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7. Author(s)
William Stockton, Robert Benz, Laurence Rilett, Douglas A. Skowronek, Sharada Vadali, and Ginger Daniels

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The Texas A&M University System
College Station, Texas 77843-3135

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16. Abstract
This research project examines the factors that bear on a decision to implement a high-occupancy/toll (HOT) lane in an existing freeway corridor. The characteristics of both facility and traffic are explored in an attempt to identify those combinations that suggest successful implementation of a HOT lane as well as those factors that will contraindicate a HOT lane. This report identifies critical issues warranting careful study during preliminary investigations. It discusses other aspects of candidate HOT lanes, such as revenue potential, equity considerations, design requirements, and operational limitations.

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William Stockton, P.E.
Research Engineer
Texas Transportation Institute

Robert Benz, P.E.
Assistant Research Engineer
Texas Transportation Institute

Laurence Rilett, Ph.D.
Assistant Research Engineer
Texas Transportation Institute

Douglas A. Skowronek, P.E.
Associate Research Engineer
Texas Transportation Institute

Sharada Vadali, Ph.D.
Assistant Research Scientist
Texas Transportation Institute

and

Ginger Daniels, P.E.
Associate Research Engineer
Texas Transportation Institute

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TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

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The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation. The engineer in charge of this project was William R. Stockton (#41188).

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INTRODUCTION

High-occupancy/toll (HOT) lanes are high-occupancy vehicle (HOV) facilities open to lower-occupancy (including single-occupancy) vehicles upon payment of a fee or toll. The concept was first articulated in a 1993 policy paper by Gordon J. Fielding and Daniel B. Klein *(1)*. HOT lanes differ from regular toll roads, which may offer discounts to high-occupancy vehicles, in that they give drivers of lower-occupancy vehicles a choice: stay in the free but congested lanes or pay a fee and enjoy a faster, more reliable, and less stressful trip in the HOT lane.

FACILITY TYPES

There are four common types of HOV lanes: reversible-flow, two-way, concurrent, and contraflow. Of these four, only two types have been used as HOT lanes: reversible-flow and two-way, which are typically separated from the general-purpose lanes and other vehicles using barriers. Reversible-flow lanes provide good service to peak directional traffic, while two-way facilities supply capacity in both directions of travel. Concurrent-flow lanes can be barrier- or buffer-separated. The buffer-separated lanes have the potential to be accessible the length of the route and would be difficult to enforce, reducing the unattractiveness as HOT lane candidate. Contraflow lanes are rare and have not been used for HOT lanes. The definitions in the following paragraphs stem from typical HOV designs. Examples of these facility types are in operation as HOV and HOT lanes throughout the country. The schematic shown in Figure 1 and the pictures in Figures 2 through 12 are illustrated examples of the various types of HOT and HOV lanes.

Reversible-flow lanes are permanent HOV or HOT facilities that carry traffic one direction in the morning and the opposite direction in the evening. These facilities can have one or more lanes and are applicable when there is an unequal traffic distribution. The unequal traffic distribution occurs when there is a substantially higher demand traveling in one direction than the other, and the pattern reverses itself between the morning and evening peak periods *(3)*. A peak/off-peak directional demand should be at least 65/35 and should be conservatively estimated. This type of peaking pattern occurs in an urban area with outlying suburbs, where most people commute to employment areas in the morning and return home in the evening. Examples of this type of reversible HOT lane are the IH-10 West Katy freeway in Houston, Texas, and IH-15 in San Diego, California (see Figure 2) *(4)*.

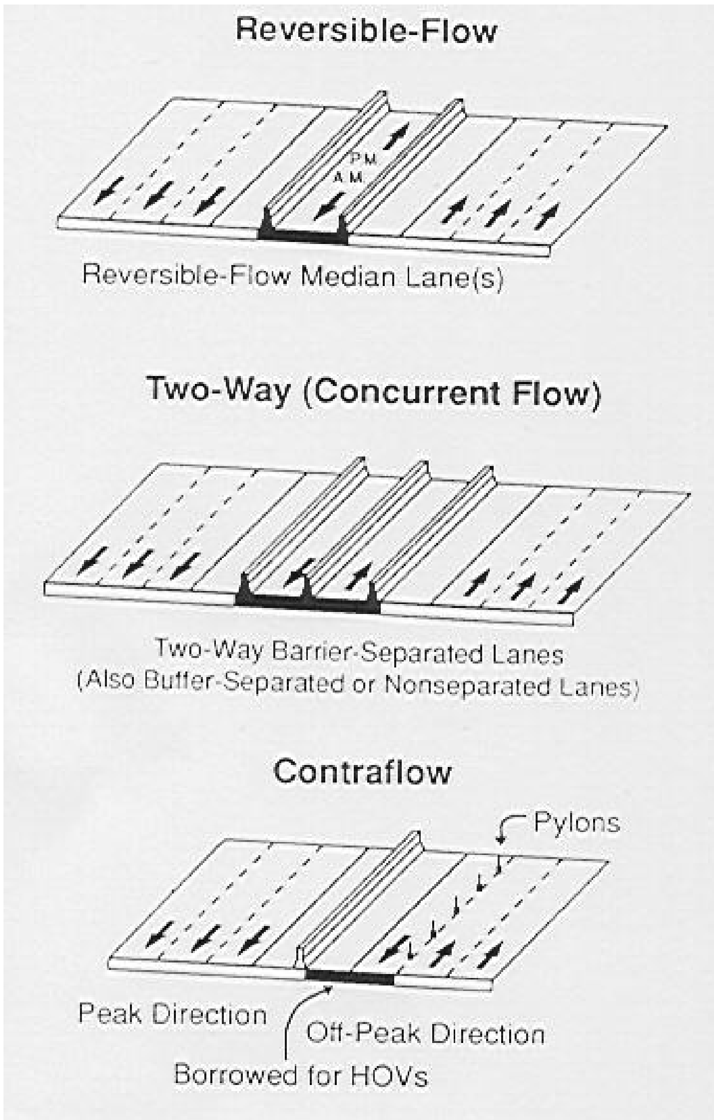

Figure 1. Schematic of HOV Operations *(2,4)*.

Figure 2. IH-10 West (Katy) Freeway Barrier-Separated Reversible HOT Lane in Houston, Texas *(2,4)*.

Figure 3. IH-395 (Shirley Highway) Barrier-Separated Reversible HOV Lane in Northern Virginia/Washington, D.C. *(2)*.

Figure 4. Limited Access Concurrent-Flow HOV Lane in Southern California *(2)*.

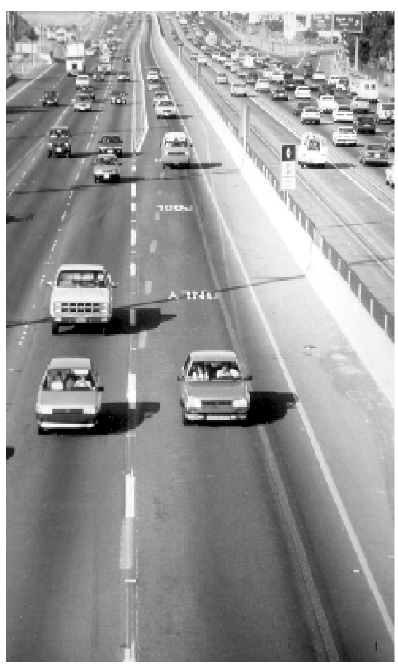

Figure 5. Entry/Exit for Concurrent-Flow HOV Lane in Southern California *(2)*.

Figure 6. IH-5 North Concurrent-Flow HOV Lanes in Seattle, Washington *(2)*.

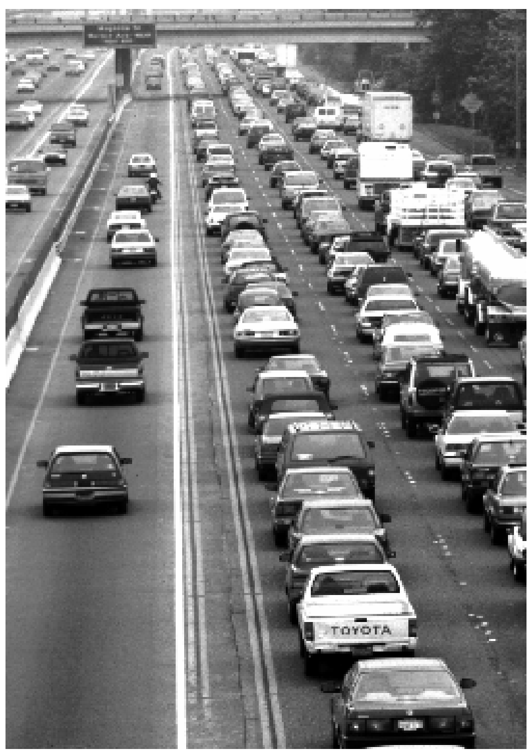

Figure 7. IH-405 Buffer-Separated Concurrent-Flow HOV Lane in Orange County, California *(2)*.

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Figure 10. IH-45 Gulf Freeway T Ramp in Houston, Texas *(2)*.

Figure 11. Drop Ramp in Orange County, California *(2)*.

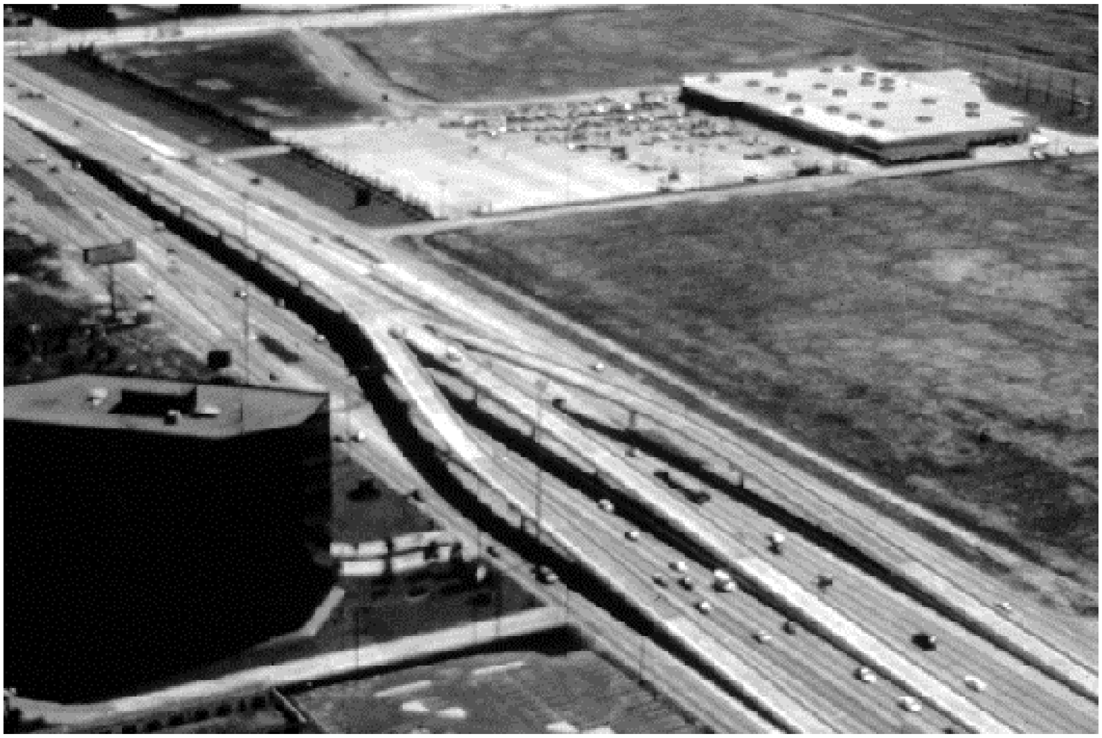


Figure 12. IH-45 North Freeway Y Ramp or Wishbone Ramp in Houston, Texas *(2)*.

Two-way/concurrent-flow operation entails using one or more buffer-separated, barrier-separated, or non-separated lanes during the peak or full-time use. This operation type is recommended when forecast volumes are almost equal or less than the peak/off-peak split of 65/35. An adequate number of users should exceed 400 vehicles per hour per direction to avoid the empty-lane syndrome *(4)*. The *HOV Systems Manual*, published by the National Cooperative Highway Research Program (NCHRP) suggests that the HOV lanes move more people than the per lane average of the adjacent general-purpose lanes *(2)*. Other criteria include having existing or forecasted recurring congestion in both directions. The Route 91 Express Lanes in Orange County, California, are examples of two-way, two-lane HOT lanes.

OVERVIEW OF OPERATIONAL HOT LANES

SR-91 EXPRESS LANES, ORANGE COUNTY, CALIFORNIA (NEW CAPACITY PROJECT)

The California State Route (SR) 91 HOT lanes project is the nation's first experiment with value pricing. These HOT lanes were built in one of the most congested corridors of California, with typical peak-period delays of 30–40 minutes. California Legislature built the project as a private for-profit investment as one of the four such private-public partnerships authorized under AB 680 legislation. The facility opened in 1995 and was constructed by California Private Transportation Company (CPTC) on land leased from the state. CPTC has 35 years to return profit to the investors after which the facility reverts to full state control.

Project Goals

The project has goals to:

- promote California's ridesharing policy and
- return a profit to the investors.

Project Design

The toll lanes are located in the freeway median between Anaheim and Riverside Counties, and the facility provides two extra lanes in each direction. The facility is 10 miles in length.

Toll Collection

All tolls are collected electronically by Automatic Vehicle Identification (AVI).

Toll Rates

CPTC can use its discretion in determining toll rates. This determination is subject only to a cap on the rate of return constraint in the franchise agreement between the company and the state and an additional franchise provision that the company must offer a ridesharing incentive. The facility uses a toll structure that varies by time of day based on a published schedule. Marketing studies conducted prior to the opening of the facility showed patron discomfort with the notion of dynamic pricing. The tolls are set using level of service (LOS) considerations (i.e., travel time savings to users compared to users of the parallel free route). A LOS "C" is the chosen criterion for toll rate setting. There is no objective of optimizing system transportation costs or any other criteria. Hence, the facility is not a strict congestion pricing experiment as economists originally advocated. The other differentiating factor is that the payment is an option for better service and is not mandatory. The LOS algorithms operate in such a way that the market prices are set according to value of time (VOT) saved that was estimated at $0.22 per minute for peak period for single occupant vehicle (SOV) commuters. Off peak and during the shoulder of the peaks prices are set to encourage use of the facility *(5).* The fee structure was based on Wilbur Smith's market research study on VOT for the facility in combination with The Wilbur Smith and Associates traffic and revenue studies *(6).*

Financing

Since the project opened, four toll rate increases have been implemented. The most current rate change was implemented on January 31, 1999, and rates range from $0.75 to $3.50. The peak-period fare has increased by $1.00 since the facility opened. There is some debate about the timing of this rate change since the current owners are now negotiating a possible sale of the facility. There is also considerable skepticism as to whether the facility can continue to maintain market share since the opening of the eastern toll road.

CPTC has its own equity capital at risk in the project in addition to taxable debt of its three bank lenders. Financing also included coordinated debt from the Orange County Transportation Authority. This risk explains the innovative approaches that had to be adopted with respect to acquiring right of way, minimizing costs, and maximizing revenue. Some background information on public-private partnership laws such as AB 680 applicable to the SR-91 facility is certainly warranted at this juncture. This law required 100 percent of all capital costs, including risky environmental impact costs, to come from nontax sources. It required 100 percent of operating costs, including law enforcement costs, to be paid out of project revenues that normally would be paid from state funds. It also required the private partner to issue the project's revenue bonds; this requirement meant issuing them at very high taxable rates (i.e., 9 percent). The project incurred capital costs of approximately $133 million.

Who Pays the Tolls

In the first two years of operation, only SOV users and HOV 2+ users paid to use the facility, while HOV 3+ users traveled free of charge. Since 1998, the HOV 3+ users have also had to pay 50 percent of the toll to use the facility.

Financial Performance

CPTC's most recent Annual Financial Statement *(7)* indicates that the company has broken even.

I-15, SAN DIEGO, CALIFORNIA (HOV-HOT CONVERSION PROJECT)

This project is located along Interstate 15, a major north/south freeway in the inland San Diego region. San Diego Association of Governments (SANDAG) is the lead agency on this project in cooperation with California Department of Transportation (Caltrans), which owns and operates the HOV lanes and the freeway facilities. The other participants are Metropolitan Transit Development Board (MTDB) and California Highway Patrol (CHP). CHP is responsible for enforcement.

Project Goals

The project goals are to:

- maximize use of the existing I-15 HOV lanes,
- test whether allowing solo drivers to use the facility's excess capacity can relieve congestion on general-purpose lanes,
- improve air quality, and
- fund new transit and HOV improvements in the I-15 corridor.

Project Design

The mainline freeway consists of four lanes in each direction. The reversible facility consists of an 8-mile stretch of two 12-foot lanes with 10-foot shoulders in the freeway median. Barriers separate the HOV lanes from the main lanes while access is available at two end points of the facility.

Toll Collection

All tolls are now collected electronically by Automatic Vehicle Identification (AVI).

Toll Rates

In its first phase of operation (December 1996 to March 1998), SOV users could use the facility by purchasing a permit that provided unlimited use for a flat monthly fee. This fee was $50 to begin with and later increased to $70. In phase two of the project, which started March 30, 1998, the permits were replaced by per trip fees. Tolls currently vary dynamically with real-time fluctuations in traffic. It was the first project to use this type of pricing strategy with tolls ranging from $.50 to as high as $4 for SOVs on normal days and $8 on abnormal days. Again, LOS considerations are the basis for toll setting with a requirement by the state to maintain a LOS "C" on the facility. Traffic volume data are used to determine when the fees should be changed and to what level.

Financing

The FHWA sanctioned $7.96 million in 1995 for the implementation of this project. Local matching funds totaling $1.99 million include State Transportation Development Act funding for express bus service in the I-15 corridor and local funding for freeway patrol service along this portion of I-15. The Federal Transit Administration (FTA) provided an additional $230,000 for the project.

Use of Revenues

State law requires that all revenue raised by the project be used exclusively for the improvement of transit service (Inland Breeze) and HOV facilities in the I-15 corridor.

Financial Performance

The project incurred capital costs of $1.85 million in conversion (this excludes the transponder's costs, which are borne by users). These costs were paid by federal grants. The project is generating revenue at the rate of approximately $1 million per year.

Pre-project Studies

Pre-project studies included:

- baseline study of commuter profile, designing implementation strategies, travel behavior, establishing pricing policies, willingness to pay, exploring technology options, pre-project data collection, and identifying customer needs and
- a number of other data collection efforts at the aggregate and disaggregate levels to study traffic impacts, travel behavior, attitudes, and preferences in the first phase of the project.

I-10 KATY, HOUSTON, TEXAS

TxDOT owns and maintains these HOV lanes, Houston Metro is responsible for operation and lane enforcement and owns and operates many of the supporting facilities and services. The purpose of the program, called "QuickRide," is to assess the potential to allow HOV 2+ carpools to use the lane for a fee during the peak hours when the HOV 3+ occupancy requirement is in effect. This project was launched on January 26, 1998.

Project Goals

The project goals are to:

- increase person-movement and
- increase average vehicle occupancy without adversely affecting HOV lane and freeway operations.

Project Design

The facility is a 13.2-mile barrier-separated reversible HOV lane located in the freeway median.

Toll Collection

AVI tags and electronic toll collection (ETC) are used on the facility.

Toll Rates

A number of different market prices and the break-even price were derived in the Feasibility Report *(7)*. The break-even price per HOV 2+ was estimated at $1.18 per vehicle. The "true" revenue maximizing market price was estimated at $3.50 assuming a value of time of $15 per hour per HOV 2+. Since there were a number of limitations in the derivation of this price, a locally comparable market price reflecting similar transportation costs was estimated at $2.00 and is the current toll rate per HOV 2+.

Financing

The Katy facility is one of the priority pricing projects funded by FHWA as a result of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991.

POLICY AND INSTITUTIONAL ISSUES

Establishing the policy and institutional base for HOT lanes is an important phase, upon which a sound assessment of feasibility can be conducted. These issues include a clear understanding of why HOT lanes are being considered, a review of the options for building/operating/managing the HOT lanes, examining the options and implications of eligibility to use the lane, and directly addressing the potential equity and fairness concerns that typically arise out of HOT lane discussions. It is important that these and other yet-to-be-identified policy issues get a comprehensive examination from the outset to assure that subsequent engineering, economic, and customer relations decisions have a sound policy context.

SYSTEM PHILOSOPHY

Implementing agencies need to clearly articulate, to themselves and to the public, the goals behind their consideration of a HOT lane. Once those goals are articulated, they provide a clear basis for future decisions. In general, HOT lanes implemented on existing HOV lanes may improve the efficient use of the available space, while newly constructed HOT lanes may allow acceleration of a project, as well as provide flexibility and control over new capacity.

