Policy Options Evaluation Tool for Managed Lanes (POET-ML) Users Guide and Methodology Description

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User’s guide for a sketch planning tool for exploring policy alternatives. It is intended for an audience of transportation professionals responsible for planning, designing, funding, operating, enforcing, monitoring, and managing HOV and HOT lanes, and considering conversion of HOV to HOT lanes. This material is also included in FHWA-HOP-09-29,</td></tr>
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Introduction

High-occupancy vehicle (HOV) lanes are reserved for vehicles with a driver and one or more passengers. These lanes, which often run parallel to general purpose (GP) highway lanes, have been implemented in over 30 U.S. cities 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. The restrictions in these lanes limit traffic demand, which can provide travel time savings along a corridor when compared to adjacent general purpose lanes. This travel time advantage is an incentive to drivers to form carpools in order to bypass congestion.

HOV lanes are one possible solution to increase transportation system efficiency. However, in practice these lanes do not always provide the advantages they advertise. Because occupancy restrictions are discrete (2+, 3+, etc.), it is difficult to achieve utilization balance in these lanes. Ideally, HOV lanes would carry between 1,500-1,800 vehicles per hour per lane, which roughly corresponds to Level of Service C conditions and operating speeds of 45 mph or higher. This level of flow would ensure a high degree of vehicle throughput, and greater overall system efficiency. However, in some areas around the country, occupancy guidelines prove to be too restrictive, resulting in empty lane syndrome, where HOV lanes experience very light demand. In other areas, peak period demand from eligible carpools can actually overwhelm the HOV lanes, leading to congested conditions. Situations with too many, or too few, vehicles using the facilities have left several HOV operators seeking solutions to improve the performance of their HOV lanes.

Fortunately, a number of policy solutions do exist to improve utilization rates in HOV lanes. The planning team has developed the Policy Options Evaluation Tool for Managed Lanes (POET-ML) to evaluate potential changes to existing HOV facilities. This tool is intended for use by HOV owners who are considering changes to their current operating policies. It will allow them to see the impacts of various alternatives and to compare these alternatives to one another. The methodology behind POET-ML is outlined in this paper.

POET-ML 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.

POET-ML is 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?

