MaX Lanes

A Next-Generation Mobility Strategy for Affordable Proximity

Autonomous Vehicles

Connecting to Job Centers

Single Seat Trips

Fast Transit Service

Public-Private Partnerships

Leveraging Existing Assets

center for opportunity urbanism

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Acronyms	
BRT	Bus Rapid Transit
CBD	Central Business District
CoH	City of Houston
HCTRA	Harris County Toll Road Authority (Houston)
H-GAC	Houston-Galveston Area Council (Regional Planning Agency)
HOT	High Occupancy Toll lane
HOV	High Occupancy Vehicle lane
LBJ	Lyndon B. Johnson (Dallas Freeway)
MaX lane	Managed eXpress lane
Metro	Metropolitan Transit Authority (Houston)
OCTA	Orange County Transportation Authority (California)
PPP	Public-Private Partnership
SOV	Single Occupant Vehicle
TIFIA	Transportation Infrastructure Finance and Innovation Act
TxDOT	Texas Department of Transportation

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MaX Lanes Briefing

A Next-Generation Mobility Strategy for Affordable Proximity

"Moving the maximum number of people at maximum speed."

By Tory Gattis, The Center for Opportunity Urbanism

1 The Urban Challenge: Affordable Proximity

What is "affordable proximity"?

The affordable proximity problem can be summed up as, "How can ever larger numbers of people live and interact economically with each other in cities while keeping the cost of living—especially housing—affordable?" The solution is simple in theory but difficult in practice: removing excessive regulatory, planning, and zoning restrictions to allow both the urban and suburban housing supply to meet demand, combined with mobility improvements to open up more areas within a reasonable commute of job centers as well as a larger potential employee pool for employers. This combination of increased housing supply and mobility reduces housing costs and the overall cost of living, which in turn increases discretionary incomes flowing through the city to improve the economy, vibrancy, opportunity, and a felt sense of prosperity[1]. This briefing is focused on the mobility side of that equation.

Why not traditional freeway expansions or rail transit?

Freeway widenings are reaching their reasonable limits in many places while congestion continues to increase. Rail investments in other decentralized, Sunbelt cities—such as Los Angeles, Dallas, Denver, and Atlanta—have been disappointing. Los Angeles in particular is a cautionary case. With $9 billion spent on new rail lines in a city with twice the density of a typical American metro and perfect walking weather year-round, they have seen overall declines in transit ridership and worsening traffic congestion[2]. Rail is incredibly expensive—typically over $100 million per mile (or far higher if grade separated)—and just not well suited for spread-out Sunbelt cities with multiple job centers built around the automobile in the post-WWII era. We need to consider innovative alternatives.

2 The Solution: MaX Lanes

Managed eXpress (MaX) Lanes: Moving the maximum number of people at maximum speed.

MaX Lanes are the next generation of HOV lanes: controlled freeway lanes using a mix of policies to keep them moving the most possible people at the maximum reasonable speed. Policies can include high-occupancy requirements, tolling (fixed, time-of-day, or real-time congestion priced), and/or eventually even limiting them to autonomous vehicles when those technologies become widely available. Public and private express buses are the primary target users, although other vehicles meeting use-policies or paying tolls may also use the lanes.

How would transit use MaX Lanes?

The goal would be comprehensive single-seat express commuter bus service from all parts of a metro to all the major job centers. Commuters would go to their nearest Park-and-Ride center by car or transit to find express bus options to each of the major job centers, using MaX Lanes for a high-speed, point-to-point ride and ending by circulating through the destination job center to get commuters close to their final destination without the need for transfers. When needed, commuters could use affordable shared-ride services for local "last mile" connections or to get around during the work day for lunches, errands, or meetings. McKinsey predicts that by 2025 these services may be as low as 17 to 67 cents per mile when automated, depending on how many people share the vehicle.[3]

What are the advantages of MaX Lanes?

Faster

1. High speed now (60+ mph), and even higher speeds in the future when they become autonomous-only, potentially opening up the far suburbs to reasonable commutes to core job centers at up to 100mph or more[4]. Net speeds are twice as fast or more than station-oriented rail or BRT.
2. Single-seat point-to-point nonstop rides with few or no transfers and minimal weather exposure as buses circulate in job centers to get riders close to their final destinations.

Flexible and Adaptable

3. More flexible and adaptable routes and service than trains.
4. Works for both public and private vehicles, including private or corporate shuttles (like, for example, Chariot and Google do today). Competition on routes, schedule, reliability, timeliness, amenities (laptop trays? better seats?), technology (wifi?), and service (seat reservations?) can improve services over time.
5. Granularity: unlike trains, buses can focus on very specific destinations within job centers. For instance, if there are two buses worth of demand at the same time going downtown from a given Park-and-Ride, those two buses could each focus on a different half of downtown, getting riders closer to their destinations faster with less circulation time. Bus size can also be adjusted to route demand, with smaller buses or vans serving less popular routes or times.

The Interstate 15 Express Lanes in San Diego, completed in 2012, is the most advanced managed lanes facility in the United States. See the appendix for more details about the project. Photo: San Diego Fastrak.

6. Policies are easily tuned over time to increase the number of people carried and their speed.
7. Ready for the future: easily adaptable for the coming wave of automated vehicles.