The three current operating projects represent good examples of how goal-setting can be approached. The SR-91 project in Orange, California, has stated goals of promoting ridesharing and returning a profit to investors. An implied goal of Caltrans is to provide additional capacity in a corridor where it would not otherwise be possible within available funding. San Diego’s goals for I-15 are to maximize the use of the existing HOV lanes, test whether SOV buy-in to the HOT lane would relieve congestion on the general-purpose lanes, improve air quality, and fund new transit service. In the case of the Katy HOT lane in Houston, the goals are to increase person-movement in the *corridor* and to improve average vehicle occupancy in the *corridor*.

While these goals vary, they all articulate why the local agencies are pursuing HOT lanes. One of the key objectives of the feasibility assessment must be to determine whether there is any realistic prospect of achieving the stated goals. Can this project promote ridesharing and, if so, how? Can it relieve general-purpose-lane congestion? Can it improve air quality? These or other appropriate questions should be put to rigorous prospective analysis before a commitment is made to HOT lanes.

INITIAL AGENCY CONSIDERATIONS

Among the earliest decisions to be made are those affecting participation. In many respects these considerations and the foregoing system philosophy go hand in hand, because the participating agencies must be the ones establishing the overall goals of the project. Key decisions include the following.

- Should this (can this) project be a public/private venture? In other words, is there sufficient demand for private investors to recoup their investment and a reasonable profit? With all of the design/build options being explored, there appear to be numerous potential alternative public/private combinations of design, build, operate, and maintain. Public agencies that can engage a private partner may find opportunities to expedite the project or to minimize the commitment of limited personnel. Furthermore, private sector operators that have broad control over pricing and eligibility (within constraints) may be able to operate a HOT lane more efficiently because they may be able to adjust faster to changing conditions than a public agency could adjust. That presumption notwithstanding, SANDAG has demonstrated considerable efficiency in their hands-on operation of the I-15 HOT lane. Decisions involving partnering should consider the goals of the projects and the potential to reach those goals with limited public control.

- What level of subsidy will be required for the HOT lane? The early results from operating HOT lanes have not demonstrated a significant revenue excess. It seems reasonable to forecast that most HOT lanes should be able to cover operating costs with toll revenues. The ability to cover capital costs is a little less clear. The most financially challenging is the SR-91 project (four toll lanes in the median), which appears to be viable after 3+ years of operation. The inherent subsidy from Caltrans is the provision of the median right-of-way at a nominal fee. All of the other capital costs were paid from bond proceeds, which are being repaid from toll revenues. Thus it appears that the minimum subsidy needed, based on experience to date, will be the provision of right of way. In the other two cases, both of which had much lower capital costs, either local agencies or the FHWA are subsidizing the operation.

- Does the potential for toll revenue allow for a needed project to be accelerated? The success of the SR-91 express lanes suggests that accelerating a project may be a realistic justification for considering HOT lanes. However, the experience with one facility cannot be used as the sole basis for determining applicability to all circumstances. The circumstances surrounding the success of SR-91 may be sufficiently unique to preclude the transferability of their results. Each potential project should be viewed very closely by specialists in forecasting toll revenues to ascertain the level and reliability of toll revenue, especially if project financing is dependent on tolls.

EQUITY AND FAIRNESS

The potential equity and fairness issues surrounding HOT lanes and value pricing in general are subjects of much discussion. The fundamental concern is that travelers, accustomed to “free” travel, will object to “pay for travel” service within a “free” corridor. The equity issue stems from concern that certain groups of travelers may be excluded from participating because they have low disposable incomes to spend on the toll. Results from studies on all three operating HOT lanes suggest that the full demographic spectrum of users participate in the HOT lanes, though higher-income users tend to take advantage of HOT lanes more often.

Numerous means of attending to the equity concerns have been broached. Providing “lifeline” type services or discounts for documented low-income users has been discussed, though no program has tried these as yet. Only San Diego has been active in addressing equity through the provision of improved transit service in the same corridor. From the inception of the San Diego project, San Diego has acknowledged its intent to use toll revenues to support transit service in the corridor.

Much of the fairness question has focused on the notion of having to pay for use of a facility that was previously free, with the term "double taxation" finding its way into the discussion. The experience of the agencies operating HOT lanes has been that the practical impact of the fairness question has been minimal. In all cases, travelers have a choice of free lanes or toll lanes. Further, in all cases the service being offered for fee was not previously available (SR-91 is a new facility, and I-15 and the Katy Freeway had (have) occupancy restrictions). Aside from complaints that HOV lanes should not exist and the lanes open to all traffic, the fairness argument has been modest.

FINDINGS

The study of policy and institutions issues revealed that the following four actions are important to successfully evaluate the feasibility of HOT lane(s) in a corridor:

- establish project goals and measurable objectives,
- determine primary participants,
- evaluate project funding options, and
- identify potential equity and fairness concerns.

PLANNING AND DEMAND ESTIMATION

PRIMARY GOALS AND OBJECTIVES

Table 1 lists some of the potential goals and objectives of HOT lane projects *(9)*. It may be seen that these goals include economic efficiency, equity, and environmental aspects, and that the overall decision making is multiple objective in nature. That is, it is unlikely that each goal can be measured using a common unit such as dollars. In order to make the necessary trade-off between these competing objectives, performance information is required, which is typically obtained from transportation planning models.

Table 1. Potential Goals and Objectives of HOT Lane Projects.

Typical Goals	Corresponding Objectives
Test/evaluate peak-period pricing strategies	Monitor and report on operations, congestion, air quality impacts, and public reaction to demonstration projects
Enhance efficiency of existing and planned HOV system	Enhance people-moving capacity of HOV lanes
Respond to negative public opinion about underutilized HOV lanes	Smooth transition from two-person to three-person HOV lane requirement
Phase in congestion pricing	Implement pricing in a way that minimizes negative public opinion Increase public familiarity with and acceptance of pricing policies/ technologies
Provide a new travel alternative–pay to bypass congestion	Reserve a portion of the capacity for congestion-free travel
Provide a no-pay or discount option for accessing priced facilities	Minimize negative impacts of pricing policy to lower income persons
Raise revenue	As a return on initial investment For new/improved transportation facilities/services To accelerate programmed capacity expansion
Maintain or increase mobility on adjacent free lanes	
Maintain or increase carpool formation and longevity rates, average vehicle occupancy, and transit use	
Enhance regional air quality	To postpone the need for investment in new construction

ESTIMATING THE DEMAND FOR HOT LANES

Because the concept of HOT lanes is relatively new, there have been few studies on either modeling HOT lanes or describing the results of HOT lane implementation. The most recent publications on the subject include the Southern California REACH Study *(9)*, the California SR-91 Variable-Toll Express Lanes Study *(10)*, the Portland Traffic Relief Options Study (*11*, *12*), the Sonoma County (CA) US-101 Variable Pricing Study *(13)*, the California Transportation Pricing Policy Study *(14)*, and the Short-Range Transportation Evaluation Program (STEP)*(15)*.

The majority of modeling approaches utilize existing modeling structures and attempt to update them in order to model the special requirements of HOT lane analysis. The most common method is to use existing regional models that are based on the four step models *(15)*. In essence the mode choice/traffic assignment sections of the four-step model are modified. This choice has taken various forms including adding a toll diversion model *(9)*, developing multiple vehicle class models *(10)*, using simultaneous estimation and stated preference techniques (*11*, *12*), and updating the mode choice nested logit model by increasing the options *(13)*. A study in London used a large-scale land use/transportation planning package known as MEPLAN (15). The second approach is to use a sketch-planning tool. The most popular is STEP, which is an aggregate quick-response type model that has been used in studies in Chicago, Illinois; Boulder, Colorado; Seattle, Washington; and various urban regions of California *(14, 15)*. It is a fully detailed travel model system that is applied at the household level. Details of the models and the studies may be found elsewhere *(9, 10, 11, 12, 13, 14, 15)*.

The model that was used in the studies was a function of the questions that needed to be answered. These questions can be broken down into short- and long-term issues. The short-term issues included modeling the effect of HOT lanes on driver decision making including route diversion, mode choice, and departure-time choice. The more sophisticated models attempted to model activity-based choices as well, and these were examined from a dynamic perspective (i.e., day of week, time of day, etc.). The longer-term effects tend to analyze the implications of road pricing on the choice of home and work location.

The best model to choose will obviously depend on the goals of the project, the data that are available, and the accuracy required. However, it is obviously important to ensure that the model allows the decision makers to analyze the effect of changing the variables that they have control over, such as pricing, capacity, and network attributes. It would also be desirable for the model to explicitly model the demand for activities, which would subsequently be translated into the demand for transportation. In this way the effect of the HOT lanes on the number of trips and where these trips start and end can be explicitly examined. That is, latent demand can be directly modeled. Equally important is the fact that the performance of the network needs to be identified in detail because of the multiple objective nature of HOT lane development. For example, not only standard aggregate metrics such as vehicle-miles of travel and person throughput need to be identified but also disaggregate measures are required to analyze equity issues.

CRITERIA FOR SUCCESS

The criteria for converting HOV lanes to HOT lanes depend on whether the HOV lane currently exists or is in the planning stages and can simply be redesigned. Table 2 suggests criteria that can be used to help in the decision-making process *(9)*.

Table 2. Criteria for Converting HOV Lanes to HOT Lanes.

Selecting new HOV lanes to be redesigned as HOT lanes
• Corridor has capacity deficiencies • Corridor is used by travelers making relatively long trips • The new lane would develop sufficient demand to attract private investment • The new lane makes sense in terms of the overall phasing for the regional HOV program • Transportation alternatives are, will be, or could be available at the time fees are implemented • Construction as a HOT lane could accelerate scheduled implementation or enhance its public benefit • Project would be cost effective
Converting existing HOV lanes into HOT lanes
• Corridor has capacity deficiencies • Corridor is used by travelers making relatively long trips • There is excess capacity on an existing HOV lane or there could be excess capacity by moving from HOV 2 to HOV 3+, and implementation would not cause adverse effects • Income revenue exceeds implementation costs • Transportation alternatives are, will be, or could be available at the time fees are implemented

Central to Table 2 is the fact that users of the HOT lane must be identified. These users can be identified based on the output of the modeling step. However, they will have certain attributes as shown in the taxonomy in Figure 13. In essence the potential users will have to 1) make trips in the HOT lane corridor during the time when the HOT lane is operational and 2) understand the operating rules of the HOT lane including number of people in automobile, times of operation, etc. Depending on the operating rules, the market of informed, educated, and motivated potential users can be estimated.

Figure 13 portrays a simple taxonomy of the target group of users. This graphic helps to visualize who the candidate users (right side in bold) may be and to understand that they are a sub-subset of the population at large. This understanding is important because large groups of users are often assumed, when in fact they constitute a small potential group.

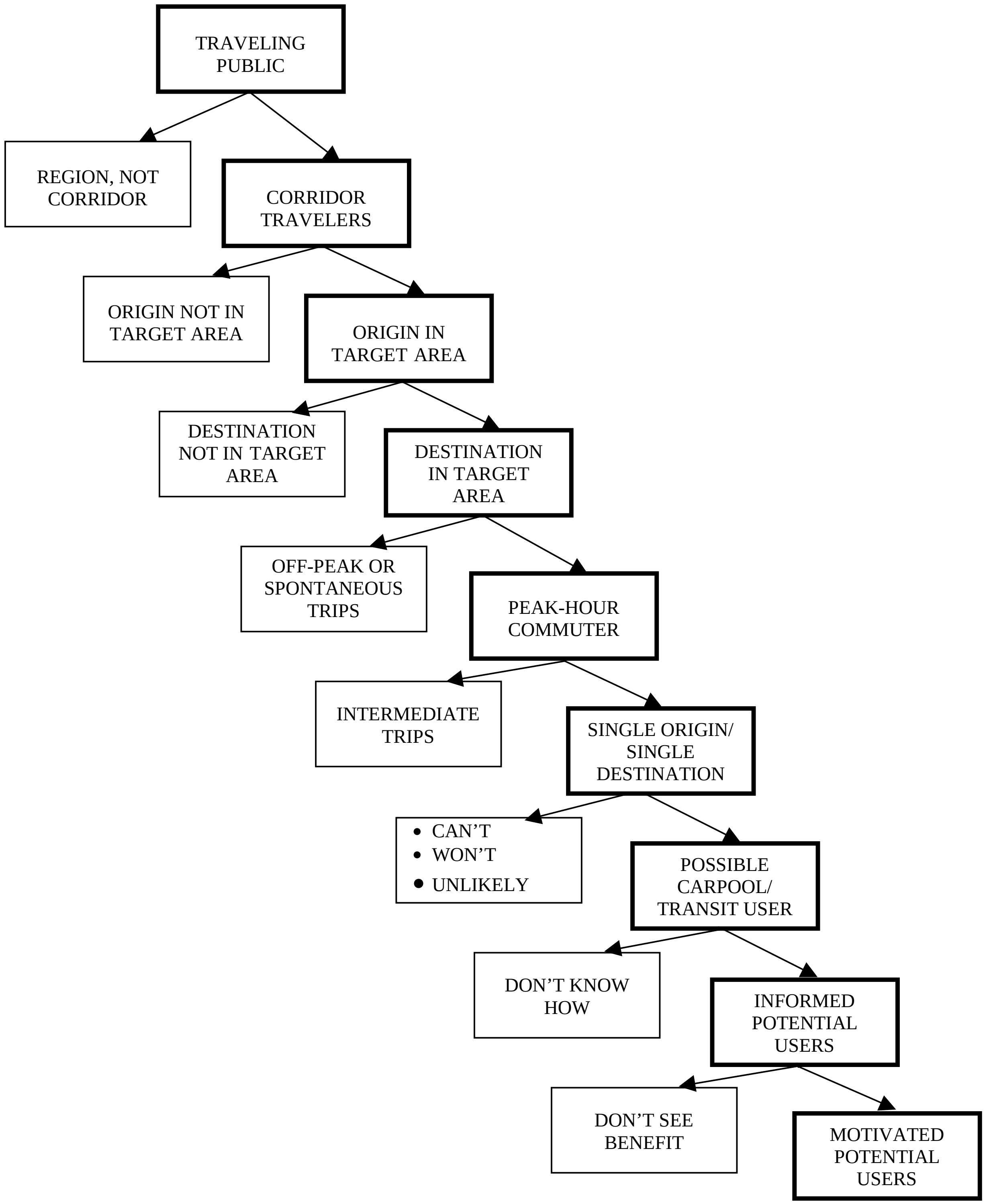


Figure 13. HOT Lane Attributes Taxonomy.

Finally, a major key to successful implementation of HOT lanes that is commonly cited is public acceptance *(16)*. In essence the public agency should encourage public involvement in the planning process. This involvement could include conducting focus groups, launching a media campaign, etc. The implementation scheme should be simple, and the advantages should be emphasized. For example, the pricing should be linked to increased freedom of choice, and the emphasis should be on characteristics valued by the drivers such as speed and reliability rather than efficiency.

RESULTS FROM HOT LANE TEST PROJECTS

While there have been few HOT lane projects in the U.S., they are being extensively studied and the preliminary, short-term results are interesting.

Changes in Person-Movement

Similar to HOV lanes, the primary measure used to analyze HOT lanes is person-movement rather than vehicle-movement. In the San Diego I-15 project total person-movement increased by more than 25 percent as shown in Table 3. Of course, whether a particular implementation will be successful will depend on a number of factors including size of potential user group, cost to use lanes, cost elasticity, etc.

Table 3. Number of Vehicles During AM and PM Peak Periods on a Typical Weekday.

	HOVs	Violators	Express Pass Users (SOV)	Total Vehicles
Before Express Pass (Oct. 96)[a]	7,900	1,400	0	9,300
After Express Pass (Oct. 97)[a]	9,300	200	1,025	10,525
After Express Pass (Mar. 98)	10,250[b]	200[c]	1,250[c]	11,700[b]

[a]SANDAG data published by USDOT in Report to Congress July 1998
[b]SANDAG data published by SANDAG in ITE Journal June 1999
[c]Calculated assuming same number of violators as in Oct. 97

Effect of Income on HOT Lane Demand

There is a common belief that only high-income travelers will pay to use HOT lanes as evidenced by the pervasive use of the term "Lexus Lanes." A study of the data from the SR-91 project in California showed a correlation between income and toll lane use, although it is important to point out that travelers in all income groups pay to use SR-91 toll lanes *(17)*. Compared to commuters in low-income groups, commuters in high-income groups were twice as likely to be frequent SR-91 toll lane users and half as likely to be non-users *(17)*. Another study of SR-91 showed that while income largely influences the decision to acquire a SR-91 transponder it was not correlated to the secondary decision of how many times to use the toll lanes *(18)*. The I-15 study showed similar results in that while all income classes used the express lanes (FasTrak), on average FasTrak customers tended to have higher incomes, more years of education, and own homes more often than not *(19)*. The study of the usage characteristics on the Katy HOT lane showed similar results in that higher income travelers had a slightly higher propensity to use the HOT lane than lower income users, though the variation was small.

Frequency of Use

Interestingly the preliminary results from the California HOT lane implementations are that most HOT lane customers are occasional users, as shown in Tables 4, 5, and 6. This finding is important because not only will the transportation agency have to identify the potential user base but also its propensity for using the facilities over a given time period (rather than simply examining a single day).

Table 4. Usage Statistics from I-15 HOT Lane Implementation.

Number of Uses in a 1-Month Period	Percent of Transponders in Each Usage Category[a] (%)
1–5	53
6–10	18
11–15	11
16–40	19

[a]Hultgren and Kawada, ITE Journal, June 1999

Table 5. Usage Statistics from SR-91 HOT Lane Implementation.

Frequency of Use for Peak Period Work Commute	Commuter Share[b] (%)
Never	46
Rarely (1–10 percent)	11
Some (10–40 percent)	9
Half (40–60 percent)	11
Most (60–90 percent)	7
Always (90–100 percent)	16

[b]Mastako and Rilett, TRR #1649, 1998

Table 6. Usage Statistics from I-10 Katy HOT Lane.

Average Weekly Frequency of Use	Number of Participants[c]	Percentage
None	104	18
One or less	297	52
1–2	107	19
2–3	37	6
3–4	16	3
5 or more	14	3

[c] TTI data

Travel Time Savings

Another interesting result is that HOT lane users tend to over-estimate the true travel time savings. For the SR-91 project the actual time savings estimated from loops consistently showed a maximum time savings of 12–13 minutes per trip, while more than one-third of survey respondents report saving more than 20 minutes per trip *(17)*. Similar results were found in the I-15 project where actual time savings from speed/delay studies showed a maximum time savings of 9 minutes per trip, while survey respondents reported an average perceived time savings of 19 minutes per trip *(20)*. These results are important for two reasons:

1) Whether, over time, this discrepancy between actual and perceived times will disappear as drivers gain more experience with the lanes. This change would obviously have a big impact on demand and the ultimate success of the HOT lanes.

2) Whether the perceived or actual travel times should be used in the mode/route choice models.

Long-Term Issues

Because the existing HOT lane projects are relatively new and the best approach to modeling HOT lane issues is unknown, longer term issues are harder to address. For example, it is unknown whether HOT lanes perpetuate sprawl. Location theory suggests that reduced commuting times (courtesy of congestion-free travel) will make it possible for commuters to travel further. However, those who pay to use HOT lanes experience an increase in out-of-pocket costs that may counteract the effect of the decrease in travel time cost *(21)*. Similarly there is no evidence that people relocate to take advantage of HOT lanes.

System Performance Measures

The performance measures that are used in modeling potential HOT lanes and analyzing existing HOT lane implementations reflect the multi-attribute objectives of the transportation agency. A listing of the important ones is shown below.

Connectivity—the ability to connect with people or places to satisfy economic, social, or other human needs. Estimate the real user cost of the connection. Gather data on highway speeds, access times/costs to activity centers, total number of trips or connections, and maximum access times for emergency services.

Environmental Quality—the health of environmental conditions. Gather data on concentrations of CO, NOx, ROG, PM10, and ozone. Assess aesthetics, community disturbance, etc.

Safety—the risk of accident, injury, and death. Gather data on accident casualties by severity rating. Conduct social surveys of perceived safety.

Equity—the distribution of costs and benefits between different groups of people. Gather data on the effect on different groups classified by transport use, location, income, age, gender, ethnicity, or disability.

System Resource Cost—the resource expenditure required to achieve connections. Measure construction, operation, and maintenance costs.

FINDINGS

The study resulted in the following key findings relative to planning and demand estimation for HOT lanes.

- Several models are available to estimate demand, the most popular of which is the STEP model.
- Criteria for success is a fairly short list and is closely aligned with criteria for HOV lane success.
- Results from existing projects show:
  - increase vehicle and persons moved,
  - some relationship between income and frequency of use,
  - most customers occasional users when a specific trip purpose warrant added expense, and
  - travelers' perception of time savings substantially higher than actual savings.

