

HOT for Transit: How High Occupancy / Toll Lanes Benefit Bus Service

Gregory Newmark
Regional Transportation Authority
175 West Jackson Boulevard #1650
Chicago, Illinois 60604

(312) 913-3236
newmarkg@rtachicago.org

INTRODUCTION

Economists have long advocated varying roadway tolls to manage congestion (Vickrey 1969); however, it is only in the last two decades, particularly with the advent of electronic toll collection, that such value pricing has emerged as a practical option in the United States. The most politically acceptable form of such tolling is thought to be high occupancy / toll (HOT) lanes (Fielding and Klein 1993). These lanes offer drivers the option to pay for access to an uncongested lane or to continue to use a parallel unpriced lane for free. To further HOT lane political acceptability, vehicles meeting an occupancy threshold can access such lanes at a discount. In most cases, the discount is 100 percent of the cost of the toll. Figure 1 presents a taxonomy of toll managed lanes based on these two attributes and places HOT lanes in the first quadrant. While such lanes account for the vast majority of congestion pricing implementations and are the focus of the current research, it is worth noting that several facilities representing the other quadrants have opened in recent years and will warrant future inquiry.

The twelve HOT lanes in operation at the beginning of 2012 have been typically promoted as a new option for drivers, but they also represent a new option for transit. To date, there has been very little comparative research into the transit opportunity represented by HOT lanes, with the most extensive examination (Turnbull 2008) considering only a quarter of current systems in the United States. This research expands the consideration of public transportation and HOT lanes to all extant systems. The purpose of this effort is to inform transportation policies to effectively integrate HOT lanes and bus services.

This work is divided into three sections. The first section provides a comparative review of all HOT lanes in the United States with a focus on their key and often distinguishing attributes. The second section examines current transit operations on all of these lanes. This section explores the provision and use of bus services as well as the transfer, if any, of toll revenues to subsidize the transit offered. The last and final section builds on the first two discussions to critically consider the impacts of HOT lanes on transit services. All sections will be of use to transportation planners seeking to best meld bus services with HOT lanes.

HOT LANES IN THE UNITED STATES

This section introduces all the HOT lanes in the United States by emphasizing their four key characteristics: provenance, configuration, tolling approach, and occupancy regulations.

Table 1 presents these twelve facilities, which are typically branded as ‘express’ lanes to emphasize their premium service. All of these facilities serve major roadways with sufficient congestion to warrant an express service, with nine on interstate highways, two on state highways, and one on a United States highway. HOT lanes are a relatively new addition to the world of transportation infrastructure, with all of these facilities built since 1995 and two-thirds since 2005.

Provenance

The provenance of a HOT lane determines whether new capacity is added or just new use of existing capacity. HOT lanes can be specially built for that purpose, a conversion of an existing high occupancy vehicle (HOV) lane, or a combination of the two.

To date, only the oldest HOT lane, Orange County’s SR-91, has been specially built. This facility was developed by a private company as a profit making venture. This unique route, built in the median of an existing and highly congested highway, traverses a mountain pass that separates employment centers in Orange County from residential sites in Riverside County. Since the corridor serves as a natural ‘bridge’ without competitive alternatives, the lane was expected to be highly profitable and garnered private interest.

More commonly, HOT lanes represent a conversion of an existing HOV lane to allow vehicles not meeting the occupancy threshold to pay to use excess capacity. Such conversions are relatively inexpensive and easy to implement as they do not require the construction of new roadways. Conversions, therefore, do not inherently add new infrastructure, but allow new use of existing infrastructure. In practice, however, successful conversions without initial infrastructure expansion often lead to subsequent capacity increases. For example, the two earliest HOV to HOT conversions, Houston’s I-10 and San Diego’s I-15, have both recently undergone significant redevelopment which included the addition of multiple new HOT lanes, and the third oldest converted HOT lane, Houston’s US-290, is similarly slated for expansion.

Finally, a third model combines expansion and conversion at the same time as was the case with Miami's I-95. There, two new HOT lanes were added and the two existing HOV lanes were converted as part of the same project.

Configuration

Four key issues regarding HOT lane configuration are length, orientation, lanes, and separation from general traffic.

The median HOT lane length in the United States is thirteen miles with all but one extant HOT lane less than twenty miles. The outlier is Salt Lake City's I-15 which currently includes forty miles of HOT lanes and is being expanded to sixty. This lane connects the many communities of the Wasatch Front that are strung along I-15 and has the least directional traffic flows of any HOT lane. Most HOT lanes, by contrast, primarily funnel traffic to a downtown area and see strong inbound flows in the morning and outbound flows in the afternoon. Possible exceptions to this centripetal orientation include the Bay Area's I-680, Orange County's SR-91, and Seattle's SR-167, which do serve commuting traffic flows, but on circumferential paths to secondary regional centers.