Affordable

8. More affordable than rail—both in capital and operating costs—especially if existing freeway lanes are converted.
9. Revenue generation from tolls to help cover costs.
10. Potential for private financing which stretches limited public taxpayer dollars further.

Public Benefits

11. More efficient use of right-of-way to move more people than a general-purpose lane bogged down with congestion.
12. Productivity: unlike driving, commuters can catch up on their 2.5 hours a day of email[5] riding express buses.
13. Environmental and congestion-relief benefits from shifting more people from single-occupant to high-occupancy vehicles. Eventually buses may be electric, natural gas, or hydrogen powered for emission benefits.

What is the maximum capacity of a MaX Lane?

The Lincoln Tunnel Exclusive Bus Lane in New York gives us a good benchmark, moving 1,850 buses with approximately 74,000 people during a typical morning rush hour (6 to 10AM) at an average speed of 35mph[6] (or 148,000 daily capacity). Even though that's a bus entering the tunnel every 8 seconds, it's not hard to imagine a future with autonomous single or double-deck buses (like Megabus or London buses) doubling or quadrupling[7] that capacity by driving at higher speeds safely while platooning closer together.

The Interstate 95 Express Toll Lanes in Baltimore, opened in 2014, feature high design standards with concrete barrier separation and full shoulders. Photo: AsphaltPlanet.ca.

3 Case Study: Houston

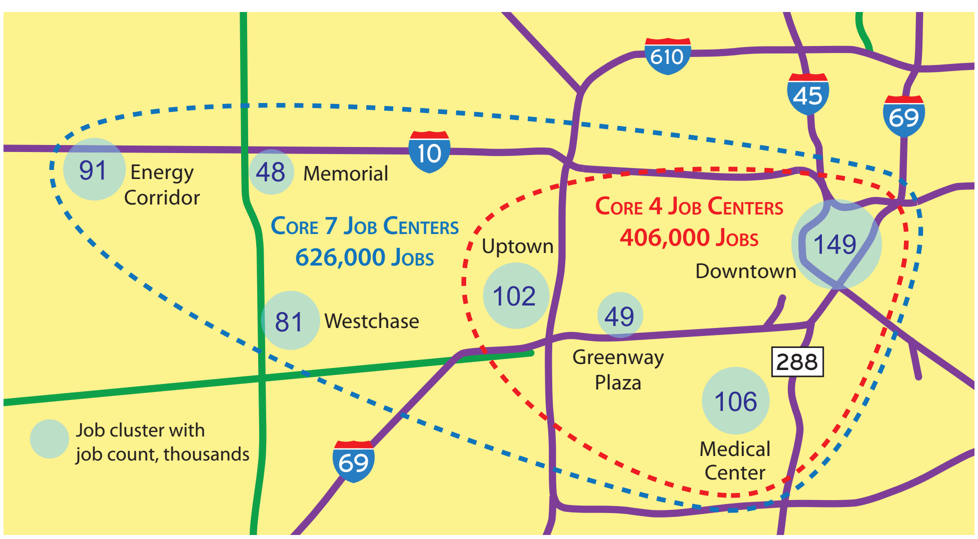
3.1 The Houston Challenge: Hollowing Out?

Houston's ongoing population growth and suburban expansion make it increasingly challenging to get workers from popular suburbs like Sugar Land, Katy, and The Woodlands to employers in core job centers like Downtown, Uptown, and the Texas Medical Center within a reasonable commute time (about an hour a day total[8]). Inrix estimates Houstonians spend 51.6 hours in congestion on average per year[9], while the Texas Transportation Institute estimates 61 hours of delay at an added cost of $1,490 per commuter per year[10]. Some major employers, such as Shell and ExxonMobil, have already abandoned core job centers for the suburbs to give their employees easier access to larger, more affordable homes in better neighborhoods with better schools—canaries in the coal mine that may be harbingers of a worrying "hollowing out" trend for the central city and its tax base. How can Houston continue job growth in the core and prevent more employers from leaving for the suburbs? Less than 7% of Houston's jobs are downtown[11], exacerbating the limited utility of any downtown-centric commuter rail solution.

3.2 Goal: MaX-A-Million

New York supports nearly two million workers in its Manhattan CBD[11] with a metro population of 20.2 million. As Houston grows from 6.8 to 10 million in the metro area over the coming decades, can it support one million jobs in its seven core job centers, or about half of a Manhattan? And can it build a MaX Lane network that can eventually support one million daily commuters?

Comparing Job Centers[11]	Employment
New York CBD	1,981,305
Houston Core 7 goal	1,000,000
Houston Core 7 now*	626,000
Chicago CBD	500,450
Houston Core 4 now	406,000
Washington DC CBD	379,215
San Francisco CBD	297,420
Boston CBD	242,900
Philadelphia CBD	239,625
Houston Downtown[12] (Core 4 & 7)	149,000
Los Angeles CBD	136,585
Houston Med Center[13] (Core 4 & 7)	106,000
Houston Uptown[14] (Core 4 & 7)	102,000
Houston Energy Corridor[15] (Core 7)	91,000
Houston Westchase[16] (Core 7)	81,000
Houston Woodlands[17]	64,365
Houston Greenway[18] (Core 4 & 7)	49,000
Houston Memorial City[19] (Core 7)	48,000



This map shows Houston's core 4 (inside red dashed line) and core 7 job centers.