DESIGN ISSUES

This chapter addresses the major design elements associated with HOT facilities. Issues such as cross-sections, separations, and access are discussed. It is intended to address the most frequently encountered design issues, not every possible design unique to specific situations. Many of the issues addressed can be applied to new HOT facilities and to HOV lane-conversion projects. The design of HOT facilities can be similar to HOV lanes with a few exceptions, such as the access points and toll collection. While recommended design practices exist for elements of HOV lanes, design standards for elements of HOT facilities cannot be completely adopted due to the lack of historical data and experience.

A high-speed facility is preferable for HOT facilities. The most appropriate design, however, will depend on the objectives of the project, land uses in the corridor, available right-of-way, and funding sources.

FACTORS AFFECTING DESIGN

New/Reconstruction or Retrofit in Existing Cross-Section

New construction or reconstruction of a roadway typically provides the most flexibility in the design of a HOT facility. Limited funding for major transportation improvement projects has forced agencies to consider options other than new construction or reconstruction of a facility. Options such as retrofitting a preferential treatment facility into the existing median of a roadway are common. A retrofit project, however, limits the design options such as the desired cross-section and number of lanes.

Objectives of the Project

A clear set of objectives and measures of success must be defined before the project can be designed (to enhance bus transit operations or large truck operations, to encourage modal shift, to generate revenue, etc.). Numerous agencies and groups will be involved in the design of the project. The participation of the appropriate agencies and individuals is key to ensuring that all groups are involved in discussing the different design elements, issues, and objectives.

Lane Uses in the Corridor

To be successful, HOV facilities require travel patterns in a corridor that are conducive to being served by transit and ridesharing. This situation typically requires long-distance commute trips to a major traffic generator such as a central business district. A HOT facility may not necessarily require similar types of corridor characteristics to be successful if the enhancement of transit bus use and carpool formation is not an objective of the project. HOT facilities, however, will likely generate substantial usage and be successful only when recurrent congestion occurs regularly on the adjacent general-purpose lanes.

Available Right-of-Way

Right-of-way constraints can be a controlling factor in the viability of options for a recommended project. Land development where right of way is required may have progressed to the point where purchasing the land (including buildings, houses, etc.) is not feasible.

Funding Sources

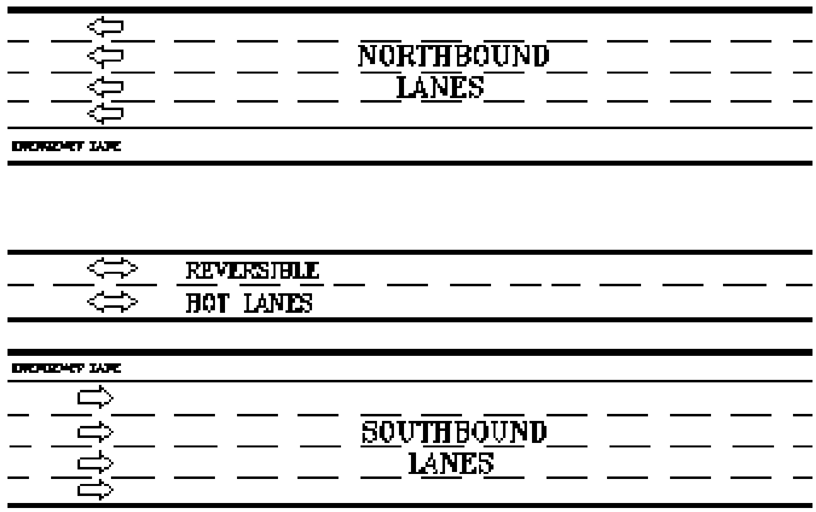
A variety of agencies could financially participate individually or jointly in the implementation of a HOT facility, including a toll authority, a state department of transportation (DOT) or a toll authority within a state DOT, transit agencies, and/or private corporations. The willingness of a particular agency to participate may vary drastically based on the objectives of the project. For example, a state DOT may want to improve operations on the freeway general-purpose lanes in the corridor, a transit agency may want to enhance bus transit operations and encourage the formation of carpools, and a private corporation may want to generate revenue.

Connectivity to Other HOV/HOT Lanes

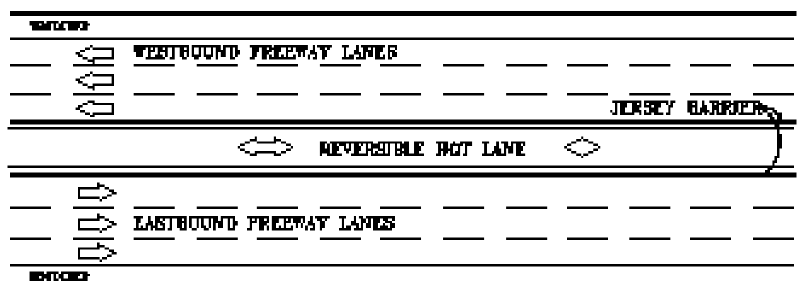
Bottlenecks in a transportation system, such as an HOV or HOT lane system, will typically occur at interchanges with other facilities. A long-range plan is necessary to allow provisions to avoid bottlenecks when additional facilities are implemented. The facilities are more effective when developed as a comprehensive system or network. In addition to the geometric connectivity at interchanges, it must be decided how different types of facilities interface (HOV lanes, HOT lanes, general-purpose lanes, etc.).

CROSS SECTION AND DESIGN CRITERIA

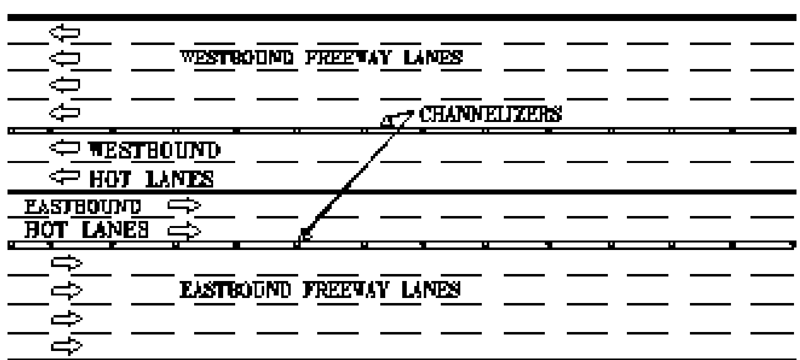
The cross sections of the three HOT facilities currently operating in the U.S. are vastly different, as shown in Figure 14. A substantial amount of research has been conducted to determine the most effective cross sections for HOV facilities *(2, 4, and 22).* Many of the recommendations from the research have assumed that users of the facilities are either trained bus or vanpool drivers or vehicle operators who use the facility on a regular basis. Desirable and minimum cross sections for HOT lanes may need to be re-evaluated if different vehicle groups (occasional-use vehicle operators, trucks, etc.) are allowed to use the facility during various times of the day as well as on weekends and holidays. For this reason the accepted design recommendations, standards, and guidelines of HOV facilities from American Association of State and Highway Transportation Officials (AASHTO), Institute of Transportation Engineers (ITE), individual states, and other groups should generally be used for HOT facilities. In addition to cross sections, other design criteria must be addressed such as design speed, alignment geometry (horizontal and vertical), gradients, cross slope (drainage and driver comfort), stopping sight distance, etc.



I-15 (Esconodido Freeway) HOT Lane
San Diego, California



I-10 (Katy Freeway) HOT Lane
Houston, Texas



SR91 (Riverside Freeway) HOT Lanes
Orange County, California

Figure 14. Cross Sections of HOT Facilities.

Width of HOT Lanes, Shoulders, and Offsets

HOT facilities can be single lane or multiple lanes. The travel lanes should be a width of 12 ft. Narrower lane widths should be considered only in special circumstances or for short distances. Full-width paved shoulders are preferred on any roadway to accommodate disabled vehicles and to provide additional area for vehicles to maneuver or recover. Shoulders should be considered where right-of-way is available or can be acquired at a reasonable cost. Shoulder width should be at least 10 ft. A shoulder width of 10 to 12 ft is enough to shelter a disabled vehicle or an enforcement officer while maintaining the operational integrity of the facility.

Reduced cross sections for HOV facilities, which can also be applied to HOT facilities, are primarily the result of retrofitting the lanes into the existing freeway. No absolute minimum standard has been established for cross section reductions, especially for short sections of roadway. Instead, each set of agencies involved in a project should agree upon reductions that impose the least adverse impact on operational and safety concerns. Extremely narrow cross sections of HOV lanes have operated well when combined with other improvements designed to treat the operational deficiencies. These improvements include vigorous enforcement, incident detection and management, and design improvements wherever possible. To ensure operational reliability, the width plus the lateral clearance should provide an envelope sufficient for passing a stalled vehicle. This distance has been determined to be approximately 20 ft. The recommended desirable and minimum cross section for one- and two-lane facilities is shown in Figure 15.

Design of Enforcement Areas

Adequate enforcement of a HOT facility is a necessary element of the project. If policies or design make a facility difficult to enforce, violation may become an attractive option to some motorists. In turn, high violation rates may threaten the integrity of the facility and could result in the loss of public support for the project. HOT facilities should be designed so that they can be safely and efficiently enforced. The safety of all persons involved (police personnel, HOT lane users, and adjacent general-purpose lane travelers) should be a key consideration in the design process. Experience indicates that poorly designed and unsafe enforcement areas will not be used.

A variety of enforcement techniques can be utilized. Each HOT lane operating concept may have different enforcement needs. Enforcement of a HOT facility with a physical separation (either barrier or pylon) from the general-purpose lanes can be accomplished by constructing enforcement stations at each of the entry and exit points where traffic is often moving more slowly. A HOT facility without a physical separation will require enforcement stations at several locations along the length of the project and will make the enforcement process more difficult.

The design of an enforcement area should provide space for police personnel to monitor the facility, to pursue a violator, and to apprehend a violator and issue a citation. Depending on the operating requirements of the HOT facility, enforcement personnel may need to determine the occupancy inside each vehicle. This procedure will require good lighting and good visibility from a safe vantage point.

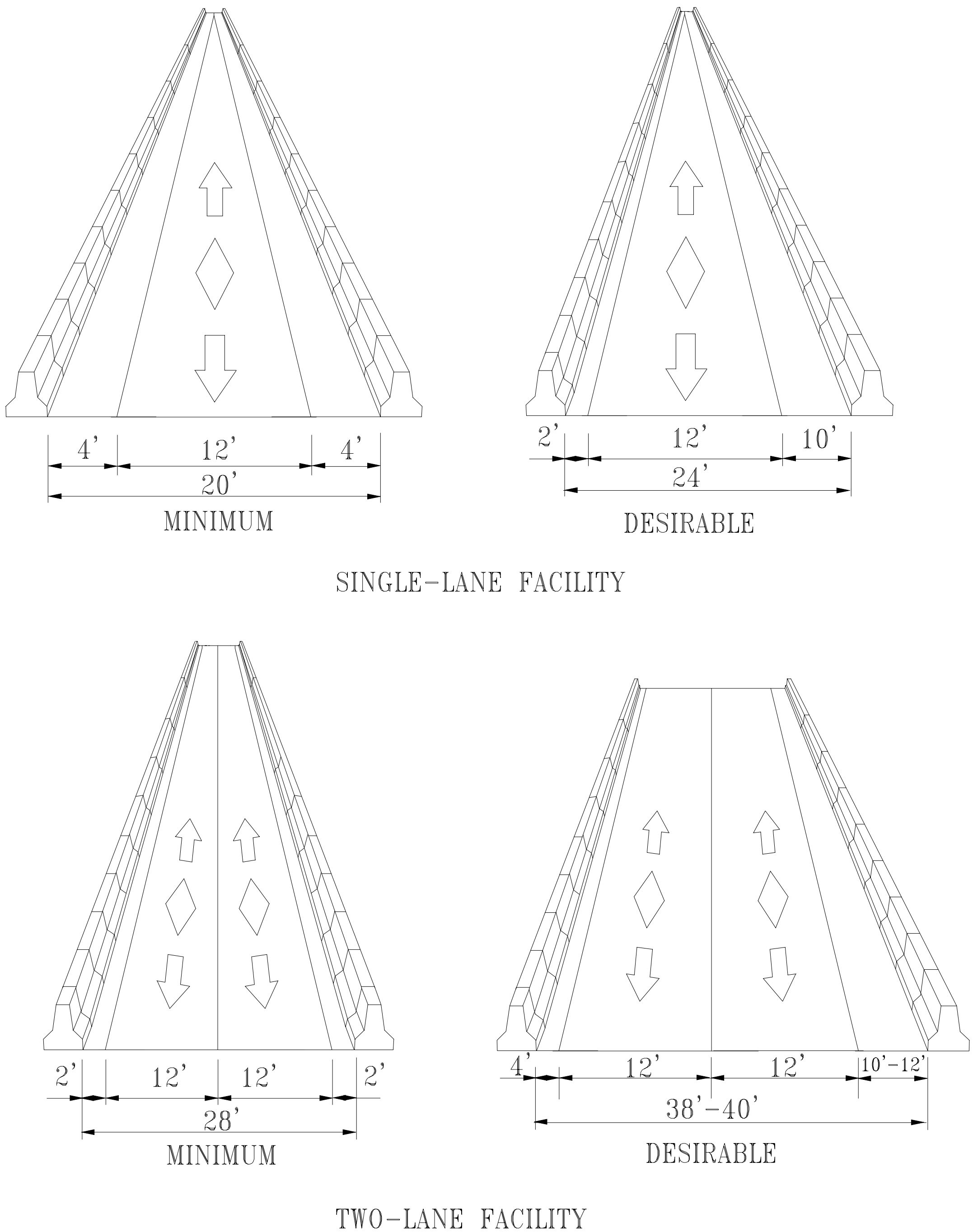


Figure 15. Cross Sections for One- and Two-Lane Reversible Facilities. ***(22)***

Other Design Considerations

AASHTO guidelines should be used to determine the appropriate values for various design elements such as design speed, horizontal and vertical clearances and curvatures, super elevation, etc. *(23)*. The more common issues are addressed below.

Gradients

AASHTO provides guidelines for gradients on freeways to encourage uniform operations throughout. These guidelines can also be used for HOT facilities. Passenger cars can typically traverse grades of 4 to 5 percent without appreciable loss in speed below that normally maintained on level roadways. Other vehicle groups, however, will have different operating characteristics. For example, a fully loaded bus or a truck can lose (or gain) a substantial amount of speed on a sustained grade. The grade, sustained length of the grade, design speed, and vehicle type must be considered when determining the maximum grade to be used. The desirable maximum grade for a 65 mph design speed is 3 percent. Depending on topography, however, gradients up to 6 percent can be and have been successfully used on HOV facilities, especially when there is a lower design speed and on direct connect access/egress ramps.

Cross Slope

The cross slope of a HOT lane on a freeway will likely be the same as the cross slope of the adjacent general-purpose freeway lanes. A HOT lane (or lanes) located in the center median of a freeway may straddle the roadway crown and have a central crown line (high point in the middle) with a downward slope toward both edges, or there can be a straight cross slope to one edge or the other. A straight cross slope, however, may not be feasible in retrofit projects where the elevation of the adjacent general-purpose lanes is fixed. A maximum cross slope of 2 percent is recommended by AASHTO for high-speed facilities *(23)*. Cross slopes of up to 2 percent are barely noticeable by motorists in terms of steering the vehicle. A 2 percent cross slope on a two-lane HOT facility with a center crown line results in motorists negotiating a total rollover or cross slope change of 4 percent when crossing the crown line. This amount of slope may cause buses to sway from side to side. In this instance a rounded or parabolic crown should be considered to reduce the reversal in the direction of centrifugal force.

Impact of Diverse Users and Vehicle Groups

The physical and operational characteristics of eligible vehicles will influence the design of HOT facilities. It is, therefore, necessary to examine all vehicle types that may be eligible to use a HOT lane. The largest of all the several design vehicles likely to use the facility with considerable frequency or a design vehicle with special characteristics that must be taken into account are typically accommodated in the design of a facility. The design vehicles may include articulated buses, recreational vehicles, and large trucks. HOV lanes have typically been restricted to buses, vanpools, and carpools that use the facility on a regular basis during selected hours of the day. HOT facilities, however, may be open longer hours each day to a more diverse group of vehicles and users. HOV lane design standards cannot, therefore, be directly adopted as HOT lane design standards.

SEPARATION FROM GENERAL-PURPOSE LANES

Several types of treatments can be considered to physically separate a HOT facility from adjacent freeway lanes such as a buffer area with pavement markings, a buffer area with channelizers (pylons), and a concrete barrier. Each treatment has issues that must be evaluated. A paint stripe or painted buffer treatment may have safety, enforcement, and toll collection difficulties. Channelizer treatments may have maintenance challenges. Concrete barrier treatments may have incident management concerns. Careful analysis must be conducted when considering design trade-offs to provide an operationally effective facility.

Types of Treatments Available

Three general types of treatments for separating a HOT facility from adjacent general-purpose lanes within a freeway right-of-way include paint or buffer separation, separation with channelizers, and barrier separation. Each type of treatment has advantages and disadvantages with respect to implementation and operation.

Non-separated or Buffer–Separated Facilities

A HOT facility with no physical separation from the general-purpose lanes (commonly referred to as concurrent-flow facilities) can either be contiguous to the adjacent general-purpose lanes or separated by a painted buffer area. These types of facilities are typically the least expensive type of treatment to implement. The implementation time is relatively short, particularly when an inside shoulder exists on the freeway. These types of facilities, however, present unique operational and enforcement concerns. Vehicles entering the freeway (generally a right-hand entrance ramp) must weave across the general-purpose lanes to access the facility on the inside of the roadway, and then weave across the general-purpose lanes to exit the freeway (generally a right-hand exit ramp).

The lack of a physical separation can result in large speed differentials between the freeway and HOT lane traffic flows, which could negatively impact the safety of motorists. Another potential disadvantage of this design is that some drivers may perceive and use the HOT lane space as a breakdown lane, causing additional hazards. This lack of separation, however, enables the access to the facility to be less restrictive and allows for location and length of access points to be easily modified. Additionally, the enforcement of this type of design will be difficult, and the compliance rate will generally be lower than other types of designs.

Separation with Channelizers

The use of channelizers to create a physical barrier can moderate the safety, enforcement, and operational problems associated with non-separated facilities. The SR-91 HOT facility in Orange County, California, utilizes this type of design. The cylindrical channelizers used on SR-91 are spaced at 12 ft intervals along the 10 mile section. Maintenance, however, to replace displaced or damaged channelizers occurs once every three weeks.

Barrier-Separated Facilities

Barrier-separated facilities are easier to enforce than non-separated lanes due to limited entry and exit points. The facilities are also somewhat safer as there is less potential for conflict between vehicles in the HOT lanes and those in the adjacent general-purpose lanes. Travel time reliability tends to be better due to the exclusive nature of the facilities, especially if direct-access ramps are provided at high volume locations. The capital costs associated with barrier-separated facilities, however, are higher. This alternative may require more right-of-way, and the limited access/egress provided by this type of facility may limit use by some commuter groups.

Two of the HOT facilities currently operating in the U.S. are barrier-separated facilities. The I-10 HOT facility in Houston consists of one reversible lane and the I-15 HOT facility in San Diego consists of two reversible lanes. Barrier-separated facilities can also be two-or-more directional lanes.

TERMINAL TREATMENTS AND INTERMEDIATE ACCESS

The design of HOV lanes has typically centered on serving park-and-ride lots and transit bus transfer areas. Access points are typically spaced at 2 to 4 mile intervals to allow for effective enforcement and a high level of operation. A HOT facility will likely have different objectives, including the origins and destinations to be served. Users must be able to easily and safely enter and exit the facility. They should easily understand how to enter and leave the facility. The terminal treatments should provide a safe transition and should not negatively affect the operation of the general-purpose lanes and the safety of motorists on the freeway.

The entry and exit points for HOT facilities will be more complicated than single HOV lanes because consideration must be given to allow for toll collection capabilities and effective signing, as well as police enforcement of the facility. The type of toll collection implemented (hangtag, electronic tolling, toll booths, etc.) will impact the design of the entry points. The use of a prepaid hangtag may have little additional design concerns while the use of toll booths may have substantial design concerns. Additionally, effective signing (regulatory and guide signs) and pavement marking will be a challenge because of the amount of information that must be conveyed to the occasional-use patron and if the toll structure is variable throughout the day.

Signing Requirements

All traffic control signing for HOT facilities should be governed by the Manual on Uniform Control Devices (MUTCD) *(24).* The MUTCD, however, does not currently provide clear guidance for the signing for "preferential lanes," especially with regard to guide signing. There are currently differences in signing standards between states throughout the country for HOV lanes, and no official guidance exists for HOT facilities. Some areas throughout the country are using guide signs with a green background and the diamond symbol while others are using the regulatory standards with black and white layouts. The signing for HOT facilities will be even critical because these facilities occur in urban areas with high traffic volumes and along major routes that may have both local and through traffic. Additionally, the concept of dynamic tolling will further complicate the matter. There exists a need for uniformity in signing to promote safety and efficiency for traffic.

