# Design and Evaluation of Nationwide Deployment of Urban Area HOT Networks

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## Introduction and Overview

Urban traffic congestion is a major problem in the United States. The 2004 Urban Mobility Report from the Texas Transportation Institute estimates the total cost to motorists (in wasted time and excess fuel consumption) of traffic congestion in the largest 85 urban areas in 2002 was $63.2 billion.[1] TTI has been doing these reports since 1982, and the total cost has increased each year. Moreover, the long-range transportation plans of most metropolitan planning organizations (MPOs) project that congestion will increase, not decrease, over the next 20 to 25 years.

In 2003 the Reason Foundation proposed a new approach for dealing with urban freeway congestion. Based on the demonstrated ability of market pricing to keep traffic flowing smoothly at high speed during rush hours on two California high occupancy toll (HOT) lanes, the report proposed that urban areas create networks of HOT lanes on their freeway systems.[2] The networks would be made up from (1) existing high occupancy vehicle (HOV) lanes converted to HOT lanes, (2) new HOT lanes added to freeways without such lanes, and (3) flyover connectors at freeway interchanges to permit seamless connections among the HOT lanes on different freeways.

The benefits of such HOT Networks would be two-fold. First, they would offer drivers a kind of "congestion insurance," meaning that wherever they needed to go on the freeway system, they would always have the option to pay for a faster and more reliable trip. Second, a HOT Network would provide an uncongested guideway for region-wide express bus service—from a functional standpoint, the equivalent of an exclusive busway.

As of early 2005, HOT Networks had attracted considerable interest. The San Francisco Bay Area's MPO included a $3 billion HOT Network in its long-range transportation plan, approved in February 2005. Studies of networks of priced lanes are under way in Atlanta, Dallas, Denver, Houston, Minneapolis/St. Paul, San Diego, and Washington, DC.

This report builds on the 2003 Reason study, which defined and analyzed HOT Networks for eight large metro areas. It extends this work, using the same basic methodology, to the 20 most congested metro areas, as defined by the 2004 TTI report. Of the $63 billion annual congestion cost estimated there, 89 percent is accounted for by the top 20 metro areas.[3] The aim of this work is to define a hypothetical network for each region, estimate its capital cost, estimate its toll revenues, and estimate the extent to which its capital costs could be financed on the basis of expected toll revenues.

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[1] David Shrank and Tim Lomax, "2004 Urban Mobility Report," College Station, TX: Texas Transportation Institute, September 2004.
[2] Robert W. Poole, Jr. and C.Kenneth Orski, "HOT Networks: A New Plan for Congestion Relief and Better Transit," Policy Study No. 305, Los Angeles: Reason Foundation, February 2003.
[3] Shrank and Lomax, Table 2, p. 14.

**Definition of HOT Network**

Priced or “managed” lanes on urban freeways come in a variety of forms. Operating policies range from Express Toll Lanes (in which every vehicle is required to pay a toll) to a version of HOT lanes in which a large number of vehicle categories is given free passage (e.g., carpools of two or more, transit vehicles, hybrid and/or other fuel-efficient or ultra-low-emission vehicles, emergency vehicles). Proposed physical configurations range from a single lane per direction, set off merely by double-striped painted lines to completely grade-separated or barrier-separated, multi-lane facilities. HOT lanes generally are defined to have limited numbers of entrance and egress points, as opposed to the continuous access sometimes afforded to HOV lanes.[4]

In this report, we use the same definition of HOT Network that we used in the original 2003 Reason policy study. Specifically, a HOT Network is an interconnected set of priced, limited-access lanes on an urban freeway system. Emergency vehicles, buses, and pre-authorized vanpools would use the lanes at no charge; all others would pay the market-based toll. Prices would vary so as to limit the number of vehicles per lane per hour to the maximum consistent with free flow. Tolling would be all-electronic, with every vehicle required to have a transponder and a toll account. Enforcement would be via video imaging of license plates of vehicles either lacking a transponder, having an insufficient account balance, or whose accounts had expired.

The HOT Network would be developed by converting existing HOV lanes to HOT, and by building additional lanes and flyover connectors to equip at least the most congested portions of the entire freeway system with an interconnected set of HOT lanes. For purposes of this study, we have assumed that the majority of the lanes would be at-grade, with elevated sections in the densest urban core areas where land values are highest. We have modeled most of the networks as consisting of two-lane facilities (some of which would be one lane plus shoulder per direction and others would be two reversible lanes). In some cases, where we know traffic demand to be especially high or the MPO already plans for two-lanes-per-direction HOV capacity, we modeled two lanes per direction. For at-grade HOT lanes, our costing did not include concrete barrier separation between the HOT lane(s) and the adjacent general purpose (GP) lane; consistent with the FHWA HOT lanes guide, we assumed that plastic pylon separators would suffice. We did assume a concrete “Jersey” barrier in the center to separate traffic flowing in opposite directions.