POET-ML Framework

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

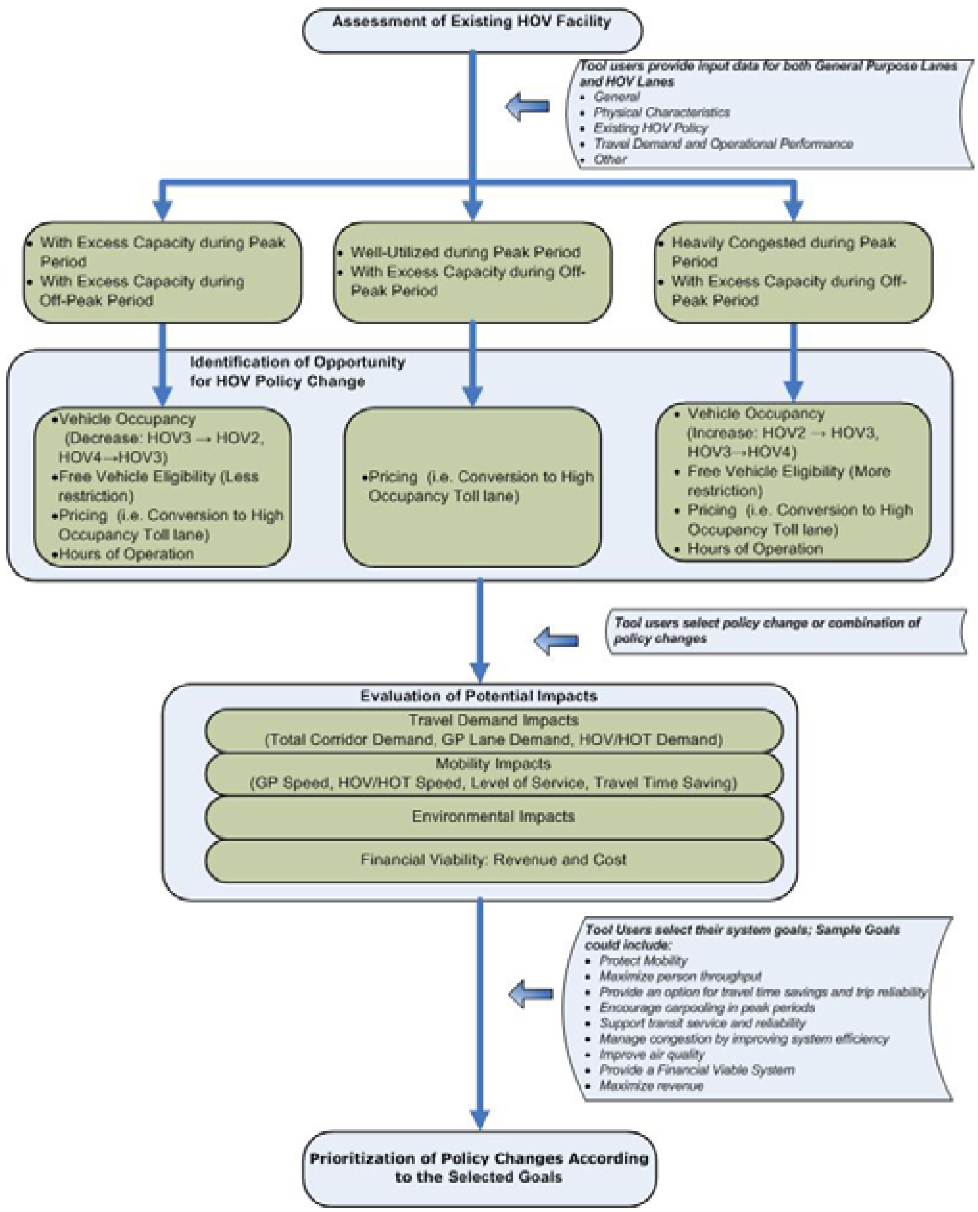

Figure 1: POET-ML Framework

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 create a new record and store a specific profile for future use by modifying the text for one or more of the input data field records. This can be done by clicking “Store Profile” in the input page. The tool has the capacity for storing 50 new profiles in addition to the HOV facilities stored in FHWA’s HOV Facility Inventory database. If all profiles are in use, the user can delete the profiles that are no longer needed by clicking the button of “Manage Profiles” and save the latest record.

Table 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 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.