Signing for HOT facilities should be planned concurrently with the geometric design. A poor geometric design cannot be overcome by signing. A HOT facility will require a combination of guide signs and regulatory signs. The MUTCD suggests the use of a white diamond symbol on all regulatory signs when signing for preferential lanes. It is suggested that some type of treatment also be applied to all HOT lane guide signs to distinguish them from general-purpose lane signs, especially when they are on shared sign structures. As a minimum this should include the diamond symbol. There has, however, been some question about the use of the diamond symbol for preferential treatment facilities other than HOV lanes. Facilities such as bike lanes and commercial truck lanes also use the diamond symbol. The use of a red and blue bar along with the diamond symbol on the top of guide signs is being considered for use in the Houston area to distinguish the HOV lane signs from general-purpose lane signs.

FINDINGS

The study of design issues for HOT lanes revealed the following findings.

- In general, HOV lane design guidelines are a very good source for guidance for HOT lane design.
- Careful evaluation of enforcement options and associated design requirements is crucial as effective enforcement will be an extremely important component of a successful HOT lane.
- Physical buffer or barrier separation of HOT lanes from general-purpose lanes is highly desirable.
- Careful attention to terminal end treatments is important because of the complex decision making that is occurring in that vicinity and upstream.

OPERATIONS

This chapter discusses many of the issues related to the operation and enforcement of HOT lanes. It is divided into sections covering operational goals and objectives, vehicle and user eligibility occupancy requirements, ingress and egress locations, incident management, and toll collection and enforcement strategies. Operational goals and objectives will guide project planning and development and serve as a reminder of the intended function of the lane. The introduction briefly describes operational alternatives such as reversible, two-way, concurrent, and contraflow. The vehicle and user eligibility section guides the user on compatible vehicle classes and various vehicle occupant strategies as well as different strategies for operating the HOT facility during different times of the day or hours of operation. This section discusses several incident management schemes using HOT lanes as a detour for the general-purpose lanes and traditional incident management techniques to maintain peak operational efficiency. Automatic vehicle identification (AVI) and license plate recognition (LPR) are two toll collection methods covered in the toll collection section. Routine, special, selected, and self-enforcement strategies as well as automated enforcement are included in the enforcement section. Since many elements must be considered in the operation and enforcement of HOT lane facilities, the above sections of this chapter are intertwined with all the sections in this report, requiring the reader to reference other chapters.

OPERATION GOALS AND OBJECTIVES

HOT lanes can be new projects or HOV lane conversions. HOT lanes provide many of the benefits of HOV facilities while trying to correct some of the potential limitations. Many HOV lanes are successful, but could be enhanced by converting to HOT lanes using vehicle occupancy and price to regulate the demand for the facility in question. HOT lanes can also provide an alternative and enhancement to a marginal or questionable HOV lane project. HOV and HOT lanes may share the same goals of enhancing regional mobility and efficiency by:

- increasing person-movement capacity of the facility,
- providing reliable high-speed travel to participants,
- providing an incentive for ride sharing or transit use, and
- potentially improving air quality by removing select vehicles from the road and providing the remaining users with more efficient travel.

Most urban areas will have these general goals and objectives, but they should also be tailored to meet the needs of the specific motorists in the corridor.

HOT lanes can enhance HOV lane operation by providing an alternative to regulate the volume on the facility. Occupancy, hours of operation, and price can all be adjusted to provide the most efficient operation of the facility. HOV lanes have many benefits, but these are all related to the perceived quality of service provided by the facility. If demand for the facility is great, travel time increases and travel time savings can become unreliable. If demand for the facility is low, the public can become frustrated with the perception of wasted tax dollars on a facility that is underutilized. Type of vehicle, user eligibility, and hours of operation can regulate demand on an HOV lane.

In addition to the above strategies, HOT lanes can regulate the demand by using price or the cost to use the facility to deter or attract travelers as needed. The toll method is discussed in this chapter, but the factors affecting the cost or price of the toll are discussed in the "Economic and Financial Issues in HOT Lane Implementation" chapter. By using price to regulate demand, groups of users or individuals other than HOV may have the opportunity to enjoy the benefits of HOT lanes. This demand-regulating alternative can help mitigate the drawbacks of HOV facilities, such as:

- too many or too few users,
- the "empty-lane syndrome," and
- the perception that the facility can be used only by a special or limited group of people.

HOT lanes provide the additional benefit of revenue that can be used to offset the operational and enforcement costs, transit improvements, construction, maintenance, etc. All these strategies are related to and incorporated into the operational goals and objectives of the facility.

VEHICLE AND USER ELIGIBILITY

The primary users of HOT lanes are buses and passenger vehicles. Other vehicle types that have been considered for travel on HOV lanes are motorcycles, deadheading transit vehicles, emergency vehicles, and commercial vehicles. The decision to allow motorcycles on a HOT facility is left up to the local authorities. Allowing motorcycles is a way of segregating this class of vehicle and is touted as a safety benefit *(4)*. Deadheading transit vehicles or allowing the return trip, typically with few or no passengers, provides operational efficiency for the transit system. A well-defined policy should be in place to avoid operational and public perception problems, especially when several transit agencies are operating in the area. Emergency vehicles are typically allowed but seldom use the facility since the location of the ingress and egress locations typically do not correspond with fire stations and hospitals *(25)*. "Any emergency vehicle that uses an HOV facility should be properly identified and involved in a legitimate mission. Use of the lane by off-duty enforcement or unmarked vehicles deteriorates public respect for the operation and its policies and should be discouraged"*(4)*. Many times special interest groups will petition local agencies for inclusion as eligible users. It is important that the operating agency holds true to the original intent of the HOT lane and communicates this intent to the general public, media, and political leaders.

HOV lanes can operate during the peak period, daytime, or 24 hour operation. With increased off-peak congestion and sufficient demand (400 vph), facility operation may be warranted throughout the day. Twenty-four hour a day operation can be successfully implemented with proper consideration to safety and operational concerns. Many reversible lanes provide convenience for HOT users except for a short period during the middle of the day when the lane is reversed.

To achieve the HOT lane goals of increased vehicle occupancy, congestion avoidance, and preventing the empty-lane syndrome, a balance must be struck between traffic demand and preserving free-flow conditions. Demand is measured in vehicles per hour or passenger car per hour per lane (PCPHPL) equivalent. Level of service B or C is considered ideal on HOV lanes, but volumes in the range of 1,700 to 1,800 and higher have been documented while maintaining free-flow conditions. The legislation that enables the IH-15 corridor to become a HOT lane requires a LOS C to be maintained on the HOT lane *(19)*. This maximum-flow condition can be constrained by geometric elements or type of facility. Buffer-separated facilities may have a lower capacity if the general-purpose lanes are congested due to the uncertainty of general-purpose traffic making erratic maneuvers into and out of the HOT lane.

Converse to the maximum flow, is the minimum flow that is required to avoid the empty-lane syndrome. Even though most HOT lanes carry at least 50 percent more people than the mixed-flow lanes, if the number of vehicles utilizing the lane is low, there will be the perception that the facility is underutilized *(2)*. A minimum of 400 to 800 vph per lane is recommended to avoid the empty-lane syndrome depending on the facility type *(4)*. The National Cooperative Highway Research Program (NCHRP) report suggests that the HOV lane move more people than the per lane average of the adjacent general-purpose lanes *(2)*. The ability to adjust the HOT lane demand can be done by changing the types of vehicles, the number of occupants, plan participants, and toll amount. Demand is one aspect to consider when determining the vehicle and user eligibility. Other considerations include:

- system continuity,
- travel time savings,
- travel time reliability,
- local and statewide policies, and
- encouragement of HOV formation.

IH-15 in San Diego has used the following occupancy criteria for its HOT lane (preliminary assessment):

- single-occupant vehicle (SOV) pays toll and
- HOV 2+ free.

The Katy (IH-10 West) freeway in Houston, Texas, has developed the following policy on HOT use (preliminary assessment):

- no SOV,
- HOV 2+ pay toll, and
- HOV 3+ free.

SR-91 in Orange County, California, has the following toll road policy (preliminary assessment):

- time of day tolls for all vehicles, and
- HOV 3+ reduced fee.

These policies may be consistent throughout the region while some may vary the eligibility policy from facility to facility. A balance must be struck between maintaining free-flow conditions, person-movement, and revenue considerations. One of the objectives of a HOT lane is to encourage HOV use. By setting a reasonably high occupancy rate, HOV usage can be encouraged by offering the benefits of less congestion, travel time savings, and a more reliable travel time.

HOT 2+ "buy-in" should be used when HOV 3+ is low but using HOV 2+ would exceed capacity. SOV "buy-in" should be considered when the HOV 2+ is well below capacity. Adding SOVs may increase revenue and more efficiently use the extra capacity of the HOV lane while always maintaining free-flow conditions. HOV 3+ should have a minimum of 400 vph projected for the first year of operation. Volumes lower than 400 vph could cause public perception problems of the empty-lane syndrome. Adjustments to the toll rate and occupancy requirement can be used to regulate the demand for the facility. However, these changes in occupancy and toll rate can cause frustration to the general public. To successfully make such changes, an intensive marketing and public information campaign may be required. Tables 7 through 9, borrowed from NCHRP Report 414, are an excellent summary of operating thresholds and guidelines.

Table 7. Vehicle Occupancy Requirement Criteria *(2)*.

Vehicle-Occupant Level	Advantages	Disadvantages
Two or more (2+) persons per vehicle	• Easiest level of carpools to form. • Often significant numbers of existing 2+ carpools in a corridor.	• May be too many 2+ carpools resulting in congestion in a HOV lane. • May not provide incentive to carpool if high number of existing 2+ carpools or help reduce vehicle trips.
Three or more (3+) persons per vehicle	• Can address congestion problems at the 2+ level. • Higher person movement capacity.	• Harder for individuals to form 3+ carpools. • May not have enough 3+ carpools to make lane look used, causing the empty-lane syndrome.
Four or more (4+) persons per vehicle	• Can address congestion problems at the 3+ level. • Higher person-movement capacity.	• Hard for individuals to form 4-person carpools. • Harder to operate on a regular basis due to individual travel needs and schedules. • May not have enough 4+ carpools to make lane look used, causing the empty-lane syndrome.
Variable requirements by time of day (3+ peak hours, 2+ other operating hours)	• Can address congestion problems during peak periods.	• May be confusing for users, especially during transition periods. • May make enforcement more difficult, especially during transition periods.

Table 8. Elements for Developing Minimum Operating Threshold Guidelines for HOV Facilities *(2)*.

Possible Elements	Comments/Possible Minimum Thresholds
Goals and Objectives of Project	The goals and objectives of a project may influence the minimum operating thresholds. For example, a project intended to give buses priority around a congested freeway segment could be expected to have a lower threshold than an exclusive HOV lane. Local policies on carpool definitions or other elements may also influence the operating thresholds and should be considered in the development of local guidelines.
Type of HOV Facility	The type of HOV facility will probably have the most influence on the development of local minimum operating guidelines. The following general levels provide an indication of the national experience and can be used in developing local guidelines: Separate right-of-way, bus only: 200–400 vphpl Separate right-of-way, HOV: 800–1,000 vphpl Freeway, exclusive two-directional: 400–800 vphpl Freeway, exclusive reversible: 400–800 vphpl Freeway, concurrent flow: 400–800 vphpl Freeway, contraflow, bus-only: 200–400 vphpl Freeway, contraflow, HOV: 400–800 vphpl HOV bypass lanes: 100–200 vphpl
Vehicle Eligibility Requirements	Lower minimum vehicle thresholds can be expected, and are usually accepted, with bus-only facilities than with facilities open to buses, vanpools, and carpools.
Vehicle-Occupancy Requirements	Lower minimum vehicle thresholds can be expected with higher vehicle-occupancy requirements.
Level of Congestion Corridor	The minimum vehicle threshold may be higher in a heavily congested corridor than in one with lower levels of congestion. Non-users in heavily congested areas may be much more vocal about a facility they feel is under-utilized than commuters in a corridor where congestion is not at serious levels.
Local Conditions	The perceptions of commuters and the public, as well as any unique local conditions, should be considered in developing minimum operating thresholds.

Table 9. Elements for Developing Maximum Operating Threshold Guidelines for HOV Facilities (2).

Possible Elements	Comments/Possible Maximum Thresholds
Goals and Objectives of Project	The goals and objectives of a project may influence the maximum operating thresholds. For example, a project intended to give buses priority around a congested freeway segment could be expected to have a lower threshold than an exclusive HOV lane. Local policies on carpool definitions or other elements may also influence the operating thresholds and should be considered in the development of local guidelines.
Type of HOV Facility	The type of HOV facility will probably have the most influence on the development of local minimum operating guidelines. The following general levels provide an indication of the national experience and can be used in developing local guidelines: Separate right-of-way, bus only: 800–1,000 vphpl Separate right-of-way, HOV: 1,500–1,800 vphpl Freeway, exclusive two-directional: 1,200–1,500 vphpl Freeway, exclusive reversible: 1,500–1,800 vphpl Freeway, concurrent flow: 1,200–1,500 vphpl Freeway, contraflow, bus-only: 600–800 vphpl Freeway, contraflow, HOV: 1,200–1,500 vphpl HOV bypass lanes: 300–500 vphpl
Vehicle Eligibility Requirements	Lower minimum vehicle thresholds can be expected, and are usually accepted, with bus-only facilities than with facilities open to buses, vanpools, and carpools.
Vehicle-Occupancy Requirements	The vehicle-occupancy requirements will influence use of a facility and the potential for congestion. A higher threshold may be needed with a 2+ requirement.
Level of Congestion Corridor	The maximum operating threshold may be higher in a heavily congested corridor than in one with lower levels of congestion.
Design Considerations	An HOV facility with geometric constraints or sections with less than standard designs may have lower maximum operating thresholds than those with standard designs.
Local Conditions and Perceptions	The perceptions of HOV lane users, commuters, and the public, as well as any unique local conditions, should be considered in developing maximum operating thresholds.

PEAK VS. OFF-PEAK TOLLS AND/OR OCCUPANCY REQUIREMENTS

To more fully utilize a HOT facility and to reduce the public perception of wasted resources, the operators of the facility can vary the occupancy and/or price constraints to assure that the lane is being utilized but is not congested. During the peak period when demand is greatest, the occupancy or toll can be increased to control the demand. In the "shoulders" of the peak period when demand is moderate, a lower occupancy or toll could be used. When varying the occupancy requirement, care should be taken to have a region-wide policy. For example, if occupancy is increased to HOV 3+ during the peak, a consistent time should be used throughout the region. The Katy freeway in Houston was converted from HOV 2+ to HOV 3+ during the peak period when travel time decreased and volumes increased. When the occupancy was changed to HOV 3+, the facility realized extra capacity that is being utilized through the QuickRide Program that allows HOV 2+ vehicles to use the facility during the peak period for a toll *(7)*. Different occupancy requirements can be used, but could cause confusion for occasional users. Varying occupancy requirements can be difficult to enforce leading to some of the following concerns:

- which clock is correct,
- occupancy requirements,
- grace periods for those entering the facility,
- toll options, and
- poor public relations.

These problems can be overcome by using a changeable message sign (CMS) at the entrance of the HOT lane facility that displays the time, occupancy requirements, and toll. This type of communication may mitigate the frustration of the traveling public. Toll options can also vary by time of day and traffic demand. SR-91 in Orange County, California, has a fully automated AVI system that charges tolls by time of day ranging from $0.50 to $2.75. In contrast, the I-15 HOT lane initially was a flat $50 fee per month (Express Pass) but has gone to a fully automated AVI toll collection method based on the level of congestion in the general-purpose lanes with fees ranging from $0.50 to $8.00 *(19)*. The Katy freeway QuickRide program uses AVI to collect a $2.00 per trip toll.

INGRESS AND EGRESS LOCATIONS

HOT lanes have typically been used for limited access or "line-haul" situations. Therefore, entrance and exit locations were spaced infrequently easing the disruption of mainlane operation and simplifying the enforcement task. In addition, HOT and HOV travel time benefits are not recognized for short trips. Entrance and exit locations should be considered at major bus operation locations such as park-and-ride and park-and-pool lots, which are staging areas where commuters gather to consolidate vehicles and are typically located near the facility. Slip ramps provide the most flexibility of entrance and exit location at a low cost, but high volumes will impact the operation of the HOT facility and general-purpose lanes. Direct connections, like T-ramps and wishbone or Y-ramps are used for higher volume locations and usually provide access to support facilities such as park-and-ride lots, other HOV facilities, and local streets. Figures 10 and 11 illustrate a T-ramp, and Figure 12 shows a wishbone or Y-ramp *(2)*.

INCIDENT MANAGEMENT

HOT lanes provide travel time savings and reliability. Incidents can influence travel time and travel time reliability. Therefore, procedures and systems should be in place to deal with these incidents to detect/verify, respond to, and clear these incidents in the shortest time possible. A time relationship of 1:3 is an accepted rule of thumb for the time it takes for traffic to recover from an incident. For example, if a stalled car is blocking one lane for five minutes it is expected to take approximately 15 minutes to recover back to free-flow conditions. Detection methods include loop detectors, cellular phones, bus operators reporting incidents, and closed circuit television (CCTV). With the exception of CCTV, the incident must be verified and the proper equipment dispatched. Incidents can be detected and removed quicker if a Motorist Assistance Patrol (MAP) or contract wrecker service agreement is in place. More serious accidents may require coordination of police, fire, and emergency medical services (EMS), as well as the hazardous material crew and the department of transportation or local road authority. Information on HOT lane closures or slowdowns is information that is vital to the user paying for the use of the facility. Typically this communication is through changeable message signs or facility personnel.

Another aspect of incident management is using the HOT lane when a major incident occurs on the general-purpose lanes. HOV lanes have occasionally been used for this purpose. Provisions and operational procedures should be in place to allow for such situations. Criteria include:

- more than half of the general-purpose lanes being blocked for more than 30 minutes,
- manmade and natural disaster evacuation procedures dictate, and
- special events.

The establishment of criteria and operational procedures to allow general-purpose traffic will greatly enhance the movement of people and goods in the event of a major freeway incident.

TOLL COLLECTION

In most situations HOT lanes operate very similar to HOV lanes with the exception of the toll collection. HOT facilities to date have had three major types of toll collections, including monthly fee, set per trip fee, and variable fee per trip. Each of these types of collection methods requires various hardware, software, and procedures to efficiently and effectively collect revenue while minimizing or eliminating the delay to the user.

The first toll method is a set fee. Typically a monthly fee is charged to the facility participants irrespective of use. This method simplifies the billing, and the participant is usually identified with a hangtag or sticker. Only registered users are able to use the facility, and the number of users is typically limited to ensure free-flow conditions. The set fee per trip basis of toll collection usually requires a tag signifying participation in the program and a means of debiting a prepaid account, which is typically done by AVI tag or LPR. The variable per trip fee is based on current mainlane traffic conditions. The concept is that the participant pays more to use the uncongested HOT lane as the congestion on the mainlanes increases. This variable pricing does require a method of measuring the mainlane conditions, as well as the ability to relay the dynamic price to use the HOT lane.

AVI vs. License Plate Recognition

Currently two technologies are being used for toll collection, AVI and LPR. AVI uses a tag that is mounted in the vehicle and read by antenna on the roadway. This information is relayed to a central database that is used to deduct and track participants' accounts. LPR uses a video image of the vehicle license to bill the owner of the vehicle for the toll. The LPR method provides the flexibility for anyone to use the facility without being required to register in the program. Frequent users of the facility would register and use an AVI tag. A higher fee is typically charged for the infrequent users to cover the additional costs of tracking down the owner, sending the bill, etc. Many toll authorities use LPR for enforcement and the E 407 in Toronto uses LPR for occasional toll road users and AVI for regular users *(26)*. All the HOT facilities are currently using AVI for toll collection *(27).* California is unique in that one account can be used for HOT and toll road/bridge tolls anywhere in the state. The QuickRid*e* program, as well as most other agencies, do not have interagency agreements or shared accounts. The same AVI tag can be used but separate accounts must be set up.