Existing facilities range between one and four lanes in width. Two facilities consist of only a single lane; Houston's US-290 is a reversible lane while the Bay Area's I-680 only runs southbound. Additional lanes are planned for both facilities. Half of the HOT lanes in the United States consist of two lanes. These are, typically, a single lane in each direction, although Denver's I-25 and the eastern portion of Minneapolis's I-394 provide a reversible double lane which switches direction with the peak traffic flow. The remaining four HOT lanes consist of two lanes in each direction. San Diego's I-15 has a movable barrier between those lanes to toggle between a two/two and a three/one lane configuration.

The HOT lanes are separated from the adjacent unmanaged 'general purpose lanes' by barriers that range in cost, permanence, and permeability from a simple painted line to concrete walls. A middle ground that has been favored in several implementations is a barrier made of breakaway plastic posts, which deter illegal entry into the lanes, but still allow for access in emergency situations (for more discussion on barriers see Hlavacek, Vitek, and Machemehl 2007; or Davis 2011). In all cases, access to the HOT

lane is limited to defined areas, a feature that has been seen as an improvement for transit operations compared to previously open access HOV lanes (Munnich and Buckeye 2007).

Tolling Approach

The physical configuration of a HOT lane is complemented by its operational structures. Table 2 demonstrates these rules regarding tolling.

All HOT lanes in the United States vary their tolls with peak traffic conditions, rely on electronic toll collection, and structure their tolling program to maximize vehicle throughput; however, these facilities differ in how they determine and charge the tolls. Two-thirds of the systems set their tolling rates dynamically based on traffic conditions. This dynamic pricing is typically automated, although Atlanta's I-85 has been using manual adjustments (as of January 2012) due to problems with their initial computerized algorithm. The remaining third of the HOT lanes publish a toll rate schedule.

These schedules are periodically tweaked to respond to changes in traffic conditions. Orange County's SR-91 is particularly active in managing its rates. The scheduled tolls are enumerated for every hour of the day for every day of the week with supplementary schedules published for national holidays. This HOT lane reviews adjusts its toll rates quarterly. Elsewhere it appears that updating the toll schedules is less structured. For example, Houston's I-10 has adjusted its schedule only once in the three years that the expanded lanes have been open. In Denver, the tolling legislation requires that the HOT lanes charge no less than the lowest express bus fare in the same corridor; as a result, a transit fare increase triggered a change in the HOT lane rate schedule.

Tolls on HOT lanes, like transit fares, are charged either by distance traveled (e.g. San Diego's I-15) or as a flat rate (e.g. Seattle's SR-167). Elements of these methods are often combined into flat rate tolling zones. Salt Lake City's I-15, for example, has four flat rate tolling zones. These distinctions in what a HOT lane toll purchases combined with variable rates makes direct comparison difficult. One approach is to focus on the upper bound by assuming that a driver travels the entire length of the lane and pays the maximum toll. This comparison is imperfect for several reasons. First, at many facilities users pay the full toll but do not travel entire length of the lane. Second, the maximum toll is set in some places (not just within scheduled rates, but also as a cap on possible

dynamic tolls) while truly variable in other places. Therefore, in some facilities with dynamic pricing, the maximum toll represents a pre-defined maximum (which may never actually be charged) or the highest toll rates ever paid (which are likely to be quite rare). Finally, the frequencies of these maximum rates at dynamically tolled facilities are likely to be much lower than at facilities with scheduled tolls. Given these disclaimers, Table 2 presents a comparison of the maximum rates (in cents) per mile. This methodology suggests maximum per mile toll rates range from a dime to a dollar. Two facilities stand out as charging particularly low maximum rates: Salt Lake City's I-15 at 10 cents/mile and Houston's US-290 at 13 cents/mile. Low maximum rates warrant concern as they may result in an underpricing of the lane and lead to overuse and congestion. This appears to be the case in Salt Lake City, where the rates were set artificially low to ensure political acceptability. There, this low toll results in episodic congestion in the HOT lane, a degradation in service from the pre-existing HOV lane. By contrast, on Houston's US-290, the low toll is combined with a two occupant requirement. This added condition appears to effectively manage demand and avoid overcrowding.

Finally, HOT lanes vary in the times that tolling is in effect. Nine facilities charge tolls everyday, while the remaining three only charge on weekdays. All of the HOT lanes that charge tolls everyday, toll for the entire period that they are open to traffic. For most lanes, this is a full twenty-four hour day; however, in Denver and Minneapolis, where the HOT lanes change directions, the facilities shut down for a few hours to accommodate the switch. The one exception is Seattle's SR-167, which tolls seven days a week, but from five o'clock in the morning to seven o'clock in the evening, not round the clock. Among the facilities that toll only on weekdays, the tolling hours also vary substantially. Houston's I-290 tolls only for an hour and a quarter in the morning, Minneapolis's I-35W (and non-reversible part of I-394) toll four hours in the morning and five hours in the afternoon, and the Bay Area's I-680 tolls for fifteen straight hours.

Occupancy Requirements

A second operational structure that defines HOT lanes is their occupancy requirements. These vary by the occupancy threshold, the hours that those thresholds are enforced, and the need to preregister carpools.