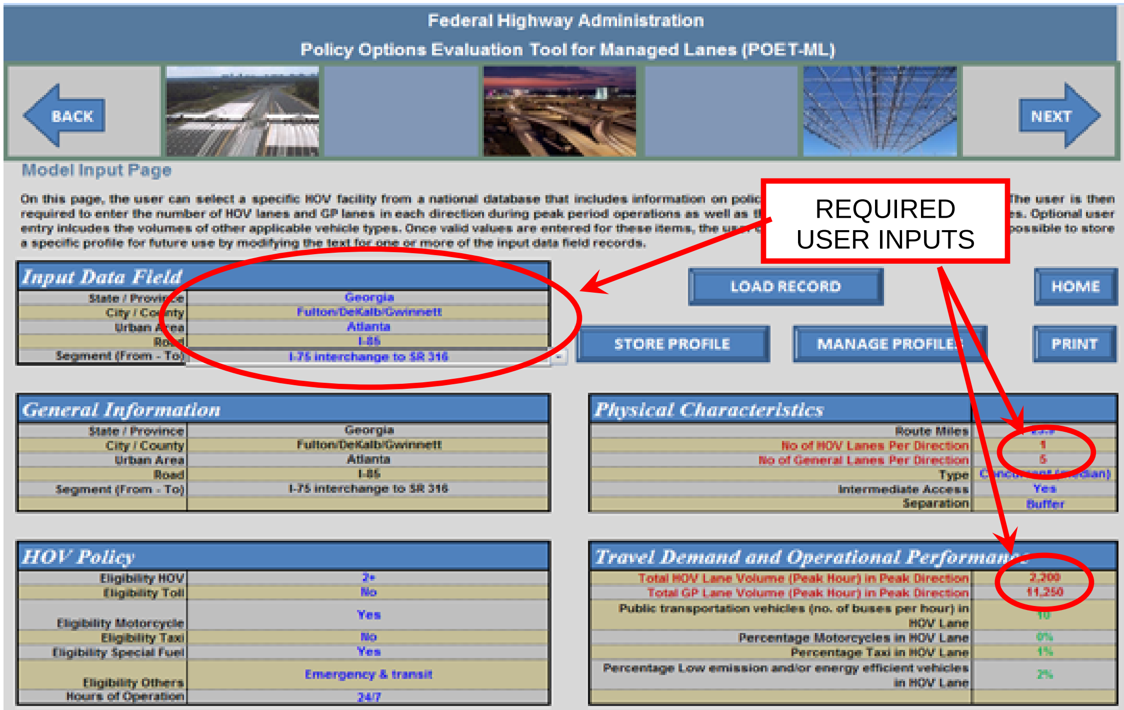

Figure 2: Model Input Page

User input, as outlined in
Table 1, 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 2 outlines the two categories and corresponding performance thresholds by default.

Table 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 Parameters page provides significant flexibility for regional customization. The user can change a number of highway capacity assumptions including free-flow speeds, hourly and daily freeway lane capacity, and the percentage of lane capacity used under LOS C conditions. Bus occupancy and passenger car equivalent information can also be updated to represent local conditions. HOV splits were assumed to be 85%, 10%, and 5% for HOV2, HOV3, and HOV4, respectively. These default values can also be modified by the user. Information used to calculate congested speeds and conditions is also customizable. V/C ratios, maximum flow rates, and minimum speeds for all LOS conditions are included in the Parameters page. Finally, the user can update vehicle emissions assumptions based on local fleet characteristics. The hourly emissions of carbon monoxide, various oxides of nitrogen, volatile organic compounds, carbon dioxide, and gallons of fuel are all included in this page and are available to update.

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 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 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.

<u>Example:</u>

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 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: 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 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 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 tool assumes that existing HOVs do not break up to form paying SOVs. Also, no transit riders are diverted to paying SOVs. In order to explore scenarios like these, the user must first implement a policy change and then return to the Parameters page to adjust the assumptions for HOV split, transit ridership, etc., as appropriate. This two step process allows the user to understand mode split changes resulting from HOV lane policy updates.

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 an 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 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 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

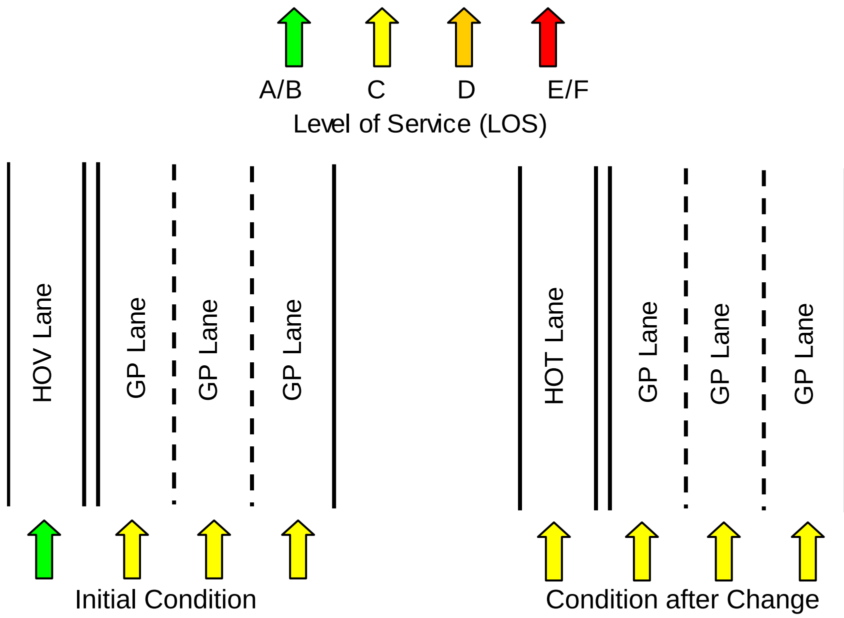

Figure 3: Scenario 1 Lane Condition Diagrams

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 . 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 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 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