* Total Houston metro area employment is approximately 3 million[20], so Houston's seven core job centers represent about 21% of the area's total employment. For comparison, Manhattan has 2 million jobs out of 9.5 million[21] in the New York metro area, matching that 21% ratio. Houston and New York are doing equally well holding on to jobs in the core while using different mobility strategies—freeways and rail, respectively.

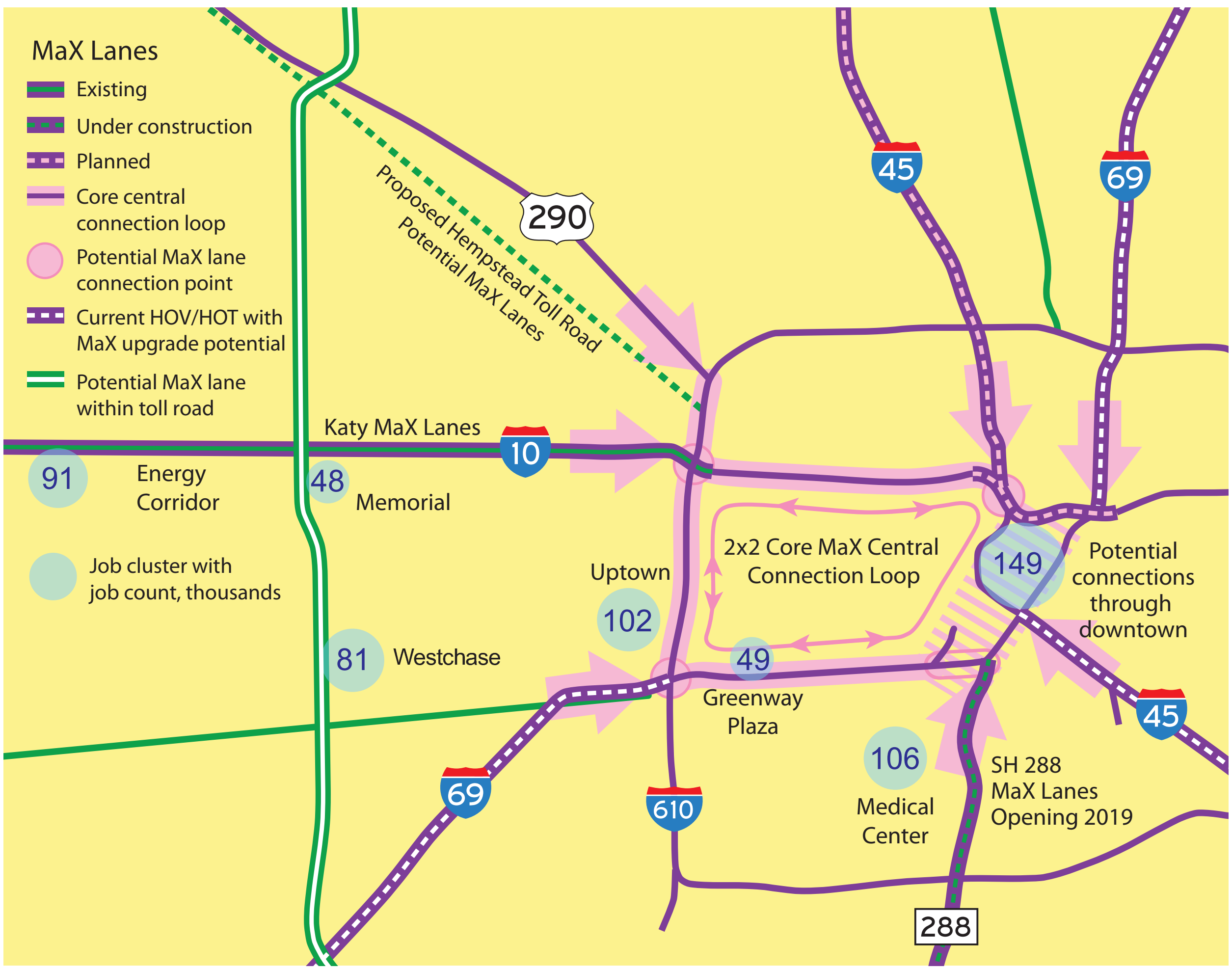
3.3 Proposed Solution: Core MaX

Our proposed solution focuses on a 2x2 bidirectional core MaX Lane network that connects the four major job centers in central Houston (six if you include the Katy Freeway managed lanes). As current or future HOV or MaX Lanes on spoke freeways are connected to this core network, commuters on those spokes are automatically linked to all of those job centers.

3.4 Capacity Estimates vs. Goal

For reference, right now the Katy Freeway MaX lanes (2x2) are generally running near capacity during peak periods and are reporting 37,776 vehicles per day (both directions) at its busiest point with 38% HOV. Weekday boardings on Metro's site for buses is 9,405. If you assume 2.2 people per HOV, that's 9,405 + 31,580 + 23,421 = 64,407 daily trips, or around 32,200 people—a bit less than half of the 74,000 people moved by the Lincoln Tunnel Exclusive Bus Lane. As demand increases over the coming decades, more of that Katy capacity will need to dedicated to buses rather than cars to get closer to the Lincoln Tunnel benchmark (and/or autonomous technology will need to allow tighter spacing at higher speeds).

