International Transport Forum

The Impact of HOV and HOT Lanes on Congestion in the United States

Discussion Paper

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Roundtable

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Reason Foundation
Los Angeles

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The International Transport Forum

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The evolution of HOV and HOT lanes in the United States

High-occupancy vehicle lanes began as a means of reducing fuel consumption and vehicle emissions, not congestion reduction. By the mid-1990s concerns arose about HOV lanes being either under-used or over-used, which led to the emergence of high-occupancy toll (HOT) lanes. One version offered excess capacity in HOV lanes to motorists willing to pay a variable toll. The other version, also known as express toll lanes, involved adding new, variably priced lanes to a congested freeway, to be partly or entirely financed by the toll revenues. Initial projects were mostly of the first kind, but the past 15 years have seen the second kind predominate in terms of lane-miles.

From busway to HOV lane

America's first high-occupancy vehicle (HOV) lanes began as bus-only lanes. The first of these was added to the Shirley Highway (I-95 and I-395) in the northern Virginia suburbs of Washington, DC, as part of that freeway's reconstruction in the late 1960s. The full 11 miles opened in April 1970 on this commuter route to and from Washington, DC. Other bus-only lanes were added to the San Bernardino Freeway (I-10) in metro Los Angeles in 1974 and to several Houston, Texas freeways in the mid-1970s.

In all three cases, transportation planners soon found that even frequent peak-period bus service used only a fraction of the bus lane's capacity, which led to opening the bus lanes to vanpools and four-person carpools (HOV-4). When considerable excess capacity still existed in these earliest HOV lanes, in the 1980s the occupancy requirement was reduced to HOV-3. When federal policy focused on HOV lanes as a way to reduce fuel consumption (less dependence on imported oil) and vehicle emissions, HOV lanes were added to the freeways in many large urban areas during the 1990s and early 2000s.

The Clean Air Act of 1990 designated HOV lanes as a transportation measure that states could use to attain compliance with federal air quality standards. And the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) encouraged the construction of HOV lanes by (1) providing 90% federal funding only for adding HOV lanes, not for adding general-purpose lanes as before, and (2) also making HOV lanes eligible for grants from the Congestion Mitigation and Air Quality (CMAQ) programme. ISTEA also responded to pressure from state transportation agencies for loosening the carpool definition to include two-person carpools (HOV-2). As a result, nearly all HOV lanes built thereafter were HOV-2.

Second thoughts on HOV lanes

As HOV-2 lanes became widespread in the 1990s, researchers and planners noticed that most of these new lanes fell into one of two categories during peak periods: either they were too full (evidencing congested conditions, in large metro areas, or were underutilised (in most other metro areas, leading to concerns about the "empty-lane syndrome"—expensive pavement having been added that was far from fully utilised. A researcher from the University of California, Berkeley modelled various HOV scenarios, concluding that an HOV lane can only be effective under a narrow range of conditions. (Dahlgren, 1995) Anti-HOV lane "revolts" took place in several states in the late 1990s, arguing for converting the new lanes to general-purpose lanes, but the federal funding most agencies had used would have had to be repaid if the use were changed, so the revolt failed.

Researchers identified a second problem, especially with the ubiquitous HOV-2 lanes. Data presented in the Commuting in America II study found that the majority of occupants in HOV lanes were not commuters sharing a ride to work (and hence reducing the number of vehicles on the road during peak periods) but family members who would be travelling together anyway taking advantage of the potentially faster trip in the HOV lane. (Pisarski, 1996) Other researchers found similar data from various metro areas, and a Transportation Research Board study found that fam-pools constituted 75% of all journey-to-work carpools in 1990 and 83% in 1991. (McGuckin et al., 2005) More-recent research, using more-detailed journey-to-work data from the American Time Use Study from 2003 to 2009, found that 41% of the 12.6% of vehicles that comprised carpools were self-identified as fam-pools (DeLoach et al., 2012). There was also some evidence that as HOV lanes expanded during the 1990s, vanpooling's popularity declined. (Pratt, 2000) There no consensus on why fam-pooling seems to be declining, but this might be due to the ongoing dispersal of jobs in suburbia, requiring two-earner families to commute in different directions.

Another problem was enforcement of the occupancy requirements. No workable automated system for verifying occupancy existed, despite many attempts. The only actual enforcement method relied on stationary or roving police cars, whose ability to stop and cite violators in the confines of an HOV lane was very limited—and whose presence while doing so could lead to a large increase in congestion. (Goodin et al., 2007) Enforcement was also costly, and hence it was sporadic, and violation rates were generally in double-digit percentages.

Yet another concern was that during the several decades when HOV lane-miles steadily increased, car-pooling entered into a long-term decline. Between 1995 and 2005, HOV lane-miles doubled from 1 500 to over 3 000. (FHWA, 2012) But from 1980 to 2010, carpooling declined from 19.7% of commuters to 9.7%. (Polzin, 2013) More-recent data show the carpool decline continuing, reaching a new low of 9.0% in 2018. (Aevaz, 2019) A forthcoming FHWA database on specialty lanes finds a total of only 2 918 HOV lane-miles as of 2020 (FHWA, 2020). Thus, conversion of HOV lanes to HOT lanes has offset the addition of new HOV lane capacity in recent years.

Development and growth of HOT lanes

In the 1991 ISTEA legislation, Congress included several pro-tolling provisions, including one that permits new, tolled lanes to be added to highways that receive federal funding. Another section authorised the Federal Highway Administration (FHWA) to commission congestion-pricing demonstration projects, under a new Congestion Pricing Pilot Program (CPPP). Although several state DOTs proposed converting HOV lanes to priced lanes, FHWA excluded such proposals (then dubbed "HOV buy-in") from consideration.

