Pre-Determining Performance-Based Measures for Managed Lanes

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The operational decisions facing managed lanes can be highly politicized and difficult to make quickly. For example, changing the operating parameters such that a user class can no longer access the lanes may require extensive public debate and ignite controversy. This research examined managed lanes across the country and found that none had developed plans on how to deal with such situations as they arise in the future. We found there are significant potential benefits for agencies if they use operational goals for their managed lane facilities to guide decision making prior to the point it becomes critical. In addition, the policies developed act as a performance promise to managed lane users.

INTRODUCTION

Over the past several years, transportation agencies around the United States have implemented many transportation innovations to meet the mobility needs of a growing population and the economy. These innovations have included High Occupancy Vehicle (HOV) lanes, High Occupancy Toll (HOT) lanes, managed lanes (ML) and toll roads. HOV lanes are those which restrict access to vehicles with multiple occupants (often two or more people per car, HOV 2+). Similar to HOV lanes, HOT lanes allow free access to vehicles with multiple occupants, and allow single occupancy vehicles (SOVs) to use it for a toll. Managed lane is a more general term that encompasses both HOV lanes and HOT lanes, plus other facilities/lanes that limit/regulate access to improve facility performance. Whenever these projects are considered, there are a range of policy decisions that must be addressed, some of which can be controversial. Moreover, the operating characteristics of a project are likely to change over time, requiring additional policy decisions to adjust operating strategies to match the new operating characteristics. A literature review indicated that very little research has been conducted specifically related to using performance measures to set toll rates, other than what is implicit in toll rate settings as a part of typical pre-project traffic and revenue analyses. As regions, areas, cities, and states further their operations to include pricing, it will be important to have thought through the process of change in advance. Doing this provides more time to actually discuss and evaluate pre-approved approaches to achieve mobility with pricing in a more efficient manner. This study reviewed the state-of-the-practice in operational performance management of tolled and managed lane facilities and captured the methods that agencies use to set tolls to manage performance. This information was used to develop a multi-faceted framework to aid in operational decisionmaking over the life of a managed lane facility.

Though a specific procedure or methodology is not required for states to determine if the operational performance of an HOV facility is degraded, the Federal Highway Administration (FHWA) suggests a minimum average operating speed for HOT facilities (FWHA 2008a). According to this source, speed should be maintained at 45 mph for HOT facilities with a speed limit of 50 mph or greater, and not more than 10 mph below the speed limit for a facility with a speed limit of less than 50 mph. Section 166(d)(2)(B) of this source provides that a facility is considered degraded if it fails to maintain a minimum average operating speed at least 90% of the time over a consecutive 180-day period during morning or evening weekday peak periods (or both for a reversible facility).

According to the FHWA (2008a), the vehicle-occupancy requirements for carpools have evolved over time from initially a three or more (3+) occupancy level used in many projects to a two-person per vehicle (2+) carpool designation currently on some facilities. Currently, 185 of the

HOV facilities in this country (54%) use purely two or more people (2+) per vehicle requirement, and there are 14 facilities that use purely three or more people per vehicle occupancy requirement (Chang et al. 2008). There are some instances in which changes in the designated vehicle-occupancy restrictions occurred over the life of an HOV facility. For instance, on both the I-10 West and U.S. 290 HOV lanes in Houston, the HOV lanes using the two or more people per vehicle occupancy requirement have experienced congestion resulting in reductions in trip time reliability and slower travel times. As a result, the vehicle-occupancy requirements were increased to three or more (3+) during the morning and afternoon peak-hours (morning only on U.S. 290). Facilities like the El Monte Busway on I-10 in Los Angeles, Nimitz Highway in Honolulu, Hawaii and the U.S. 290 and I-10 West HOV lanes in Houston require three or more occupants during specific peak hours and a two or more people per vehicle requirement at other times (Burris and Stockton 2004). Studies have shown that in changing from HOV2 to HOV3+, vehicle demand may be reduced by 75% to 85% (California Department of Transportation 2003). Such adjustments may be too severe if only a moderate reduction in demand is necessary to maintain free-flow conditions.

Though the FHWA has provided recommendations on vehicle occupancy requirements and performance standards for HOT lane projects in the United States, the operating characteristics of a project are determined by local factors that are likely to change over time as well. The following sections present a brief literature review and describes existing and future operating policies of several facilities.

LITERATURE REVIEW

Texas has a long-standing tradition of using variable operating strategies to meet the needs for mobility. Toll roads were first initiated in the Dallas-Fort Worth area with the completion of the Dallas-Fort Worth Turnpike in 1957. This facility and others are operated by the North Texas Toll Authority. The toll roads in Houston, operated by the Harris County Toll Road Authority and the Central Texas Turnpike Project in the Austin area and Loop 49 in Tyler operated by the Texas Department of Transportation (TxDOT), are traditional toll roads with a toll rate determined by vehicle type regardless of occupancy or time of day. The advantage of this methodology is its simplicity; it is easy to communicate with the user. However, it does not manage congestion on the facility and does not fully utilize the limited capacity of the facility (Goodin et al. 2011).

To address urban freeway congestion, transportation planners have looked to HOV lanes for the past three decades. Beginning with the I-45 Contraflow Demonstration Project in Houston, HOV facilities in Texas have proven to be an effective mobility strategy by offering a reliable high-speed option with travel time savings for bus riders, carpoolers, or vanpoolers. Texas has also had unique experience in addressing operational concerns by modifying vehicle eligibility requirements in HOV lanes and evaluating the impacts, particularly on the Katy HOV lane in Houston. When the Katy HOV lane was opened in 1984, only authorized buses and vanpools were allowed. Gradually between 1984 and 1987, 4+ carpools, then 3+ carpools, and then 2+ carpools were allowed, and with each step the change was evaluated from an operational standpoint.