Currently or in the near future, a total of 9 potential MaX Lanes can come into the core: two each on 288 and 10W, and one each on 69S, 69N, 45N, 45S, and 290. Longer term, 69S and 45N, could go from 1 to 2, 290/Hempstead could add 2, and 10E could add one, bringing the total up to 14 MaX Lanes of capacity into the core. If we use the 74,000 commuters per day Lincoln Tunnel benchmark, that's a maximum



This map shows how the Core MaX Central Connection Loop will connect the MaX lanes approaching Houston from all directions, providing the interconnected MaX lane network with access to multiple job centers.

capacity increase from 666,000 commuters to 1.04 million commuters, achieving our MaX-a-Million goals. And it's worth noting the Lincoln Tunnel benchmark is without any autonomous platooning, higher speeds, or double-decking of buses, all of which could stretch it higher or keep it the same while still allowing room for SOV and HOV cars.

3.5 Challenges and Issues

Design and Engineering

3.5.1 Interconnections: Can innovative and cost-effective ways be found to interconnect MaX Lanes, especially spokes to the Core MaX network? Traffic circles may be worth considering, especially if we assume an all-autonomous future where safety and speed will be more easily maintained through the circles.

3.5.2 Planning: How should current TXDoT plans be modified to support MaX Lanes, especially the Core MaX network? In particular, the West Loop express lanes and plans to rebuild the downtown freeways.

3.5.3 Conversions: Can and should free lanes be converted to MaX Lanes if they'll move more people faster? What about HCTRA's existing tolled lanes? The west side of Beltway 8 is a particularly good candidate for left lane conversions. Converting free lanes would require legislation as well as public support, so conversions may need to be deferred until after initial MaX Lanes have proven effective and popular.

Policy and Management

3.5.4 Oversight: Clear agency responsibilities are needed among TxDOT, METRO, HCTRA, CoH, H-GAC, management districts, and others—including setting MaX Lane policies. How can we ensure a good system is put in place for evaluating, implementing, monitoring, and adjusting policies to meet the goal of moving the maximum number of people at maximum speed? (including transit vs. single-occupant vehicles)

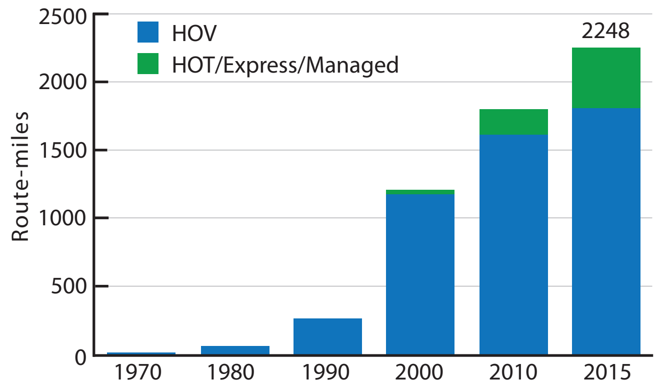
3.5.5 Public vs. Private Operators: Consideration should be given to public vs. private bus operators as well as Park & Ride lots. Could private bus operators use METRO's lots? Could underutilized private lots —like malls and large churches—be used for Park & Ride service? Should METRO use its tax increment to subsidize private commuter bus services on a per-passenger-mile basis and incentivize more commuters out of their cars? Could management districts offer services to their job centers?

Cost and Financing

3.5.6 Public vs. Private: Private funding, typically via public-private partnerships, requires sufficient revenue to achieve a profit, emphasizing toll-paying single-occupant vehicles and limiting or precluding transit and HOV.

Appendix contributed by Oscar Slotboom*

The inclusion of lanes which provide premium, higher-speed travel during peak periods has become a standard feature of urban highway expansions in the United States. With tremendous growth in the 1990s, HOV (high occupancy vehicle) lanes are now commonplace, most often as concurrent flow carpool lanes, widely used in California, and also as reversible, barrier-separated lanes, which are widely used in Houston. As of the end of 2015, there were 2248 route-miles (also called centerline miles) of HOV and managed lanes, with 4473 lane-miles.[22]