Enforcement

Several strategies can be used to enforce HOT lanes. The type of facility influences the enforcement strategy. For instance, barrier-separated facilities allow limited access to the facility, which makes enforcement easier. Four enforcement strategies are being used on HOV facilities; however, the two shown in bold appear to be most applicable to HOT lanes:

- routine enforcement,
- **special enforcement,**
- selected enforcement, and
- **self-enforcement.**

Enforcement policies should protect traveler safety, travel time, and discourage unauthorized users. Routine enforcement utilizes existing patrols to monitor and enforce the HOT facility. This alternative is unlikely considering the public perception and potential loss of revenue involved with this type of enforcement. **Special enforcement** entails dedicated equipment and manpower to enforce HOT compliance. Typically, additional manpower and resources are required to protect the public image and toll revenue of the facility. Selective enforcement is a combination of routine and special enforcement varied by time of day, location, and level of effort. This keeps violators off guard since they do not know when, where, or how intensely enforcement activities are being performed. The final enforcement strategy is **self-enforcement** or facility users police themselves. Users report violators giving the time, location, and license number. A brochure or personalized letter is usually sent to the violator explaining the policy of using the HOV or HOT lane. Multiple reports of the same license plate are forwarded to the patrolling officers. Self-enforcement is typically used in conjunction with other enforcement strategies. Special enforcement will typically be used on HOT lanes to enforce occupancy regulations and reduce revenue loss. Sufficient space, lighting, and visibility should be thought of early in the enforcement plan (see “Design”). To date, only barrier-separated HOT lane facilities are in operation. Mixed-flow and shoulder lanes have not been demonstrated as good candidates for HOT lanes due to the increased problems of enforcement. Public acceptance and a firm commitment by the enforcement agency are crucial for this type of facility to be successful.

Emerging technologies hold promise for the costly HOT enforcement issue. Several states have passed legislation allowing:

- use of photographic, digital, and video systems to be used to identify violators;
- mailing of traffic citations and warning letters to the registered owner of a vehicle violating the policy; and
- mass screening of license tags to identify habitual violators.

Once a violator has been identified and apprehended, adequate penalties must be in place to discourage willful violators. A general feeling among HOV operators is that occupancy violations should be a moving violation with points or demerits applied to the violator's driving record. It has also been proposed that fines should be graduated to further discourage willful occupancy violators. In contrast, the toll community typically takes the stance of issuing the equivalent of a parking ticket. This ticket is typically used to cover the toll and associated processing costs. The moving violation is typically a more severe punishment but requires both the vehicle and the driver to be identified, which could be difficult if an automated procedure is used. The non-moving violation only needs to identify the vehicle, requiring the owner of the vehicle to pay the fine.

Automated occupancy enforcement has been tried with some success using video technology *(28)*. The Dallas study used LPR and several cameras to determine occupancy. Manual review of the license plates and occupancy was required. Informational brochures were sent to suspected violators, since current legislation does not recognize video occupancy enforcement. Advances in cameras, light sources, hardware, and software are relatively slow for this developing market, although progress is being made.

FINDINGS

The study revealed the following findings related to HOT lane operation.

- A deliberate decision should be made regarding eligible groups, and that decision should be strictly maintained.
- Target flow rates (maximum and minimum) should be established and tolls and occupancy adjusted to maintain the desired ranges.
- Dynamic signing should be considered to advise travelers of current eligibility requirements and usage tolls.
- Entrances and exits should consider bus operations and park-and-ride lots to encourage HOV use.
- Careful consideration should be given to toll collection options.
- Enforcement options should be weighed as a part of the operational planning.

ECONOMIC AND FINANCIAL ISSUES

PRICING ISSUES

A number of different pricing strategies were discussed in the previous chapter. The goals of the project will strongly influence the toll setting method. However, some of the following parameters deserve explanation, as they could be components of an "optimal" pricing strategy. Toll setting is a challenge when the HOT lanes compete with parallel free routes.

Value of Time

It is important to note that the perceived value of time (VOT) estimate that is used for analyzing HOT lane pricing and demand issues should be appropriate for the problem at hand. In addition, it is essential that the underlying behavioral model used for the assessment is appropriate.

- VOT values are required for designing optimal prices of the second best nature to the extent that they impact delay costs.
- The difference between HOT-lane VOT and general-purpose VOT could be used for toll price determination.

Validity of Current VOT Estimates for Pricing

Existing perceived VOT estimates are invalid for an assessment of rate changes for existing facilities within Texas. The most recent VOT estimates for the state of Texas were computed by Chui and McFarland based on speed choice decisions of travelers and are updated for current use by adjusting them for inflation. However, they are inappropriate for assessments of HOT lane toll rates and little emphasis has been placed on this issue *(29)*.

VOT Distribution

The assumption is that the market for HOT lanes is heterogeneous. Ignoring this inherent heterogeneity as is done currently in pricing decisions would be tantamount to limiting the revenue potential and underestimating the potential welfare gains. Academicians are now suggesting that it may be better to design optimal prices using the VOT distribution in the pricing decisions because of the many reasons discussed earlier under revenue generation. However, this approach is an entirely new area of research even for aficionados of second best road pricing and such ideas cannot be implemented for some time.

Willingness To Pay

Willingness to pay (WTP) estimates have been used in the past for pricing decisions. The goal of market research is to identify the willingness to pay function or the marginal benefit curve of travelers. VOT is an implicit parameter in this research and can also be used for toll setting. However, WTP is the preferred approach for determining rates on new projects and first-time

HOV–HOT lane conversions. In the case of I-15 HOT lanes, Wilbur Smith Associates conducted a baseline market survey using focus groups and telephone surveys to assess the willingness to pay for permits during the peak period. The WTP estimates also help analyze equity aspects of the project.

Another use for WTP analysis is in the evaluation of the potential for future changes in pricing strategies. The design for any WTP study is critical and is dependent on the stage of the project at which it is conducted.

Factors Determining Pricing Decisions

For a publicly funded project, public acceptability of the project is always critical. It is more critical initially, thus implementing agencies can set their prices high enough only to cover basic expenses in the start. This low toll is necessary to create a reliable base of future patronage. This approach should improve diversion behavior and in the long term will be consistent with both improved mobility and revenue generation assuming other issues related to pricing and revenue use in initial and later years have been dealt with. It is therefore recommended that:

- Initially low peak and off-peak rates should be imposed. This dual approach is good for public acceptability initially but not good for revenue generation or welfare. This approach is also not good for demand management. These initial low rates can be based on willingness to pay market studies.
- At a later stage, when demand is stimulated and elasticity improves, such projects can implement other pricing techniques to effectively manage demand and at the same time raise revenue.

A privately funded project, however, will be primarily concerned with revenue generation. The success of such projects will rely on the effective management of demand to raise revenue. Their pricing structures will in general be much higher than those of publicly funded projects.

A final comment in this regard is needed to conform to some guidelines in price setting. Hau provides some excellent criteria that a good road pricing system must follow. From the user's point of view the following criteria can be put forward *(30):*

- The system should be simple and user friendly.
- Drivers should be informed about prices ahead of time and place. Otherwise, the system will fail to be incentive-correct.
- User privacy should prevail.
- Transaction costs should be low, and billing and charges should be easy to check.

From the operator's point of view the following points should be emphasized:

- The system should be able to directly influence traffic flows and improve efficiency.
- Tolls should be demand-responsive.

- The system should be reliable and easy to enforce.
- The system should be able to generate information for investment decisions.

From the public's point of view the following criteria may apply:

- The road pricing system should bring about larger benefits than costs.
- The system should minimize intrusion on urban and natural environments.
- Charges for different vehicle types should be easy to differentiate.
- The system should be fair and be combined with relevant alternatives. Fairness can be achieved by following the principle of revenue-neutrality in toll setting. A peak-load pricing strategy can easily attain these criteria, especially if revenues are channeled back to the transport system at large.
- The system should be compatible with other traffic-related payment systems, and it should possibly include add-on options.

Prices

A number of different types of pricing strategies could be implemented based on the goals of the project. These include:

- *Break-even* type in which the price is set such that the operating, maintenance, and debt service costs are covered. This strategy is typically done over the term of the bonds issued for initial construction of new projects.
- *Second best prices*, which include the true efficiency maximizing price or the profit maximizing prices. This strategy is one that is based on the relation between demand, willingness to pay, and marginal costs of operating the facility. These characteristics have yet to be implemented.
- *Market prices* based on a number of other criteria reflecting the different objectives of the agency operating the facility including:
  - prices based on other toll rates already operating within the region and
  - prices based on comparable facilities in nearby states after appropriate cost of living adjustments.
- Prices based on compatibility with rates on other modes.[1]
- Value of travel time savings associated with using the facility as compared to alternate free routes.[2]
- Willingness to pay.
- Toll sensitivity analysis.

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[1] I-10 Katy, Houston

[2] A variant of this approach has been used in the SR-91 case. A VOT has been assumed and rates have been calculated.

The point here is that revenue generation is strongly dependent on the pricing strategy. When prices are set to meet travel time constraints and/or other criteria these prices may or may not be below the revenue maximizing prices for a given demand level. In other words, there could be a conflict between demand management goals and revenue management goals of the operating agency.

Regardless of how the price is set, it is necessary to ascertain the “toll sensitivity” of revenue or, in other words, how revenue potential can change with changes in toll rates as well as pricing strategies (time of day pricing, dynamic pricing). There are two factors that need consideration in the analysis: 1) the current pricing strategy and 2) the future pricing strategy. The analysis can be fairly simple, but data intensive, when prices are independent of congestion. When prices have anything to do with congestion, however, the revenue potential is much more complex and will require an examination of traffic and congestion patterns, as well as diversion rates. In the case of SR-91, the revenue potential was also assessed under the assumption of a future pricing strategy with dynamically varying congestion-based prices. Toll sensitivity curves were derived from a study of hypothetical time-of-day diversion curves at different assumed toll rates. These toll sensitivity curves also indicate average optimum tolls of $2.00 during peak hours in the major travel direction and $1.00 for the off-peak hours *(31)*.

Rate of Increase in Toll Rates

Price setting should also contemplate the manner and frequency of potential toll rate increases.

- There is a need to have good forecasts of the rate of growth of project costs as well as debt service costs. This need implies that the choice of interest rate and the method of annualization are critical.
- There is a need to identify what rate of increase in tolls is required to offset these costs.

Historically, capital costs of constructing new toll projects have increased as rapidly as operating and maintenance costs. Concomitant with inflation, the interest costs of borrowing funds have also increased. Toll rate changes have typically failed to keep pace, thus eroding the revenue generating potential of such projects, and have reduced the number of projects that can be considered financially feasible on a self-supporting basis. This failure is a concern for new and costly HOT lane projects. Rate changes are complex from a political standpoint, and increases in prices could lead to traffic deterrence further limiting the revenue potential in the face of inflation.

REVENUE GENERATION ISSUES

Financial Feasibility of HOT Lanes

The primary question for financial feasibility is whether HOT lanes can generate enough revenue to cover operating and maintenance costs and capital costs. The evidence on this issue is limited to the experiences of the I-15 project in San Diego and the SR-91 facility in Orange County, California. Strictly speaking, the I-15 project is not a valid example because all costs are covered by federal dollars, but it still indicates that HOT lanes can provide a continuous source of revenue to cover at least operating and maintenance costs. If one were to make generalizations based on I-15's experience, HOV lane conversions can generate enough revenues to cover their operating and maintenance costs and over time their capital costs as well. One reason for this conclusion is that conversion capital costs are fairly low relative to new lanes, as clearly indicated in the I-15 case.

Whether HOT lanes can generate enough revenue to cover costs for *new projects* is another question. An analysis of SR-91 indicates a three-year break even time period based on annual reports, but it also raises a number of other questions. Robert W. Poole and Kenneth Orski, in a recent Reason Policy Report, make a strong case for HOT lane financial feasibility *(32)*. They also mention that there is evidence from a feasibility study (US 101 in Sonoma County, California) indicating that a low-cost version of the project could cover both its operating/maintenance costs and capital costs from toll revenues, while the higher cost version could do so only if the higher end revenue estimates (based on variable rather than flat tolls) were achieved *(32)*. On the contrary, the analysis conducted in this report adopts a more conservative approach to the question of financial feasibility of HOT lanes.

Based on the available evidence of operational projects, it may be too soon to answer these questions related to financial feasibility. One reason for this ambiguity is that traffic growth occurs over a period of time, and it is always expected that new projects will need to wait it out because innovations need longer assessment periods. We may have a clearer picture a few years from now. Figure 16 demonstrates the complex interplay of variables and issues that make assessment of the financial feasibility a challenge. University of California, Irvine, is currently studying the interrelationship between financial, political, institutional, and equity issues for four California toll roads. Issues being researched include whether tolls can generate enough to cover highway construction costs and a study of factors such as public opinion that affect likelihood of project implementation and policy success.

Economists argue that transportation facilities generally exhibit increasing returns to scale and large sunk costs (irreversible costs). What this argument implies is that the theoretical optimal prices that are close to marginal costs will not generate enough revenue for projects like SR-91 to be financially feasible. Hence, such companies require a subsidy. They could also adopt pricing schemes designed to generate more revenue than marginal costs but tend to leave usage about the same. SR-91 benefited in both cases. The project received subsidy from the government because it is built on public right-of-way. It also employs pricing schemes that are designed to make more profits for the company. Hence, both these factors also need to be considered when assessing financial feasibility of costly new capacity projects.

Financial feasibility of HOT lanes also depends on three other factors: 1) the rate of toll increase and choice of interest rate, 2) toll collection costs, and 3) degree of risk for private projects. Investment bankers maintain that modernizing an existing congested interstate is the least risky. The most risky and least likely to receive financing at a reasonable rate would be a green-field project dependent on future nearby land development like the Dulles Greenway toll project.

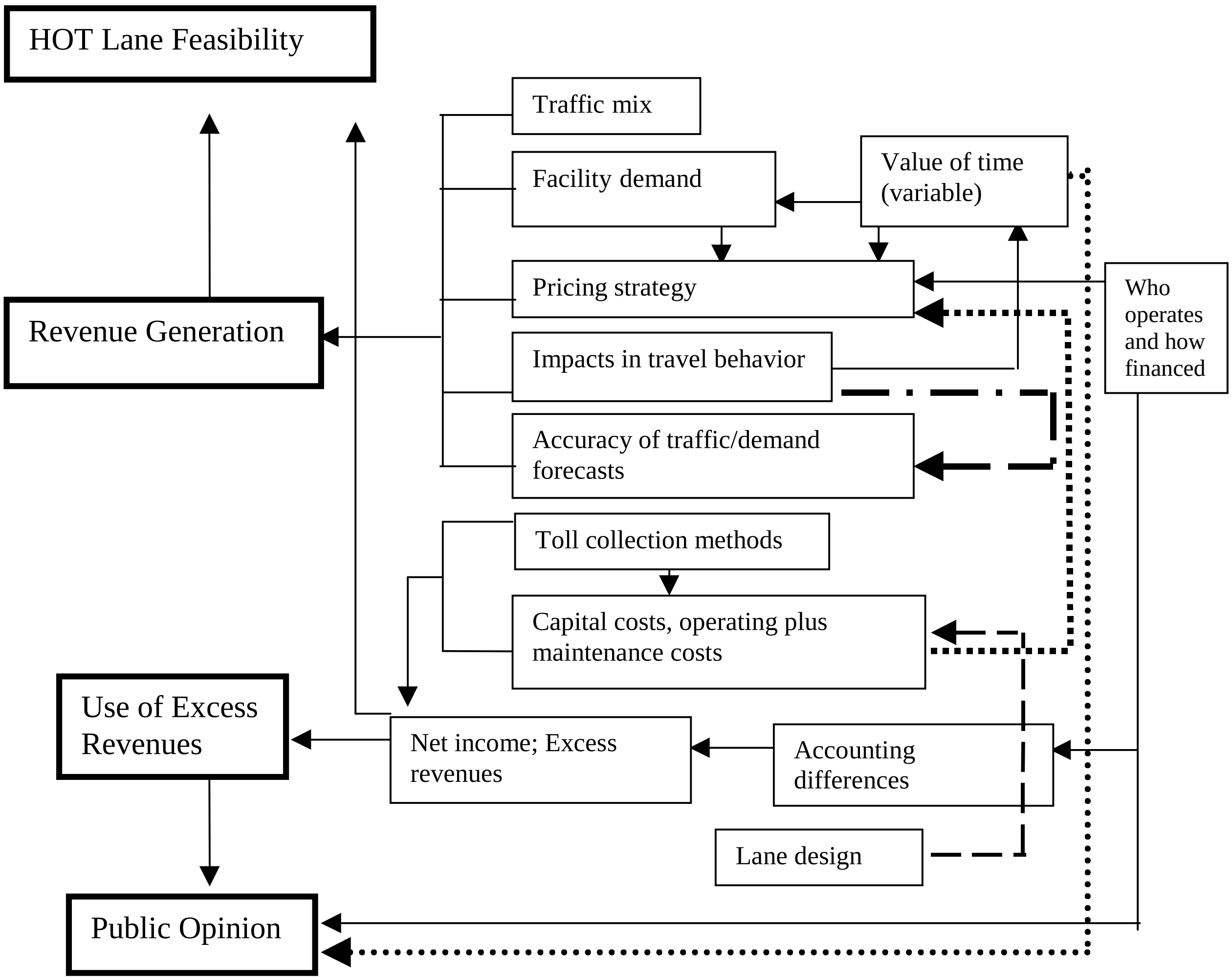

Figure 16. Interplay of the Different Factors and Issues Impacting HOT Lane Financial Feasibility.

Value of Time

Value of Time Assumed in Revenue Forecasts

The relationship between revenue growth and values of travel-time savings needs to be free of any mis-specifications. The success of a toll lane really depends on travel-time savings. Hence, VOT becomes an important variable. Assuming an average value will lead to forecast errors. For a given travel time, a HOT lane could reduce the variability associated with the travel time. Both sources of time benefit (time savings and variability) must be correctly predicted in order to predict use of the facility and therefore revenue generation potential. Revenues from toll facilities will depend, among other factors, upon the assumptions made pertaining to the inputs in the revenue forecasting process. It is critical to examine these inputs because errors in their use could contribute to substantial errors in the forecast and increase the forecast variability *(33)*. Revenue can be overestimated for new toll roads when actual values of travel-time savings are small. The true relationship between revenue generation and travel-time savings then becomes the critical question. Assuming high VOTs could lead to revenue over-projections, meaning it takes longer to break even. ITF Intertraffic, a subsidiary of Diamler-Benz, AG, has funded an ongoing research study undertaken by University of California to investigate some of these issues for the SR-91 facility, and this study needs to be monitored.

Perceived VOT Is Variable

VOT is likely to vary for different user groups and therefore different travel markets using the facility simultaneously. There is a need to consider these aspects in demand forecasting. For example, there may be a group that uses transponders and others that do not. This difference could make the task of assessing the range of revenue generating potential harder. The more commonly noted groups in the VOT literature pertain to those divided by income levels and trip purpose.

One two-stage approach (although not a problem-free one) to addressing this problem and its influence on revenue could be applicable when there is a price differential for different user groups. In the first stage, forecasts generated from traditional assignment models are calibrated to match observed conditions. In the second stage, the changes in demand-to-toll changes and the consequent changes in revenue generation are assessed *(34)*. Figure 17 illustrates, in partial equilibrium terms, how the demand or the marginal willingness-to-pay function can vary by VOT group and, in essence, market segmentation occurs when a toll is charged. The high VOT groups are typically business travelers, and low VOT groups tend to be leisure travelers (groupings by other criteria could also be used). The high VOT group has the most inelastic demand or least price-responsive demand compared to other groups.

In essence, for any specific vehicle or trip type there is group variation and the market is not homogeneous but is assumed to be so for revenue generation assessment. The cost of doing so, in this case, leads to forecast errors. This difficulty makes traffic mix important and it also calls for an identification of different user groups.

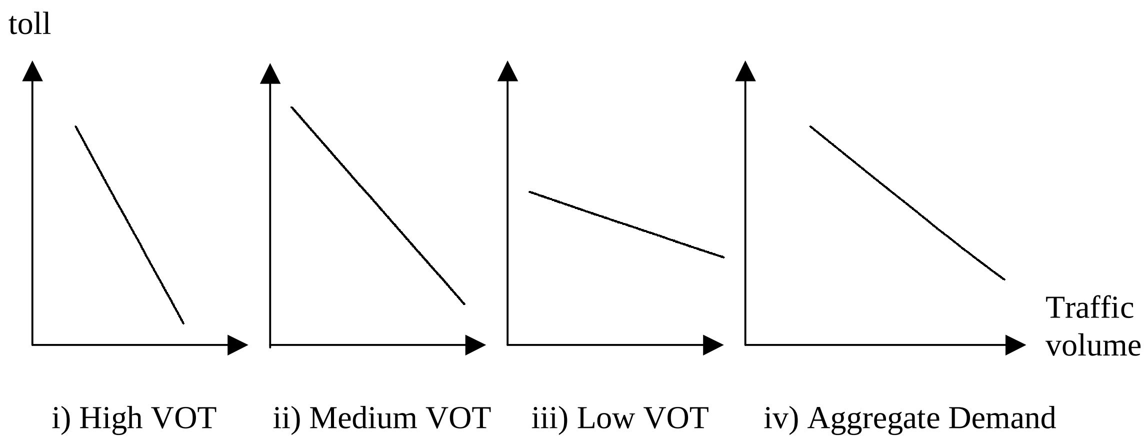

Figure 17. Demand for Travel by VOT Group and Aggregate Demand.