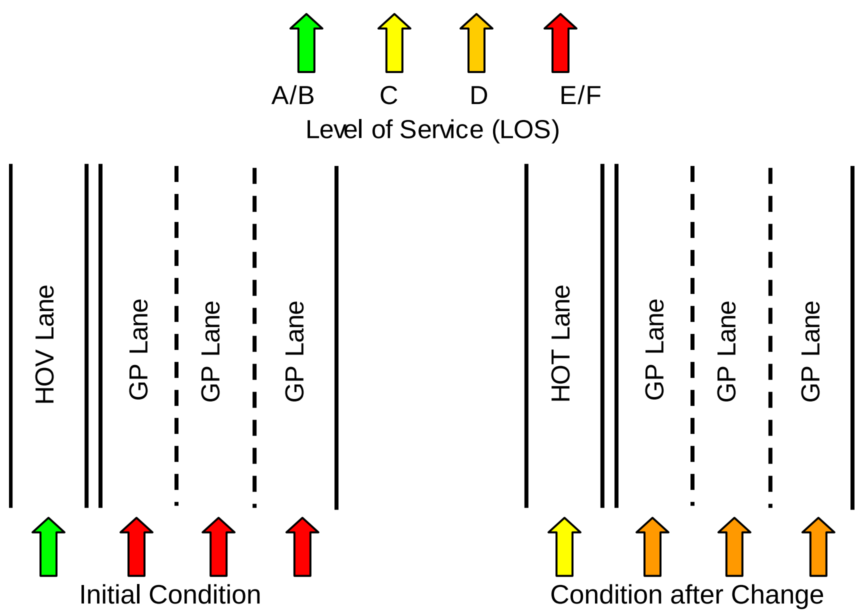

Figure 4: Scenario 2 Lane Condition Diagrams

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 and parallel facilities. The methodology for this diversion of vehicles *out* of the managed lane mirrors that for the diversion *into* the managed lane described previously. The diversion of the traffic into the GP lanes and parallel facilities depends on the congestion level of GP lane facilities. The splits of ineligible HOV vehicles are coded as parameters in the Tool. If the user desires to vary the diversion of ineligible HOV vehicles, he or she has the flexibility to adjust these parameters.

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 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 and parallel facilities. 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 .

Table 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 and parallel facilities in response to the occupancy policy change, are responsible for the increased GP lane congestion.

Table 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	7,085
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

