile*	
Number of Working Days per Year	*250 (from Parameter Page)*	
Gross Annual Revenue	*Total Daily Revenue * Number of Working Days Per Year +* *Total Daily Revenue * (365 - Number of Working Days Per Year) ** *Ratio of Weekend Revneue and Weekday Revenue*	
Annual Toll Operation Costs	*(Peak Hour Tolling Vehicle Trips + Daily Tolling Vehicle Trips)** *((Number of Working Days Per Year + (365 - Number of Working Days Per Year)* ** Ratio of Weekend Revneue and Weekday Revenue))* ** Annual Toll Operation Cost Per Transaction)*	
Travel Benefits (Categorized by Lane Type: HOV Lanes and GP Lanes when compared to Existing HOV Policy Scenario)		

Daily User Mobility Benefits (Travel Time Savings * VOT of $/hr)	*Difference on Peak Hour Total Vehicle Travel Delay (With Policy Change v.s Exisiting Policy)* VOT ($/Hr) + Difference on Daily Total Vehicle Travel Delay (With Policy Change v.s Exisiting Policy)* VOT ($/Hr)*
Fuel Cost Savings (Gallons)	*Difference on Peak Hour Total Vehicle Travel Delay (With Policy Change v.s Exisiting Policy)* Gallons of Fuel /Hour + Difference on Daily Total Vehicle Travel Delay (With Policy Change v.s Exisiting Policy)* Gallons of Fuel /Hour*

Note:
HOT Peak Hour Travel Time Saving = GP Lane Peak Hour Travel Time - HOT Lane Peak Hour Travel Time
HOT Daily Travel Time Saving = GP Lane Daily Travel Time - HOT Lane Daily Travel Time

Table 4-17: Financial Feasibility Calculations

Financial Feasibility	With Selected Policy Changes	
	HOV Lane	GP Lane
Toll Revenue and Toll O&M Cost (Only apply to Scenario with Policy Change of Pricing on Existing HOV Lanes)		
Number of vehicles paying a toll in peak hours	=1,252	
Number of vehicles paying a toll in other Daily Periods	=15,029	
Total Daily Revenue	=1,241 * (49-30.4) + 15,029 * (33.6-25.5) * 25/60 = 60,341	
Total Daily Revenue per Mile	=60,341 / 23.9 = 2,525	
Number of Working Days per Year	250	
Gross Annual Revenue	=60,341 * 250 + 60,341 * (365-250) * 0.25 = 16,820,054	
Annual Toll Operation Costs	=(1,252 + 15,029) * (250 + (365-250) * .25) * .15) = 610,557	
Travel Benefits (Categorized by Lane Type: HOV Lanes and GP Lanes when compared to Existing HOV Policy Scenario)		
Daily User Mobility Benefits (Travel Time Savings * VOT of $/hr)	=(18,200 – 5,750) + (90,350 – 28,275) = 74,525	
Fuel Cost Savings (Gallons)	=(728 - 230) + (3,614 – 1,131) = 2,027	

- **Step 4: Evaluation of Goals and Objectives**

The analysis does not end with step 3. Recognizing that regional goals largely dictate transportation policy decisions, POET-ML includes an evaluation of selected policy adjustments in order to understand their ability to address common goals. The tool will employ a simple matrix that relates policy changes with common goal statements. This matrix will be populated with values that reflect the relative strength of each policy in addressing each goal. Example goals include the following:

  - Protect Mobility
  - Maximize person throughput
  - Provide an option for travel time savings and trip reliability
  - Encourage carpooling in peak periods
  - Support transit service and reliability
  - Manage congestion by improving system efficiency
  - Improve air quality
  - Provide a Financially Viable System

The user will then be able to refine the selected policy adjustment package based on this evaluation and return to the quantitative steps in the tool to re-evaluate this selection. In this way, the user will be able to strike an appropriate balance between quantitative and qualitative policy acceptability.