Despite this initial lack of FHWA support, two pioneering HOT lane projects were developed in California in the early 1990s. (Fielding et al., 1993) Both required state enabling legislation. The first project was one of four privately-financed highway projects authorised under a 1989 statute. This project added two HOT lanes each way in the wide median of a highly congested freeway, SR 91 linking Riverside County to Orange County. The second project converted the under-utilised reversible HOV lanes on I-15 in San Diego County to HOT lanes.

By the time these two projects opened to traffic, in December 1995 for SR 91 and December 1996 for I-15, FHWA had embraced the term High Occupancy Toll (HOT) lanes and had changed the name of the pilot programme to the Value Pricing Pilot Program (VPPP). During the 1990s and early 2000s, FHWA held workshops to explain HOT lanes—both new capacity and HOV-lane conversions—to state and metro-area transportation planners. The author of this paper participated in a number of those workshops.

The initial projects were mostly conversions of under-performing HOV lanes. The state DOTs viewed these projects, post-conversion, as still primarily HOV lanes that were simply inviting a limited number of non-HOVs to use their excess capacity, regulated by a variable price. Nearly all these conversions retained the two-person occupancy requirement for non-toll access (HOV-2).

Projects to add new priced lanes to congested freeways took longer to materialise, since the cost of adding one urban freeway lane each way for, say, ten miles could easily be USD 1 billion or more. State DOTs generally did not have the funding for such major projects, which would require long-term financing based on the toll revenues (as in the case of the original SR 91 project, which for a decade was the only HOT lane project financed based on its toll revenues). The second project of this kind began as an unsolicited proposal to Virginia DOT in 2002 to add two HOT lanes each way on 14 miles of the highly congested I-495 Beltway around Washington, DC. The USD 2.3 billion project was developed under Virginia's 1995 Public-Private Transportation Act, with a mix of state funding, private equity, toll revenue bonds, and a federal transportation loan. Its successful financing, during the financial markets turmoil in 2007, encouraged similar projects in Colorado, Florida, Georgia, Texas, and Washington State in the subsequent decade.

As HOT lanes of both types (HOV conversion and new capacity) began operations in large metro areas, the idea of adding them to most or all of a metro area's congested freeways gained momentum. (Poole et al., 2003) By the middle of the century's second decade, such networks had been included in the long-range transportation plans of Atlanta, Dallas, Denver, Houston, Los Angeles, Minneapolis/St. Paul, San Diego, San Francisco, Seattle, and metropolitan Washington, DC. Networks were also emerging de-facto in portions the metro areas of Charlotte, Miami, and Jacksonville.

The US Transportation Research Board's Managed Lanes Committee maintains a database of priced managed lanes. As of January 2019, it included 39 such projects in operation in ten states. (Transportation Research Board, 2019) This tally is somewhat out of date, due to the untimely death of the database coordinator in late 2019, but an update is underway as of mid-2020. The International Bridge, Tunnel & Turnpike Association (IBTTA) maintains a "Tollminer" database that, as of 31 March 2020 listed 53 priced managed lane projects in operation nationwide in 11 states, comprising 766 centre-line miles. A forthcoming database compiled by the US Department of Transportation includes 52 priced managed lane projects in 15 states, totalling 1 842 lane-miles. (FHWA, 2020) But since neither the IBTTA database nor the DOT database are public at the time of writing, the analysis in this paper is based on 2019 data from the TRB database. The larger IBTTA and DOT totals reflect the continued opening of new HOT lanes during 2019 and 2020.

As noted above, the first decade of managed (HOT) lane development mostly involved the conversion of existing HOV lanes to HOT lanes, continuing to require a minimum occupancy of two people for access at no charge. In the second decade, especially in projects that involved converting an existing HOV lane and adding a new lane alongside (at a significantly higher cost), occupancy requirements were frequently changed to three or more persons (e.g., I-95 in Miami, I-85 in Atlanta, I-25 in Denver). In the case of two multi-billion-dollar lane-addition projects in Dallas (I-635) and Fort Worth (I-820 and SR 121/183), the financing agreement called for HOV-2s to get a 50% discount on the variable toll rather than free passage. Other billion-dollar-scale new-capacity HOT projects, such as I-495 in northern Virginia and I-405 in Seattle, adopted HOV-3 as the minimum occupancy required for free passage. Yet another trend that appeared in the second decade of the century was six new-capacity managed-lane projects in which all personal vehicles are required to pay the variable toll (with buses and vanpools the only high-occupancy vehicles exempted). Table 1 includes all these projects.

Thus, over the 25 years in which HOT lanes have been evolving, the policy on occupancy has changed considerably. Of the 39 projects in the TRB database, only 19 still allow vehicles free passage with only two occupants (HOV-2). Those with higher occupancy requirements total 20, with two offering HOV-2 vehicles a 50% discount on the variable toll, 11 requiring three occupants (HOV-3) for free passage, one (SR 91) offering HOV-3s a 50% discount during peak periods, and six charging all personal vehicles. This might be described as a gradual shift of HOT lanes from being (1) HOV lanes that offer excess capacity to single-occupant vehicles at a price to being (2) express toll lanes that offer faster and more-reliable trips to paying customers but offer free or discounted passage to some form of higher-occupancy vehicles (including buses and vanpools). In mid-2020, LA Metro, which operates the express lanes on Los Angeles County freeways, announced its planned HOV-5 project, under which the minimum occupancy for free passage will become five occupants, with a sliding scale of prices for lower-occupancy vehicles. (Shoup, 2020)

The other change has been from (1) simple conversions of single-lane HOV lanes into single-lane HOT lanes to (2) projects that add significant capacity to freeways that in some cases had not had HOV lanes. Examples include the new express toll lanes added to the I-495 Beltway outside Washington, DC, the LBJ (I-635) freeway in Dallas, the North Tarrant Express project in Fort Worth, and the I-405 project in Seattle. In the early stages of procurement in Maryland (and hence not included in the TRB database) is a USD 9 billion project to add express toll lanes to the I-495 Beltway and I-270 in the Maryland suburbs of Washington, DC. In the TRB database, simple HOV-2 conversions total 454 lane-miles. Projects that converted existing HOV lanes and added additional lanes totalled 356 lane-miles. And projects that are 100% new capacity total 787 lane-miles.