When congestion worsened on the Katy Freeway HOV lane, the occupancy restriction was shifted back to carpools with three or more occupants (HOV3+) during the peak periods. Houston is the only location where HOV2+ lanes have been successfully converted to HOV3+ lanes (note that I-95 in Miami recently converted from HOV2+ to HOT3+). There are many congested HOV lanes across the country in cities such as Los Angeles, Seattle, Long Island, and Atlanta, where life-cycle operating frameworks were not put in place to identify the performance thresholds that would trigger a change from two or more to three or more occupants per vehicle. As a result, one of the most pressing issues facing HOV operators today is how to address growing congestion in HOV lanes through increasing occupancy requirements given the absence of an operating policy framework.

One step beyond HOV lanes are HOT lanes, which use both occupancy and pricing restrictions as a strategy for meeting multiple performance objectives in congested urban freeway corridors. Operational HOT lanes use both variable pricing and dynamic pricing to manage SOV demand for the HOT lane. Variable pricing, where the price of access for SOVs varies based on time of day and day of week, is currently in operation on four HOT lanes (I-25 near Denver, SR-91 near Los Angeles, I-10 in Houston, and U.S. 290 in Houston [HOV2 pays on U.S. 290]). Dynamic pricing, where the price of access for SOVs varies based on current traffic conditions, is currently in operation on seven HOT lanes (SR 167 in Seattle, I-95 in Miami, I-394 and I-35 in Minneapolis, I-15 in San Diego, I-680 in Alameda County, California, and I-15 in Salt Lake City).

Pricing (variable and dynamic) has been demonstrated in practice as the only strategy that has the ability to truly manage demand on a real-time basis (Goodin et al. 2011). Take for example, the operating policy of the I-394 MnPass express lane in Minnesota. The dynamic pricing on this lane is designed to ensure continuous free flow in the lanes by adjusting the toll up or down depending upon the amount of traffic in the lanes (Burris and Goel 2009). SOVs must pay the variable per-trip fee to use the lanes during peak hours. The amount of the fee is posted on changeable message signs located just before the entrances to the MnPASS lanes. The fee can be adjusted as often as every three minutes to keep traffic at free-flow levels. This works well as a short-term method to keep traffic at free-flow levels on this lane, and it is working well on all HOT lanes. In the long term, it is possible to have too many HOVs to allow SOVs access to the lane at any price. However, there is no predetermined level when this change would occur or a policy regarding how it would happen. Without these policies and thresholds in place, adjustments to the operating procedures can be a difficult and time-consuming process.

DATA COLLECTION

A state-of-practice review through phone interviews of key personnel in agencies with operational projects plus website exploration of individual managed lanes projects across the country were used to obtain data for this study. Data and information were collected to answer the questions in the Appendix. These questions related to the goals and objectives of the projects, changes in toll rates, the presence of a policy framework for the facility and changes in that framework, how changes in the policy framework were communicated to stakeholders, and stakeholder reaction to changes in policy. Additional information was gathered on the types of performance data used and how they are collected. The study gathered this information from randomly selected 20 projects, which included HOT lanes, express lanes, a priced queue jump, conversions from HOV to HOT, and traditional toll roads. Information on 12 of the projects was collected via phone interview and the rest through exploration of project websites and other sources. Because of space limitations, we discuss in detail six projects in this paper.

RESULTS

SR167 HOT Lanes Pilot Project

Washington State's first HOT lanes opened on State Route 167 (SR 167) on May 3, 2008. The HOT lanes were converted from existing HOV lanes and now offer SOVs the option to pay a toll to use the lanes. Two general purpose lanes remain toll-free and open to all traffic in each direction. Carpools of two people or more, vanpools, transit, and motorcycles use the HOT lanes toll free (Washington Department of Transportation 2010). To ensure traffic in the HOT lane always flows smoothly, the toll paid by the SOVs is adjusted every five minutes and ranges from $0.50 to $9.00 based on real-time traffic data, including vehicle speed and traffic volumes, which are collected by loops underneath the pavement. The toll rate varies with traffic such that it is higher when traffic slows down and it is lower when traffic is moving at a high speed. In addition to testing the HOT lane concept, the goals of the project included gauging public interest, gathering data, improving freeway efficiency (speed and traffic volumes), and safety (crashes, etc.) plus the ability to finance improvements (reconstruction and operations costs) through tolls. Performance data, speed in this case, are collected by loops located every half mile, and tolls are used to finance the construction, operation, and improvement costs in this corridor.

The Washington Department of Transportation (WSDOT) proposed an initial toll range with a price cap of $9.00. Once the cap is reached, the HOT lanes will be reverted to HOV-only lanes. The $9.00 price cap was partially selected by looking at Minneapolis' I-394 price range. The Washington State Legislature (WSL) requires the Transportation Commission to review the toll charges periodically to determine appropriate toll rates, which maintain travel time, speed, and reliability on the highways (WSL 2005). WSDOT annually reports to the Transportation Commission and the legislature on operations and findings. The report includes data regarding facility use, a review of the impacts of the HOT lanes on several areas—including freeway efficiency and safety, effectiveness of transit, throughput, and vehicle movement by mode, if collected toll revenue is sufficient to finance improvements and transportation services, and the impacts on all highway users (WSL 2005). As stated in the Revised Code of Washington (RCW 47.56.403) (WSL 2005), the commission may offer a toll discount to inherently low-emission SOVs. The department is also responsible for, through modifying the pilot project, addressing identified safety issues and mitigating the negative impacts to HOV lane users. The pricing algorithm used by this project was designed to maintain speeds of at least 45 mph for 90% of the time during rush hour in the HOT lanes. If deemed appropriate, the Commission may vary the toll by time of day, level of congestion, vehicle occupancy, and other criteria. Combining the traffic volume and lane speed, the pricing algorithm software calculates the corresponding toll rates every five minutes to manage the number of single occupant vehicles entering the HOT lanes.

After the first year of operation, WSDOT stated that the HOT lanes were working by saving people time, providing commuters with more options, and improving the use of SR 167 (WSDOT 2010). For example, commuters in the HOT lanes typically save three to eight minutes on each trip, depending on direction. During the first year of operation, the project did not have adverse effects on safety. In fact, from May 2009 through December 2009 there was a 17% reduction in monthly collisions. Despite this finding, additional data are needed to corroborate it.