One way of addressing the variability issue is to assume that the distribution of income is similar to that of VOT and then use demand forecasting packages like EMME2 for assessment of impacts *(35)*. Many times this assumption may be violated and without an assessment of perceived VOT this approach cannot be justified and other approaches are required. The variability of VOT between different user groups and the potential impact on the range of revenue potential is currently being investigated for the SR-91 lanes and other toll roads in Orange County, California.

The issues confronting the operator are listed below. These issues will be more important for private operators.

1) What is the traffic profile (SOV users, carpoolers, other vehicle types)?
2) Is the assumed average VOT for revenue generation justified?
3) Is there an information advantage to considering variability by using a market-segmented approach?
4) What information is gained when using the distribution of VOT?
5) What is the role of reliability?

Figures 18a and 18b illustrate some of these issues using facility demand curves and level of service type pricing. Figure 18a shows two sets of demand lines, B and B1, and Figure 18b shows sets A and A1 at two speeds x and y mph (x > y). Both of these aggregate demand curves slope down because people have different VOT, and because some have better alternatives than others. Toward the right is the low-VOT group, users with flexibility whose demand would be the most price sensitive. Toward the left are the high-VOT users, those with inflexible schedules, poor alternate routes, or some combination of these factors, who essentially have the least price sensitive demand.

One set of demand curves (sets A and A1) is linear and the other is concave (sets B and B1) to the origin. The difference is essentially due to the difference in the number of high- and low-VOT users. In the concave demand curve set (Figure 18a), most users are high-VOT users on the left-hand side and on the right are a number of marginal users who do not value the facility as much. In the somewhat linear demand curve (Figure 18b), some users value the facility highly, some value it moderately, and some only a little.

Suppose the capacity is Q* with an equilibrium speed of y mph. Assuming that it is desired to have an equilibrium speed of x mph, the Highway Capacity Manual indicates that traffic needs to be kept at Q2 in order to attain this free-flow speed. Given the set B demand curves, a toll of P1 would then have to be charged, generating revenue of P1CQ1O. If the relevant demand was set A, then only a price of P2, which is less than P1, could be charged and generate total revenue of P2HQ2O, which is less than P1CQ1O. With some modification, these demand curves can also be used to show equity issues, political acceptability issues associated with pricing, and welfare impacts; however, the key factor in determining these aspects is the shape of the demand curve, which will hinge on the VOT distribution.

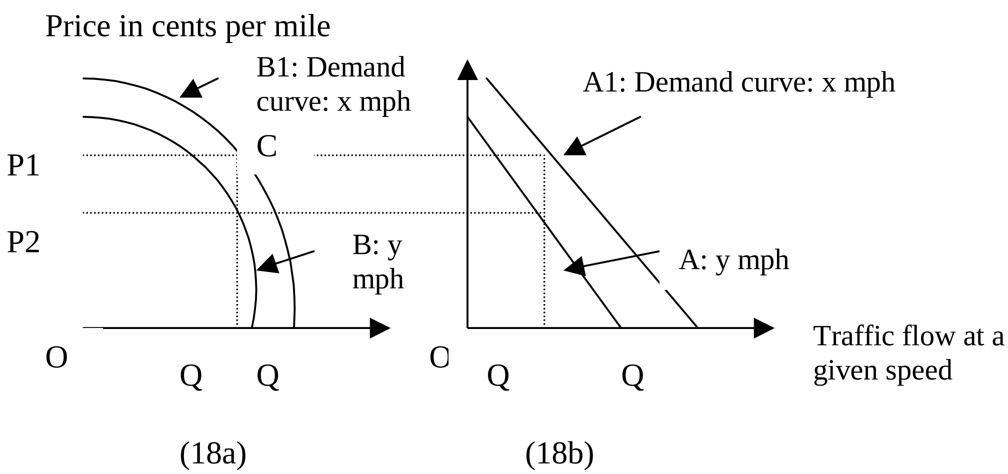

Figure 18a–18b. Aggregate Demand Curves for Travel (at a given speed), Equilibrium Prices, and Revenue.

VOT Changes Induced Due to Rate Changes

VOT is likely to change when toll rates change, and this is likely to distort the travel time savings. Without having insight into the induced VOT changes, it would be hard to build better predictive models of revenue generation changes from potential toll revisions. This change would require VOT adjustments/assessments after every toll change. Currently this is a difficult task to address (at least in Texas) but ample data have been compiled for the SR-91 and I-15 facilities, both of which have observed toll revisions, making them prime candidates for tracking changes in actual VOT addressing this issue.

Project Location

The toll road literature suggests that when revenue generation becomes critical then potential new projects should be located in the vicinity of high-income areas in congested urban areas (34). This aspect of revenue generation due to future project location could lead to land use effects and equity issues. One implication of this potential is that such impacts need to be assessed at different stages of the project. Such an approach has been adopted in the I-15 project. Research has demonstrated the direct relation between VOT and profits of the facility especially for private operators *(35)*. Changes in VOT could have the largest single impact on profits, suggesting that potential operators should pay particular attention to the demographics of their intended clientele. Another point to note is that revenue generation implicitly involves luring the portion of high-VOT users (i.e., general VOT) in the "tail" of the VOT distribution of the corridor users by using incentive packages. These high-VOT users have the highest delay and inconvenience costs. In the case of SR-91 Express Lanes, the toll structure was designed to attract travelers with VOT greater than or equal to $13 an hour.

Facility Demand Curve

VOT is an implicit parameter influencing the demand for the HOT lanes. Figure 17 shows that VOT provides more information about demand segmentation by group. The aggregate demand for travel at any given point in time is, however, an aggregation of all VOT groups. Furthermore, the number and proportion of different VOT users determine the shape that the aggregate demand assumes and the direct demand elasticity for the whole group. The problem is that the demand curve will shift over time, induced by changes in the value of time, money, and travel behavior. However, assessment of the demand, even if it is at a given point in time, could help in the assessment of revenue generation as well as addressing the price sensitivity question.

Factors Affecting Diversion Rates

It is necessary to determine the factors affecting the rate of diversion to the HOT lane from the alternative free route in order to project return on investment to the extent that these factors provide information about the demand for the facility. Factors that require consideration are:

- nature of project (i.e., intra-city projects present greater challenges because of the variation in the time savings due to traffic concentrations at different times of the day and days of the week),
- peak duration range of VOT values,
- robustness of diversion rates to alternative toll pricing strategies, and
- amount of time that it takes to make the "switch decision" for different user groups. To the extent that this variable reflects diversion rates, a greater knowledge of this issue is certainly warranted in order to establish a base for future patronage. If a facility is privately financed and operated, this issue is of even greater importance since there is an even greater need to forecast the future stream of revenue payments more accurately.

A related issue is the need to identify the type of incentives that need to be put into place in order to attain a certain rate of adaptation to the HOT lane. Another related issue that impacts demand modeling efforts is whether this level of capture should or should not be assumed to vary throughout the day (i.e., should demand models focus on time of day modeling or other approaches?).

Dynamic Pricing Versus Time of Day Pricing in Managing Demand

The problem is that there is still a small amount of uncertainty about prices with dynamic pricing even if there are set maximum limits at different times of the day. In principle, dynamic pricing violates the transparency condition that a good road pricing system should follow *(36)*. This could lead to a "bidding game" at least in the beginning, and the beneficial impacts will tend to occur with a lag as people learn over time. The pertinent question is which one leads to a better peak spread, especially in congested areas, and also promotes a move to higher occupancy modes. However, issues such as these need more examination. This issue is as much a revenue-related pricing issue as it is a demand management one.

Since there are no projects that have implemented both variable time-of-day pricing and dynamic pricing at some stage of the project or the other, there is no evidence to guide decision making. For either of these two strategies to be effective as demand management strategies, we have to assume that travelers are rational and are willing to make the dollar cost and congestion (travel time) trade-off decisions between the HOT lane and free network. The point is that the cost per saved minute is the determining factor and not the absolute size of the toll. Under both scenarios the cost per minute saved will vary as a function of both relative congestion and the toll (variable or dynamic). In a 1995 study, Wilbur Smith and Associates touted the potential for variable pricing as a demand management tool *(6)*. The study makes a number of interesting points.

- Off-peak discounts are most acceptable to the public, but they are ineffectual for demand management and revenue generation.
- Rush-hour surcharges are needed to move traffic out of peak hours, and the amount will vary by facility.
- Rush-hour surcharges are necessary to raise revenue.
- Demand management implicit in variable pricing is contrary to patron service philosophy.

Many of the same points can be made of dynamic pricing. Since dynamic pricing uses real-time traffic data to derive congestion based tolls, it does seem to suggest that it may be more effective than variable tolls in managing demand. Travel times could improve, as well as reliability. While the potential for either variable or dynamic pricing can certainly be evaluated using field data, even from sites that currently employ fixed toll rates, the effectiveness of one over the other will surely depend on learning behavior of users. Godbe Research and Analysis Group conducted such a study of I-15 lane four express pass user focus groups (current pass users, past pass users, HOV users, and SOV users) to evaluate the potential for dynamic pricing *(37)*.

Assumptions Regarding "Other" Inputs in the Demand/Revenue Forecasting Process

Assumptions regarding inputs including land use forecasts, commercial vehicle modeling, perception of toll levels, and the annualization process of traffic and cash flows need to be assessed. This aspect is also a demand estimation issue. Should a traditional four-step modeling process be used, and given that micro-simulation models such as TRANSIMS are still not completely ready for use, a number of modifications need to be made to the demand forecasts. Regardless, some of these issues lead us to conclude that traditional methods are inadequate to handle some of these issues and need to be modified and/or new methods need to be considered.[3]

Range of Revenue Generation Potential

Determination of the range of revenue generation potential for HOT lanes is a complex issue. This complexity is because the revenue potential is strongly dependent on the interplay of a number of factors, each of which is discussed below. In particular, the revenue generating potential of the HOT lane(s) is dependent on demand level for the facility, traffic mix, pricing strategy adopted, and changes in travel behavior induced by the introduction of such facilities. The demand level on the toll lane is impacted by factors like actual toll rate, travel speed on alternate facilities, and parallel "free" routes (i.e., the extent to which factors such as degree of congestion impact the facility usage). The discussion below is formulated as a series of questions that could be raised in assessing the revenue generating potential of a new facility or the conversion of an existing facility to one that is based on user charges.

- There are many interacting issues in estimating the range of revenue generating potential. Consequently, there are many unknowns impacting revenue generation and financial feasibility of HOT lanes. At a minimum, a sensitivity analysis under different scenarios and alternate values of crucial parameters such as demand elasticities is recommended. More generally, the burden of proof should be placed on the proponents of the project (especially if it is a costly project) to show that the evaluation is robust to reasonable variations in crucial forecasts and under varying assumptions of toll prices and vehicle occupancy. HOT lane projects (especially private ones) require a toll sensitivity analysis to demonstrate revenue fluctuations to toll rates as well as different pricing strategies.

Revenue Generation Versus Demand Management Goals

Private operators are likely to have revenue maximization as one of their primary goals and will set prices accordingly. On the contrary, publicly funded projects are more likely to have demand management and welfare maximization as their primary goals. These public projects are also more likely to be HOT–HOV lane conversion projects. The choice of goals implicit in the pricing strategy will influence revenue generation. The pricing strategy selected may cause a conflict between demand management goals and revenue management goals of the operating agency, because, theoretically, there are no optimal market prices that can simultaneously achieve both objectives. In practice, however, the experiences of I-15 lanes and SR-91 lanes in California suggest that it is possible to design prices that bring the apparently conflicting objectives together

[3] This is a demand estimation issue and will not be discussed in this part of the report.

regardless of the nature of the operator. One factor that makes this possible is the existence of strong demand within the corridor and high pre-existing levels of congestion. It will not be misplaced to suggest that these are necessary conditions for financial feasibility along with VOT and willingness to pay.

REVENUE USE ISSUES

Use of Excess Revenues

Three criteria must be used to decide the use of excess revenues:

- Political acceptability: One of the keys to political viability of value pricing experiments is to establish a clear link between toll revenues and expenditures on things that citizens want.
- Economic efficiency criteria require that revenues need not be strictly "earmarked" or that revenues be disbursed according to how much individuals pay. All that is required is a redistribution formula ensuring that revenues be used to benefit society. This result is easily accomplished.
- From an equity perspective, the redistribution formula should depend on equity criterion that is selected (i.e., horizontal or vertical (38) or other definitions).

Definition of Net Income and Accounting Practices

In general, since lane conversions could cost much less than they can potentially generate in revenues, how the excess revenue is defined and used is much more of an issue for HOV lane conversions than new HOT lanes.

What constitutes a proper definition of net revenues? This is a problematic issue. Two points need to be mentioned. First, of the three operational HOT lane projects in the country, the net income issue is currently redundant for one (I-15), the second one is privately financed (SR-91), and the third is a federal demonstration project (I-10). This leaves very little to draw inferences from. Second, because of the first aspect and because of the similarity of HOT lane projects to toll projects, we need to look beyond these three projects to toll lane projects in general. When this approach is used, differences in accounting principles used by toll agencies make it difficult to show if there could be some standardization in the definition. A recent report corroborates these findings *(39)*.

It is important to note that historically toll revenues have constituted almost 90 percent of the total income of toll agencies. This situation is true even in the case of SR-91. Depending on accounting principles used, there could be other income sources including investment income, interest income, and other income. These other sources have historically been very low. Regardless, these different sources of income cannot be considered independently because they could be used for deferring different types of expenditures.

How the net income available for use is defined will therefore depend on a number of factors including accounting principles and also on the type of financing used. As the SR-91 case illustrates, when the HOT lane(s) project is completely privately financed there is no obligation to earmark revenues for purposes other than those mentioned earlier. Probably because of the partnership nature of the company that started SR-91, the definition of "net or excess income" is also somewhat changed. Its "net operating income" is actually gross depreciation, amortization, and interest expenses. One possible explanation for this is that since it is a private company, it has complete control on cost allocation.[4] On the contrary, should a public agency utilize debt financing, then revenue bonds covenants require that debt retirement should be the primary responsibility. In other words, net income is defined net debt service costs including other operating costs and maintenance costs. The excess revenue, if any, can be diverted to satisfy equity considerations such as improving transit services within the corridor. ISTEA stipulates that toll revenues be first used for debt service when federal funds are used for reasonable return on investment, and for covering operation and maintenance costs of the facility. Only toll revenues in excess of these requirements should be used for transportation purposes under Title 23 *(40)*.

The I-15 lanes in San Diego are federally funded with one of the goals being increased national acceptance of congestion pricing. All revenues are earmarked to fund transit and carpool services within the corridor (Inland Breeze-Route 900). When the project becomes self-sustaining, then revenues will be diverted to cover operating and maintenance costs of the facility and the balance, if any, will be directed to Inland Breeze.[5]

The possibilities and options for financing for private HOT lanes are increasing. These options include value capture techniques and tax increment financing. This factor will also have substantial implications for accounting principles used by HOT lane projects to define net income.

EXPENSE

Expense Categories

A partial list of the different expense categories that could apply to HOT lane projects is provided below based on the experiences of I-15, San Diego, and SR-91 Express Lanes. Not all of these will apply to all HOT lane projects. Some of these will apply only in new HOT lane projects like those proposed on the Lyndon B. Johnson Freeway in Dallas, Texas.

- *Capital costs*: These costs are generally costs related to development, integration, and construction of a new facility. These costs totaled approximately $133 million for the 10-mile SR-91 project and $1.85 million for the 8-mile I-15, San Diego project. Costs falling into this category are the following:

[4] The auditors notes indicate that the SR-91 cost allocations are in agreement with the Section 3.6(b) of the Amended and Restated Development Franchise Agreement for SR-91 Median Improvements between CTPC and State of California Department of Transportation Company (Caltrans). They are, however, not intended to be in conformity with Generally Accepted Accounting Principles (GAAP).

[5] Source: Correspondence with Ms. Sharon Gordon, FHWA.

  - equipment costs applicable to HOV lane conversions as well as new projects (video enforcement, computer hardware and software, plastic pylons, changeable message signs, gantries, and electronic toll collection (ETC) reading equipment);
  - leasehold improvements, development costs, and start-up costs applicable primarily to new projects; and
  - financing costs incurred to secure debt.
- *Other expense categories:* Some of the other expense categories encountered by toll agencies include:
  - debt expenditures for revenue bonds,
  - interest payments on loans,
  - depreciation and amortization costs,
  - toll collection costs, and
  - service area maintenance.
- *Operating and maintenance costs* (O&M costs): For the SR-91 facility these costs were on the order of $6.3 million as of 1996 relative to a revenue of $7 million. In 1997, the same facility's costs increased to $9.1 million and revenues increased to $13.9 million. For reference, the operating data for SR-91 are provided in the Appendix (Figures A1 and A2). Operating costs for HOV–HOT lane conversions include staff to sell/lease tags, maintenance of the ETC system, marketing and advertising, and possibly higher enforcement costs because of the importance of credible enforcement to the revenue stream. For these two projects, the cost categories and their amounts are shown in Table 10 below.

Table 10. Operating and Maintenance Costs Categories for SR-91 and I-15 HOT Lane Projects.

SR-91 (1998 O&M Costs) *(50)* **(New Lanes)**	**I-15 (Annual O&M Costs) (HOV–HOT Conversion)** *(19)*
• Customer service, facility operations, and administration: $5.72 million • Repair and maintenance: $237,620 • Police service (enforcement): $568,607 • Promotional credits: $130,098 • Base franchise fee: NA but = $120 in 1996 • Professional services: $130,000 • Management and technical services: $776,630 • Income taxes deemed paid: $ 0 • Net reserve contributions: $ 0 • Property and franchise taxes: $1.26 million	• Customer service: $343,000 • Maintenance and warranty: $71,000 • Police service enforcement: $100,000

Percent of Expenses Covered by Revenue

There is no straight answer to the question of whether SR-91 is covering its costs. According to the annual financial statements, it appears that the SR-91 facility has always covered its operating and maintenance costs. The company has been successful in covering only a fraction of depreciation and amortization costs with their operating income and with its beginning of year cash and investments. However, one interesting point to note is that operating costs do not include interest expenses. These interest expense costs, depreciation, and amortization totaled approximately $17.4 million as of 1997[6] and are unavailable (as a separate category) for 1998. Once this aspect is considered then the 1997 reported operating income of $4.75 million turns into a loss of $12.7 million. Another point to note is that the ratio of interest and other financing costs to proceeds from partner contributions and loans has increased from 11 percent in 1996 to 59 percent in 1997. This increase is not a good sign even if you assume the unlikely scenario of a 50-50 split between partner contributions and loans. This ratio basically implies that the company is borrowing more to pay off part of the interest on loans already issued. The company claims it has covered all of its outstanding costs as of 1998. What is worrisome is that the 1998 Annual Report does not present any details, making it difficult to assess whether the company has successfully paid off its interest expenses without incurring more loans.[7]

In light of all the factors mentioned, the SR-91's ability to cover all costs as of 1998 seems questionable. However, it is too soon to tell if this will continue to be a problem. The performance of a new facility like SR-91 requires a longer evaluation timeframe. For the present, it is enough to say that it is generating enough to cover O&M costs and part of depreciation, amortization, and interest expenses. One factor that made this possible in 1998 was the company's decision to charge half-tolls for HOV 3+ carpoolers instead of traveling free of charge[8] and to increase peak-period toll for SOV users. However, the three-year breakeven is still commendable in the light of the laws mentioned earlier, although the nature of the project's success is less clear. Much still depends on the ability of the SR-91 to retain its market share.

In the case of the I-15 project, the federal grant covered all O&M costs, therefore every dollar earned is profit for the facility. However, the performance of SR-91 or I-15 cannot be attributed to any one factor. On the other hand, what we are observing today is the result of a complex interplay between the financial, political, and institutional factors and issues as is amply evident from Figure 16.

FINANCIAL ISSUES

Who Pays Will Impact Tolling Flexibility and Vehicle Occupancy

If we ask what are the conditions for maintaining tolling flexibility and vehicle occupancy, we will realize that the first criterion is public acceptability. The second condition is the franchising agreement (valid for private projects), which has been discussed earlier. In this part, we will limit ourselves to a discussion of the first condition. In other words, people have to be willing to pay, which is only possible when there is demand for the product. In our entire experience with tolling projects, it is always the users who have paid.

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[6] The SR-91 facility was funded using conventional financing by a private firm. The firm issues taxable revenue bonds at 9 percent interest rate which lead to the high level of debt service costs.

[7] The company claims it has covered its "debt service obligations" of $11.12 million for 1998 and hence broken even.

[8] This was allowed by the franchise agreement if the company failed to achieve a 1:2 debt coverage ratio after the first two years of operation.