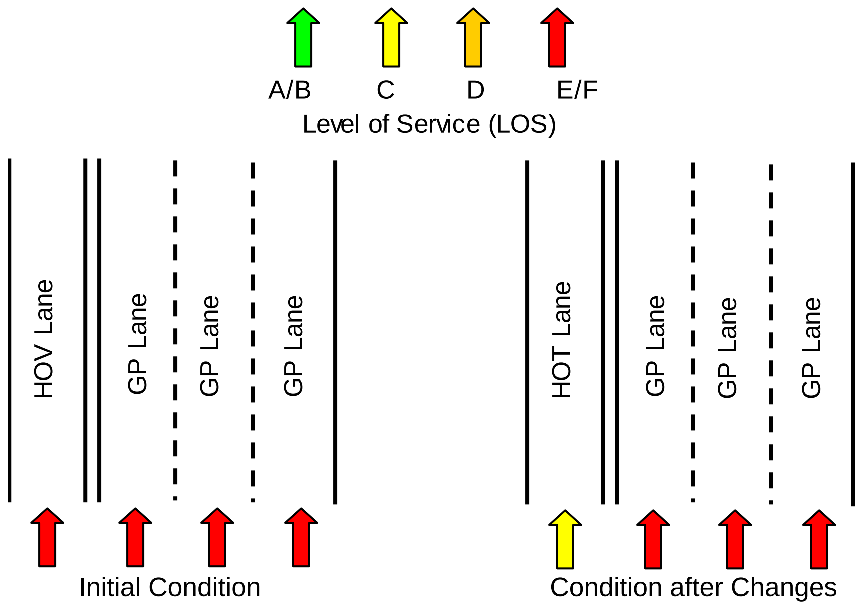

Figure 5: Scenario 3 Lane Condition Diagrams

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 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 , 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. 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 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

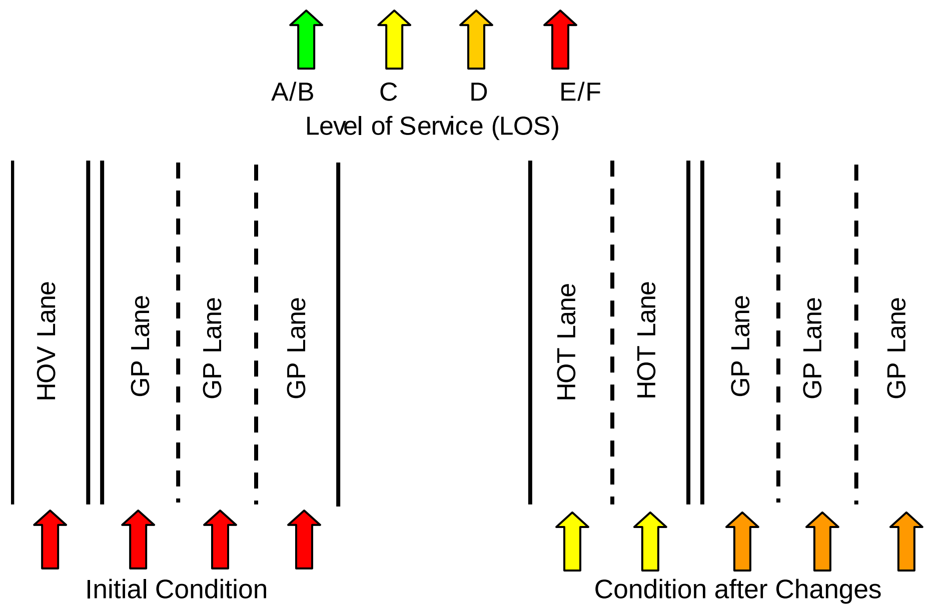

Figure 6: Scenario 4 Lane Condition Diagrams

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 the daily to Peak Hour Conversion factor. Table 9 outlines those travel demand impacts and its corresponding calculation methodology. The table also includes values from the earlier example.

Table 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:** $PeakHour(Carpools(Free) + Buses + Motocycle + Taxi + SpecialFuel + PayingVehicles)Persons$			

	GP Lane: *Peak Hour GP Lane Vehicle Trips * Average Auto Occupancy Rate* **HOV Lane:** =4,665 + 200 + 0 + 36 + 36 + 0 = 4,938 **GP Lane:** =11,250 * 1.1 = 12,375
Peak Hour Carpool Persons (Free)	*Peak Hour Carpools (Free) Vehicles Trips * Carpool Occupancy Rate* =2,121 * 2.2 = 4,665
Peak Hour Others (Transit)	*Peak Hour Bus Vehicles Trips * Bus Occupancy Rate* =10 * 20 = 200
Peak Hour Motorcycle	Peak Hour Motorcycle Trips * Average Auto Occupancy Rate =0 * 1.1 = 0
Peak Hour Taxi	*Peak Hour Taxi Trips * Average Auto Occupancy Rate* =17 * 2.1 = 36
Peak Hour Special Fuel	*Peak Hour Special Fuel Vehicle Trips * Average Auto Occupancy Rate* =33 * 1.1 = 36
Peak Hour Tolling	*Peak Hour Tolling Trips * Average Auto Occupancy Rate* =0
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* **HOV Lane:** =25,452 + 120 + 600 + 0 = 26,172 **GP Lane:** =11,250 * 12 = 135,000
Daily Carpools (Free) in HOV Lane*	*Peak Hour Carpools(Free)* Daily to Peak Hour Conversion Factor* =2,121 * 12 = 25,452
Daily Buses in HOV Lane*	*Peak Hour Buses * Daily to Peak Hour Conversion Factor* =10 * 12 = 120
Daily Others in HOV Lane*	Peak Hour (Motorcycles + Taxi + Special Fuel Vehicles) * Daily to Peak Hour Conversion Factor =(0 + 17 + 33) * 12 = 600
Daily Paying Vehicles in HOV Lane*	*Peak Hour Paying Vehicles (Free) ** *Daily to Peak Hour Conversion Factor* =0