Express Toll Lanes on I-30/Tom Landry in Dallas

In Dallas, the express toll lanes on I-30 are managed HOV lanes in the median of a general purpose freeway. The I-30 corridor serves as the region's test bed for value pricing so that potential strategies can be examined and adjusted before being applied in other corridors. The MLs have been established to serve several objectives such as "reduce SOV travel by providing travel-time and pricing incentives to HOVs and transit passengers; make available high-speed reliable travel to all users in the corridor (>50 mph); and create revenue generation to pay for the MLs' ongoing operation and maintenance" (Macias et al. 2009). In accordance with approved regional policies, SOVs are allowed to use the managed HOV lanes by paying a fee. The facility initially opened as HOV-only lanes in the first phase and is proposing to shift into "Express Lanes" later once installations of tolling equipment are completed (currently anticipated to open sometime after 2012).

During the HOV-only phase, HOV2+, vanpools, motorcycles, and transit vehicles will be allowed to use the facility free. Variable pricing will be applied in the second phase and certain users (HOVs and motorcycles carrying a valid transponder) will receive a discount during peak hours (6:30 a.m.–9:00 a.m. and 3:00 p.m.–6:30 p.m.). The current HOV-only mode is being operated by the Dallas Area Rapid Transit (DART), which is responsible for lane opening/closing, incident management, lane communications, operational enforcement, occupancy enforcement, and performance data collection. Performance data are collected on a regular basis and help in developing the pricing algorithms for the project.

During the value pricing phase, two stages are planned: fixed schedule mode and dynamic mode. Poe and MacGregor (2008) indicated that "a fixed-fee schedule will be applied during the first six months of operation; dynamic pricing will be applied thereafter. The toll rate will be set up to a \$0.75 per mile cap during the fixed-schedule phase. Toll rates will be updated monthly during the fixed-schedule phase and single-occupant vehicles will pay the full rate. During the dynamic-pricing phase, tolls will be rebated if the average speed drops below 35 miles per hour." In the fixed schedule mode, the toll rate schedule is manually calibrated to maintain the desired level of service (average speeds greater than 50 mph) (Macias et al. 2009). The frequency of the calibration cannot be more than once every 30 days. The dynamic mode will start operating after the initial 180 days of operation in the fixed schedule mode. It is anticipated that the initial use of the collected revenue will be to pay for toll collection, and operational and maintenance costs of the managed lane. Depending on the extent and funding of the pricing infrastructure, there may be a need to use any excess revenue to offset capital expenditures.

SR 91 Express Lanes in Orange County

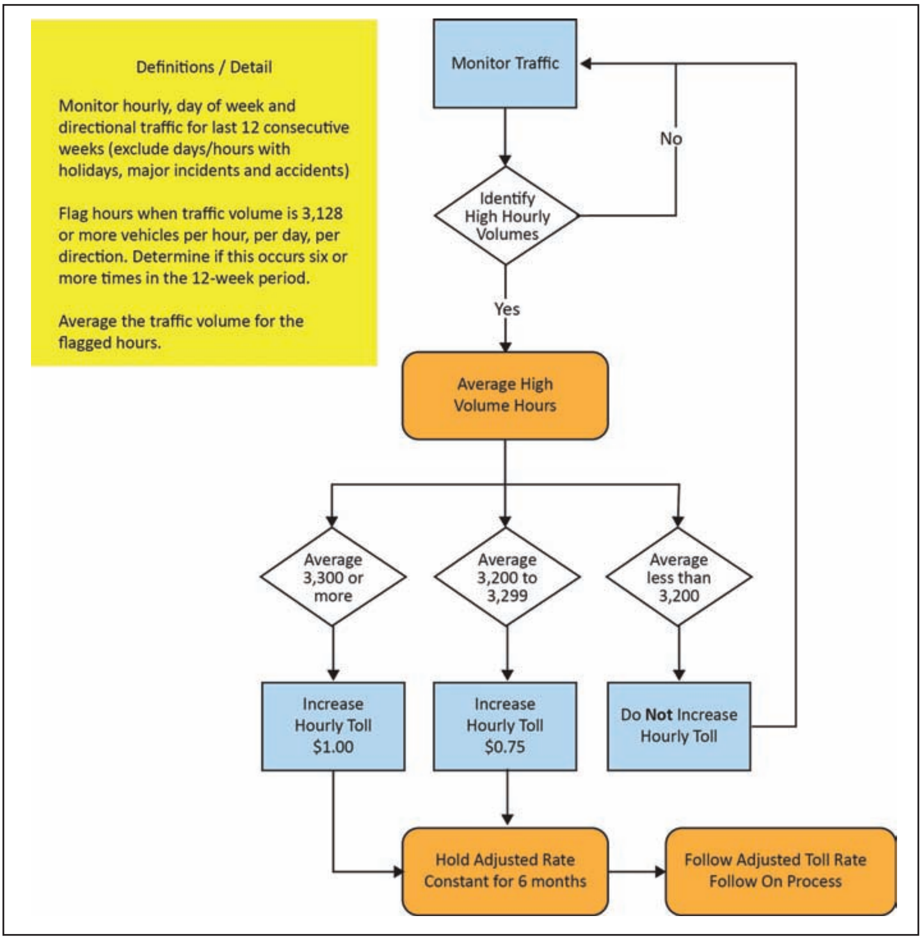
The SR 91 Express lanes began as California's first modern, privately owned toll road. The facility is 10-miles long with two lanes in each direction and all tolls are paid electronically. The road was purchased by the Orange County Transportation Authority (OCTA) in 2003. As the operating agency, the OCTA sets toll policies to optimize traffic at free-flow speeds. This toll adjustment serves several goals such as: a) reducing congestion by diverting traffic to non-peak period, b) maintaining free-flow speed on the express lanes and offering travel time savings, c) meeting increasing travel demand in the future, and d) generating sufficient revenue for the operations and maintenance of the express lanes. The performance data collected are hourly, daily, and directional traffic volumes. This project defines a "super peak" as the hourly period per day and per direction when traffic volumes meet or exceed a designated trigger point defined as 92% of the maximum optimal capacity of the lanes (3,400 vehicles per hour [vph] per direction).