Theoretically, all users should pay tolls and the congestion pricing literature does not exclude any group from toll payment (i.e., users pay toll regardless of vehicle occupancy). From an implementation standpoint, however, such a rigid view may not be publicly acceptable especially if implemented on an existing HOV lane. In practice, HOV 3+ vehicles and transit riders are often exempt from tolls and enjoy subsidized travel as the experience of I-15, I-10, and SR-91 have shown. SR-91 started charging its HOV 3+ plus riders in 1998 only because it was necessary to raise more revenues in order to break even.

If only SOVs and HOV 2+s are charged then tolling flexibility can be maintained as well as vehicle occupancy. Should HOV 3+ carpoolers and transit riders also pay? Charging them can raise revenues and impact the rate of return positively. This arrangement is clearly possible for new projects but may be a self-defeating strategy on HOT–HOV lane conversions because prices will be set to stimulate travel and enhance acceptability and such a policy may price them off the road. This price structure could negatively impact the ability, to exercise any flexibility in its toll structure and also vehicle occupancy or person moving capacity. In the case of SR-91 Express Lanes, charging carpoolers half tolls since 1998 did lead to reductions in the amount of carpoolers so average vehicle occupancy was impacted. Some recent research on tolling carpoolers for HOT–HOV lanes suggests that toll differentiation across commuting modes is possible but should be cautiously implemented.

Issues in Retrofit Versus New/Construction

A recent study by Reason Public Policy Institute mentions that in most cases the HOT–HOV conversions should be more than self-supporting from the new toll revenues because it is less costly *(32)*. The capital costs include costs incurred on plastic pylons, changeable message signs, gantries, toll reading equipment, and computer hardware and software. The operating costs include only staff for operation, tag selling and leasing, maintenance of the toll collection system (assuming it is electronic toll collection), marketing and advertising, and enforcement costs.

In the case of new construction, in certain cases, the addition of a HOT lane at grade in the median may also be self-supporting if no major interchanges need to be rebuilt. Public-private partnerships may make such projects easier for public agencies to carry out. The authors of the Reason Public Policy Institute report also mention that new HOT lanes that are grade separated (especially elevated lanes, where space is very tight) are unlikely to be financially feasible—in the sense of annualized revenues exceeding annualized cost of the project. That does not mean that the project is not worthwhile—since the alternatives are almost certainly other projects that will have significant costs but will not generate any revenues. In between these extremes are a number of possible projects that will be partially or largely self-supporting, but may require some support from conventional (i.e., fuel tax) highway sources *(32)*.

FINDINGS

There are a number of important findings regarding the economic and financial aspects of HOT lane feasibility.

- Willingness to pay (WTP) may be the best approach for establishing toll rates.
- Hau proposes comprehensive criteria for pricing, considering the user, the operator and the public points of view *(30)*.
- Historically toll rates have not risen as fast as capital and O&M costs, creating revenue shortfalls for toll operations.
- Other factors, including rate of toll collection costs and degree of private project risk, need to be considered.
- As numerous factors affect revenue generation, sensitivity analyses should be performed to assess and address vulnerabilities.
- Pricing strategies may require compromises between goals, such as revenue generation and demand management.
- Criteria for deciding on use of excess revenues should include political acceptability, economic efficiency, and equity.
- HOT-HOV conversion projects can be financially feasible. It is too soon to make judgments on feasibility of new capacity projects.

PUBLIC ACCEPTANCE OF HOT LANES

BACKGROUND

In the 1970s the federal government offered money to cities to support demonstrations of pricing. But "the opposition was so great from businesses, community groups and the media that all studies were terminated before demonstration plans could be developed." *(41)*. Almost 30 years later, the idea of value pricing has risen again, this time through the use of HOT lanes as a politically acceptable approach to pricing. The momentum can be attributed to improvements in tolling technology and the potential to combine pricing with HOV facilities. Although the HOT lane concept has received considerable praise, it is still subject to the public acceptance barriers that originally prevented widespread introduction of such projects in this country.

Each of the three existing HOT lane projects that have been reviewed in this study has utilized different methods to measure public acceptability, both before and after implementation. Despite the differences in the methods, there are similarities in the findings from these evaluations and lessons to be learned about the willingness of the public to accept a new kind of transportation strategy.

SR-91 Express Lanes—Orange County, California

The SR-91 evaluation study included traveler opinion surveys to measure commuters' views on the project and associated public policies and to compare pre-project opinions with later personal experience. Surveys were conducted in late 1995, spring 1996, late 1996, and spring 1997 in sample categories of SOV, HOV 2+, and HOV 3+. The study also included an opinion survey of area business representatives, conducted in late 1996, to measure their views on the impacts of the express lane facility.

Levels of approval for various aspects of the project rose throughout the course of the study. Although the idea of variable tolls was initially unpopular (with a 45 percent approval rating), later surveys showed a significant increase in approval (to about 60 percent). Approval levels for operating the highway as a private business also rose. They were in the 35–45 percent range both before and five months after the facility's opening—and the winter 1996 survey showed that approval levels had since increased to 50–60 percent.

Opposition to toll financing was recorded, expressed as a general sense of "unfairness." But about 60 percent of commuters felt tolls were an effective means to address congestion problems, and this percentage increased as commuters witnessed the tangible travel-time savings in both HOT and general-purpose lanes. Overall, there was a high level of acceptance for congestion pricing.

I-15 FasTrak—San Diego, California

SANDAG has used a combination of market surveys and focus groups to measure public opinion both before and after implementation of the project.

Focus groups of I-15 commuters were conducted in mid-1997 prior to the switch from monthly pass (Phase I interim operations) to a per-use dynamic fee system. Participants comprised the following categories: current ExpressPass users (CEU), past ExpressPass users (PEU), HOV, and SOV. According to the study, the project was perceived as successful in pursuing congestion relief, improving existing facilities, and generating revenue. At that point in the project, there were some reservations expressed for the planned switch to the per-use trip fee.

As part of the focus group effort, the participants were guided through a "bidding game" meant to show how the project might be affected by real preferences and actions. To determine pay-per-use preferences, moderators asked respondents how much they would be willing to pay to use the Express Lanes once during an average morning commute. Respondents were then provided different information that might affect the price they were willing to pay. The game demonstrates the learning process consumers go through when they consider purchasing a good. This process involves a base valuation of the good, a second valuation once information on the product is provided, and a series of further valuations due to strategic bidding for a limited good or product.

Of the four groups, the CEU group offered the highest average bids at all stages of the bidding game. The SOV group offered the lowest average bid prices of the four groups at each stage of the bidding game. The highest average willingness-to-pay (WTP) was recorded among the CEU group, and the lowest average WTP was recorded among the SOV group. Results of the overall focus group study indicated the following.

- Before project implementation:
  - public opinion generally favorable,
  - existing carpoolers less favorable,
  - solo drivers who were likely to use the facility more favorable, and
  - indications of price sensitivity.

- At conclusion of Phase I:
  - ExpressPass users remain enthusiastic about program,
  - carpoolers have not reported negative impacts,
  - evidence of price sensitivity (some users left program because of cost),
  - low level of understanding and knowledge of project (particularly by non-ExpressPass users),
  - general support for the principle of pricing, and
  - project's objective to support transit service is not widely known or supported.

The I-15 *Attitudinal Panel Study* began in the fall of 1997 as the first of five "waves" of surveys to be completed by the end of 1999. In addition to the categories of users identified in the focus groups described above, the telephone surveys included other I-15 users and I-8 users (as a control corridor). A total of 1,500 commuters are being surveyed in each wave.

Results from the first wave of surveys reveal the following:

- Eighty-nine percent of ExpressPass users view the project as a success.
- Seventy-seven percent thought the program was fair to both travelers in the Express Lanes and in the I-15 mainlanes.
- Very few respondents (4 percent) were aware that revenues were being used for improved I-15 transit service. Only 2 percent of all respondents favored using excess revenue for transit, while a combination of 46 percent favored extension of the HOT lanes or improvements to the mainlanes of I-15.
- The only negative feedback or negative media coverage on the project thus far has been related to the expanded bus service, which has not gained the expected ridership.

I-10 QuickRide—Houston, Texas

Before implementation of the "QuickRide" program, METRO arranged for the meetings of two citizen focus groups— one for users of the Katy HOV lane and one for nonusers.

For the user group, income equity was not a significant issue. The respondents were not concerned about double taxation for users either. Bus riders worried, however, that most QuickRide users would be drawn from bus riders rather than SOVs. Most felt that excess revenue should be used to improve transit service or to improve HOV lane operations. The group actually recommended against implementation of priority lane pricing because they felt that the cost and efforts were not worth the benefits.

Although the nonuser group represented a broader range of incomes and ethnic groups, its members were not concerned about income equity either. But the issue of double taxation was perceived as a problem. The group also recommended against pricing for the following reasons: "charging tolls on a public road is unfair;" "agencies do not need more money and can not be trusted…" and "the project seems to be going in the wrong direction by encouraging people to drive."

After implementation of the QuickRide program, surveys were conducted again of users and nonusers. In this case, most of the comments from the users dealt with customer service issues such as police scanners, the monthly stickers, the rudeness of METRO police, and the price of the program. Most respondents agreed that the program was "great" and would like to see it continued.

Responses from the nonusers included: "[The HOT lane] should be open to two-person vehicles," "[METRO] should allow SOVs to use the HOV lane for a fee," " the price is too high," and "[METRO should] open the HOV lane when there is an accident on the main lanes." The most frequent responses from nonuser two-person carpools as to why they have not yet signed up for the program were: 1) that the HOV lane should be free and 2) they don't know how to sign up.

BARRIERS TO PUBLIC ACCEPTANCE

The largest barrier to HOT projects is the opposition to tolls—either due to the perception of additional tax or due to complicated and often confusing tolling schemes. The precedence of tolls in an area can be an advantage if the public is familiar with the concept. But motorists may also be less receptive to tolls if they are accustomed to an older, manual form of tolling, which is less popular. Value pricing overall tends to be more acceptable on new facilities than existing ones. But with HOT lane projects, the pricing is applied to only a portion of the facility, resulting in more choices for the driver, and is therefore more likely to be seen as an improvement on the existing facility. Many motorists are opposed to tolls because a portion of their taxes already goes to pay for roads, and they feel they are being "double-taxed." However, the issue of double taxation is less of a concern when value pricing only a portion of a facility since the toll is then optional within the same facility. The availability of a "free" option coexistent with the priced lane or lanes is a significant distinguishing factor in the public acceptability of HOT lanes versus wholesale facility or network pricing.

Equity issues primarily relate to who gets to use the lanes, at what cost, and how the generated revenues are used. Some fear that the value-pricing concept of HOT lanes is too restrictive, benefiting only the more affluent drivers. Some oppose the HOV idea entirely, and support a pure toll road, while others believe that the lanes should remain free for all HOVs. Often those concerned about the inequity can be placated if they are convinced that the revenue will be used in an "equitable manner."

Other issues of opposition are less clearly related to equity, but still have a perceived "unfairness" about them. A tolling private facility, SR-91 faced initial opposition specifically to private, for-profit projects. I-15 researchers found opposition to the inclusion of toll-free HOV 2+s. I-15 focus group participants responded negatively to dynamic pricing, which was seen as "price gouging." They were unclear about why this was so unacceptable, but for them it was.

Public acceptance issues are often location specific. A report from the Claremont Research Institute *(42)* shows variation in travel among different corridors, indicating "a geographic dimension to travel behavior." In another report that studied five counties in California, researchers found that "[HOT lane policies] were strongly disliked in Ventura County," whereas they had support from the majority of residents in the other four counties surveyed (Los Angeles, Orange, San Bernardino, and Riverside). Other factors, such as the local political context of a project, can create barriers to public acceptance. The SR-91 project, for example, was initially opposed by residents of Riverside County because it replaced an originally planned HOV lane to be funded by Orange County. Riverside County was especially disturbed since it had already funded and partly built the HOV lane on its side of the border. (But the county's opposition has been at least partially addressed by the fact that HOV 3+s are allowed to use the lane at reduced rates.)

SELLING POINTS OF HOT LANES

HOV options and tolling can be powerful allies in terms of obtaining public acceptability for value pricing. The HOT concept seems to provide a feasible compromise between HOV and toll road advocates, improving on (or in some cases even resuscitating) underutilized HOV lanes and allowing for limited tolling opportunities where they have not otherwise been applied.

HOT lane projects have the potential to provide benefits to the following:

- the individual driver, who receives additional choices and predictable travel times;
- the HOV network, which has the potential to benefit from more riders; the riders themselves will have faster and more predictable travel times; increased bus ridership is also likely to increase support for transit, thereby improving service even further; and
- the "whole" system—by providing more person-based capacity for the system, HOT lanes can potentially offer benefits to the remaining components of the network.

In addition to the general HOT lane concept, specific projects have their own selling points. For example, SR-91 and I-10 use preset toll schedules, which at least in the initial stages of a project are more popular than dynamic variable pricing. I-15 and I-10 can emphasize that their distribution of revenue will benefit the public. Respondents in the I-15 study increasingly recognized the benefits of the program. At first, the groups felt the program would "reduce stress, save time, and improve the safety of their commutes." By the end they had added that it would "help in emergencies, get people to work on time, ease congestion, maximize utilization of the lanes, and increase the options available to SOV drivers."

A positive visual image can reinforce the selling points. When Houston's Katy HOV lane was functioning with additional capacity due to a HOV 3+ occupancy restriction, the transportation agency found that the public was often more concerned with "perceived" failure (the visual image of empty lanes) than figures demonstrating actual efficiencies. Ideally, value pricing mitigates the "empty lane syndrome," encouraging a positive public perception.

If selling points are effectively incorporated into a marketing scheme, they make a significant difference. Two studies in Oahu, Hawaii, and in Los Angeles showed that when presented as "a time-of-day charge to manage congestion by inducing shifts to transit and travel times," only 15 percent (Oahu) and 20 percent (Los Angeles) of respondents favored the concept. But when presented as "a user fee wherein those using the facility the most pay the most and where fees go toward road development and maintenance," 42 percent of the Oahu respondents accepted the idea. Likewise, a 1990 poll of San Francisco Bay Area residents by the Bay Area Council found 65 percent of those polled would support an increase of $1 for solo drivers under the condition revenues supported efforts to clean the air *(43)*."

IDENTIFYING POTENTIAL ADVOCATES AND OPPONENTS

Value pricing should be viewed in the context of the political environment for which it is proposed. Opportunities for coalition-building should be examined, as well as the activity levels of local citizen groups and institutions. Potential advocates and opponents can be divided into the following: business groups, environmental groups, government leaders, and transportation professionals.

Business Groups

As traffic congestion and its related costs increase and former solutions become less feasible, many cities, states, and MPOs search for alternatives to government-funded transportation. In some cases, businesses have advocated pricing exemptions for commercial vehicles. But such exemptions may undermine the effectiveness of the scheme or may intensify opposition from other motorists *(3)*. Business groups should remain involved with pricing policies such as HOT lanes. The Coalition for Local Environmental Solutions and a Competitive Economy (COALSCE) is an example of a group that represents several businesses in its study of congestion relief tolls in the Los Angeles area.

Environmental Groups

Many environmental groups promote value pricing, although some do not. The Chesapeake Bay Foundation opposes HOT lanes because it would like to see HOV lanes retained as bus-only lanes *(5)*. Those groups that support the concept point to benefits such as: reduced energy use, air emissions, and water runoff; the preservation of open space; and more cost-effective infrastructure investment. Among those who have supported congestion pricing are: the Environmental Defense Fund, the Sierra Club, the Tri-State Transportation Coalition (in New York City), the Pennsylvania Environmental Council, the Oregon Environmental Council, and the Clean Air Coalition (in Los Angeles) *(6)*. Some environmental groups support pricing with the goal of setting the tolls high enough to reduce driving, and then using revenues to fund non-highway projects such as Amtrak or bicycle improvements.

Government Leaders

In dealing with government leaders, attention should be paid to two current trends: a general distrust of the government and the devolution to local governmental control. Reflecting government distrust, the public has questioned the government's ability to effectively manage the revenues as well as the complex technological systems involved with tolling. But the success of current projects, combined with increasingly localized control, can help to increase the confidence level of both politicians and citizens. Although congestion does not adhere to political boundaries, a shift to local implementation of congestion pricing may be more efficient.

Transportation Professionals

Transportation professionals include planners, engineers, and economists. Transportation engineers and planners are often interested in value pricing as it relates to overall system management as well as the potential to reduce peak-period trips. Some, however, worry that value pricing will be seen as a "cure-all." Because it is not, pricing should be proposed in conjunction with other elements of a regional transportation strategy, such as land use regulations, transportation demand strategies, intelligent transportation systems technologies, and transit. Transportation economists tend to support pricing options as they increase overall efficiency. Many suggest replacing the current gas tax (and other highway funding sources) with value pricing *(7)*. Others think the gas tax should remain, but that revenues from value pricing should be redistributed to all motorists or all taxpayers in the most equitable manner.

When gauging support from different interest groups, it is important to keep the goals of the project in mind. Decisions about the use of revenue will be important in terms of maintaining support for HOT lanes—for many groups, their support is almost entirely dependent on it. For example, environmental groups support HOT lanes with the assumption that revenues will be used to support alternatives to automobile use, whereas many other supporting interests want revenues to pay for additional highways and expanded HOT lanes. It will be a challenge to retain support from both types of groups without sacrificing the goals of one or the other.

Public Education Approaches

Public education in the area of value pricing is critical. It is important to consider the geographical and historical context of the project in addition to its related selling points, barriers, and interest groups. Different groups should be targeted in public education efforts to ensure they have information about what concerns them most. In the I-15 project, for example, carpoolers and transit users had the least favorable impression of the program. They were assured that they would retain top priority and continue to use the lanes for free. If it is the policy of the project to use excess revenues to improve transit and carpool service in the corridor, it is important for this particular user group to be aware of that.

In general, few citizens fully understand the current system of transportation financing and most are unfamiliar with issues like marginal cost and price elasticity as they relate to transportation. There is also unfamiliarity with new technologies in electronic tolling. Many people feel that value pricing would not change their travel behavior (or that of others). Developing a simple message for communicating the concept of pricing can be valuable in gaining support.

In the case of I-10, it was determined during the evaluation phase that focused marketing and public education regarding the logistics of the program could enhance usage. Half of the non-users were not aware of QuickRide, 60 percent had not heard of the program via mass media, and 50 percent were either unaware or misinformed regarding the logistics of the program, including the procedure for signing up. Initial and ongoing marketing is a key component of early and continuing success.

Efforts to increase general awareness of pricing programs are necessary. In the I-15 study, "when asked what express lanes were called, respondents were hard pressed to come up with an official name." The I-15 researchers recommended that SANDAG clearly communicate the goals of the ExpressPass program, "decide on a clear name for the lanes and tell the public where the money is being spent." A report entitled *Buying Time: A Guidebook for Those Considering Congestion Relief Tolls in Their Communities (44)* suggests using a name that sounds positive. For example, rather than "congestion pricing," the city of Boulder calls it "congestion relief," Portland uses the phrase "traffic relief options," and both the New York Toll Authority and the operators of SR-91 in Orange County, California, have referred to variable pricing as "incentive tolling."

The I-15 study recommends using the facility's message board to emphasize the values expressed in the pre-project focus groups—values of simplicity, efficiency, and reliability. Messages can help to explain discount pricing so that the public understands there is a maximum toll rate, and any variance on the price is perceived as a discount. "Travel time reliability" can also be dealt with in messages. The uncertainty of travel times has led to trips that involve large periods of "buffer time," incorporated into the trip, characterized by early departure times from the origin of the trip. The reliability provided by ExpressPass substantially shortens that buffer time, and that benefit can be advertised.

FINDINGS

The HOT lane projects evaluated in the studies described have used different methods to measure public acceptance. The I-15 evaluation study in particular places great emphasis on the attitudinal and behavioral aspects of both users and non-users of the program and, as such, it offers important insight into public acceptability of HOT lane projects. A significant lesson in public acceptance of HOT lanes can be learned from these projects: initial skepticism as well as openly expressed opposition to the pricing concept did not prevent the projects from carefully and judiciously moving forward. Post-implementation feedback has revealed a general reversal from negative to positive public opinion regarding the concept of pricing in HOV lanes.

The political nature of a community and its interest groups should be considered, but not without the acknowledgment that political climates can change rather drastically. In 1978, the California State Transportation Board suggested that "users should be required to pay a fair share of the costs that occur from their use [of transportation facilities]." But this idea was strongly opposed at the time by interest groups *(45)*. Value pricing has since received much support, as evidenced by the success of the two HOT lane projects in southern California.

According to the authors of *Road Pricing for Congestion Management (46)*, projects that are politically acceptable should exhibit the following characteristics:

- be fairly simple in design,
- build incrementally on previously existing arrangements or experience,
- address clearly understood and widely supported objectives, and
- involve transparent financial flows that facilitate public trust in the use of the monies.