By definition, all HOT lanes provide a discount to vehicles meeting an occupancy threshold. Those thresholds, however, vary by facility. Eight HOT lanes define a high occupancy vehicle based on two occupants, while the remaining facilities require a third occupant. The conversion of HOV to HOT lanes in both Miami and Atlanta, where the pre-existing lanes were approaching capacity, was used as an occasion to raise the occupancy requirements from two to three people. While this combination of policies may be necessary for managing throughput, at least in Atlanta, the timing of the two together was not well received by the public. The perception was that the toll authority was suddenly charging for something that had been free.

Typically, cars meeting the HOV requirements ride free on HOT lanes at all times tolling is in effect; however, two surprising variations to charge HOV users exist among lanes with scheduled tolls. Houston's I-10 tolls round the clock, but only offers the HOV discount during designated hours in the morning and afternoon peak periods; outside of these designated times, HOVs must pay the same rates as SOVs to use the managed lanes. Orange County's SR-91 has taken an opposing approach. That facility also tolls round the clock, but allows HOV free access at all times except the highest demand period (the eastbound afternoon weekday peak). During those hours, HOVs are charged half the scheduled toll rates for SOVs.

Finally, three HOT lanes, Orange County's Sr-91, Miami's I-95, and Atlanta's I-85, all of which have a three person occupancy threshold, require users to pre-register as HOVs to enjoy the reduced toll rates. Pre-registered carpools receive a distinct transponder which identifies their vehicle as and HOV. The purpose of this pre-registration is to reduce informal carpooling, particularly among family members. In Miami HOV registration is limited to carpools of three adults commuting for work purposes. In Atlanta, people are able to go online to change the HOV status of their transponder. This allows some added flexibility for HOT lane users while discouraging unplanned carpooling.

TRANSIT ON HOT LANES IN THE UNITED STATES

The focus of this review is on how HOT lanes affect transit service. This portion provides a cross-sectional comparison of current transit activities while the subsequent portion explores the longitudinal impacts of implementing HOT lanes. The transit elements to be considered here are the supply of bus services and park and ride lots and the demand for those services.

Bus Service Provision

Table 3 identifies two key findings. First and most fundamental, bus service exists on all HOT lanes. The fact that transit exists on any demonstrates its compatibility and the fact that it exists on all demonstrates its complementarity to HOT lanes. Second, this transit provision is almost exclusively express service. Of the 121 bus routes identified using HOT lanes, only four charge local rates (Minneapolis's #146, #535, #643; Houston's #131). This finding is not surprising given longer distance routes with limited stops have the most to gain from the reliable travel times offered by HOT lanes.

The predominance of express routes has several further implications for transit on HOT lanes. First, the long distance orientation increases the likelihood of routes crossing over jurisdictional boundaries. As a result, in four of the ten regions, multiple operators provide the bus service. These cases largely reflect routes that originate in a county different from the one in which the HOT lanes are located, such as a Riverside County bus using Orange County's SR-91. This reality will require additional effort to coordinate services and information for users. Miami's I-95 website, for example, presents unified information on all bus routes using the facility despite their operation by two different agencies. (No other HOT lane website even points to the availability of any bus services let alone merge information from different operators.) Second, there is a strong commuting orientation for riders and consequently very little weekend service. Only six bus routes on HOT lanes currently run on weekends and even fewer on Sundays. Similarly, in many corridors there is rather limited service in the non-peak direction. Third, bus services on HOT lanes command relatively high fares including four dollars or more along nine of the HOT lanes. Finally, there are typically two tiers of express bus pricing along HOT lanes which reflect distinctions in the distance traveled (Atlanta has two distance rates), the quality of service (San Diego offers 'express' and 'premium express' service with nicer buses), or the operating agency (Riverside Transit Agency and

the Orange County Transportation Authority charge different express rates along the same corridor). The one exception is Houston which has three distanced based express bus pricing tiers as well as one local rate. Table 3 demonstrates that the vast majority of routes, charge the higher fare.

The bus routes themselves can be grouped into two general categories based on how they collect their passengers. Some routes serve as their own feeder lines while others collect people already assembled at transit centers and park and ride lots. While many routes do a little of both, places in which the former approach predominate tend to have a ‘messy bouquet’ pattern of bus service while places in which the latter approach predominate have more of a ‘long stem rose’ pattern. The ‘bouquet’ pattern is most evident in Minneapolis where each of the two HOT lanes boasts more than twenty-five bus routes. The ‘long stem rose’ pattern is far more common, with many fewer direct routes serving major collection locations.

These patterns are also visible in the ratio of the number of bus trips to the number of routes, as shown in Table 3. Generally speaking, the ‘messy bouquet’ pattern has lower ratios than the ‘long stem rose pattern.’ The HOT lanes in Houston, Miami, and Seattle stand out for their high ratios (all over 40), which reflects many buses traveling the same limited number of routes. By contrast, the HOT lanes in Minneapolis, Salt Lake City, and Atlanta stand out for their low ratios (all under 20), which reflects fewer buses traveling over a larger number of routes. Too much should not be made of these observations. They primarily indicate different approaches to transit provision on HOT lanes.