In designing the networks for each of the 20 metro areas, we used (unchanged) the designs for the initial eight that were developed for Reason’s 2003 study, with only a single change (noted in the next section) for the Washington, DC network. Also, we have created a combined network in one case which TTI presented as separate metro areas. Specifically, we aggregated TTI’s San Francisco/Oakland and San Jose into a single S.F. Bay Area network.

[4] Benjamin Perez and Gian-Claudia Sciara, *A Guide for HOT Lane Development*, Washington, DC: Federal Highway Administration, 2003.

**Network Designs for 20 Most-Congested Metro Areas**

As noted in the previous section, the 20 most-congested metro areas (as measured by TTI's estimated 2002 congestion cost for each) have been configured as 19 metro areas for our analysis. Table 1 summarizes TTI's figures for travel delay, excess fuel, and congestion cost for these 19 regions.

Table 1
2002 Congestion Figures, Largest Urban Areas

| Urban Area | Travel Delay (1000 hours) | Excess Fuel (million gallons) | Congestion Cost $ millions |
|---|---|---|---|
| LA/Orange County | 625,063 | 931 | $11,231 |
| NY/Newark/CT | 394,709 | 646 | $ 7,079 |
| Chicago | 237,849 | 365 | $ 4,221 |
| SF/Oak/San Jose | 201,210 | 322 | $ 3,650 |
| Dallas/Ft. Worth | 147,482 | 239 | $ 2,603 |
| Miami | 144,824 | 221 | $ 2,558 |
| Washington, DC | 126,626 | 203 | $ 2,274 |
| Houston | 123,547 | 198 | $ 2,178 |
| Detroit | 109,056 | 176 | $ 1,939 |
| Philadelphia | 105,528 | 172 | $ 1,871 |
| Atlanta | 97,220 | 168 | $ 1,717 |
| Boston | 81,105 | 130 | $ 1,440 |
| Phoenix | 72,148 | 116 | $ 1,289 |
| San Diego | 72,126 | 119 | $ 1,314 |
| Seattle | 65,276 | 110 | $ 1,175 |
| Baltimore | 59,760 | 101 | $ 1,069 |
| Minneapolis/St Paul | 54,606 | 93 | $ 971 |
| Denver | 54,123 | 83 | $ 954 |
| Riverside/SB Cos. | 49,800 | 80 | $ 904 |

Source: TTI "2004 Urban Mobility Report, Table 2

Two general issues came up in a number of these metro areas. One was how to handle bridges and tunnels and the other was how to deal with planned new toll roads.

For existing bridges and tunnels, we did not assume that new HOT lanes would be added. We extended the HOT Network up to key bridges and tunnels (e.g., in San Francisco, New York, and Baltimore) and left it up to local discretion whether to dedicate an existing lane on the bridge or tunnel as HOT or to assume that since existing toll plazas provide a metering function, congestion on the bridge or tunnel would be less than on the freeway lanes on either side.

In several cases new toll roads are planned in urban areas (e.g. the Northwest Corridor in Denver and the InterCounty Connector in the Maryland suburbs of Washington, DC). Since these new toll roads will use electronic toll collection and may use variable pricing, they will interface usefully with our proposed HOT Networks. But since their toll revenues will be needed to pay for their own construction costs, we did not include either their costs or their revenues in our calculations.

Los Angeles/Orange County Network

This network builds on the extensive (624 lane-mile) system of HOV lanes already in place. It adds new lanes on key links that today lack such lanes, in particular all of US 101 and SR 60 and SR 22, much of I-10 and I-605, and portions of I-5 and I-405. It also adds HOT lanes on the Orange County toll roads (SR 73, SR 241, and SR 261). We estimate that 231 of the new lane-miles would have to be built as elevated sections, due to land-use constraints. Another major expense would be adding 93 flyover connectors. The total network would include 1,009 lane-miles.

New York/Newark/SW Connecticut

This large metro area has 80 existing lane-miles of HOV, on the Long Island Expressway and the New Jersey Turnpike. Because many of the region's freeways are pre-World War II "parkways" not designed to Interstate specifications, we have generally confined the HOT Network to Interstate routes (with the exception of a portion of Grand Central Parkway, to provide access to LaGuardia Airport). In New Jersey, the network encompasses I-95 from I-287 to the George Washington Bridge and links from I-95 to the principal river crossings. On Long Island, its principal east-west link is the Long Island Expressway (I-495) plus a link between the Triboro and Whitestone Bridges and north-south links on I-278 and I-678. In the Bronx and Westchester, I-95 (as far as Stamford, CT) and I-87 (to the Tappan Zee Bridge) are the main links, along with I-278 and I-287. The network encompasses 494 lane-miles, of which 289 would be elevated.