The successful HOT lane projects implemented thus far exhibit these qualities and consequently enjoy a high level of public support.

EVALUATION OF HOT LANES

THE IMPORTANCE OF PROJECT EVALUATION

The "evaluation" of a project can be thought of in three stages:

- in the planning stage, where HOT lanes are one of many alternatives being considered;
- before and after implementation, to see if the planning projections and project objectives are met; and
- on a continual basis, to make sure benefits continue and to assess the need for operational improvements (i.e., changes in toll structure or category of users to continue offering high level of service).

The chapter titled "Planning and Demand Estimation" addresses the first stage. This chapter focuses on implementation and operational stages.

Thorough "before-and-after" studies and ongoing project evaluation are uncommon for highway improvement projects, typically because of budgetary limitations. Highway innovations such as HOV lanes and Intelligent Transportation System (ITS) infrastructure, for example, are frequently implemented without a clear articulation of goals, measures of effectiveness, threshold values, and the collection of baseline and post-implementation data to be used to assess project benefits. In the rush to implement, the baseline data collection, in particular, is neglected.

Texas has been an exception at the national level with regard to the collection of baseline data and ongoing evaluation of HOV lane performance. This evaluation has not been the case for HOV lanes in many states, which have recently become the targets of criticism, resulting in several facilities being converted to general-purpose lanes. Although some HOV lanes are poorly conceived to begin with, the presence of ongoing monitoring could have provided the opportunity to convert these lanes to HOT lanes. Once the negative publicity gains momentum in these contentious situations, the concept of introducing tolling simply fuels the fire. One of the principal advantages of ongoing monitoring is the agency's ability to take a proactive approach to addressing a deficiency before losing the ability to initiate a solution.

Ongoing monitoring and evaluation take on another dimension with HOT lanes with the introduction of variable pricing. Modifications in both static and dynamic toll structures cannot be based on actual operating conditions unless there is some type of continual data collection and evaluation. In order to maintain a high level of service for the users of the facility—for transit, other HOVs, and paying customers—conditions must be monitored, evaluated, and tolls adjusted accordingly. Ongoing monitoring resources are pivotal in maintaining a premium level of service on the facility.

DEVELOPING AN EVALUATION PLAN

Defining HOT Lane Goals

The primary question that must be answered before an evaluation plan can be devised is: "What are the goals of the project?" There may be a need to first step back and answer the question, "What are valid, reasonable goals of HOT lanes?"

Table 11 offers insight into the kinds of overall project goals that may be appropriate for HOT lanes. Whether a HOT lane can reasonably achieve a particular goal listed below depends upon a number of factors, such as the project needs, the HOT lane design/configuration, characteristics of the corridor and target users, and institutional arrangements. HOT lane goals will vary depending upon whether a project is a retrofit of an existing HOV lane or construction of new, multiple express lanes with HOV preference. Goals can differ according to geographical area depending on the characteristics of the target users. Goals should be identified that are unique to the area and situation. The publicly stated needs of a project are critical to identifying project goals. If the problems to be addressed by the project do not fit those that can be addressed by HOT lanes, then maybe HOT lanes are not the right solution.

Table 11. Potential Goals of HOT Lane Projects.

Potential Goals of HOT Lanes	▪ Maximize capacity ▪ Increase person trips ▪ Generate revenues for operations or capital ▪ Improve air quality ▪ Improve safety ▪ Isolate vehicle types to improve operations and safety ▪ Improve utilization of HOV lane(s) ▪ Provide a travel alternative ▪ Increase vehicle occupancy in a corridor ▪ Help HOV lanes be more acceptable ▪ Increase tolling/pricing acceptability ▪ Increase private sector involvement ▪ Provide congestion relief

Measures of Effectiveness for HOT Lanes

The defined goals and publicly stated needs form the basis of defining multiple objectives for a HOT lane project. By measuring the outcomes and comparing them to the objectives, the success of the project is determined. For every objective there should be at least one measure of effectiveness (MOE). Each project will have multiple MOEs directly related to the goals as defined through the project development and public participation process. And for each MOE there will be corresponding data needs that represent statistically valid analyses.

Specific MOEs will vary depending upon the objective and the type of HOT lane. For example, an existing HOV lane that is underutilized can potentially increase usage by tolling a class of vehicles not otherwise allowed, thereby maximizing the capacity of the existing facility. The performance would be evaluated based on how well that objective is achieved by collecting data that measure changes in HOV lane utilization. On the other hand, construction of new, multiple HOT lanes may be intended to reduce congestion by adding capacity, reducing travel time, and providing users with a premium service when their value of time is high. The evaluation plan under this scenario should focus on ways to measure these specific objectives.

Communication of MOEs needs to take place before the project is implemented. Transportation agencies frequently have difficulty communicating technical data to those in decision-making roles and to the public. The challenge in defining performance measures is to develop measures that are easily understandable and unambiguous, while at the same time descriptive and specific enough to withstand rigorous technical analysis. Measures of safety, travel speed, and travel time are the kinds of measures that the public can easily understand and appreciate.

The development of MOEs in the project planning phase, therefore, needs to take into account the audiences to which they will be communicated. Beyond this step, there is a need to identify the most effective communication mechanisms following project implementation for reinforcing project goals, providing evaluation results, and informing customers of operational changes (such as adjustments in price).

HOT LANE PROJECT EVALUATION EXPERIENCE

In this section, each of the evaluation experiences of the three existing HOT lane projects is presented. Goals, objectives, MOEs, data collected, use of results, and communication mechanisms are described.

SR-91 Express Lanes Evaluation

The SR-91 project is a private, for-profit venture, one of four such private-public partnership experiments authorized by the California Legislature in the early 90s. The ultimate goal for the private entity is to maximize profit. The project, however, provides a valuable opportunity to observe how travelers respond over time to congestion-based road pricing and other innovative features of the facility. Caltrans and USDOT have sponsored an evaluation study conducted by Cal Poly to assess how travelers respond over time to "value pricing":

- What are public attitudes about the concept of tolls that are tied to levels of congestion?
- What shifts in travel are induced by this new travel option for different population segments?
- What changes have occurred in the use and performance of the transportation facilities in and near the SR-91 corridor?

Longitudinal data collection and impact assessment occurred for a period from mid-1994 (prior to the facility opening in December 1995) through June 1997. General measures of effectiveness were identified:

- corridor congestion,
- vehicle occupancy,
- route shifts,
- time-of-day shifts,
- transit and ride-share mode shifts, and
- public opinion.

The specific data collected to assess the project effectiveness were:

- traffic counts;
- vehicle occupancy counts;
- speed runs;
- counts of public transportation operations and patronage;
- park-and-ride lot usage;
- information on accidents and other significant incidents;
- data about special events, weather, and newsworthy occurrences that might affect traffic and travel;
- trip origin and destination data for peak periods prior to opening and a year after;
- perceived travel problems, traveler needs, opinions about Express Lane characteristics; and
- reactions of area businesses.

I-15 FasTrak Evaluation

The FasTrak evaluation is an extensive $1.4 million assessment of numerous aspects of the I-15 HOT lane operation. San Diego State University and Wilbur Smith Associates are performing evaluation work for SANDAG. The monitoring and evaluation framework for the project was designed to meet federal requirements for pricing project evaluations as well as the needs of SANDAG and other project partners. The evaluation effort includes the following features:

- evaluation waves—phased monitoring in April and October 1997, 1998, 1999;
- baseline data—collected April and October 1996;
- concurrent data collection in a control corridor (I-8);
- macroscopic and microscopic—aggregate travel data and disaggregate individual user data; and
- a mix of longitudinal (travel behavior changes over time) and cross-sectional studies (time-based studies on traffic, land use, and businesses).

One of the primary goals of the evaluation effort is to provide a base of information to assist decision makers when they consider conducting similar projects in the future. Twenty-two technical reports for Phase I alone were prepared covering a wide range of quantitative data. Funding for the four-year evaluation period has been provided by FHWA under the Congestion Pricing Pilot Program, now known as the Value Pricing Program under TEA-21.

The overall stated project objectives are to:

- maximize use of existing I-15 Express Lanes,
- test whether allowing solo drivers to use the Express Lanes' excess capacity can help relieve congestion on the mainlanes of I-15,
- improve air quality,
- fund new transit and HOV improvements in the I-15 corridor, and
- use a market-based approach to set tolls.

A summary of the key issues studied is provided in Table 12.

Use of Evaluation and Monitoring in Dynamic Tolling Operation

When the I-15 HOT lane operation moved into Phase II in March 1998, a conversion was made from monthly permits to AVI transponders for fee collection. During that process, the data collected on the facility through loop detectors and transponders were used to formulate the initial pricing levels under dynamic tolling.

In the dynamic tolling operation, real-time traffic conditions on the HOV lanes dictate the per-trip fee for SOVs. California State Law requires that LOS "C," or free-flow conditions, be maintained on all HOV lanes. To maintain these conditions, traffic volumes are collected every six minutes by loop detectors, the LOS is computed, the toll is adjusted if necessary, and the price is displayed on signs located prior to the facility entrances. Ongoing monitoring has facilitated SANDAG's modification of the original dynamic pricing structure, modified in August 1998, which reduced the maximum off-peak toll and encouraged greater usage in the "shoulder" of the peaks. Through data collected before and after the pricing change, SANDAG has been able to identify statistically significant modifications in time-of-day use, particularly in the morning peak period, as a result of the change in pricing structure.

Table 12. Summary of Issues Evaluated for the I-15 FasTrak Project.

Key Issues	Key Issue Specifics	Data Source
Transportation and Traffic Impacts (macroscopic)	▪ SOV usage of HOV lane ▪ HOV lane LOS integrity ▪ Traffic volume changes: historical and project data ▪ Speed/delay changes ▪ Vehicle occupancy/classification changes	WSA and SDSU traffic studies of I-15 and I-8
Transportation and Traffic Impacts (microscopic)	▪ Mobility changes ▪ Time-of-day travel changes ▪ Trip purpose changes ▪ Trip chaining changes ▪ Modal changes ▪ O-D & route changes ▪ Travel time changes ▪ Travel perception changes ▪ Changes in traffic satisfaction level	Panel survey
High-Occupancy Vehicle Use Impacts (macroscopic)	▪ Changes in HOV use ▪ Changes in Transit use ▪ Net trip reduction (if app)	SDSU and WSA traffic studies of I-15 and I-8
High-Occupancy Vehicle Use Impacts (microscopic)	▪ SOV to HOV shifts ▪ Bus use shifts ▪ Long-term high-occupancy transition predictions	Panel survey
Air Quality Impacts	▪ Changes in AM/PM volumes ▪ Changes in vehicle compositions ▪ Changes in speed distributions ▪ Changes in relevant pollutant emissions	▪ Caltrans statistics ▪ WSA/SDSU occupancy classification study and SDSU occupancy study ▪ WSA/SDSU speed delay study ▪ Application of Calif. and EPA air quality models
Violation and Enforcement Issues for HOV Lanes on I-15	▪ Definitions of violations/ violation classification for I-15 ▪ Changes in violation quantities/rates ▪ Assessment of enforceability/ enforcement procedures ▪ Cost of enforcement	Relevant data from CHP/ SANDAG/ Caltrans
Traffic Incident Issues	▪ Incident classification ▪ Incident comparison ▪ Congestion pricing incident impact	CHP/ Caltrans data

SDSU: San Diego State University
WSA: Wilbur Smith Associates
CHP: California Highway Patrol
Caltrans: California Department of Transportation
SANDAG: San Diego Association of Governments

Table 12 (cont.). Summary of Issues Evaluated for the I-15 FasTrak Project.

Public Information About and Community Response to SOV "Buy-in" Program Issues	▪ Public information level ▪ Promotion activities and their effectiveness ▪ Evaluation of outreach efforts ▪ Assessment of public correspondence ▪ Evaluation of media coverage ▪ Panel attitudes toward "buy-in" program ▪ Level of support for the project ▪ Level of support to maintain acceptable LOS on HOV lanes ▪ Price acceptance dynamics ▪ Best use of revenues from project ▪ Levels of information about the project ▪ Reasons for leaving the project	▪ SANDAG/media data ▪ SANDAG data ▪ Minutes from meetings ▪ Correspondence ▪ Tapes, articles, etc. ▪ SDSU Attitudinal Panel data
Pricing System Issues	▪ Pricing system changes ▪ Pricing level changes ▪ Technical performance/functionality ▪ Collection effectiveness ▪ Cost dynamics ▪ Personnel requirements/procedures ▪ Maintenance requirements	*Field observations* ▪ Phase I and II contractor documents ▪ SANDAG/ Caltrans/ CHP data
Financial, Economic, and Distribution Results	▪ Evaluation of project-related costs and revenues ▪ Impact on regional economics and local business ▪ Profile of "buy-in" program users ▪ Source of payment for "buy-in" participation ▪ Environmental justice issue—incidence of costs and benefits ▪ Cost elasticities	▪ SANDAG ▪ SDSU truck study on I-8, I-15 ▪ Panel survey registration data ▪ Panel survey, correspondence, focus groups ▪ Outreach program, waiting list dynamics
Institutional Issues	▪ The characteristics of "project stakeholders" and their role in its success ▪ Evaluation of implementation policies, procedures, and agreements ▪ Role of project management team ▪ Role of local elected officials ▪ Role of FHWA ▪ Role of SANDAG ▪ Role of CALTRANS ▪ Role of others ▪ Transferability of results	▪ Meetings ▪ SANDAG materials ▪ Observation from meetings ▪ Legal documents ▪ Coordination of projects ▪ Overall San Diego congestion pricing coordination effort ▪ Information on Caltrans participation in the project

SDSU: San Diego State University
WSA: Wilbur Smith Associates
CHP: California Highway Patrol
Caltrans: California Department of Transportation
SANDAG: San Diego Association of Governments

I-10 QuickRide Evaluation

The overall project goal of QuickRide is to improve utilization of the Katy HOV lane *(7)*. Table 13 highlights the secondary objectives and MOEs used to evaluate the project. Other measurements were made of usage and revenue fluctuations, such as the daily level of fluctuation in usage related to factors such as freeway mainlane incidents and special events, and correlation of contributing factors to usage. The cost of the evaluation conducted by TTI was $110,000 and was sponsored by FHWA as part of the Congestion Pricing Pilot Program under ISTEA.

FINDINGS

Evaluation and monitoring are important yet overlooked aspects of transportation improvement projects. Post-project monitoring is a particularly critical component of successful projects that have an operational emphasis, such as HOT lanes.

Through this research, general goals that are most commonly associated with HOT lanes, both HOV conversion projects and new HOT lane construction, are identified. Once specific objectives are outlined based on the goals of the project, then measures of effectiveness can be defined, which in turn determine baseline (pre-implementation) and ongoing data collection needs for statistically valid analyses. Measures related to travel speed, travel time, and safety are easily communicated to a wide range of audiences and are useful for measuring project effectiveness.

Ideally, threshold values for typical measures of effectiveness should be defined as well, although the current practical experience is far too limited to define general threshold values. A guideline on the length of time that a HOT lane should be operational before results can be accurately assessed is also needed. This guideline is especially important for privately operated ventures that are seeking a rate of return on investment. As more projects move forward and the experience base increases, additional guidelines on project evaluation and monitoring can be developed.

Table 13. Evaluation Framework for QuickRide.

Overall Project Goal: Improve Utilization of the Katy HOV Lane

GOALS	OBJECTIVES	MEASURES OF EFFECTIVENESS	DATA COLLECTED	USE OF RESULTS
Corridor Improvement	▪ Increase person movement ▪ Form HOV 2s from SOVs	▪ Increase in vehicle occupancy ▪ Increase in HOV 2 without decrease in bus usage or other HOV 3+	▪ Before/after vehicle occupancy counts ▪ Before/after HOV 2, bus ridership, and HOV 3+ carpools	Identify the need to: ▪ Continue pilot project ▪ Adjust price ▪ Increase HOT lane usage Provide useful lessons for future HOT lane projects
Traffic Operations	▪ Maintain HOV lane operating speeds ▪ Minimize adverse impacts to mainlanes ▪ Reduce HOV lane violation rates	▪ Change in operating speeds on HOV lane ▪ Change in mainlane operating conditions/speeds ▪ HOV lane violation rates	▪ AVI-measured speeds ▪ AVI speeds, Transtar video observation ▪ Occupancy counts and enforcement records	
Financial Viability	▪ Set effective trip pricing ▪ Generate sufficient revenue to cover operating expenses	▪ Usage level at initial price ▪ Actual costs less account revenues	▪ Volume of HOV 2s in HOV lane ▪ METRO records	
Public Acceptance	▪ QuickRide participant satisfaction ▪ Adequate enforcement ▪ Acceptance by non-HOV travelers ▪ Perceived impact on freeway mainlane users	▪ Perception of service offered ▪ Perception of level of enforcement ▪ Perception of utilization of HOV lane by non-users ▪ Limited negative impact as perceived by freeway mainlane users	▪ All perceptual data collected via surveys of users and non-users	

SUMMARY OF FINDINGS

Each of the previous chapters concluded with a series of findings about the specific subject. Those findings are repeated here so the reader can review them all as a summary of issues related to the feasibility of HOT lanes.

POLICY AND INSTITUTIONAL ISSUES

The project of policy and institutions issues revealed that the following four actions are important to successfully evaluating the feasibility of HOT lane(s) in a corridor:

- establish project goals and measurable objectives,
- determine primary participants,
- evaluate project funding options, and
- identify potential equity and fairness concerns.

PLANNING AND DEMAND ESTIMATION ISSUES

The study resulted in the following key findings relative to planning and demand estimation for HOT lanes.

- Several models are available to estimate demand, the most popular of which is the STEP model.
- Criteria for success is a fairly short list and is closely aligned with criteria for HOV lane success.
- Results from existing projects show:
    - increase vehicle and persons moved,
    - some relationship between income and frequency of use,
    - occasional use most common when a specific trip purpose warrant added expense, and
    - travelers' perception of time savings substantially higher than actual savings.

DESIGN ISSUES

The study of design issues for HOT lanes revealed the following findings.

- In general, HOV lane design guidelines are a very good source for guidance for HOT land design.
- Careful evaluation of enforcement options and associated design requirements is crucial as effective enforcement will be an extremely important component of a successful HOT lane.
- Physical buffer or barrier separation of HOT lanes from general-purpose lanes is highly desirable.
- Careful attention to terminal end treatments is important because of the complex decision making that is occurring in that vicinity and upstream.

OPERATIONS ISSUES

The project revealed the following findings related to HOT lane operation.

- A deliberate decision should be made regarding eligible groups, and that decision should be strictly maintained.
- Target flow rates (maximum and minimum) should be established and tolls and occupancy adjusted to maintain the desired ranges.
- Dynamic signing should be considered to advise travelers of current eligibility requirements and usage tolls.
- Entrances and exits should consider bus operations and park-and-ride lots to encourage HOV use.
- Careful consideration should be given to available toll collection options.
- Enforcement options should be weighed as a part of the operational planning.

ECONOMIC AND FINANCIAL ISSUES

There are a number of important findings regarding the economic and financial aspects of HOT lane feasibility.

- Willingness to pay (WTP) may be the best approach for establishing toll rates.
- Hau proposes comprehensive criteria for pricing, considering the user, the operator and the public points of view *(30)*.
- Historically toll rates have not risen as fast as capital and O&M costs creating revenue shortfalls for toll operations.
- Other factors, including toll collection costs and degree of private project risk, need to be considered.
- As numerous factors affect revenue generation, sensitivity analyses should be performed to assess and address vulnerabilities.
- Pricing strategies may require compromises between goals, such as revenue generation versus demand management.
- Criteria for deciding on use of excess revenues should include political acceptability, economic efficiency, and equity.

PUBLIC ACCEPTANCE OF HOT LANES

Significant emphasis has been placed on public acceptance for HOT lane projects. Key findings are as follows.

- Initial skepticism as well as openly expressed opposition to the pricing concept did not prevent some projects from carefully and judiciously moving forward. On the other hand, fear of low public acceptance has stopped some projects entirely.
- Post-implementation feedback has revealed a general reversal from negative to positive public opinion regarding HOT lanes.

- One study concluded that there were four key characteristics to a politically acceptable project:
  a) fairly simple in design,
  b) built incrementally on previously existing arrangements or experience,
  c) address clearly understood and widely supported objectives, and
  d) involve transparent financial flows that facilitate public trust in the use of the monies.

EVALUATION OF HOT LANES

The review of evaluation and monitoring issues revealed a few key findings.

- Evaluation measures are derived from the goals and objectives developed for the project. Those measures form the baseline for determining whether a project is successful.
- Measures related to travel speed, travel time, and safety are the most easily communicated to the public and are therefore useful for measuring project effectiveness.
- Current experience is too limited to establish threshold values for measures of effectiveness.
- A guideline is needed to suggest how long a HOT lane should be operational before its success or failure is established. Currently, no such guideline is available.

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