Park and Ride Provision

The major collection location for HOT lane bus services is the park and ride lot and every HOT lane is served by at least one such lot. Many HOT lanes are served by park and ride lots that are significantly upstream from the HOT lane itself. Conversely, many park and ride lots along a HOT lane do not serve the transit needs of the corridor, either because they are designed for carpooling or because they serve a perpendicular alignment. Table 4 presents the existing park and ride lots that are both located within a mile buffer of the HOT lane and serve bus routes that actually traverse the HOT lane.

By this definition, three quarters of HOT lanes have at least one park and ride lot along their corridor. Of these facilities, the median number of lots is five with an average spacing of one lot every three miles. The median number of parking spaces in these lots is 1,845, with a median ratio of 513 spaces per lot or 160 spaces per mile of HOT lane.

Many of these lots have been designated as a transit center. While this term varies from transit agency to transit agency, it generally refers to a node where multiple bus lines and even modes come together to facilitate transferring. For example, lots in Miami, Seattle, and Salt Lake City also serve parallel commuter rail lines. An additional level of integration is to offer direct access ramps from such lots to the HOT lane. All of the park and ride facilities in Houston offer direct access ramps as well as four currently in operation in San Diego.

Transit Ridership

Table 5 presents the most recent information on average weekday transit ridership along HOT lanes. These numbers demonstrate that HOT lanes can be an effective complement to transit services with a third of the facilities carrying more than 8,000 transit riders per day. In Minneapolis, the combined 25,183 rider transit patronage on the two HOT lanes is only 17 percent less than the ridership on that city's light rail line.

The median load factor for bus service on HOT lanes is 23 riders per bus. Salt Lake City enjoys double this number as the average load factor. This high utilization is based in part on the large commuter buses that use the corridor.

Toll Revenues and Transit Subsidies

Table 6 presents revenue information for these HOT lanes, which range widely from \$25 thousand along Houston's US-290 to \$41 million along Orange County's SR-91. It appears from the limited data that are available, that the older lanes are all making profits at this point. Four of the HOT lanes use some of those profits to subsidize transit service in the corridor. These subsidies range from \$179 thousand dollars in Minneapolis to \$2.6 million in Miami.

HOT LANES IMPACTS ON TRANSIT

HOT lanes impact transit in four main ways. They can affect operations of transit service, they can affect transit ridership, they can bring attention to transit along the corridor, and they can bring funding.

Attention

Perhaps the most fundamental impact that HOT lanes bring to bus service in the corridor is public attention. HOT lane projects, to date, have always entailed controversy regarding social equity. There are typically concerns about income equity, namely that lower income people will not be able to purchase access to the premium lane, about modal equity, namely that transit users who currently enjoy the benefits of an HOV lane will lose out if single occupancy drivers can purchase access to the same lane (Lari and Buckeye 1999; Weinstein and Sciara 2006), and infrastructure equity, namely that the region is investing in short term roadways rather than longer term transit solutions (Ungemah, Swisher, and Tighe 2005).

Resolving these controversies typically involves public support for transit. For example, the income equity concern leads to policies to invest in transit along the corridor. A survey of metropolitan planning organizations found that in order to show that benefits of pricing projects were broadly distributed there was often a portion of revenues devoted to transit. The authors note that “Public and political support comes from a feeling that there is some benefit for everyone. This often means that some portion of revenue from tolls should be used to enhance other modes of travel, such as transit, and that transit service be integrated into the project design so that transit passengers benefit directly. Transit access to the congestion priced or managed lanes should be addressed during the planning process” (Loudon, Synn, and Miller 2010). The modal equity concerns are often accompanied by calls to keep HOT lane tolls higher than the fares of the buses that run on those lanes (Lari and Buckeye 1999; Weinstein and Sciara 2006) which became law in Denver. Similarly, public pressure has caused HOT lane marketing to promote transit (Ungemah, Swisher, and Tighe 2005; Munnich and Buckeye 2007). The infrastructure concern is addressed by commitments to transit infrastructure, such as enhanced bus service and direct access ramps (Ungemah 2007; K.T. Analytics and Cambridge Systematics 2008; Loudon, Synn, and Miller 2010; Greene and Smith 2010).

Funding

As noted in the previous section, equity concerns often lead to funding increases for transit. These take two main forms. First, transit may be a substantial component of the initial project costs. For example, in Minneapolis (I-35W) the majority of the capital costs went to transit supportive infrastructure, such as new park and ride lots and the purchase of new buses. Second, portions of the tolls collected are hypothecated for transit use. Although as Loudon et al. (2010) note “the expectations for revenue generation by decision makers and the public are often inflated.” To date, as shown above, relatively small amounts of toll revenues have transferred to transit. Nonetheless, as King (2009) points out they may represent a significant portion of the transit costs in the corridor. This appears to be the case for San Diego (I-15) and Miami (I-95).

Operations

A third concern is whether HOT lanes will impact transit operations, specifically speed and reliability, along the corridor. Here the provenance of the HOT lane is significant. It is reasonable to assume that a specially built HOT lane will improve transit speeds and reliability, both by increasing overall traffic capacity and by controlling demand in the managed lane; however, the impact of an HOV to HOT conversion is less clear. A common concern is that the addition of non-HOV traffic, as part of a conversion, will degrade pre-existing transit travel times and reliability (Turnbull 2008).