The express lanes megaprojects are generally financed based on the projected revenues from the variable tolls. Most such projects are being procured as long-term public-private partnerships (P3s), with the state DOT typically providing about 14% of the budget and the private partner providing an average of 29% equity, with the balance of the project being financed by loans and revenue bonds. (Poole, 2020) A more recent trend is for state DOTs themselves to finance such megaprojects by issuing revenue bonds, with examples being Colorado DOT’s USD 276 million C-470 express lanes in Denver and Riverside County, California’s USD 1.4 billion SR 91 extension project. State-issued revenue bonds for these projects have received BBB bond ratings comparable to those of P3 express lanes projects. (Monroe et al., 2019)

HOT lane performance

Variable pricing is aimed at keeping traffic flowing smoothly during peak periods, offering both time savings and reliable trip times. Data from HOT lanes has enabled researchers to quantify the wide range of value of time, value of reliability, and value of urgency reflected in users’ willingness to pay. Data also show that people of a wide range of incomes use HOT lanes, with most users driving in them only for high-value trips. Car-pooling has been in a long secular decline, and HOT lanes may have contributed to this trend. On the other hand, HOT lanes have been beneficial to super-high-occupancy vehicles such as express buses, which can now bypass congestion.

Research findings on customers

Some of the most important research findings from priced managed lanes have concerned the value of travellers' time. The large majority of transportation policy analysis, prior to the emergence of priced lanes, assumed a single "value of time" for all motorists using a highway. This was often based on the average wage in the geographical area, or some fraction or multiple thereof. Sometimes different multiples or fractions of the average wage were used for personal and business travel.

The advent of variable pricing led to research on what people actually chose to pay (revealed preference) for using priced lanes. The first express toll lanes project, on SR 91 in Orange County, provided one of the first large data sets available to researchers. One team used data from this corridor to discern that those choosing to drive in the priced lanes were paying for two attributes: the value of time saved (VOT) and the value of travel-time reliability (VOR). (Small et al., 2006) There were large distributions of both VOR and VOT among those using the corridor on any given day. Moreover, by comparing the frequency of individual motorists' decisions to use the express lanes, the researchers found that these values can be different for the same individual, depending on the circumstances and purpose of a trip.

Another motorist value affecting the choice to use HOT lanes was identified in a 2020 working paper: the value of urgency (VOU). (Bento, et al., 2020) The authors used detailed data from the I-10 express lanes in Los Angeles, with more than 982 000 observations from February through December 2013. They selected this corridor because its multiple entry and exit points enabled motorists to make last-minute decisions to use portions of the express lane when they deemed it to be worth paying the variable toll. They define VOU as "a discrete WTP [willingness to pay] to meet a schedule constraint, recognising that individuals often face penalties for failing to meet a schedule constraint." They estimated that the value of urgency represented 87% of the average toll, and accounts for many decisions to choose the express lanes for specific (rather than everyday) trips.

Another, and somewhat unexpected, research finding was the demographics of those who choose to use HOT lanes. Critics in many metro areas where such lanes were being developed often derided them as "Lexus Lanes," implying that they would be used mostly or entirely by owners of expensive vehicles such as Lexus, BMW, and Mercedes-Benz. Until HOT lanes were in operation, this allegation could not be assessed with data. Over the years, many state DOTs that operate HOT lanes have used data from their electronic toll systems, which identify the owner of the vehicle and its make and model, for enforcement and billing purposes. Most of the studies found that the distribution of vehicles in the HOT lanes was similar to the distribution of vehicles in the adjacent general-purpose (GP) lanes. For example, Washington State DOT identifies all toll transactions on its SR 167 and I-405 HOT lanes by vehicle make. For the I-405, which has far more traffic than SR 167, non-luxury vehicles including Ford, Chevrolet, Nissan, and Toyota accounted for 67% of all transactions. No data were available for the composition of vehicles in the general-purpose lanes, but the four vehicle makes cited here are among the best-selling vehicles in the United States. (Washington State DOT, 2020). While Texas DOT has not done likewise, the operator of the NTE HOT lanes does annual customer surveys, which include the vehicle make. Its 2018 survey found that 60% of transactions were from six major non-luxury brands, comparable to the Washington results. (Hinkle, 2019) However, one study found that in the case of I-85 in Atlanta, the estimated value of vehicles in the HOT lanes was 23% greater than that of vehicles in the GP lanes. (Guensler et al., 2019)

The most detailed study of HOT lane users concerns the recently completed HOT lanes on I-405 in the Seattle area. (Hallenbeck et al., 2019) The research team had access to data on every transaction in the lanes during 2018, and they estimated the aggregate user savings in travel time at 800 000 hours. Their data explain how overall usage differs from the typical daily composition of users, as shown in Table 2. These data document an informal rule of thumb among HOT lane traffic forecasters: that 90% of the users are in the lanes only occasionally while 10% of them use the lanes very often. That is shown in the third column of the table. The fourth column explains how the I-405 HOT lanes could generate USD 31 million in revenue in 2018, with a broad mix of user types showing up on a typical day. The equity implications emerging from this study are discussed below.

Impact on transit use

Most large metro area transit agencies operate express bus service on HOV and HOT lanes. Prior to the emergence of HOT lanes, the HOV lanes in many congested freeway corridors were often themselves congested, due to large numbers of fam-pool users and violators (vehicles not meeting the occupancy requirement). Hence, the express bus service was less-effective than transit agencies hoped would be the case, since the express buses often travelled in stop-and-go traffic similar to what existed in the GP lanes.