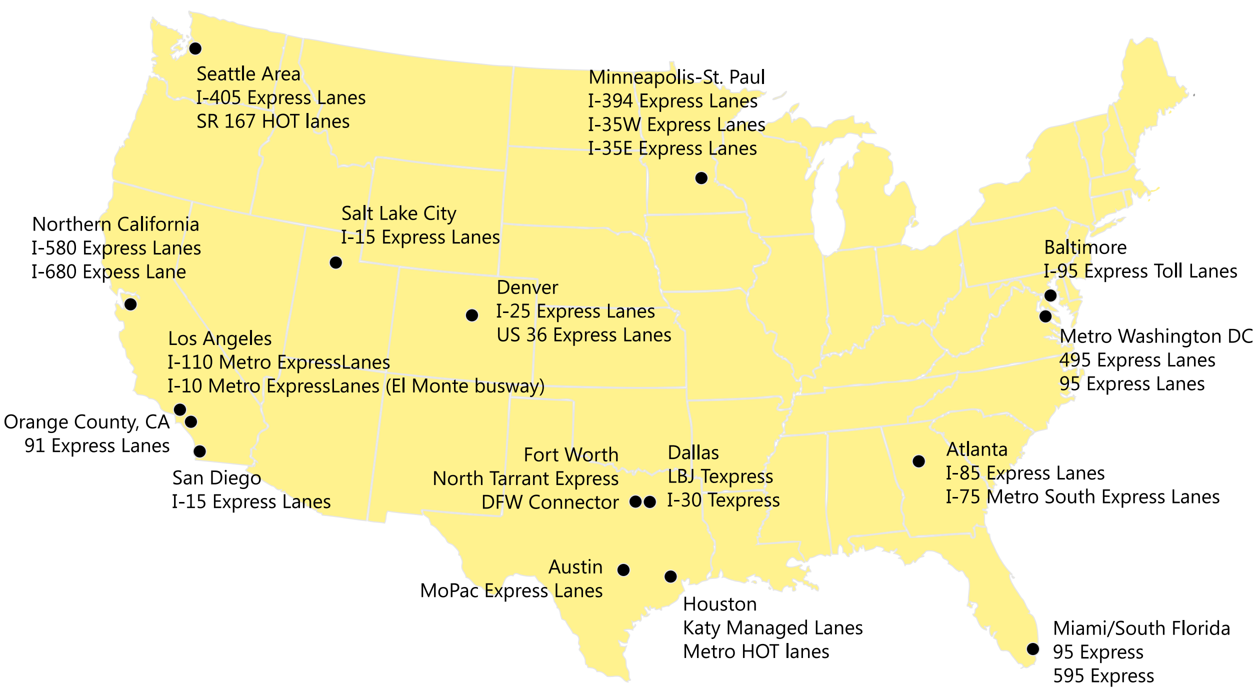


Data: Chuck Fuhs and Texas A&M Transportation Institute

A review of the nation's inventory of these managed lanes (including both HOV and HOT/express/managed) in 2016 provided the following findings[22]

- 21 states operate managed lanes on freeways
- A total of 32 metropolitan areas operate managed lanes
- Between 2010 and 2015, route-miles increased 25%
- Tolled express lanes are 19% of total route-miles

The map below shows a non-comprehensive listing of operational tolled managed lanes in 2016.



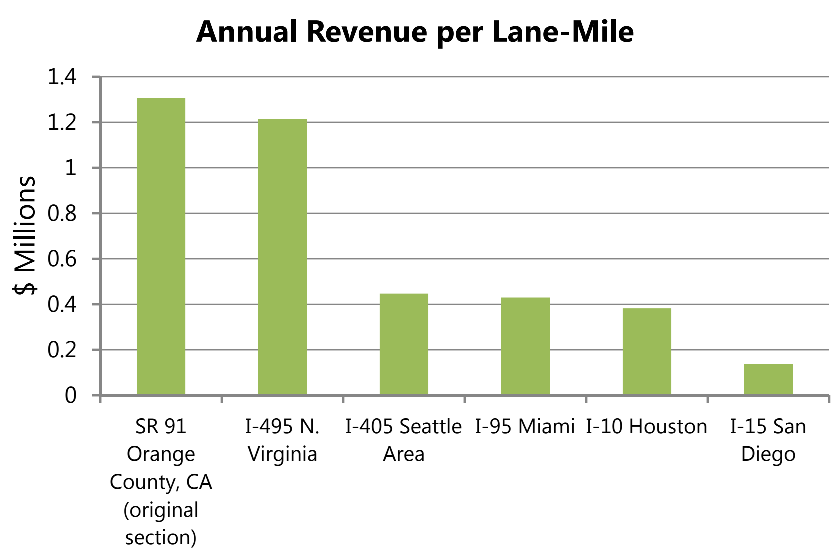
While all managed lanes are intended to provide high-speed service during peak congestion, the characteristics of managed lanes vary widely due to the specific features of projects relating to financing, management, engineering , design standards and service objectives.

* Oscar Slotboom is author of the books *Houston Freeways, A Historical and Visual Journey* (2003) and *Dallas-Fort Worth Freeways, Texas-Sized Ambition* (2014). He operates the web sites HoustonFreeways.com and DFWFreeways.com.

		Examples/Characteristics
Financing	Public	I-15, San Diego, $1.4 billion I-10, Houston, $2.7 billion (entire project, incl. regular lanes) I-95 Miami, $234 million (phase 1)
	Public-private partnerships	I-495 Northern Virginia, $2 billion I-635 Dallas, $2.6 billion (including rebuilding regular lanes) North Tarrant Express, Fort Worth, $1.15 billion (phase 1) I-595, Fort Lauderdale, $1.2 billion (overall cost $1.8 billion)
Lower-cost projects tend to be fully financed by public transportation agencies, but funding-challenged transportation agencies, especially in Texas, Florida and Virginia, have turned to public-private partnerships to get big, expensive projects built.		
Objective and management	Promote carpooling and transit	2+ carpools free use Connectivity to transit centers
	Provide SOV commute alternative and generate revenue	In most systems, tolls are dynamically adjusted to maintain a minimum speed
	Profit	No discount for carpools Maximize toll rates for profit
There is normally a trade-off: the more carpooling is encouraged, the less revenue is generated. In general, publicly financed projects are more friendly to carpooling and transit, while public-private partnerships have financial obligations to meet, and therefore seek to maximize revenue and profit.		
Design standards and construction cost	Low	No shoulders on managed lanes and adjacent regular lanes; non-barrier separation with pylons or striping; direct access from adjacent regular lanes only; narrow lanes
	High	Barrier separation, full shoulders, direct access to transit centers, standard width lanes
Many projects can be implemented “on-the-cheap” by using low standards, converting existing HOV lanes, or having favorable design conditions such as medians. These projects can have a cost around $10 million per route mile. Higher standards and situations which are not amenable to low-cost construction can be far more expensive, up to $100 million per route mile and higher.		