Figure 2 presents a matrix that illustrates the possible impacts by comparing the traffic flow conditions between the former HOV lane and the new HOT lane. The core issue is whether there is congestion in either period. In theory, both HOV and HOT lanes are designed to eliminate any congestion, but that goal may not hold up in practice.

Reviews of HOV to HOT lane conversions have largely shown neutral impacts on transit (Turnbull 2008; Munnich and Buckeye 2007; K.T. Analytics and Cambridge Systematics 2008). This thinking is summarized by a U.S. Department of Transportation report that “generally, HOT Lane conversions have achieved their goals of gaining better use of underutilized HOV lanes and maintaining congestion free travel for toll paying users without subjecting HOV and transit users to lower service levels” (K.T. Analytics and Cambridge Systematics 2008). However, specific cases show distinct outcomes. Turnbull (2008) noted that the increased SOV use on the former HOV lane in Denver

overwhelmed a traffic light at the lane exit ramp causing delays. This problem was identified and successfully addressed. In Salt Lake City (I-15) anecdotal reports suggest that the conversion from HOV to HOT lanes increased congestion during peak periods due to underpricing and poor enforcement of the lanes. This congestion is thought to degrade bus operations. Such impacts need not be negative or neutral. Where existing HOV lanes are already congested, the conversion to a HOT lane may provide coverage to raise the HOV requirement and thus better manage flows while still allowing access to the lane. For example, Miami (I-95), which raised the occupancy requirement and added a lane, saw a fifteen minute reduction in travel times along the managed lane (cite?). Atlanta (I-85) implemented their HOT lane in part to avert the trend towards increasing HOV congestion (Meyer et al. 2006).

Ridership

A secondary concern is that HOT lanes will impact transit ridership.

Positive impacts could include people switching from driving a single occupant vehicle to taking the bus to gain reliability with travel times. This should be particularly strong with a new HOT lane where bus times are expected to improve dramatically. One review of transit ridership on Orange County (SR-91) contradicted this assumption and found “there was no significant effect on transit use (1%) in the corridor” (K.T. Analytics and Cambridge Systematics 2008).

Negative impacts could include people that formerly took the bus for time reliability of the HOV lane will switch to driving in the HOT lane. Chum and Burris (2008) surveyed existing bus riders in corridors that were designated for HOV to HOT conversions to estimate mode switching and found that roughly 4.1% of transit riders would switch to SOV; however, 13.7 percent would shift towards casual commuting. Studies of behavior have shown (quote those quoted in Chum and Burris) that transit ridership increased along the new HOT lane along Minneapolis (I-394) compared to the 35W HOV corridor which was used as a control (Munnich and Buckeye 2007) and now has its own HOT lane. In Houston, 10 percent of people that signed up for quickRide used to ride the bus (may be hedging their bets) (Burris and Stockton 2004).

REFERENCES

- Barker, W. G., and S. E. Polzin. 2004. "Synergies of Bus Rapid Transit and High-occupancy Toll Lanes: Simulation of Bus Rapid Transit in Congested Corridor with Roadway Value Pricing." *Transportation Research Record: Journal of the Transportation Research Board* 1884: 3–9.
- Burris, M. W., and B. R. Stockton. 2004. "HOT Lanes in Houston-Six Years of Experience." *Journal of Public Transportation* 7: 1–22.
- Chum, G. L., and M. W. Burris. 2008. "Potential Mode Shift from Transit to Single-Occupancy Vehicles on a High-Occupancy Toll Lane." *Transportation Research Record: Journal of the Transportation Research Board* 2072: 10–19.
- Davis, M. 2011. *Current Industry Trends for Separating Express Lanes from General Purpose Lanes*. White Paper. Atkins, Ltd.
- Fielding, G. J., and D. B. Klein. 1993. *High Occupancy/toll Lanes: Phasing in Congestion Pricing a Lane at a Time*. Reason Foundation.
- Greene, E. R., and C. Smith. 2010. "Congestion Pricing on Highways in Chicago, Illinois." *Transportation Research Record: Journal of the Transportation Research Board* 2187: 68–75.
- Hlavacek, I., M. Vitek, and R.B. Machemehl. 2007. *Best Practices: Separation Devices Between Toll Lanes and Free Lanes*. Austin, TX: Texas Department of Transportation.
- K.T. Analytics, and Cambridge Systematics. 2008. *Value Pricing Pilot Program: Lessons Learned*. Final Report. Washington, D.C.: USDOT Federal Highway Administration.
- King, D.A. 2009. *Remediating Inequity in Transportation Finance*. Washington, D.C.: Transportation Research Board.
- Lari, A.Z., and K.R. Buckeye. 1999. "High-occupancy Toll Lane System: A Concept Plan for the Twin Cities." *Transportation Research Record: Journal of the Transportation Research Board* 1659: 111–118.
- Loudon, W.R., J. Synn, and H. Miller. 2010. "Consideration of Congestion Pricing and Managed Lanes in Metropolitan Transportation Planning." *Transportation Research Record: Journal of the Transportation Research Board* 2187: 60–67.
- Meyer, M.D., L. Saben, W. Shephard, and D.E. Drake. 2006. "Feasibility Assessment of Metropolitan High-occupancy Toll Lane Network in Atlanta, Georgia." *Transportation Research Record: Journal of the Transportation Research Board* 1959: 159–167.
- Munnich, L.W., and K.R. Buckeye. 2007. "I-394 MnPASS High-Occupancy Toll Lanes: Planning and Operational Issues and Outcomes (Lessons Learned in Year 1)." *Transportation Research Record: Journal of the Transportation Research Board* 1996: 49–57.
- Orange County Transportation Authority. 2011. *100 Million Trips: 91 Express Lanes Fiscal Year 2010-2011 Annual Report*. Orange, CA.
- Schott, B.P. 2011. *Harris County Toll Road Enterprise Fund Basic Financial Statements for the Fiscal Year Ended February 28, 2011*. Harris County, TX: Harris County Toll Road Authority.