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* **HOV Lane:** =55,980 + 2,400 + 864 + 0 = 59,244 **GP Lane:** =12,375 * 12 = 148,500
Daily Carpool Persons (Free) in HOV Lane*	*Daily Carpools Persons (Free) * Daily to Peak Hour Conversion Factor* =4,665 * 12 = 55,980
Daily Bus Passengers in HOV Lane*	*Daily Buses Passengers * Daily to Peak Hour Conversion Factor* =200 * 12 = 2,400
Daily Other Persons in HOV Lane*	Peak Hour (Motorcycles Persons + Taxi Persons + Special Fuel Persons) * Daily to Peak Hour Conversion Factor =(0 + 36 + 36) * 12 = 864
Daily Paying Persons in HOV Lane*	*Peak Hour Paying Persons (Free) * Daily to Peak Hour Conversion Factor* =0

*Only applies to HOV Lane.

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 10 outlines the information to be included for these mobility impacts and the detailed calculation methodology of those mobility impacts. The table also fills in these formulas, under the existing conditions, with values from the example cited earlier.

Table 10: 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	$\frac{Total\ Peak\ Hour\ Vehicle\ Trips\ (With\ PCE)}{\#of\ Lanes * Hourly\ Freeway\ Capacity\ Per\ Lane\ (vph)}$ =2,200 / (1 * 2,200) = 1.0			
Peak Hour Travel Speed (mph)	$\frac{Free\ Flow\ Speed}{1 + alpha(Peak\ Hour\ V/C)^{beta}}$ =65 / (1+0.9 * (1)^3) = 34.2			
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* 0.9< Peak Hour V/C<=1.0, LOS = E			
Peak Hour Corridor Travel Time (minutes) - Congested Condition	$\frac{Route\ Miles * 60}{Peak\ Hour\ Speed(mph)}$ =(23.9 * 60) / 34.2 = 41.9			
Peak Hour Total Vehicle Travel Delay (hours)	$(\frac{Route\ Miles}{Peak\ Hour\ Speed(mph)} - \frac{Route\ Miles}{Free\ Flow\ Speed(mph)})$ $* Total\ Peak\ Hour\ Vehicle\ Trips$ (23.9 / 34.2 – 23.9 / 65) * 2200 = 728			
Peak Hour Total Vehicle Travel Delay * Cost of Vehicle Delay ($/hr)	$Peak\ Hour\ Total\ Vehicle\ Travel\ Delay * VOT\ (\$/Hr)$ =728 * 25 = 18,200			
Peak Hour Travel Efficiency (Speed * Volume)	Peak Hour Speed * Total Peak Hour Vehicle Trips =34.2 * 2,200 = 75,240			
Daily				
Daily V/C	$\frac{Total\ Daily\ Vehicle\ Trips\ (With\ PCE)}{\#of\ Lanes * Daily\ Freeway\ Capacity\ Per\ Lane\ (vph)}$ =26,160 / (1 * 35,000) = 0.75			
Daily Travel Speed (mph)	$\frac{Free\ Flow\ Speed}{1 + alpha(Daily\ V/C)^{beta}}$ =65 / (1 + 0.9 * (0.75)^3) = 47.2			
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* 0.5< Daily V/C <=0.75, LOS = C
Daily Corridor Travel Time (minutes) - Congested Condition	$\frac{Route\ Miles * 60}{Daily\ Speed(\ mph\ )}$ =(23.9 * 60) / 47.2 = 30.4
Daily Total Vehicle Travel Delay (hours)	$(\frac{Route\ Miles}{Daily\ Speed(\ mph\ )} - \frac{Route\ Miles}{Free\ Flow\ \ Speed(\ mph\ )})$ $* \ Total\ \ Daily\ Vehicle\ Trips$ (23.9 / 47.2 – 23.9 / 65) * 26,160 = 3,614
Daily Total Vehicle Travel Delay * Cost of Vehicle Delay ($/hr)	$Total\ \ Daily\ Vehicle\ Travel\ \ Delay * VOT\ (\$/Hr)$ =3,614 * 25 = 90,350
Daily Travel Efficiency (Speed * Volume)	$\text{Daily Travel Speed} * \text{Total Daily Vehicle Trips}$ =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 11.