Chicago Network

Chicago has a fairly extensive urban toll road network (Tri-State Tollway, East-West Tollway, North-South Tollway). Although it is converting over time to electronic toll collection, it seems unlikely to switch to variable pricing. Hence, we have assumed that (premium-priced) HOT lanes would be added to those tollways to form part of the HOT Network, just as they would be added to the area's freeways. Except for a few short stretches of state-highway freeway, the entire Chicago-area network is based on Interstates, including major portions of I-90/94, I-290, I-294, I-55, and I-355. About 44 lane-miles would be elevated downtown, out of a total of 369 lane-miles. Chicago has no HOV lanes to convert, so all the lanes in the network would be new construction.

San Francisco Bay Area Network

The Bay Area has the country's second-largest HOV lane system, with 285 lane-miles as of 2003. These would form the core of a 583 lane-mile system. The major additions would be those freeways currently lacking HOV lanes, including major portions of US 101, SR 24, I-880 and I-580, and portions of I-680. Elevated lanes would be needed for 58 lane-miles, primarily on US 101 and I-880. As noted previously, the Metropolitan Transportation Commission's 2030 plan, adopted in February 2005, calls for a $3 billion HOT Network that encompasses some but not all of what is proposed here.

Dallas/Ft. Worth Network

The Dallas metro area currently has 80 lane-miles of HOV lanes, primarily on I-35E, the LBJ Freeway (I-635), and I-30. Plans are under way to replace the HOV lanes on I-635 with HOT lanes, as part of major reconstruction, and the private sector has proposed express toll lanes on SR 121 and SR 183. Our proposed network encompasses an extensive set of the planned HOV lanes (to be built as HOT instead) plus missing links on US 75, US 45, and I-30. The resulting system would provide east-west HOT lanes on SR 121/183, I-635, and I-30 and north-south/radial links on US 75, I-35E and I-35W, and SR 12. It would total 500 lane-miles, of which four would be elevated, in downtown Dallas.

Miami Network

Miami has only a single HOV facility, on I-95, its major north-south freeway. That facility is currently the subject of an investment-grade traffic and revenue study as a possible HOT-lane project. Express toll lanes are also being considered for two existing tollways, SR 821 (the Homestead Extension of Florida's Turnpike) and SR 836 (the Dolphin Expressway). Our proposed network includes these proposed HOT lanes as well as HOT lanes on SR 874, SR 826, and SR 112, plus a new north-south route called the Central Parkway. The total system would be 237 lane-miles, with 34 of them elevated.

Washington, DC Network

The DC metro area has a fairly extensive system of HOV lanes (170 lane-miles), primarily radial, on I-95, I-395, I-66, and I-270. The private sector has proposed adding HOT lanes on the Beltway (I-495) in Virginia, and also to expand and convert to HOT the HOV lanes on I-95 and I-395 approaching the District from the south. And in 2004, the Transportation Planning Board's Regional Mobility and Accessibility Study proposed a network of priced lanes that includes some non-freeway links.[5] Our proposed HOT Network is a bit more modest, comprising 475 lane-miles, including the entire Beltway and all freeway radial links to the Beltway, and I-66 and I-395 within it. (Reason's 2003 Washington, DC network included the entire proposed InterCounty Connector, but for consistency with other proposed networks in the present report, we have excluded such new toll roads from the proposed network to be evaluated here.)

Houston Network

Houston has been a pioneer in developing express bus service on HOV lanes and in experimenting with HOT lanes. Its 133 miles of existing HOV lane supports extensive bus service on US 59 and US 290, as well as I-10 and I-45. Two modest HOT lanes exist on I-10 and US 290, and the former is in the process of being replaced by a much larger (two lanes per direction) HOT lane project with variable pricing. Our proposed network would extend HOT lanes on I-10 to the east side of Houston and add them on the entire I-610 beltway. The network would total 447 lane-miles.

Detroit Network

[5] The map and list of roadway segments was distributed at a meeting of the TPB Task Force on Value Pricing for Transportation on Jan. 19, 2005. Available at www.mwcog.org/uploads/committee-documents/o1xbXF020050216160240.pdf.

Detroit has no HOV lanes, and although it has considerable congestion, three of the four main radial freeways do not experience serious congestion; only I-94 merits that designation. More serious congestion exists on suburban freeways, including I-75 in the Troy and Pontiac areas, the east-west I-696 and I-96, and the north-south I-275 and SR 39 (Southfield Freeway). Our network encompasses these congested routes, adding 322 lane-miles, of which 20 through downtown Detroit would be elevated.

Philadelphia Network

The Philadelphia metro area has no existing HOV lanes. Among its congested freeways are I-95 from below the airport through downtown to I-276, the radial I-76 from the Pennsylvania Turnpike through downtown and into Camden, I-476 from Conshohocken to I-95, and I-276 from where I-76 splits off to its intersection with the New Jersey Turnpike. These routes form the basis of our proposed HOT Network for the Philadelphia metro area. It would consist of 248 lane-miles, of which 39 though downtown would be elevated.