- Turnbull, K.F. 2008. "High-Occupancy Toll Lanes and Public Transportation." *Transportation Research Record: Journal of the Transportation Research Board* 2065: 36–40.
- Ungemah, D. 2007. "This Land Is Your Land, This Land Is My Land: Addressing Equity and Fairness in Tolling and Pricing." *Transportation Research Record: Journal of the Transportation Research Board* 2013: 13–20.
- Ungemah, D., M. Swisher, and C.D. Tighe. 2005. "Discussing High-occupancy Toll Lanes with the Denver, Colorado, Public." *Transportation Research Record: Journal of the Transportation Research Board* 1932: 129–136.
- Vickrey, W.S. 1969. "Congestion Theory and Transport Investment." *The American Economic Review* 59 (2): 251–260.
- Washington State Department of Transportation. 2011. *SR 167 HOT Lanes Pilot Project: Third Annual Performance Summary (May 2008 - April 2011)*.
- Weinstein, A., and G. C. Sciara. 2006. "Unraveling Equity in HOT Lane Planning A View from Practice." *Journal of Planning Education and Research* 26 (2): 174–184.

Table 1. HOT Lanes in the United States

Region	Name	Corridor	Opened ^a	Miles	Lanes	Reversible	Barrier with Untolled Lanes
Orange County	91 Express Lanes	SR-91	Dec 1995	10	4	No	Plastic Posts
San Diego	I-15 Express Lanes	I-15	Dec 1996	20	4	Partial	Concrete Wall
Houston	Katy Freeway Managed Lanes	I-10	Jan 1998	12	4	No	Plastic Posts
Houston	Northwest Highway QuickRide	US-290	Dec 2000	15	1	Yes	Concrete Wall
Minneapolis	I-394 MnPASS Express Lanes ^b	I-394	May 2005	8	2	Partial	Painted Lines / Concrete Wall
Salt Lake City	I-15 Express Lanes	I-15	Sept 2006	40	2	No	Painted Lines
Denver	I-25 Express Lanes	I-25	June 2006	7	2	Yes	Concrete Wall
Seattle	SR-167 HOT Lanes ^c	SR-167	May 2008	12	2	No	Painted Lines
Miami	95 Express	I-95	Dec 2008	7	4	No	Plastic Posts
Minneapolis	I-35W MnPASS Express Lanes ^c	I-35W	Sept 2009	16	2	No	Painted Line
Bay Area	I-680 Sunol Express Lanes ^d	I-680	Sept 2010	14	1	No	Painted Lines
Atlanta	I-85 Express Lanes	I-85	Sept 2011	16	2	No	Painted Lines

^aThis date refers to the first opening of the HOT lane while the remaining columns refer to current conditions. In some cases, particularly San Diego (I-15) and Houston (I-10), the facilities have been expanded so that current conditions do not reflect those when the lane opened.

^bMinneapolis (I-394) is composed of two segments. The western segment from I-494 to SH-100 consists of a single dedicated lane in each direction painted line separated from the general purpose lanes. The eastern segment from SH-100 to I-94 consists of two reversible lanes concrete barrier separated from the general purpose lanes.

^cHOT lane is longer in the northbound direction than the southbound direction. The longer length is presented here and used for subsequent calculations.

^dThis lane currently only operates in the southbound direction. Subsequent calculations, such as bus ridership, consider flows only in one direction.