SECTION 5: CONCLUSIONS

This study examined the performance of HOV lanes based on the goals and objectives under which those HOV lanes were designed to operate and the factors that can best contribute to the success of HOV lanes, through targeted and focused outreach to HOV operators. An HOV Lane Compendium was developed that documented the basic characteristics of current and proposed High-Occupancy Vehicle (HOV) lanes throughout the United States. A survey and follow-up interviews with HOV facility owners was conducted in order to reveal why HOV lanes are successful, why some owners are considering policy changes, and what are the future expectations of HOV lanes. Then, a Policy Options Evaluation Tool for Managed Lanes (POET-ML) was developed to quantify the impacts of pricing and other policy shifts on the operational performance of the nation's HOV lanes.

The results of the HOV operator survey and interviews revealed similar operational challenges and common categories of performance characteristics across HOV systems nationally. Localized habits and usage trends produce significant differences in outcome expectations for policy changes. In general, there does not appear to be a "one size fits all" understanding of the approaches to HOV policy change for improved operations. There are, however, distinct characteristics and lessons learned that increase the chances for successful policy implementation under certain conditions. Identifying an appropriate policy change, or set of policy changes, is just an initial step in addressing HOV lane performance challenges. Bringing these changes to bear is the next challenge. The following is a summary of conclusions on factors and policy change, as identified by HOV operators:

- Areas with general public familiarity and acceptance of tolled facilities (i.e., areas where toll roads are currently in operation) are more likely to buy into new pricing concepts.
- Federal rules can provide support to defuse politically charged policy issues that, while they may improve level-of-service, are unpopular in the region.
- Even slight operational changes to hours of operation can have significant impact on general-use lanes due to commute patterns and congestion levels prior to and immediately following peak-period HOV operation. A thorough analysis of operations implications is very important before deciding on a shift of HOV policy.
- Because an HOV occupancy policy increase can cause sharp decreases in eligible carpool formation, and because it can negatively impact general-use lane congestion during peak periods, pricing is currently viewed as a more promising lane management approach. But pricing approaches require significant facility/technology and time investments for implementation.
- Complementary policy changes, such as occupancy changes or access changes, almost always go along with conversion to HOT facilities, to make the conversion work as intended. Such changes may be implemented incrementally.
- Pricing implementation is increasingly viewed by the HOV/HOT community as feasible in congested areas only with the addition of new lanes and transit infrastructure. In some regions, this may be the only approach by which "new capacity" may be financed and built.
- Pricing implementation has often not been successful without a political champion and clearly defined relationships and responsibilities between agency partners.
- Close coordination with FHWA on design exceptions and other geometric concerns will be paramount in future pricing implementation projects in urban areas with limited right-of-way and capacity-building options.

The Policy Options Evaluation Tool for Managed Lanes (POET-ML) was developed to enable HOV operators and policy-makers the ability to observe how HOV policy changes will impact the performance of HOV facilities, employing both quantitative analyses and qualitative reality checks. This tool was designed to be flexible enough to allow a user with little information to gain a comprehensive understanding of the current operational effectiveness of a specific HOV facility and to evaluate the impacts of potential policy changes. HOV operators with more extensive input data, and a motivation for more customized results, are granted access to adjust a number of model assumptions in order to account for regional variation.

Every HOV lane is unique in its demand composition and operations. Policy changes will leave a unique footprint with respect to operational performance and financial feasibility. It is important to recognize that the impacts of such policy changes will vary significantly depending on localized conditions including but not limited to travel times, trip purposes, and driver willingness to pay. In the documentation of POET-ML, we organized the multitude of potential inputs and outcomes into a manageable number of typical scenarios (Scenario 1: HOV & GP Lanes Both Under Capacity; Scenario 2: HOV Lane Under Capacity & GP Lanes Congested; and Scenario 3: HOV Lane & GP Lanes Over Capacity [Increased Restrictions]; and Scenario 4: HOV Lane & GP Lanes Over Capacity [Additional Capacity]). Each scenario varies with respect to mobility impacts, environmental impacts, and financial feasibility. POET-ML provides high-level impacts of proposed HOV policy adjustments – more detailed analysis is recommended prior to implementation of any policy changes identified in the tool.

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