The toll rates for the SR 91 express lanes are determined following OCTA toll policies (OCTA 2003). To implement these policies, the operating agency continually monitors hourly traffic volumes in the SR 91 express lanes. Traffic volumes greater than 3,128 vehicles per hour per direction are flagged for further review. If the average directional volume of flagged traffic exceeds 3,300 vehicles per hour, the toll is increased by \$1.00. If the average directional volume of flagged traffic is between 3,200-3,299 vehicles per hour, the toll is increased by \$0.75. If directional volumes are less than 3,200 vehicles per hour, then the toll is not changed (see Figure 1). The current minimum toll is \$1.00 (\$0.10/mile) and the maximum is \$9.90 (\$0.99/mile). A review is conducted six months after a toll increase that examines the most recent 12 consecutive weeks of traffic volumes. Weeks that a major traffic anomaly occurred due to a holiday or an accident/incident are not counted. If traffic volumes have dropped by a large amount (see Figure 2), the toll is reduced by \$0.50 to encourage more demand and subsequently better use of the SR 91 Express Lanes. There is at least a 10-day notice to the OCTA's Board of Directors and customers prior to a toll adjustment becoming effective. Tolls outside "super peak" hours are adjusted to account for annual inflation.

To encourage carpooling, there are discounts for vehicles with three or more persons (HOV3+). Such vehicles can ride free in the SR 91 express lanes during most hours, except from 4:00 p.m. to 6:00 p.m. weekdays in the eastbound direction when they pay 50% of the toll. This exception will remain in effect unless the debt service coverage ratio is projected to be 1.2 or greater for a six-month period. In that case, HOV3+ will travel completely free every day (OCTA 2003).

The SR 91 Express Lanes 2009 Annual Report (OCTA 2009) indicated that the "Three Ride Free" trips accounted for 22% of the total SR 91 express lanes trips, and this Three Ride Free policy turned out to be effective in encouraging "more people to ride together and cut their travel time and

Figure 1: Toll Policy Decision Process



Source: OCTA (www.91expresslanes.com)

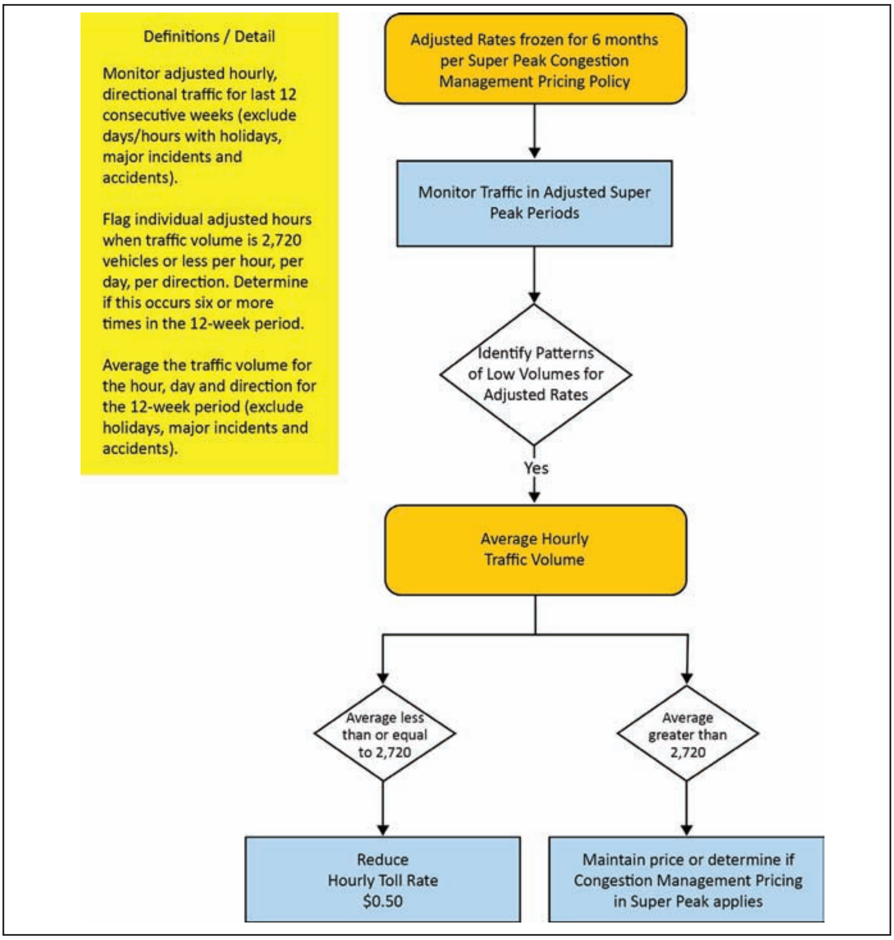
save money during tough economic conditions." The report also states that apart from being used for operations, maintenance, and debt payments, excess revenues will be used for improvements along the SR 91 corridor.

MnPASS Express Lanes on I-394 in Minneapolis, Minnesota

The conversion of the original I-394 HOV lanes to HOT lanes in Minneapolis was authorized by the Minnesota Legislature in 2003, and the first phase of the project opened in May 2005. The HOT lanes were the first of their kind in Minnesota. These lanes are known as the MnPASS Express Lanes and allow SOVs to pay a toll to access the HOV lanes. However, carpools and buses have priority and use the HOV lanes toll-free.