If variable pricing in the HOT lanes succeeded in keeping those lanes flowing well during peak periods, the expectation was that faster and more reliable travel times would make express bus service using HOT lanes more attractive. Limited evidence from empirical studies generally supports this. A 2013 study examined HOT lanes' impact on bus transit in three metro areas: Atlanta, Miami, and Minneapolis. (Pessaro et al., 2013) The researchers found bus travel time savings of 17 minutes in Miami, five minutes in Atlanta, and 4.5 minutes in Minneapolis. And ridership increased by 57% in Miami, 13% in Minneapolis, and 11% in Atlanta (though that increase had begun prior to the HOV to HOT conversion). Most operators of current and planned express toll lanes appreciate the synergy between freer-flowing lanes and better express bus service. In mid-2020, Maryland DOT unveiled its plans for express bus service on the express lanes currently being procured for the Maryland half of the Capital Beltway (I-495) and I-270. (Bass, 2020)

Impact on car-pooling

Research on the first HOV-to-HOT conversion (I-15 in San Diego) found that carpool volumes increased alongside the new traffic of paying customers. (Supernak, 2005) Some have speculated that after the lanes were priced, those who might have paid the toll to gain travel-time savings realised they could get the same saving without paying the toll if they found someone to carpool with. But most later studies have found a decrease in carpool volume after HOV-to-HOT conversion, especially in projects that raised the minimum occupancy for free passage from two to three.

For example, on I-85 in Atlanta, the conversion from HOV-2 to HOT-3 led to a 30% decrease in carpooling in the HOT lane. (Guensler et al., 2013) In a similar conversion on I-95 in Miami, carpooling also decreased. In the Miami case, the shift from HOV-2 to HOT-3 was accompanied by a policy change aimed at reducing or eliminating fam-pools. Three-person carpools were exempted from the toll only if they were registered with the Miami-Dade County ride-sharing agency and periodically verified by the employer(s) of the participants. In addition, researchers have long understood that (non-fam-pool) three-person carpools are more difficult to form and sustain than two-person carpools. The Miami project focused its person-throughput goal on expanded express bus service rather than expanded car-pooling, and as noted above, that goal was accomplished.

Equity concerns

Perhaps the most comprehensive study of equity in HOT lanes is the recent I-405 study. (Hallenbeck et al., 2019) By analysing all paid transactions in the lanes in 2018, the researchers found that one-time users had the lowest median income (USD 63 000) compared with the average of all other users (USD 125 000). But when they looked into which motorists used the lanes at which times, they found that high-income users tended to pay lower average tolls than low-income users. Looking specifically at those with incomes below USD 35 000, on any given day such users accounted for 20.1% of AM peak traffic and 12.3% of PM peak traffic. Both time savings and reliability were much higher during those peak periods, with reliability valued higher in the morning (USD 47/hour for all users) than in the PM peak (USD 19/hour for all). The value of time was closer to being the same, at USD 47 in the AM peak and USD 43 in the PM peak.

Perhaps the most important equity result was the researchers' findings on the net benefit of trips (value of savings vs. cost of the toll). When measured by income, the net benefit was inversely proportional to income, at about USD 2.50/trip for the lowest-income users to about USD 1.70 for those with USD 100 000 incomes and a declining value thereafter to about USD 1.45 per trip for those at USD 400 000. These findings support the intuitive notion that lower-income service-workers, for example, face higher consequences than professional workers for being late to work (in the AM peak) and the risk of high per-minute late fees if picking up children from daycare (in the PM peak).

Another way to look at equity is via social welfare analysis. In a presentation at the Transportation Research Board 2020 Annual Meeting, researchers analysed the relative social welfare implications of four alternative road capacity additions: a general-purpose lane, an HOV lane, a HOT lane, and tolling all lanes. (Do et al., 2020) They used data from the Dallas/Fort Worth metro area on traffic patterns across the limited-access highway network. In addition to congestion impacts, such as travel time, VMT, and toll revenues, they estimated energy consumption and emissions for each delivery alternative (including no-build). This enabled calculation of general travel cost (monetary cost of travel time and toll payments) for each. The last step in the analysis was the regional economic impacts of each alternative.

Based on the quantitative data for travel time, general cost, and social welfare, the researchers created a matrix to rank each of the four options (plus no-build) on: corridor travel time and network travel time; corridor general cost and network general cost; and social welfare. This was done for both 2020 and 2030. The HOT (called "priced ML") alternative ranked highest in social welfare for the highway network and second-best for the corridor in both 2020 and 2030. In 2030, it also ranked highest in travel time benefits network-wide. They concluded as follows: "Our analysis reveals that the Priced ML option offers the highest increase in social welfare, about USD 7 billion, which is well beyond its costs. Another important policy implication is that the welfare impact of this option is substantially higher during rush-hour periods."

To be sure, this is just a single study. But it is based on detailed data from one of America's largest and fastest-growing urban areas, where expanding the capacity of the highway network is a given. It also relied on three proven models: the regional traffic demand model, the Motor Vehicle Emissions Simulator (MOVES) model for emissions analysis, and the IMPLAN input-output model to estimate regional economic impacts.

The HOV/HOT enforcement challenge

Specialised lanes that restrict access based on vehicle occupancy pose a difficult enforcement challenge. For HOV lanes, the illegal use by single-occupant vehicles can lead to congestion which reduces or eliminates the travel-time savings intended to reward those who share rides. Fam-pools do likewise but are not prohibited except via (rare) requirements for registered car-pools. For HOT lanes, there is an added cost from illegal use: loss of toll revenue. If the HOT lane's cost of construction has been financed based on toll revenues, illegal use creates a revenue drain. But even if the HOT lane was created inexpensively by converting a former HOV lane, the presence of numerous cheaters reduces the pricing power of the variable tolling and thereby reduces the intended congestion-reduction benefits.