Table 2. Operational Characteristics of HOT Lanes

Region	Corridor	Tolling				HOV		Notes
		Approach	Max (¢/mile)	Days	Hours	#	Tag	
Orange County	SR-91	Scheduled	98	Everyday	24	3+	Yes	HOV3 pays ½ price of toll in eastbound lanes from 4:00 – 6:00pm weekdays, otherwise HOV3 is free
San Diego	I-15	Dynamic	40	Everyday	24	2+	No	--
Houston	I-10	Scheduled	33	Everyday	24	2+	No	HOV2 only free 5:00 – 11:00am and 2:00 – 8:00pm on weekdays. Otherwise HOV2 is tolled.
Houston	US-290	Scheduled	13	Weekdays	1¼	3+	No	During tolling hours (6:45 – 8:00am), HOV2 can buy access to this HOT3 lane. At other times, this lane operates as a HOV2 lane.
Minneapolis	I-394	Dynamic	100	Everyday ^a	22	2+	No	The reversible lanes are HOT2 at all times except when they close for the two direction changes on weekdays, each of which takes an hour. The dedicated lanes are HOT2 during peak hours in the peak direction (6:00 – 10:00am eastbound; 2:00 – 7:00pm westbound).
Salt Lake City	I-15	Dynamic	10	Everyday	24	2+	No	--
Denver	I-25	Scheduled	57	Everyday	20	2+	No	HOT2 at all times except when they close for the two direction changes on weekdays, each of which takes two hours.
Seattle	SR-167	Dynamic	75	Everyday	14	2+	No	Tolling hours are from 5:00am – 7:00pm everyday.
Miami	I-95	Dynamic	100	Everyday	24	3+	Yes	HOV3 is restricted to three or more pre-registered adults commuting to work. No 'informal' HOV.
Minneapolis	I-35W	Dynamic	50	Weekdays	9	2+	No	HOV2 always free. HOT2 during peak hours in the peak direction (6:00 – 10:00am northbound; 2:00 – 7:00pm southbound).
Bay Area	I-680	Dynamic	54	Weekdays	15	2+	No	Tolling hours are from 5:00am – 8:00pm weekdays.
Atlanta	I-85	Dynamic	90	Everyday	24	3+	Yes	HOV3 status must be set for transponder in advance.

^a Minneapolis (I-394) tolls everyday on its reversible portion and on weekdays on its dedicated lanes. It is here classified among the facilities that toll everyday.

Table 3. Bus Service on HOT Lanes

Region	Corridor	Operators	Weekday Bus			Fares		Bus Route Numbers
			Routes	Trips	Trips / Routes	Highest	Lowest	
Orange County	SR-91	2	2	39	20	4.50	3.00	<u>216</u> , 794
San Diego	I-15	1	6	141	24	5.00	2.50	<u>20</u> , 810, 820, 850, 860, 880
Houston	I-10	1	6	391	65	4.50	1.25	<i>131</i> , 221, 222, 228 (\$3.75), 229 (\$3.75), 298
Houston	US-290	1	4	236	59	4.50	3.25	214 (\$3.75), 216 , 217, 219
Minneapolis	I-394	4	38	559	15	3.00	1.75	490, 587, 589, 643 , 649, 652, 663, 664, 665, 667, 668, 670, 671, 672, 673, 674, 675, 677, 679, 680, 690, 691, 692, 697, 698, 699, 742, 747, 756, 758, 764, 772, 774, 776, 777, 790, 793, 795
Salt Lake City	I-15	1	12	76	6	5.00	5.00	471, 472, 473, 801, 802, 803, 804, 805, 806, 807, 808, 810
Denver	I-25	1	12	434	36	5.00	4.00	<u>BV</u> , BF, BX/BMX, <u>L</u> , HX, T, 31X, 40X, 80X, 86X, 120X, 122X
Seattle	SR-167	2	2	88	44	4.00	2.50	566 , 952
Miami	I-95	2	4	259	65	2.35	2.35	95 Golden Glades, 95 Dade-Broward Express, I-95 Express Miramar, I-95 Express Pembroke Pines
Minneapolis	I-35W	4	26	458	18	3.00	1.75	146 , 156, 440, 460, 464, 465, 467, 470, 472, 475, 476, 477, 478, 479, 491, 492, 535 , 552, 553, 554, 558, 578, 579, 597, 684, 695
Bay Area	I-680	1	1	30	30	4.00	4.00	180
Atlanta	I-85	2	8	133	17	4.00	3.00	101, 102 , 103, 410 , 411, 412, 413, 416

Note: Information current for January 2012. In the Bus Line Number column, **bolded** routes charge the lower fares and underlined routes have weekend service, *italicized* routes are local. Houston has multiple fare levels which are noted in (parenthesis) for routes that do not charge the highest or lowest fare.