As stated in the provisions of the toll lane legislation (MnDOT 2003), the Commissioner of Transportation is responsible for the implementation of user fees on HOV lanes. The commissioner could also adjust the occupancy requirements to HOV3+ to ensure traffic flows freely. However, it is likely that the legislature would want to be involved in that decision. The goals of the HOT lane are to improve operating efficiency in trunk highway corridors and provide travelers with more options. Moreover, the legislation defines the way collected fees are to be used: "1) repay trunk highway fund or other fund source for cost of equipment and modifications in the corridor, 2) cover the costs of implementing and administering the fee collection system" (MnDOT 2003), and excess

Figure 2: Adjusted Toll Rate Follow On Process (Super Peak Adjusted Rates Only)



Source: OCTA (www.91expresslanes.com)

revenues shall be spent half on capital improvement in this corridor and the other half transferred to the Metropolitan Council for expansion and improvement of bus transit services in this corridor. The I-394 project goals are: “1) to improve the efficiency of I-394 by increasing the person- and vehicle-carrying capabilities of HOV lanes, 2) to maintain free flow speeds for transit and carpools in the Express Lanes, 3) use excess revenue to make transit and highway improvements in the I-394 corridor, 4) to use electronic toll collection and 5) to employ new Intelligent Transportation System (ITS) technologies such as dynamic pricing and in-vehicle electronic enforcement” (Minnesota Department of Transportation 2004). The use of the toll revenue is directed by the authorizing legislation: first to cover operating costs, then if there is any excess revenue, to make transit and highway improvements in the I-394 corridor.

The I-394 project is designed for better use of the capacity in the corridor. Traffic speeds are maintained at or near posted limits by a dynamic pricing strategy which adjusts the toll rates based on demand and use of the lanes. Information on travel speeds and traffic density in the lanes are collected by loop detectors located every half mile on the highway. According to the legislation, the toll rates may adjust by time of day or vary with congestion. The express lanes remain free to HOVs and motorcyclists during peak hours and to all users in off-peak periods. The toll rates are dynamically adjusted every three minutes to manage the traffic at free-flow speed. The average peak period toll varies between $1.00 and $4.00 depending on the level of congestion in the MnPASS express lanes, and the rates are set between $0.25 per segment up to a maximum of $8.00

for traveling the entire corridor. This ensures that traffic in the MnPASS express lanes continues to flow at 50 to 55 mph.

Since the conversion of the I-394 HOV lanes to HOT lanes in 2005, the performance of the entire facility has improved significantly and it has received wide public satisfaction and support (URS Corporation 2008). The amount of traffic on the MnPASS lanes has increased by 33%, peak hour volumes have increased by 5%, while the HOT lane still maintains targeted levels of service. The goal of maintaining 50-55 mph on the MnPASS lanes at least 95% of the time has been achieved. A comparison of crash rates over the last three years shows there has been a 12% decline since MnPASS began.

Also, the operators have the authority to override the current state of the HOT lane. The three override states are: "Closed to all traffic in either direction; Open to HOV traffic only northbound or southbound ($0.00 rate for HOV, all others are violations); Open to all traffic ($0.00 rate for all, no violators)" (MnDOT 2008). In emergencies or special situations, the override state reflects the 'state' of a lane and independent of the rate information.

Express Lanes on Interstate 15 (I-15) in San Diego: Previous and Current Policy

Previous Policies (Prior to March 2009). The "FasTrak" pricing program in San Diego was implemented in April 1998. This program allows SOVs to pay a toll each time they use the express lanes and the toll rates vary with time of day and traffic flow in the I-15 express lanes. These express lanes extend from SR 56 in the north to the SR 163 and the I-15 split in the south. It is currently (July 2011) open as a two-lane reversible facility but is being widened and will be four lanes in 2012. Fees are adjusted in $0.25 increments as frequently as every six minutes to help maintain free-flow traffic conditions on the express lanes. The toll varies between $0.50 and $4.00, and it could be as high as $8.00 during very congested periods. Pricing is based on maintaining a level of service (LOS) "C" for the express lane facility (Wilbur Smith Associates 2009). This LOS of "C" equates to nearly a free-flow traffic condition. The primary goals of the project are to maximize the use of the existing I-15 express lanes and to fund new transit and HOV improvements in this corridor. According to the Value Pricing Project Quarterly Report (FHWA 2008b), approximately 75% of the traffic on the I-15 express lanes travel for free during weekdays (HOV2 or more for free) and the rest are SOV paying customers. Collected tolls are used to pay for express bus service in the corridor, HOV enforcement, and operations, and maintenance costs of the Electronic Toll Collection (ETC) system, and the customer service center. In 2002, about $2.2 million in toll revenues were collected; approximately 50% was used to fund the Inland Breeze Express Bus Service operating in the corridor and the other 50% to the enforcement activities of the California Highway Patrol, the operation of the ETC system, and the customer service center (FHWA 2008b). Survey results of public responses to the concept indicate that both users and non-users of the dynamically priced express lanes strongly support the use of price as a strategy to improve traffic (FHWA 2008b).

Supernak et al. (2001) evaluated the I-15 pricing project using a wide range of quantitative data, including traffic volumes, travel modes, vehicle speeds, travel times, and violations, and found that it made better use of the express lanes, increased subscriber vehicles, and generated sufficient revenue to fund transit improvements in the corridor. Also they found that it did not negatively affect the number of carpools on the express lanes and there were substantial increases in HOV volumes during its implementation. In addition, due to its good performance in redistributing traffic from the middle of the peak to the peak shoulders, FasTrak is capable of maintaining free-flow conditions at all times, as required by California law, despite steadily increasing volumes on the express lanes.

Current Policies (Post March 2009). The extension of the I-15 express lanes from SR 56 to Del Lago opened in March 2009 and with it, all express lanes (SR 163/I-15 split to Del Lago) now operate as described. The lanes are designed to provide a platform for new technology, including electronic sensors monitoring the traffic flow, a sophisticated congestion pricing system that adjusts the toll rate based on the level of congestion in the express lanes, and a moveable barrier allowing for directional expansion during the morning and afternoon peaks. All these innovations provide sufficient flexibility to meet current traffic demand and accommodate projected growth in the future. Although there are no written goals, our survey revealed that maximizing throughput and efficiency of the system was paramount. Carpools, vanpools, and transit have priority to use the express lanes, and the remaining capacity is sold to SOVs. The collected tolls are used in maintenance of back office operations, customer service, operations and maintenance of the facility, including moving the reversible barrier, and excess revenues that go to a reserve account. The survey respondent also indicated that the transit operator receives $500,000 per year from excess revenue if available.