The most common means of enforcing the occupancy requirement is highway patrol officers driving alongside the specialised lane or stationed in an area adjacent to and accessible to that lane, so as to visually observe the number of people in the vehicle. This method is costly and relatively ineffective. First, the officer may have no feasible way of causing an offending vehicle to stop, which generally requires chasing it with lights and siren and signalling for it to pull over and stop. Most HOV and HOT lanes do not have readily available safe areas to do this. And a police chase and subsequent pull-over of the offender is highly likely to create a traffic jam in the HOV or HOT lane, defeating its larger purpose. Second, due to the high cost of patrol officers, most agencies use them only occasionally for visible enforcement demonstrations, in hopes that lane users will be deterred from future violations for fear of getting caught.

Although various companies have developed prototypes of camera systems for automated occupancy detection, none has proved to be workable. The most comprehensive survey of such technologies was funded by FHWA. (Goodin, et al., 2007) It identified and assessed roadside systems using several different technologies and an array of proposed in-vehicle systems (which would have required mandates on auto companies to install such systems on all new vehicles). The survey paper also pointed out the privacy implications of in-vehicle technologies, which might make them legally and politically infeasible.

Many of the occupancy-detection approaches under discussion in 2007 were focused mainly on two-person (HOV-2) detection, since in the early 21st century, most of the lanes in question were two-person HOV lanes. Detecting back-seat passengers (as in HOV-3 and HOT-3 lanes) was understood to be more difficult, due to such factors as tinted glass and various third-occupant locations in the back seat.

Since 2010, several new approaches have been developed. The most-commonly adopted is a switchable transponder. It comes equipped with a switch that the driver can set to indicate the number of persons in the vehicle, and the electronic tolling system receives that information along with the vehicle identity. The stated number of occupants is used to charge the appropriate toll. Unfortunately, this approach depends on the honesty of the user and does not have a built-in enforcement method.

While several companies – Conduent, Indra, and TransCore – are currently offering improved camera systems, and several state transportation agencies are testing them, (Baldassari, 2019) no such systems are in regular operation on HOT lanes as of mid-2020.

The newest approach relies on smartphone technology. The basic concept is that a HOT lane user who wishes to obtain free or low-cost passage must register and carry in the vehicle a beacon that can detect the presence of one or more smartphones. (Carma, Inc., 2018) This system has been tested by several HOT lane operators, including in Austin (TX), the San Francisco Bay Area, and several others. The company's website in June 2020 states that the system is in operation on the TEXpress lanes in the Dallas/Ft. Worth metro area. (Carma, Inc., 2020) It is an option for motorists who choose to equip their vehicles and shared-riders with interfaces to the electronic tolling system.

The smartphone approach is an improvement over switchable transponders and camera systems, but it does not address the fam-pool problem, which adds many non-paying vehicles to HOT lanes, reducing both the tolls' pricing power and the system's revenue. In a TRB paper, Poole proposed an electronic enforcement system, building on the I-95 Miami concept of registered carpools. (Poole, 2009) In the Florida DOT system, carpools must be employer-sponsored and registered with the local ride-sharing agency. Transponders for those registered are identified as such and charged the appropriate zero or discounted toll by the electronic tolling system. But if the driver travels without the other car-pool members, the only enforcement is the slim possibility of a highway patrol officer spotting the vehicle's car-pool decal and seeing only one occupant. Georgia DOT adopted the registered carpool approach for its I-85 HOT lanes, but enforcement there also depends on the visual acuity of the occasional highway patrol officer.

Poole's proposal called for the system to provide free or discounted passage only during peak periods, which could easily be included in the electronic tolling software. Enforcement would consist of the DOT and the ride-sharing agency periodically verifying whether the registered carpool was still in operation. If it were not, the tolling system would re-designate the relevant transponders as ordinary ones, to be charged the regular toll rates. This proposal has not been adopted.

HOT lanes and freeway pricing

Lessons learned from HOT lanes may provide insights into applying pricing to all lanes of congested freeways. HOT lanes grew rapidly when the federal government shifted rhetorically from "congestion pricing" to "value pricing." A possible approach to persuade policy makers and motorists would emphasise the value added by modest peak/off-peak pricing of general-purpose lanes, rather than portraying congestion pricing as a means of shifting people away from freeway travel.

Pricing's potential and political difficulties

The growth of variably priced lanes over the 25 years since the SR 91 lanes opened has introduced millions of motorists to variable pricing, aimed specifically at reducing peak-period congestion. While many economists were confident that such pricing would be effective, state DOTs and many pundits were sceptical. Yet with more than 1 800 variably priced lane-miles now in operation, the transportation community (including most state DOTs) generally understands why and how they work. But having a few lanes priced while the rest of the freeways remain seriously congested is only a partial solution to the economic and environmental costs of congestion on those vital roadways.

Could pricing be expanded to the rest of the limited-access system's lanes? The original policy paper that introduced the term "HOT lanes" (Fielding et al., 1993) carried the subtitle "Phasing in congestion pricing a lane at a time." While that idea is theoretically possible, it is generally considered to be quite difficult, politically, even though the benefits would likely be large.

One estimate of benefits was made by FHWA. In its major report on conditions and performance of the US highway system for 2008, agency analysts used the FHWA Highway Economic Requirements System to estimate the amounts of future highway investment that would have benefits greater than costs. One set of scenarios applied congestion pricing to all Interstate Highway segments where congestion occurs. In the scenario whose aim was to invest enough to keep Interstate highway and bridge physical condition and performance from declining over the subsequent 20 years, the annual investment need was estimated as USD 24.8 billion. But if congestion pricing were implemented, it would cut that amount by more than half, to USD 11.6 billion per year. And in the scenarios examining improving conditions and performance, the scenario using a benefit/cost ratio of at least 1.5 would require an annual investment of USD 39 billion without congestion pricing, but only USD 24 billion with pricing. (US Department of Transportation, 2010) And there would also be environmental benefits, with much less traffic operating in stop-and-go conditions that generate the highest output of greenhouse gases.