Atlanta Network

This large metro area has 128 lane-miles of HOV lanes in place, and plans to add 262 additional lane-miles. However, those plans are now subject to modification as new interest is rising over proposed HOT or Express Toll Lanes on freeways such as GA 400, I-75, and I-285 (the Perimeter). Our proposed network would add 358 lane-miles and 55 flyover connectors, encompassing the entire Perimeter and all the radial freeways (I-75, I-85, I-675, I-575, I-20, GA 78, GA 166, and GA 400).

Boston Network

Boston was one of the first metro areas to abandon several proposed freeway routes, so the region's freeway system is smaller than most others. It has 12 miles of existing HOV lanes, on the Southeast Expressway and on I-93 north of the Charles River. Our proposed network would include all of Rt. 128 (I-95), I-93 from I-95 on the south through the city to I-95 on the north, the Mass Turnpike (I-90) from Rt. 128 to the Central Artery Tunnel, Rt. 3 approaching I-93 from the south, and Rt. 1 from I-93 to SR 99 in the northern suburbs. It would total 162 lane-miles, of which 55 would be elevated or in tunnels.

Phoenix Network

The rapidly growing Phoenix metro area has 73 lane-miles of HOV in place on its freeways and plans for more. In 2002 the MPO completed a study of possible HOT lanes (called Value Lanes[6]), but thus far has not planned to implement them. We drew on that study and on maps of current congestion to develop a proposed HOT Network. Since congestion is currently highly directional, we assumed that most of the network would be two-lane reversible facilities. It would consist of 196 lane-miles, of which 20 would be elevated, in downtown Phoenix. The major east-west routes would be I-10, SR 202, and US 60, with north-south I-17, SR 51, SR 101, and SR 143.

San Diego Network

[6] Parsons Transportation Group, "High Occupancy Lanes and Value Lanes Final Report," Arizona DOT and Maricopa Association of Governments, August 2002.

Although it has only 26 lane-miles of existing HOV, San Diego's MPO is already committed to the Managed Lanes concept, with one eight-mile stretch of 2-lane HOV on I-15 converted to a HOT lane and plans to expand that facility and do larger ones on three other freeways. Our proposed network builds on those plans to create a network of 447 lane-miles, of which 21 would be elevated. The principal north-south corridors would be I-15, I-5, I-805, SR 163, and SR 125, with east-west links on SR 52, SR 54, and SR 94.

<u>Seattle Network</u>
The Puget Sound region has an extensive system of HOV lanes, encompassing some 205 lane-miles, with plans to add more. It is close to launching the conversion of one of those facilities, on SR 167, to be the region's first HOT lane. Our proposal would add 231 lane-miles at-grade and another 69 elevated. The system would total 505 lane-miles, covering the entire freeway system: north-south routes I-5, I-405, SR 167, and SR 509 and east-west routes SR 16, SR 518, SR 520, and I-90.

<u>Baltimore Network</u>
This metro area experiences congestion primarily on portions of its Beltway (I-695) and on the principal radials heading to the Beltway: I-795, I-95, and the Baltimore-Washington Parkway. Our network therefore encompasses the northern two-thirds of I-695, I-95 from MD 32 on the south and to MD 152 on the north, and I-795 from MD 140 to the Beltway. Since the region has no existing HOV lanes, this would be all new construction, totaling 158 lane-miles, 25 of which would be elevated. Nine flyover connectors would be required.

<u>Minneapolis/St. Paul Network</u>
The Twin Cities have nearly 41 lane-miles of HOV in place, and have planned to add to this system. However, the Minnesota DOT and the Metropolitan Council are currently engaged in a comprehensive MnPASS Toll Lane System Study to assess the feasibility of overlaying a system of priced lanes on the region's freeway system.[7] We have drawn from that study's preliminary findings to configure our proposed HOT Network. It would add HOT lanes to the entire beltway (I-694/I-494), the I-94 approaches to the beltway east and west, I-35W from 145th on the south to SR 10 on the north, I-94 from the beltway on the east to downtown Minneapolis, and I-394 from west of downtown to the beltway. The network would consist of 267 lane-miles, of which 13 would be elevated.

<u>Denver Network</u>
Like the Twin Cities, the Denver metro area is currently the subject of a statewide study by the Colorado Tolling Enterprise (CTE), which seeks to identify corridors where the addition of toll lanes would be feasible.[8] We drew on that study's preliminary findings to help define our proposed HOT Network. Denver has a relatively new tolled beltway encompassing about 60 percent of the circumference of the metro area (E-470 and the new Northwest Parkway). The southwest quadrant (C-470) is non-tolled, but is being

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[7] Cambridge Systematics, "MnPASS Systems Study, Technical Memorandum #4," Minnesota Department of Transportation, Dec. 2, 2004.
[8] Wilbur Smith Associates, "CTE Preliminary Traffic & Revenue Study," Denver: Colorado Department of Trannsportation, December 2004.

considered for priced express lanes. The final western portion of this beltway is expected to be built as a toll road. For purposes of our HOT Network definition, then, we considered the addition of HOT lanes only on the non-tolled C-470 portion of the beltway. The other portions of this beltway are both tolled already and not currently congested, so they were not included in the CTE's current study. Drawing on that study for the other corridors where the greatest demand for congestion relief exists, we defined the network to include C-470, I-70 from E-470 to downtown Denver, I-25 from downtown to SH 7, US 36 from Boulder to I-25, its de-facto continuation as I-270 to I-70, and I-225 from SH 83 to I-70. With a combination of two-land and four-lane facilities, the network totals 282 lane-miles, of which 34 would be elevated.