Contrary to the previous volume-based pricing system, in 2009 the I-15 express lanes started a distance-based pricing strategy that dynamically varies the per-mile toll rate every few minutes based on the level of traffic in the express lanes to maintain free-flow traffic. The initial rates were developed by Wilbur Smith Associates (2009) and approved by the legislature and the San Diego Association of Governments (SANDAG) Board. The SANDAG Board of Administration has the authority to set toll rates between $0.50 and $8.00. The current pricing approach on the reversible express lanes ensures level of service "C" by measuring actual volume and comparing it to the facility's design capacity. Density is measured at four toll plazas and it is also used as performance data. The toll-setting algorithm considers density at downstream plazas to make adjustments to the current toll rates.

HNTB Corporation (2006) indicates that Caltrans has installed vehicle detectors at strategic locations along the express lanes and adjacent to the general purpose lanes to collect congestion data. Vehicle location, speed, and volume data are collected through inductive loop detectors for all lanes and segments in both directions and are transmitted to the Traffic Management Center (TMC). With these data, operators in Caltrans TMC can compare the performance of the I-15 corridor between the express lanes and the general purpose lanes, and then make effective traffic management decisions.

The express lanes provide all travelers with a reliable travel option. HOVs, motorcycles, transit, and approved hybrid vehicles continue to use the lanes free. However, SOVs now have the option to pay to use the lanes and receive a reliable trip. Statistics from SANDAG show that the average traffic volume on the entire I-15 facility ranges from 170,000 to 295,000 vehicles a day and vehicles on the general purpose lanes (GPLs) usually are subject to 30 to 45 minutes delay at peak periods. Traffic in the corridor is projected to be approximately 380,000 vehicles a day by 2020 (San Diego Association of Governments 2010), which necessitates improvements in pricing strategies to meet growing demand.

Interstate 95 (I-95) Express (Miami). In December 2008, the northbound express lanes on I-95 between I-195/SR 112 and NW 151st Street on I-95 were opened for tolling in Miami-Dade County. Carpools (HOV3+), hybrid vehicles, and South Florida Vanpools drive toll-free after registering with South Florida Commuter Services. Motorcycles and emergency vehicles can use the express lanes toll-free and do not need to register. The goals of the project are to maximize throughput, improve operations of HOV lanes which were over capacity during peak periods, increase HOV restrictions from four hours to 24 hours daily, and utilize the surplus capacity of the HOV lanes when available by making SOV drivers pay a toll. Other goals are to maintain free-flow speed and travel time savings on the express lanes, increase trip reliability, and provide incentives for transit and carpooling. Still others are to reduce congestion by diverting traffic to non-peak periods, meet increasing travel demand in the future, and facilitate trip-reducing carpool formations.

To achieve the goal of maintaining free-flow speed on the express lanes, traffic equilibrium was found between the target of maintaining 45 mph speed for most of the time and not setting the toll so high that this speed is achieved 100% of the time. To maintain free-flow conditions (45 mph) along the express lanes, the operating agency used an algorithm guided by project-specific rules, which enabled the software (Express Lanes Watcher) to recommend toll changes every 15 minutes. The software collects real-time traffic data from the express lanes, compares it to historical data, and analyzes this information to dynamically generate tolls based on traffic density within the express lanes. The toll rates were set by the Florida Legislature on recommendations from the Florida Department of Transportation (FDOT). The congestion-priced tolls vary from $0.25 to $3.50 between the Golden Glades Interchange to downtown Miami, and they can increase to $7.10 when traffic experiences extreme conditions to offer trip reliability similar to those choosing the express lanes. The rates are equivalent to a minimum $0.03/mile to a maximum $1.00/mile (FDOT 2010). A minimum $0.25 toll is collected for each segment travelled. Toll rates are set based primarily on speed, though there are other affecting factors such as density and occupancy. Slight changes to operations are under the jurisdiction of FDOT. However, significant deviations to operating policies have to be approved by the Florida Legislature. There have been no changes to date.

Performance data (speed, volume, and occupancy) are collected every 0.33 mile on the freeway, including the express lanes and general purpose lanes. The operating speeds and LOS in the express lane and adjacent GPLs are collected via microwave sensors (WaveTronix and Electronic Integrated System Incorporated [EIS]) and loops on ramps. Tolls are the sole source of revenue and are used in priority order for operation and maintenance of the lanes, repaying the contractor who put up advance funding, transit, and any state road.

DISCUSSION

The study found that most surveyed agencies had some written goals and objectives (see Table 1). In addition, pricing is frequently used as a tool to meet these goals. However, in the long term, most express lanes must confront more than just pricing (for example, occupancy requirements) will need to change to meet the goals of the facility. No agencies contacted have an advance policy to address changes in the number of passengers required for free travel in a HOT lane. This difficult decision is always left to a future governing body.

Also, the study found that most agencies operating express lanes have preferred vehicles, including buses, carpools, motorcycles, and sometimes low emission vehicles. Although the express lanes may be operating with a set of high priority user groups in mind, it may be useful to rank the groups to ensure that operational or policy changes are accommodated and decisions made based on the groups most preferred. The survey revealed that the preferred vehicles for express and other managed lanes are transit, HOV3+, HOV2, SOVs, low emission/"green" vehicles, fuel efficient vehicles, motorcycles, off- and on-duty law enforcement/ambulance/fire vehicles, and trucks. Low-income travelers were mentioned but not explicitly given any priority or discount.