Despite large benefits, congestion pricing on a broad scale has been proposed far more times than it has been implemented. What stands in the way is opposition by public officials who believe the majority of people would see themselves as losers from pricing. A World Bank economist suggested that three groups of people would be affected: the tolled (who pay the price because of their high value of time), the tolled-off (who divert to slower alternatives like parallel arterials or transit) and the un-tolled (who are already on parallel arterials and whose travel would be made worse by those who divert). (Hau, 1992)

Over the years, a number of proposals have been made to compensate the presumed losers or the public officials who would block congestion pricing on their behalf. Small proposed using two-thirds of the pricing revenue for various rebates and tax reductions in the metro area with priced freeways and the remaining third for regional transportation improvements. (Small, 1992). More than a decade later, a team of researchers proposed that 100% of the net revenues be allocated to the jurisdictions through which the priced freeways extend, in proportion to route-miles or lane-miles. (King et al., 2007) This proposal suffers from jurisdictional problems, among others, in that the freeways in the United States are owned and operated largely by state governments, while the jurisdictions in which they operate are an array of local cities and counties. And state DOTs, whose revenues from per-gallon fuel taxes are beginning a precipitous decline, would be loath to give up a replacement revenue source to operate, maintain, and eventually rebuild their most costly infrastructure.

An evolutionary pricing strategy

A more-recent TRB paper proposed a different approach to reaching the goal of priced freeways. (Poole, 2011) This assessment began by questioning the long-standing assumption of a single price to be charged to all personal vehicles.

As noted previously, assuming a single value of time for all users at all times is incorrect. People have different values of time, of reliability, and of urgency depending on many factors, including the specifics of individual trips. This finding predates the advent of HOT lanes. Shmanske first suggested different prices for different lanes on a congestion-prone highway. (Shmanske, 1991) In a subsequent paper, he described a model of a multiple-price system for the San Francisco-Oakland Bay Bridge, in which he found “the gainers clearly outnumber the losers” and “the dollar amount of the gains is clearly greater than any losses imposed” compared with the status quo of the same tolls for all users. (Shmanske, 1993) He also noted that the pioneers of congestion pricing, including Walters (1961), Vickrey (1969), and Mohring (1985) “have ignored the possibility of non-uniform pricing.” While some did consider that there might be a range of values of time among highway users, “none of those papers even mentions the possibility of varied tolls at the same time.” We might excuse those pioneers by remembering that high-speed variable electronic tolling did not exist when they were writing.

Thus, instead of the current status quo on freeways with HOT lanes, where most people pay zero and the special-lane users pay a premium price that reflects higher values of time, an alternative pricing policy for the entire freeway is two-tier pricing—basically regular lanes and premium lanes. The basic toll charged in the regular lanes would be enough to cover at least the operating and maintenance costs of those lanes and would be higher at peak times than at non-peak times. It would be presented to road users as the replacement for declining revenue from per-gallon fuel taxes, rather than as a way to limit use of the freeway (though it would undoubtedly incentivise some users to shift to off-peak times or to transit). By contrast, if all lanes were priced at the same rates as the premium lanes, there would likely be very large numbers of peak-period travellers tolled-off to parallel arterials and made worse off. Moreover, the premium lanes would continue to be the preferred less-congested or non-congested guideway for express bus service, providing an alternative in the same corridor for those with somewhat higher values of time than those in the regular lanes but who could not regularly afford to drive in the premium lanes.

The "evolutionary" aspect of this approach to freeway pricing lies in how it would be implemented over time. The most favourable setting for this approach is very large metro areas that are in the process of building networks of HOT (variably priced) express lanes. At present, when priced lanes are in operation on only a fraction of the region's congested corridors, only those who commute regularly in those corridors (via an express lane, less-congested general-purpose lane, or an express bus in the express lane) understand and appreciate the benefits of pricing. By the time such lanes exist on most of the congested corridors, this understanding will be far more widespread.

At the same time (perhaps ten years from now), declines in the annual revenue from per-gallon fuel taxes will have begun cutting noticeably into state transportation budgets. Transportation policy makers will be able to make the case to expressway users that a different way to pay for this infrastructure will be needed, such as per-mile charging. And since limited-access highways can be priced using conventional electronic tolling technology that is already widely used and accepted, applying it to freeway general-purpose lanes will avoid the kinds of privacy concerns that arise in proposals to replace all fuel taxes with charges for miles driven on all roadways.

Thus, the case for freeway pricing can be presented as a value proposition for those who commute via freeways, whether by car or express bus. This is the opposite of proposals that focus explicitly on reducing road use—which many people perceive as punitive. It mirrors the change in terminology by Congress and FHWA that took place in the early years of HOT lanes. The original programme was called the Congestion Pricing Pilot Program and focused on pricing as a way to reduce demand on freeways. Within a few years, the terminology and emphasis changed as the programme was renamed the Value Pricing Pilot Program. Instead of pricing as a way to get fewer people to use freeways during peak periods (punitive) the new emphasis was on pricing to make peak-period commutes work better by offering a better alternative for high-value trips. The proposed approach would apply this concept to the entire freeway.

Tables

Table 1. Types of US HOT Lanes

Facility (Highway Name or Number)	State	HOV conversion lane-miles	HOV + new lane-miles	New lane-miles	HOV-2 free	HOV-2 discount	HOV-3 free	HOV-3 discount	All pay
SR-91	Calif.			40				X	
I-15	Calif.		80		X				
I-110	Calif.	38.7			X				
I-10	Calif.	43.1					X		
I-680	Calif.	34.8			X				
SR-237 + I-880	Calif.	13.4			X				
I-25 Central	Colo.			10			X		
US 36	Colo.		38						
C-470	Colo.			28					X
!-25N	Colo.			12			X		
I-70 Mt.	Colo.			13					X
I-95, Ph. 1	Florida		28.4				X		
I-95, Ph. 2	Florida		28				X		
I-595	Florida			33					X
I-85	Georgia	31					X		
I-75S	Georgia			24					X
I-95	Maryland			33					X
I-394	Minn.	21			X				
I-35W	Minn.		27		X				

I-35E	Minn.			18	X				
I-10 Katy	Texas			48	X				
I-45N	Texas	19.9			X				
I-45S	Texas	15.5			X				
US 59N	Texas	20.2			X				
US 59S	Texas	15.5			X				
US 290	Texas	13.5			X				
I-635 LBJ	Texas			191.8		X			
DFW Conn.	Texas			14.5	X				
NTE Ph. 1	Texas			200		X			
I-30W	Texas			24	X				
I-635E	Texas	19.5			X				
MOPAC	Texas			22					X
I-45	Texas			20	X				
I-15	Utah	144			X				
I-495	Virginia			56			X		
I-395	Virginia		26				X		
I-95	Virginia		84				X		
SR-167	Washington	24			X				
I-405	Washington		45				X		
Totals		454.1	356.4	787.3	19	2	11	1	6

Source: Transportation Research Board, 2019.