<u>Riverside/San Bernardino Network</u>

This fast-growing region, called the Inland Empire, is just to the east of Los Angeles and Orange Counties. It is linked to them by I-10, SR 30 (an extension of I-210), SR 60, and SR 91, all east-west freeways. Like the rest of this region, it already has extensive HOV facilities totaling 90 lane-miles. Because two key freeways in this region (SR 60 as far as I-15 and I-15 from there northward) are planned by the MPO for toll truck lanes, and it would be difficult to include both HOT lanes and truck lanes on the same freeway, we have excluded those two segments from the planned network. It therefore includes I-10 from the Los Angeles County line to Calimesa on the east, SR 30 from the county line to its termination at I-10, SR 60 from I-15 eastward to Gilmore Springs, I-15 from Temecula to I-10, SR 91 from the Orange County line to SR 60, and I-215 from I-15 on the north to Perris on the south. The network totals 410 lane-miles, of which 69 would be elevated.

## Network Cost Estimates

In the 2003 Reason HOT Networks study, we derived and used national-average cost figures for the four main components of a HOT network. They are the costs of:

- Constructing new lanes at grade, per lane-mile;
- Constructing new elevated lanes, per lane-mile;
- Constructing flyover connectors, per interchange quadrant;
- Conversion of the system to electronic tolling (gantries, transponders, video equipment, etc.)

In that study we queried the Federal Highway Administration, several MPOs, and several engineering firms to obtain current (as of 2002) cost figures for urban, at-grade freeway lane-mile additions. The average from all our sources was $7.4 million per mile, which was the figure we used for each network in that study. New elevated lane-miles were much harder to obtain reliable estimates for, but from the limited available data, we settled on $25 million per elevated lane-mile. Equally difficult was estimating the cost of urban freeway flyover connectors, with a wide variation from project to project. Again, using judgment, we settled on $40 million per quadrant (i.e., one-fourth of the possible set of connections of a north-south and east-west freeway). Finally, drawing on several HOV-to-HOT feasibility studies, we arrived at a ballpark estimate of $120,000 per lane-mile.

For this study, we drew on more recent work, a 2003 assessment of a congressional proposal to add "FAST Lanes" to urban and rural Interstate highways.[9] In that study, for urban lane additions we began with the most recent FHWA Highway Economic Requirements System (HERS) data for urban freeway lane additions.[10] That report gave a 1997 figure of $8.256 million per lane-mile (at-grade). First, we adjusted this using the Engineering News Record Construction Cost Index to $9.265 million (2002). Next we adjusted this nationwide number for the considerable variation that exists in construction costs among states, using data from R. S. Means Company.[11] From their data, we developed a construction cost index for each state, and used it to adjust the national-average figure. Drawing from that work, the adjustments to our national-average figures are presented in Table 2.

Table 2
State-Specific Unit Costs for HOT Network Components

| State | Factor | At-Grade Lane | Elevated Lane | Flyover Conn. |
|---|---|---|---|---|
| Arizona | 0.940 | $8.71 million | $23.5 million | $37.6 million |
| California | 1.222 | $11.32 | $30.6 | $48.9 |
| Colorado | 1.004 | $9.30 | $25.1 | $40.2 |
| District of Columbia | 0.940 | $8.76 | $23.5 | $37.6 |

[9] Robert W. Poole, Jr., "Estimated Investment Generated by FAST Lanes Legislation," Arlington, VA: Fluor Enterprises, September 2003.
[10] *HERS Volume IV: Technical Report*, Table 7-11, Washington, DC: Federal Highway Administration, December 2000
[11] R.S. Means Company, *Construction Cost Data* (available at www.rsmeans.com).

| | | | | |
|---|---|---|---|---|
| Florida | 0.832 | $7.70 | $20.8 | $33.3 |
| Georgia | 0.930 | $8.60 | $23.2 | $37.2 |
| Illinois | 1.074 | $9.95 | $26.8 | $43.0 |
| Maryland | 0.912 | $8.45 | $22.8 | $36.5 |
| Massachusetts | 1.114 | $10.32 | $27.8 | $44.6 |
| Michigan | 1.020 | $9.45 | $25.5 | $40.8 |
| Minnesota | 0.807 | $7.48 | $20.2 | $32.3 |
| New Jersey/New York | 1.089/1.384 | $11.50 | $30.9 | $49.5 |
| Pennsylvania | 1.047 | $9.70 | $26.2 | $41.9 |
| Texas | 0.850 | $7.91 | $21.2 | $34.0 |
| Washington | 1.060 | $9.87 | $26.5 | $42.4 |

For the cost of electronic tolling equipment, we used national cost figures, since this equipment is sold into a national market.