The goals, performance measures, change triggers and preferred user groups, if available, are shown in Table 2. Notice that the SR 91 Express Lanes in California are the only example where specific traffic volumes, and therefore congestion levels, result in specific price changes. This project had the most clearly defined triggers and actions to ensure performance. Originally built by a public-private partnership, the OCTA bought out the franchise eight years after its initial opening (Corridor Watch 2007).

> "One of the challenges faced when OCTA bought the SR 91 Express Lanes was how to design and implement a congestion management toll policy administered by a board of publicly elected officials. OCTA implemented a Toll Policy that adjusted toll rates based on the number vehicles on the SR 91 Express Lanes and based on its stated goal to maintain a "free flow" commute at all times. As a result, toll adjustments do not need a Board vote each time ... To date, OCTA has adjusted 18 peak period hours based upon traffic volumes" (The International Bridge Tunnel and Turnpike Association 2010).

It is difficult to imagine a public agency going to its board of directors 18 times over nine years for a change (usually an increase) in toll rates.

All the HOT/Express/MLs projects recognize that varying the toll rate for the least preferred user group (SOVs in most of these cases) is necessary to ensure the free flow of traffic. For some lanes, this policy effectively manages demand for many years due to the capacity of the lanes and

Table 1: Summary of Typical Goals and MOEs of Investigated Projects

General Goal	Project Goals	Measures of Effectiveness
• High-speed travel	• Improving freeway efficiency • Maintain desired level of service • Save travel time • Maintain free flow speed • Maintain a speed for 90% of the peak periods • Congestion reduction	• Average speed • LOS
• Optimize revenue	• Generate revenue • Fund new transit and HOV improvements • Generate revenue to pay off bonds	• Revenue • Violation rate
• Optimize throughput	• Increase person- and vehicle-carrying capabilities of HOV lanes • Maximize the use of the existing Express Lanes • Effectively use the excess capacity of the Express Lane and the whole freeway • Maintain a "quality throughput" • Optimize traffic flow (throughput) • Maximize throughput and efficiency	• Person throughput per hour • Persons in HOVs + Buses per hour
• Safe travel	• Safety • Reduce serious crashes from trucks	• Number of Crashes • Incident clearance time
• Reliable travel	• Reduce congestion	• 95th % travel times • Buffer index

low usage from toll-free (HOV2+ and transit) vehicles. However, there are other facilities where usage by toll-free vehicles will soon eliminate the excess capacity sold to SOVs. This is particularly true in high growth states, like Texas, and where the managed lane is a single lane per direction. At that point, policy makers will be faced with the difficult decision of what changes are required to once again meet their performance objective.

This decision is politically difficult as it will require eliminating some groups' toll-free status. The challenge is how to identify which group(s) and at what point (based on how much performance has degraded) should they be eliminated. If such decisions are made when the project is initiated, then user groups would know well in advance what changes will occur to keep a performance promise on the facility. For example, when an HOV lane becomes a HOT lane and allows SOVs for a toll, the SOVs would know that when average speeds drop to a certain point they would no longer be given tolled access to that lane. Therefore, decision makers should consider these complex issues long before the situations on their facilities become critical. They should also provide policy guidance for many years into the future.

The benefits of such a policy include a clear performance promise to users that the lane will not fall below a certain minimum acceptable standard. If it were to get close to that trigger point, then measures to fix the problem are already set. As well, the implications of poor facility performance are known well in advance. As an example, the user group to be removed from a lane knows this well in advance and will not be surprised by it. The literature review revealed no HOT lanes with set policies on how to deal with SOVs once the volume of HOVs reaches the capacity of the lane. Likely, SOVs will be restricted from using the lane during peak periods, but this decision will be

Table 2: Summary of Goals, MOEs, and Preferred User Groups of Investigated Projects

Project	Specific Goals	MOEs	Preferred user groups
SR167 HOT Lanes Pilot Project	• Maintain travel time, speed, and reliability on the facility	• Speeds • Volume	• HOV2+ (with exceptions requiring HOV3+), vanpools, transit, and motorcycles toll free • SOVs pay toll
Express Toll lanes on I-30 in Dallas	• Maintain average speeds greater than 50 mph	• Maintain average speeds greater than 50 mph	*HOV-only phase*: • HOV2+, vanpools, motorcycles, and transit toll free *Variable pricing phase*: • HOVs and motorcycles carrying a valid transponder receive discount
SR 91 Express Lanes in Orange County	• Reduce congestion through diverting traffic to non-peak period • Maintain free flow speed on the Express Lanes and travel time savings • Meet increasing travel demand in the future • Generate sufficient revenue for the operations and maintenance of the toll lanes	• Hourly, daily, and directional traffic volume • Travel Time • Trigger point: 92% of the maximum optimal capacity	• HOV3+ free (50% off during peak hours) • HOV3+ free during peak hours if debt service coverage ratio is ≥ 1.2 for a 6-month period
MnPASS Express Lanes on I-394 in Minneapolis	• Improve the efficiency of I-394 by increasing the person- and vehicle-carrying capabilities of HOV lanes • Maintain free flow speeds for transit and carpools • Use excess revenue to make transit and highway improvements in I-394 corridor • Use electronic toll collection • Employ new Intelligent Transportation System technologies	• Traffic density • Travel speed	• Carpool and buses free • HOVs and motorcycles free during peak hours • All users free during off-peak periods
MnPASS I-35W Corridor in Minneapolis	• Allow the unused capacity of the HOV lanes to be used by SOV drivers paying a toll • Maintain the service (free flow traffic at 55 mph) to carpools and transit on the managed lanes	• Traffic speed • Volume • LOS determined by traffic density	• Transit • Carpools

Table 2 (continued)