Table 4. Park and Ride Lots along HOT Lanes with Relevant Bus Service

Region	Corridor	Lots		Spaces			Descriptions
		Total	Per Mile	Total	Per Lot	Per Mile	
							Organized from furthest out to downtown, where applicable.
Orange County	SR-91	0	0.000	0	0	0	--
San Diego	I-15	12	0.600	1,845	154	92	Escondido Transit Center (580); Felicita Ave (30); Del Lago Transit Station (160); Rancho Bernardo Rd (15); Rancho Bernardo Transit Station (190); Rancho Carmel Dr (125); SR56 (70); Sabre Springs / Peñasquitos Transit Station (250); Stoney Creek Rd (132); Paseo Cardiel (88); Freeport Rd (102); Poway Rd (103);
Houston	I-10	2	0.167	2,623	1,312	219	Addicks P&R (2,428); Northwest Transit Center (195)
Houston	US-290	4	0.800	4,596	1,149	306	Northwest Station (2,361); W. Little York (1,102); Pinemont (938); Northwest Transit Center (195)
Minneapolis	I-394	5	0.625	1,351	270	169	Plymouth Road Transit Center (111); CR 73 (732); General Mills Boulevard (123); Louisiana Ave Transit Center (330); Park Place (55)
Salt Lake City	I-15	5	0.125	1,459	292	37	160N 600W, Kaysville (231); Layton Hills Mall (379); Thanksgiving Point Station (422); 100 E. Main St, American Fork (227) American Fork Station (200)
Denver	I-25	0	0.000	0	0	0	--
Seattle	SR-167	5	0.417	1,985	662	165	Auburn Station (631); Auburn P&R (358); Kent Station (996);
Miami	I-95	0	0.000	0	0	0	--
Minneapolis	I-35W	5	0.313	2,566	513	160	Heart of the City (370); Burnsville Transit Station (1,376); St. Lukes (100); South Bloomington Transit Center (195); Knox Ave (525)
Bay Area	I-680	1	0.071	127	127	9	Mission Boulevard (127)
Atlanta	I-85	2	0.125	1,060	530	66	Discover Mills (554); Indian Trail (506)

Counting lots within a mile from the lanes. Note that many upstream lots serve the lanes. **Bolded** lots have direct access ramps. I have only included lots that are served by the buses that use the HOT lanes. In many cases there are lots which serve other bus lines or vanpools.

Table 5. Weekday Bus Trips and Ridership on HOT Lanes

Region	Corridor	Bus			Ratios	
		Trips ^a	Riders	Rider Count Period (s)	Riders / Trip	Riders / Mile
Orange County	SR-91	39	450	March 2010; Oct 2011	12	45
San Diego	I-15	141	2,158	Spring 2011; Nov 2011	15	108
Houston	I-10	391	8,027	Fiscal Year 2011	21	669
Houston	US-290	236	4,526	Fiscal Year 2011	19	302
Minneapolis	I-394	559	13,789	Calendar Year 2009	25	1,724
Salt Lake City	I-15	76	3,477	Calendar Year 2011	46	87
Denver ^b	I-25	434	14,840	Aug – Dec 2011	34	2,120
Seattle	SR-167	88	2,334	Oct-Dec 2011; Dec 2011	27	195
Miami	I-95	259	4,286	June 2011	17	612
Minneapolis	I-35W	458	11,394	Calendar Year 2009	25	712
Bay Area ^c	I-680	30	307	Calendar Year 2011	10	22
Atlanta	I-85	133	3,179	Sept 12 – Oct 7, 2011	24	199

^aTrips based on January 2012 schedules. It is possible that the number of trips have changed since the ridership counts were made.

^bThe B, L, and 120X routes also operate some service in the reverse commute direction. This service does not use the HOT lanes, but the data on those trips and ridership are included in these totals.

^cSince the Bay Area (I-680) HOT Lane is only southbound, only buses running in that direction and their ridership are counted.

Table 6. Revenues and Transit Subsidies of HOT Lanes (Fiscal Year 2011)

Region	Corridor	Operating			Subsidy	
		Income \$	Expenses \$	Margin %	Net \$	Per Profit %
Orange County	SR-91	41,245,590	22,381,682	46	0	0
San Diego	I-15	4,015,371	2,456,865	39	1,000,000	64
Houston	I-10	6,715,041	NA	NA	0	0
Houston	US-290	25,469	NA	NA	0	0
Minneapolis ^a	I-394	--	--	--	--	--
Salt Lake City	I-15	439,474	711,896	-62	0	0
Denver	I-25	2,553,591	2,003,131	22		
Seattle	SR-167	750,446	1,092,346	-46	0	0
Miami	I-95	15,085,957			2,610,185	
Minneapolis ^a	I-35W	2,640,684	2,509,593	5	179,000	137
Bay Area	I-680	628,961				
Atlanta ^b	I-85	--	--	--	--	--

^aThe income and expenses in Minneapolis are collected jointly; however, subsidies are currently only allocated along the I-35W corridor. This is expected to change in 2014 when the capital costs of I-394 are paid back. The expected transit subsidy on that corridor will likely be between \$100-200K.

^bThe Atlanta (I-85) HOT lanes opened in fall 2011 and do not have a full year of operations.

Sources (Orange County Transportation Authority 2011; Washington State Department of Transportation 2011; Schott 2011)

Figure 1. Taxonomy of Toll Managed Lanes

		High Occupancy Vehicle Discount	
		Yes	No
Parallel Lane Exists without Value Pricing	Yes	Quadrant 1 <i>Example:</i> SR-167 HOT Lanes (WA)	Quadrant 2 <i>Example:</i> None exist in U.S.
	No	Quadrant 3 <i>Example:</i> SF-Oakland Bay Bridge (CA)	Quadrant 4 <i>Example:</i> Intercity Connector (MD)

Figure 2. Impact Matrix of HOV to HOT Conversions

		HOV Congested	
		Yes	No
HOT Congested	Yes	Neutral	Negative
	No	Positive	Neutral