Using the unit-cost figures from Table 2 and the design features of each proposed network from the previous section, we created a spreadsheet to compute the capital cost of each network. That spreadsheet is reproduced as Table 3.

Table 3
HOT Network Capital Costs

[insert cost spreadsheet here]

As can be seen, the networks range from a bit over $2 billion (Baltimore and Phoenix) at the low end to $12-13 billion at the high end (New York and Los Angeles). Most fall in the range of $3-6 billion.

## Network Revenue Estimation

Estimating the revenues from a HOT Network is very different from projecting toll revenue on a conventional toll road. We first summarize the general procedure used in Reason's 2003 study and then update it with the most recent data on actual HOT lane toll levels on the two successful California projects. The final step is to apply the methodologies to the 19 networks defined here.

For a conventional toll road, the problem is to estimate how much traffic can be attracted to the toll road, given that it must compete with alternate routes without a toll. By contrast, with a HOT lane, the premise is to appeal to that fraction of the users of a highly congested freeway who value their time most highly and are eager to pay for a faster and more reliable trip. In the 20 metro areas where the 19 proposed networks are located, motorists are wasting $56 billion per year due to congestion, according to TTI. Some fraction of them will pay some fraction of that to bypass that congestion. The problem is to figure out how high a toll is needed in order to fill the free-flow capacity of the HOT lane, but to deter any larger number of vehicles per hour from using it.

Highway engineers differ, but many consider the free-flow capacity of a single freeway lane to be 1,700 vehicles per lane per hour. (Somewhat higher capacities are possible on a multi-lane facility.) Our aim is to accommodate that level of traffic in the peak direction during peak hours. Because our defined operating policy is that buses and authorized van-pools will be given no-charge access to the HOT Network, we will assume an average of 100 of those super-high-occupancy vehicles per lane per hour. That leaves 1,600 paying customers per lane per hour, during peak hours, in the peak direction. For two-way HOT-lane facilities, we will assume lower tolls (one-half the peak-direction level) and an average of 1,100 paying vehicles per lane per hour. Thus, on a two-way facility, during peak hours the average flow over the two lanes will be 1,350 vehicles/lane/hr.

Next, we must estimate the level of peak-period toll that can be charged. Our best source for this is actual data from the I-15 and SR 91 HOT lanes in California. In a recent Reason policy study, the lead author of this paper analyzed data from those two HOT lanes.[12] For the 91 Express Lanes, the peak-period, peak-direction toll averages 40 cents per mile; for the I-15 Express Lanes, it averages 30 cents per mile.

The 91 Express Lanes are located in what is by far the most-congested metro area in the United States, not merely by the total amount of hours or dollars but also by its intensity. TTI measures the intensity of congestion by the annual number of delay hours per traveler. The average Los Angeles-area driver suffers 93 delay hours per year; in San Diego the corresponding figure is 47 hours. In fact, as Table 4 shows, Los Angeles and San Diego are fairly good proxies for the high and low ends of congestion intensity among the 19 metro areas of interest in this report. Accordingly, we used this table to assign peak-period, peak-direction toll rates to the metro areas in proportion to their congestion intensity.

[12] Robert W. Poole, Jr., Peter Samuel, and Brian F. Chase, "Building for the Future: Easing California's Transportation Crisis with Tolls and Public-Private Partnerships," Policy Study No. 324, January 2005.

Table 4
Congestion Intensity and Resulting Toll Rates

| Metro Area | Annual delay hours per traveler | No. peak hours/day | Peak-period, peak-direction toll | Non-peak direction peak toll | Average peak toll |
|---|---|---|---|---|---|
| LA/Orange | 93 | 7 | .40 | .20 | .30 |
| Wash, DC | 67 | 6 | .36 | .18 | .27 |
| SF/Oak/SJ | 63 | 6 | .36 | .18 | .27 |
| Dallas/Ft W | 61 | 6 | .36 | .18 | .27 |
| Atlanta | 60 | 6 | .36 | .18 | .27 |
| Houston | 58 | 6 | .33 | .165 | .25 |
| Riverside/SB | 57 | 7 | .33 | .165 | .25 |
| Chicago | 56 | 6 | .33 | .165 | .25 |
| Boston | 54 | 6 | .33 | .165 | .25 |
| Detroit | 53 | 6 | .33 | .165 | .25 |
| Miami | 52 | 6 | .33 | .165 | .25 |
| NY/NJ/CT | 50 | 7 | .33 | .165 | .25 |
| Baltimore | 48 | 6 | .30 | .15 | .225 |
| San Diego | 47 | 6 | .30 | .15 | .225 |
| Seattle | 46 | 6 | .30 | .15 | .225 |
| Denver | 45 | 6 | .30 | .15 | .225 |
| Phoenix | 45 | 5 | .30 | .15 | .225 |
| Mpls/St Paul | 42 | 6 | .30 | .15 | .225 |
| Philadelphia | 40 | 5 | .30 | .15 | .225 |