Table 11: Matrix of Environmental Impacts[1]

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.

[1] Source: Environmental Protection Agency

Table 12 outlines the information to be included for the environmental impacts and the calculation methodology of these two performance measures. The table also fills in these formulas, under the existing conditions, with values from the example cited earlier.

Table 12: 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 Average Emission of $(CO + NO_X + VOC)$ =728 * 0.68 * (14.44 + 1.27 + 1.91) = 8,723			
Carbon Dioxide (kg)	Peak Hour Total Vehicle Travel Delay * Gallons of Fuel / Hour * Passenger Car Average Emission of Carbon Dioxide =728 * 0.68 * 8.79 = 4,351			
Daily				
Air Quality (kg)	Daily Total Vehicle Travel Delay * Gallons of Fuel / Hour * Passenger Car Average Emission of $(CO + NO_X + VOC)$ =3,614 * 0.68 * (14.44 + 1.27 + 1.91) = 43,302			
Carbon Dioxide (kg)	Daily Total Vehicle Travel Delay * Gallons of Fuel / Hour * Passenger Car Average Emission of Carbon Dioxide =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 13. The table also presents example calculations assuming that occupancy restrictions were changed from 2+ to 3+ in the example cited previously.

Table 13: 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)* =1,252	
Number of vehicles paying a toll in other Daily Periods	*Daily Tolling Vehicle Trips* *(from Travel Demand Impacts)* =15,029	
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* =1,241 * (49-30.4) + 15,029 * (33.6-25.5) * 25/60 = 60,341	
Total Daily Revenue per Mile	*Total Daily Revenue / Route Mile* =60,341 / 23.9 = 2,525	
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* =60,341 * 250 + 60,341 * (365-250) * 0.25 = 16,820,054	
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)* =(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 $/hr)	Difference on Peak Hour Total Vehicle Travel Delay (With Policy Change v.s Existing Policy) * VOT ($/Hr) + Difference on Daily Total Vehicle Travel Delay (With Policy Change v.s Existing Policy) * VOT ($/Hr) =(18,200 – 5,750) + (90,350 – 28,275) = 74,525	

Fuel Cost Savings (Gallons)	Difference on Peak Hour Total Vehicle Travel Delay (With Policy Change v.s Existing Policy) * Gallons of Fuel /Hour + Difference on Daily Total Vehicle Travel Delay (With Policy Change v.s Existing Policy) * Gallons of Fuel /Hour =(728 - 230) + (3,614 – 1,131) = 2,027

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

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 reevaluate this selection. In this way, the user will be able to strike an appropriate balance between quantitative and qualitative policy acceptability.

Conclusion

POET-ML employs both quantitative analyses and qualitative reality checks so that HOV operators can select the best set of policy adjustments for their region. This tool is 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, will be granted access to a number of model assumptions in order to account for regional variation. However, the ultimate goal of this tool is to provide a sketch-level planning analysis of proposed HOV policy adjustments. More detailed analysis is recommended prior to implementation of any of the policy changes seen in this tool.

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