Table 2. I-405 HOT Lanes Usage Data, 2018

Group	Frequency (trips per year)	Fraction of Users (%)	Daily Composition (%)
Single users	1	48.4	2.9
Monthly users	2-40	43.9	20.6
Weekly users	41-120	4.7	20.0
Regular users	121-250	2.1	22.4
Daily users	151-600	1.0	23.5
High users	>600	0.0	10.6

Source: Hallenbeck et al., 2019

References

Aevaz, R. (2019), "2018 ACS Survey: While Most Americans' Commuting Trends Are Unchanged, Telework Continues to Grow, and Driving-Alone Dips in Some Major Cities," Eno Center for Transportation. https://www.enotrans.org/article/2018-acs-survey-while-most-americans-commuting-trends-are-unchanged-teleworking-continues-to-grow-and-driving-alone-dips-in-some-major-cities/ (accessed 15 April, 2020)

Baldassari, E. (2019), "How to Catch Carpool Cheats in the Bay Area," *Times-Herald Online*. https://www.timesheraldonline.com/2019/07/29/how-to-catch-cheats-in-the-bay-area , accessed 15 April, 2020)

Bass, R. (2020), "MDOT Considers New Transit Options on Capital Beltway Managed Lanes," 16 June, 2020 [https://localdvm.com/news/i-270/mdot-considers-new-transit-options-on-capital-beltway-managed-lanes] (accessed 19 June, 2020)

Bento, A. et al. (2020), "Avoiding Traffic Congestion Externalities: the Value of Urgency," Working Paper 2956, National Bureau of Economic Research. https://www.nber.org/papers/w26956

Carma, Inc. (2018), "Carma Verified Ride Automated Vehicle Occupancy Verification Business Case," [www.gocarma.com] (accessed 10 June, 2018)

Carma, Inc. (2020), "Use GoCarma on DFW TEXpress Lanes for HOV Toll Discounts," www.gocarma.com (accessed 5 June, 2020)

Dahlgren, J. (1995), "Are HOV Lanes Really Better?" *Access*, No. 6. https://accessmag.org/spring-1995/are-HOV-lanes-really-better (accessed 20 June, 2020)

DeLoach, S, et al. (2012), "Not Driving Alone? American Commuting in the Twenty-First Century," *Transportation*, Vol. 39, pp. 521-537. https://link.springer.com/article/10.1007/s11116-011-9374-5

Department of Transportation (2010), *2008 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance*, p. ES-16. https://www.fhwa.dot.gov/policy/2008cpr/

Do, W. et al. (2020), "A Comprehensive Welfare Impact Analysis for Road Expansion Projects: A Case Study," Presentation at Transportation Research Board 2020 Annual Meeting, held in Washington, DC, 13-15 January, 2020. https://www.sciencedirect.com/science/article/pii/S2213624X19301117

FHWA (2012), *Priced Managed Lanes Guide*, FHWA-HOP-13-007. https://ops.fhwa.dot.gov/publications/fhwahop13007/

FHWA (2020), *List of National Specialty Lanes* (draft), forthcoming Autumn 2020.

Fielding, G., et al. (1993), "High Occupancy Toll Lanes: Phasing in Congestion Pricing a Lane at a Time," Reason Foundation. https://reason.org/wp-content/uploads/files/22b593c21e642143157e65dc5223ce9a.pdf (accessed 5 May 2020)

Goodin, V., et al. (2007), *Automated Vehicle Occupancy Verification Technologies*, Report FHWA-HOP-07-132, Federal Highway Administration. https://ops.fhwa.dot.gov/publications/publications.htm

Guensler, R, et al. (2013), "Atlanta, Georgia I-85 High-Occupancy Vehicle to High-Occupancy Toll Conversion: Analysis of Vehicle and Person Throughput," Report No. FHWA-GA-13-10-03, Georgia Department of Transportation. https://smartech.gatech.edu/handle/1853/51624

Guensler, R. et al. (2019), "Factors Affecting Atlanta Commuters' High Occupancy Toll Lane and Carpool Choices," *International Journal of Sustainable Transportation*, pp. 1-12. https://www.sciencedirect.com/science/article/pii/S2210539519303050

Hallenbeck, M. et al. (2019), "I-405 High Occupancy Toll Lanes Usage, Benefits, and Equity," University of Washington eScience Institute. www.depts.washington.edu/trac/bulkdisk/pdf/I-405ExpressTollLanesDSSGEquityFinal.pdf (accessed 8 December, 2019)

Hau, T. (1992), "Economic Fundamentals of Road Pricing," Working Paper No. 1070, The World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/258151468767386173/economic-fundamentals-of-road-pricing-a-diagrammatic-analysis

Hinkle, R (2019), "Vehicle Survey Results, 2016-2018," Presentation at Tarrant Transportation Summit, Hurst, Texas, 14 February, 2019.