To estimate the annual toll revenue produced by each HOT Network, we use its total number of lane-miles and first calculate the amount of revenue generated during peak periods. Table 4 gives us the estimated number of peak hours per weekday, in most cases drawn from the MPOs' latest long-range transportation plan (but estimated where not available). This is shown in the spreadsheet in Table 5. Next, we convert this daily peak revenue to an annual basis by multiplying it by 250 weekdays. But these networks would operate 24 hours a day, seven days a week, since the 91 Express Lanes have demonstrated that there is a demand, at much lower toll rates, to use them at all times. In fact, between 20 and 25 percent of annual Express Lanes revenue comes from non-peak operations. Rather than attempting to estimate a set of off-peak toll rates, we simply add a sum for off-peak revenue, based on 22.5 percent of the total. Peak plus off-peak gives us total annual revenue.

To account for operating and maintenance costs, we conservatively estimate these as requiring 10 percent of the annual gross revenue. Thus, the final number of interest is the annual net revenue produced by each network. This is the amount available to pay for the capital costs via toll revenue financing.

Table 5
Estimated HOT Network Revenues

[insert revenue spreadsheet here]

## Bonding Capacity

In a conventional toll road, revenues are relatively low in the early years, when people are just getting used to the road and the tolls. There is a “ramp-up” period, which is very difficult to predict accurately, when traffic builds up to “normal” levels over five or more years. The 91 Express Lanes experienced such a ramp-up period, but within its first five years had reached capacity and had to begin periodic toll increases during peak hours in order to maintain free-flow conditions. The “annual” toll revenue that we have estimated in Table 5 is a proxy for the first year of full-capacity operations, at the conclusion of the ramp-up period.

Again, in a conventional toll road, annual revenue increases beyond that point would depend on additional volume (which would gradually reduce the level of service). But on a HOT lane, where the whole point is to maintain free-flow conditions, annual revenue will increase steadily year after year, as tolls are raised regularly to maintain free-flow in the face of increasing demand. In the previously noted 2005 policy paper, four value-priced managed-lane projects were modeled in more detail than is possible in this brief paper. In each case, a 40-year spreadsheet was created. Ramp-up period toll rates were based on current HOT lane experience. But for the remainder of the 40 years, they were adjusted annually by the Consumer Price Index, so as to keep them at least constant in real terms as demand increased. This procedure probably understates the extent of increases that would be necessary in fast-growing metro areas, though it may be adequate for older, more stable regions.

What we need to be able to estimate is the bonding capacity of a rapidly increasing stream of annual toll revenue. In conventional toll roads, a common rule of thumb is that toll revenue bonds in an amount approximately 10 times the post-ramp-up annual revenue stream can be issued. We used this conventional rule in Reason’s original (2003) HOT Networks study. But the experience of creating 40-year spreadsheets for the 2005 “Building for the Future” report suggests that this method greatly understates the actual bonding capacity.

Table 6 presents several key figures from that study, drawn from the four modeled projects. To be very conservative, we use the year-10 annual revenue as the baseline figure, and compare it first with the year-25 revenue (to show how much it increases) and then with the net present value of 40-years’ revenue (which is a proxy for how much can be financed based on that revenue).

As can be seen, revenue increases dramatically over the 15 years from year 10 to year 25. So to get a better handle on bonding capability, we compute the net present value (NPV) of the 40-year revenue stream. We then compare this with the post-ramp-up annual revenue, here conservatively taken as the revenue in year 10. The NPV of total revenue generated is a proxy for how much that revenue stream can finance as an up-front bond issue. We can see that this sum is between 12 and 20 times as much as the annual revenue in year 10, safely past ramp-up. Hence, rather than using the traditional toll-road rule of thumb of 10 times annual steady-state revenue, we propose using a conservative 15 times the year-10 revenue as a rule-of-thumb for HOT lane projects.

Table 6
Estimating Bonding Capability

| | San Diego Managed Lanes | Palmdale Tunnel | Los Angeles Toll Truckway | SF Bay Area Toll Truckway |
|---|---|---|---|---|
| Year-10 gross revenue | $285 million | $156 million | $985 million | $1067 million |
| Year-25 gross revenue | $681 million | $369 million | $2534 million | $2573 million |
| Ratio | 2.4 | 2.4 | 2.6 | 2.4 |
| NPV of revenue, 40 yrs. | $5624 million | $2602 million | $16660 million | $12373 million |
| NPV/year-10 revenue | 19.7 | 16.7 | 16.9 | 11.6 |

Source: Poole, Samuel, and Chase, "Building for the Future," op cit.