This plot shows how toll revenue can vary widely based on the project’s specific circumstances and objectives. Lane-mile revenue leader SR 91 in Orange County, CA, benefits from high demand and a market which can sustain high tolls, while providing free use for 3+ HOV. The 495 Express Lanes in Virginia, a mostly privately financed project, emphasizes profit and revenue over carpooling and transit. Most other managed lanes are free to 3+ carpools only, and privately operated facilities may provide no preferential treatment for carpools.

The Interstate 15 Express Lanes in San Diego are intended and managed to promote transit and ridesharing, allowing free access to 2+ carpools. During peak periods, only 20% of vehicles are toll-paying single-occupant vehicles. Houston also allows free use for 2+ carpools

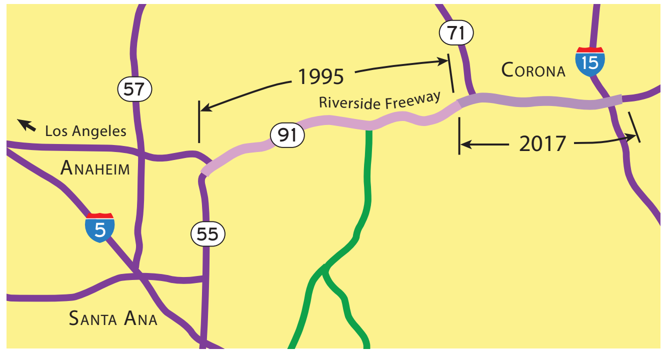


Data: project annual reports, web site data, data supplied by agencies

91 Express Lanes

California 91, Orange County, California

The first managed lanes in the USA, and the most financially successful

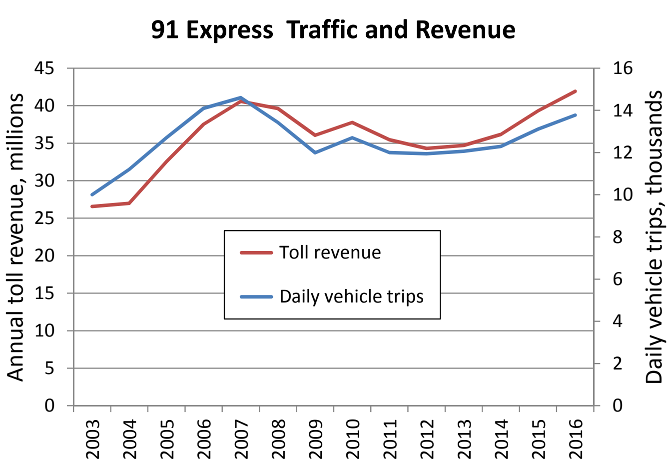


Opened	1995, 10 miles; 2017, 8 mile extension
Lanes	2x2
Length	18 miles
Cost	$126 million (original); $1.4 billion for 2017 extension with regular lane improvements
Financing	Originally 100% private; purchased by public entity in 2002; 2017 extension public
Design	Low-to-medium standards with no shoulder and pylon separation
Objective	SOV alternative and promote carpooling
Toll Policy	Fixed with peak-hour premium rates

The 91 Express Lanes on SR 91, the Riverside Freeway, was the first managed-lane facility in the United States and is the most successful in terms of traffic and revenue. It was originally a privately financed and operated project, with 10 miles opening in 1995 at a cost of $126 million. It was the first all-electronic toll facility in the United States, featuring four new lanes in the median of the freeway, although limited space precluded an emergency shoulder on the express lanes and eliminated the interior shoulder of the main lanes.[23]

In the early 2000s traffic congestion on the regular lanes of SR 91 remained a serious issue, but non-complete clauses in the toll agreement prevented improvement to the regular lanes until 2030. To eliminate the non-complete clause, the Orange County Transportation Authority in 2002 agreed to purchase the toll lanes for $207.5 million, taking over the facility in January 2003.[24]

Traffic and revenue steadily increased until 2007, reaching a plateau due to the Great Recession. In 2016 the 91 Express lanes reported annual revenue of $52 million ($42 million in toll revenue) with traffic volume of 13.7 million. By 2016 OCTA had distributed $29 million in excess revenue to highway and transit projects in the corridor. In March 2017 the managed lanes were extended 8 miles eastward into Riverside County in a $1.4 billion project which also added regular lanes.