King, D., et al. (2007), "The Political Calculus of Congestion Pricing," *Transport Policy*, Vol. 14, pp. 111-123. https://ideas.repec.org/a/eee/trapol/v14y2007i2p111-123.html

McGuckin, N. et al. (2005), "The Journey to Work in the Context of Daily Travel," Presentation at TRB Census Data for Transportation Planning Conference, 11-13 May, 2005. https://pdfs.semanticscholar.org/3e5d/e5e5c47994fda29c477fc649eafeab7b441f.pdf

Mohring, H. (1985) "Profit maximization, cost minimization, and pricing for congestion-prone facilities" Logistics and Transportation Review 21 27-36.

Monroe, S. et al., (2019) "Managed Lanes Driven to Strong Performance," Fitch Ratings. https://www.fitchratings.com/research/us-public-finance/managed-lanes-performance-strong-untested-in-recession-03-12-2019 (accessed 12 December 2019)

Pessaro, B., et al. (2013), "Impacts to Transit from Variably Priced Toll Lanes: Results from U.S. Department of Transportation Urban Partnership Agreements," *Transportation Research Record 2396*, pp. 117-123. https://trid.trb.org/view/1240680

Pisarski, A. (1996), *Commuting in America II*, Urban Land Institute, 1996. https://downloads2020.com/v7/?pid=6&offer_id=390&ref_id=81b35b1a5c2aa5c81ff722aB9J4TU4Eq_e6cef1e4_3f0e4cf5&sub1=e6cef1e4&keyword=Commuting%20in%20America%20II%20-%20Alan%20Pisarski&sub8=Commuting%20in%20America%20II%20-%20Alan%20Pisarski&m=Commuting%20in%20America%20II%20-%20Alan%20Pisarski

Polzin, S., et al. (2013), "Brief 10: Commuting Mode Choice," *Commuting in America 2013*, American Association of State Highway & Transportation Officials. http://americandreamcoalition.org/2015Conference/CommutinginAmerica/CA10-4.pdf

Poole, R., et al. (2003), "HOT Networks: A New Plan for Congestion Relief and Better Transit," Reason Foundation. https://reason.org/wp-content/uploads/files/536de94066a3400358dfe2ccf7c84403.pdf

Poole, R. (2009), "Automating Hot Lanes Enforcement," Paper No. 09-0385, Presentation at Transportation Research Board 2009 Annual Meeting held at Washington, DC, 12-14 January, 2009 https://reason.org/wp-content/uploads/files/automating_hot_lanes_enforcement.pdf

Poole, R. (2011), "Rethinking the Politics of Freeway Congestion Pricing," Paper No. 11-0166, Presented at Transportation Research Board Annual Meeting held at Washington, DC, 24-26 January 2011. https://reason.org/commentary/rethinking-politics-freeway-pricing/

Poole, R. (2020), “Annual Privatization Report: Transportation Finance,” Reason Foundation, Table 8. https://reason.org/privatization-report/annual-privatization-report-2020-transportation-finance

Pratt, R, et al. (2000), “Traveller Response to Transportation System Changes, Interim Handbook,” Transit Cooperative Research Program. www.onlinepubs.trb.org/onlinepubs/tcrp/tcrp_webdoc_12.pdf (accessed 22 June, 2020)

Shmanske, S. (1991), “Price Discrimination and Congestion,” *National Tax Journal*, Vol. 44, No. 4, pp. 529-532. https://www.ntanet.org/NTJ/44/4/ntj-v44n04p529-32-price-discrimination-congestion.pdf

Shmanske, S. (1993), “A Simulation of Price-Discriminating Tolls,” *Journal of Transport Economics and Policy*, Vol. 27, No. 3, pp. 225-235. http://www.bath.ac.uk/e-journals/jtep/pdf/Volume_XXV11_No_3_225-235.pdf

Shoup, D. (2020), “It’s Time to Try Congestion Pricing in L.A.,” Bloomberg News, 2 July, 2020 https://www.bloombergnews.com/news/articles/2020-07-02/the-case-for-congestion-pricing-in-los-angeles (accessed 6 July, 2020)

Small, K. (1992), “Using the Revenues from Congestion Pricing: A Southern California Case Study,” Reason Foundation. https://reason.org/wp-content/uploads/files/e4fd396beaca800d7829f1a01296a7d1.pdf (accessed 20 June 2020)

Small, K., et al. (2006), “Differential Road Pricing, Express Lanes, and Carpools: Exploiting Heterogeneous Preferences in Policy Design,” *Brookings-Wharton Papers in Urban Affairs*, pp. 53-96. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=893163

Supernak, J. (2005), “HOT Lanes on Interstate 15 in San Diego: Technology, Impacts, and Equity Issues,” Presented at PIARC Seminar on Road Pricing with Emphasis on Financing, Regulation, and Equity, Cancun, Mexico, 11-13 April, 2005. https://www.researchgate.net/publication/242256760_HOT_Lanes_on_Interstate_15_in_San_Diego_Technology_Impacts_and_Equity_Issues

Transportation Research Board (2019), “Projects Database,” TRB Managed Lanes Committee, https://managedlanes.wordpress.com/2017/07/07/projects-database (accessed on 22 May, 2020).

Vickrey, W. (1969), “Congestion Theory and Transport Investment”. American Economic Review, Vol. 59, issue 2, 251-60

Walters, A.A. (1961), “The Theory and Measurement of Private and Social Cost of Highway Congestion”. Econometrica, Vol. 29, No. 4, pp. 676-699.

Washington State DOT (2020), “Good to Go Customer Account Database, 2019 March through 2020 March,” provided to the author 1 July 2020

The Impact of HOV and HOT Lanes on Congestion in the United States

This paper describes the evolution of high-occupancy vehicle lanes (HOV) and high-occupancy toll lanes (HOT) lanes in the United States. It evaluates their performance and analyses the impact on carpooling and public transport. The demographics of HOV and HOT lane users and the implications for equal access are also examined. The paper also proposes ways to apply lessons learned from the success of HOV and HOT lanes to the political challenges of road pricing.

All resources from the Roundtable on Congestion Control Experiences and Recommendations are available at: https://www.itf-oecd.org/congestion-control-experience-recommendations-roundtable.

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