Using that rule of thumb, in Table 5 we estimate the size of toll revenue bond issue for each network. Then, by comparing this number with the estimated network cost from Table 3, we find that two of the networks appear to be financeable solely via toll revenue bonds, and several others could cover 90 percent or more of their costs. This is generally true of the larger networks, where both the intensity and gross amount of congestion is the highest. Older eastern cities, where construction costs are high, growth is low, and transit is better developed, are the farthest from being self-financeable from toll revenue bonds. Detroit stands out among this group at 72 percent, perhaps because most of the network would be in the metro area's suburbs.

## Conclusions and Recommendations

At the outset, we noted the very large annual congestion costs in the 20 metro areas covered by this study. The idea of HOT Networks is to offer commuters the opportunity to avoid some of this cost by paying to use the Network. Based on the model presented here, how much of this congestion cost would be avoided by using each Network? One way to measure this is by equating what HOT Network customers are willing to pay to use it during rush hour to the value of the time they save. We do this in Table 7, comparing the annual congestion cost in each metro area with the annual peak-period gross revenue from each Network.

Table 7
Value of Time Saved by HOT Networks

| Urban Area | TTI Congestion Cost ($millions) | HOT Network Revenue ($millions) | Percent of Congestion Cost |
|---|---|---|---|
| LA/Orange County | $11,231 | $715 | 6.4% |
| NY/Newark/CT | 7,079 | 292 | 4.1 |
| Chicago | 4,221 | 187 | 4.4 |
| SF/Oak/San Jose | 3,650 | 319 | 8.7 |
| Dallas/Ft. Worth | 2,603 | 273 | 10.5 |
| Miami | 2,558 | 120 | 4.7 |
| Washington, DC | 2,274 | 260 | 11.4 |
| Houston | 2,178 | 226 | 10.4 |
| Detroit | 1,939 | 163 | 8.4 |
| Philadelphia | 1,871 | 94 | 5.0 |
| Atlanta | 1,717 | 266 | 15.5 |
| Boston | 1,440 | 82 | 5.7 |
| Phoenix | 1,289 | 74 | 5.7 |
| San Diego | 1,314 | 204 | 15.5 |
| Seattle | 1,175 | 230 | 19.6 |
| Baltimore | 1,069 | 72 | 6.7 |
| Minneapolis/St Paul | 971 | 122 | 12.6 |
| Denver | 954 | 128 | 13.4 |
| Riverside/SB Cos. | 904 | 242 | 26.8 |

These results show rather striking differences. Generally speaking, they show that the HOT Networks defined in this study would achieve more bang for the buck in newer, auto-oriented metro areas, especially California's Inland Empire, Seattle, San Diego, and Atlanta. The least percentage reduction in congestion would occur in older, eastern metro areas such as New York, Chicago, Philadelphia, Boston, and Baltimore. This may be the case because the freeways in the former group carry a much higher fraction of all vehicle trips and would therefore benefit more from the addition of a HOT Network than older metro areas where surface streets account for a larger portion of traffic congestion.

Two surprising departures from this pattern are Los Angeles and Phoenix. Both are auto-oriented Sunbelt metro areas, but in both cases, their networks would relieve only about six percent of total congestion. For Los Angeles, one possible explanation is that its total freeway lane-miles per square mile and per thousand population are among the lowest of all U.S. metro areas. Hence, a large fraction of all peak-period trips make use of arterials and other surface streets, by necessity. Phoenix has built its freeway system mostly in the past decade, and it may be that it handles a smaller share of traffic due to established travel patterns based on the region's extensive arterial system.

We can conclude from this that HOT Networks can offer the most congestion relief to drivers in large metro areas with extensive suburban freeway systems. But it should be remembered that such networks also offer substantial benefits to bus rapid transit, offering the equivalent of exclusive busways for such service. This benefit would be available on all 19 of the Networks evaluated here.

On an aggregate basis, these 19 networks would cost $98 billion to construct. Our estimate is that $71 billion (72 percent) of this cost could be recovered from toll-paying customers. Thus, conventional transportation funding sources (federal and state fuel taxes, and whatever other state/local sources may exist, such as local transportation sales taxes) would have to cover $27 billion. By comparison with traditional highway and mass transit programs, in which the federal government picks up 50 to 80 percent of the capital costs, a federal HOT Networks program that had to cover, on average, just 28 percent of the cost could be seen as quite a bargain.

Since a HOT Network is both a highway project and a mass-transit project, it would be a suitable object of a joint Federal Highway Administration/Federal Transit Administration program. FHWA funding could be targeted at the portion of highway infrastructure costs not covered by toll revenue financing, while FTA funding could be targeted at adding direct-access ramps for buses and on-line or off-line bus stations, some with park-and-ride lots (as SANDAG currently plans for its planned set of Managed Lanes).