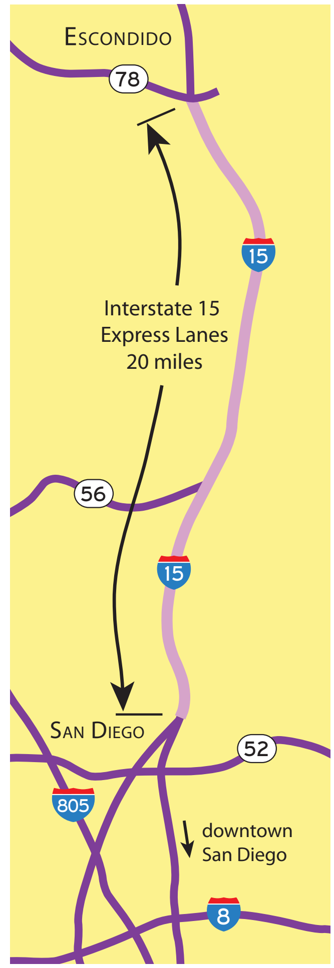
Data: OCTA annual reports

Orange County Transportation Authority

I-15 Express Lanes

Interstate 15, San Diego, California

The most advanced managed lanes, with a movable center barrier and fully integrated with transit



The most advanced managed lane facility in the United States is the 20-mile-long Interstate 15 Express Lanes in north San Diego. The facility includes four lanes with a movable center barrier, allowing the lanes to be configured to have three lanes in the peak direction. Other highlights include five direct access ramps, 16 additional access points and transit stations directly integrated into the managed lanes with bus rapid transit.[25]

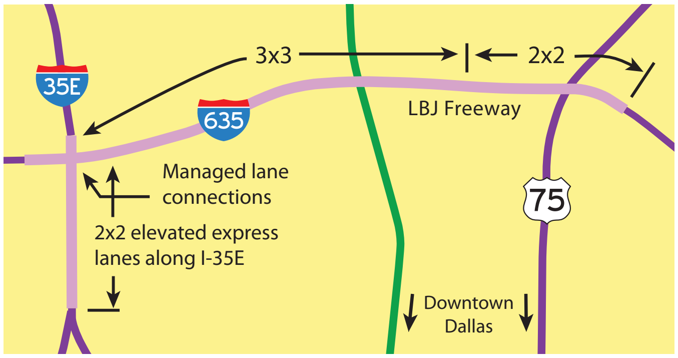
The managed lanes originally opened in 1988 as a reversible, two-lane HOV facility. The managed lanes were expanded to their current configuration between 2008 and 2012 in a $1.4 billion project. The main objective of the managed lanes is to promote transit and carpooling, with free access for 2+ carpools, vanpools, motorcycles, and permitted clean air vehicles. With its transit and carpool emphasis, the managed lanes have only 20% single-occupant vehicles during peak periods, with 46,700 vehicles per weekday just south of State Route 56. With the low percentage of toll-paying single occupant vehicles, the I-15 Express Lanes generate less revenue than comparable facilities, $9.6 million annually in 2015.[26]

Opened	Original 2-lane reversible lanes: 1988; Managed lanes: 2008 to 2012
Lanes	4, configurable as 2x2 or 3x1
Length	20 miles
Cost	$1.4 billion for upgrading to 4 managed lanes
Financing	Public
Design	High standards with barrier separation, a movable center barrier, many access points and integration with local transit
Objective	Carpooling and transit service
Toll Policy	Real-time dynamic

San Diego Fastrak

LBJ Texpress Lanes Interstate 635 Lyndon B. Johnson Freeway, Dallas, TX

The most impressive engineering and design for managed lanes in the USA



The facility with the most complex and expensive design features is the LBJ Texpress managed lanes on Interstate 635 in north Dallas. The project generally has 3 managed lanes in each direction in a trench underneath the main lanes, with typically half of the regular main lanes on a bridge structure over the trench. Another section along Interstate 35E features long elevated structures, and the interchange at Interstates 635 and 35E includes direct connections between the managed lanes. The project included the reconstruction of the eight regular traffic lanes on Interstate 635 and improvements to the frontage roads.

Opened	Three phases, 2013 to 2015
Lanes	3x3 and 2x2
Length	12 miles
Cost	$2.6 billion, including reconstruction of 8 regular lanes on Interstate 635
Financing	Public-private partnership with investor funds, public funds and TIFIA loan
Design	Very high standards with full separation of managed lanes and dedicated connections
Objective	Profit
Toll Policy	Real-time dynamic

A public-private partnership was used to construct the $2.6 billion project. Like the engineering design, financing was also complex, with funding coming from four main sources, including an $850 million loan from the U.S. Department of Transportation's Transportation Infrastructure Finance and Innovation Act (TIFIA), $490 million from the Texas Department of Transportation, $664 million from investor funds and $615 million from private activity bonds.[27]

Since the LBJ Texpress is a for-profit facility, local government funds are used to subsidize discounts for carpools. The project management reported strong revenue after a year of full operation, $20 million in Q3 2016 and $21 million in Q4 2016. The LBJ Texpress lanes are positioned to become the highest-grossing managed lanes facility as traffic grows.[27]

The managed lanes are underneath the Interstate 635 main lanes.

Elevated express lanes along Interstate 35E.