Project	Specific Goals	MOEs	Preferred user groups
Express Lanes on I-15 (San Diego)	*Previous policies*: • Maximize the use of the existing I-15 Express Lanes • Fund new transit and HOV improvements in this corridor *Current Policies*: • Maximize throughput and efficiency of the system	*Previous policies:* • LOS *Current Policies*: • Volume • Density	• Carpools and vanpools • Transit • Remaining capacity sold to SOVs
Express Lanes on I-15 (Salt Lake City)	• Effectively use the excess Express Lane capacity and support the effective use of the capacity of I-15 as a whole • Maintain 55 mph for 90% of the peak periods on weekdays by limiting the number of permits purchased by SOVs • Clearly define toll rates to the driver	• Volume (transponder reads) • Speed	Toll Free: • HOV2+ • Motorcycles • Emergency vehicles • Transit • Clean-fuel vehicles (with C plate from DMV)
95 Express (Miami)	• Maximize throughput • Improve operations of HOV lanes which were over capacity during peak periods • Increase HOV restrictions from four to 24 hours/day and utilize surplus capacity of the HOV lanes, when available, by SOV drivers paying a toll • Maintain free flow speed on the Express Lanes and travel time savings • Increase trip reliability • Incentivize transit and carpooling • Reduce congestion through diverting traffic to non-peak period • Meet increasing travel demand in the future, and • Facilitate trip-reducing carpool formations (as opposed to "fampools")	• Speed • Traffic density • Volume • Occupancy	Toll Free: • HOV3+ • Hybrid vehicles • Motorcycles • Emergency vehicles • South Florida vanpool
SR 73 Toll Road in Orange County	• Generate revenue to pay off bonds • Optimize traffic flow (throughput)		• All vehicles pay the toll

Table 2 (continued)

Project	Specific Goals	MOEs	Preferred user groups
C-470 Tolled Express Lanes	• Minimize congestion • Reduce traveler delay • Improve reliability on C-470 between I-25 and Kipling		• All vehicles pay the toll
Queue jumps in Lee County	• Maximize throughput	• Speed	• All vehicles pay the toll
Toll Roads in Illinois	• Divert non-essential truck traffic from peak periods of travel • Reduce congestion • Improve safety, such as reduce crashes from trucks	• Volume/ throughput	• Will likely begin as HOV2+ • Passenger vehicles: constant rate • Commercial vehicles: varying rate by time of day
Regional System of Variable-Priced Lanes in the Washington, DC Region	• Manage traffic in reasonably free-flow conditions through adjusting toll rates • Maximize not only number of vehicles but also throughput via integrating transit service as part of the variably-priced lanes system		• HOV2+ facility
Pennsylvania Turnpike	• Raise revenue		
Inter County Connector (ICC) and Express Toll Lanes (ETL) on I-95 in Maryland	• Goals of ICC & ETL Optimize revenue • Optimize traffic Goals of ICC Encourage travelers to cancel or postpone their trips when congestion levels are higher • Generate revenue Goals of ETLs • Maintain relatively free-flow traffic conditions in the ETLs by encouraging travelers to use the GPLs or to shift travel to a less congested time	• LOS • Target revenue	• All vehicles pay the toll

Table 2 (continued)

Project	Specific Goals	MOEs	Preferred user groups
Express Toll Lanes on I-75 in Atlanta	• Increase throughput as well as number of vehicles in the corridor • Maintain free-flow speeds in the managed lanes • Increase trip reliability • Provide travel alternatives by accommodating transit and/or carpools		• HOV free (cars only)
Conversion of HOV lanes to HOT Lanes on I-85 in Atlanta	• Provide users in HOT lanes reliable travel times in this corridor by effective use of the managed lanes along I-85 north of Atlanta through dynamic pricing • Maintain average speeds 45 mph or more for 90% of the peak period		Toll free: • HOT3+ • Transit • On-call emergency vehicles • Motorcycles • Vehicles with alternative-fuel vehicle (AFV) license plate
ELDP Projects in Texas	• Goals of ELDP • Manage high levels of congestion Optimize traffic • Reduce emissions in a non-attainment or maintenance area • Finance added Interstate lanes for the purpose of reducing congestion • Performance Goals of IH635, I-30, and I-35E • Address the effects on travel, traffic, and air quality • Address the distribution of benefits and burdens • Address the use of alternative transportation modes • Address the use of revenues to meet transportation or impact mitigation needs	• Average speed • Traffic volume and changes • Number of incidents • 95th and 80th petcentile travel times	• HOV • Vanpool • Transit

made when congestion becomes critical and may come as an unwelcome surprise to SOV users of the facility. Therefore, a policy set in advance removes the need for difficult policy decisions at multiple points in the facility's life, most of which would be likely done in haste due to the failing performance of the facility and the critical need for a decision. Finally, it guides the data collection needs for measuring the performance of the facility.

CONCLUSION

In conducting this state-of-practice review, many organizations from around the country were investigated for any "performance promises" they might have on any of their facilities. Although many verbally expressed interest in the idea, only one had clearly defined triggers and actions to ensure performance. This was the SR-91 Express Lanes in California, where specific traffic volumes, and therefore congestion levels, result in specific price changes. Others, particularly the dynamically priced HOT lanes, had something similar where they raise their tolls to ensure smooth traffic flow every few minutes. However, none had a plan where, if the price consistently rose to a certain threshold on a daily basis, the lane would stop accepting paying customers at that time of day.

Similar to a performance promise is the federal legislation that requires traffic speed on HOT lanes to exceed 45 mph for 90% of the time during peak periods. Frequently failing to meet this requirement may force the removal of SOVs from a facility. Fortunately, all HOT lanes have used pricing to avoid this problem. This was the closest any facility came to pre-determined vehicle occupancy adjustments based on performance measures.

Finally, the goals and objectives for the many projects proved interesting and insightful. However, how a facility would meet the goals when traffic congestion rises to a point where price alone is not the answer is unknown. This is a difficult decision left to future policy makers and would possibly "surprise" the facility users.

APPENDIX

Survey Questions

- Are there specific project goals/objectives?
- How do projects address toll rate changes?
- Is there a policy framework for the operation of the facility? How was it developed? Who was involved?
- Have there been changes in policy? If so, what caused them?
- How are the changes communicated to the public and other stakeholders?
- What is the reaction to policy or toll rate changes?
- What performance data are collected?
- How are performance data collected?

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