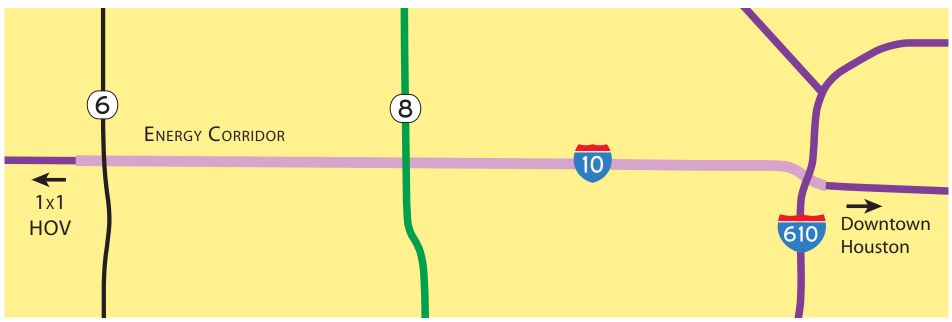
Katy Managed Lanes

Interstate 10 Katy Freeway, Houston, TX

Four managed lanes serve Houston's Energy Corridor

Through the 1980s and 1990s, Houston had a program of adding one-lane reversible, barrier-separated transitways to most of its radial freeways. Houston entered the managed lane era in grand style with the Katy Managed Lanes, included in the $2.7 billion corridor expansion completed in 2008.

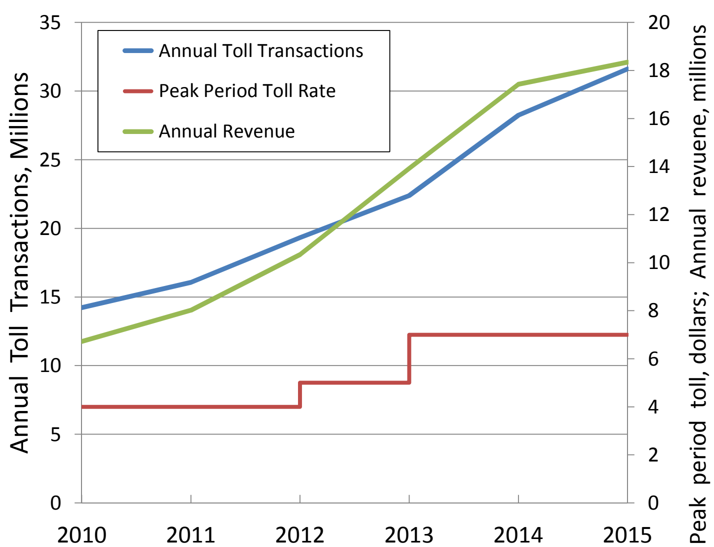
The managed lanes have been a success, running at capacity during peak periods, with the freeway among the busiest in the United States with 375,000 vehicles per day at its busiest point in 2015.[30] The Katy Freeway serves Houston's Energy Corridor, with its concentration of employers in the oil and gas industry, and the sprawling western suburbs.



2016 Data[29]		
	Average weekday traffic, busiest point	38,600 vehicles/day
	Percent HOV at peak period	38%

Opened	2008
Lanes	2x2
Length	12 miles
Cost	Included in a $2.7 billion major corridor expansion, including new regular and frontage road lanes
Financing	Public, including a contribution from the Harris County Toll Road Authority
Design	High standards with full shoulders on the regular and managed lanes.
Objective	Promote carpooling and transit
Toll Policy	Fixed with peak hour premium rates

Katy Freeway Managed Lanes Revenue Growth



Data: Harris County Toll Road Authority annual reports[28]

95 Express Lanes

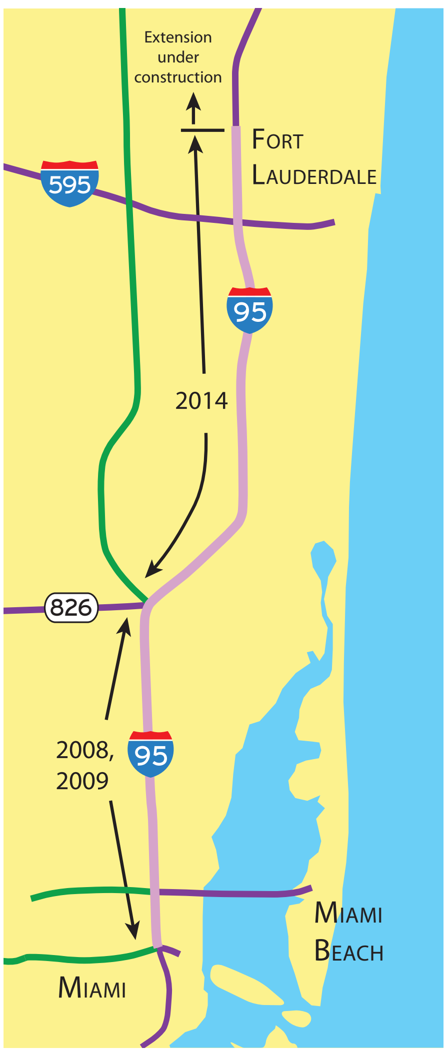
Interstate 95, Miami to Fort Lauderdale, Florida

By using using low standards, managed lanes were created quickly at a relatively low cost

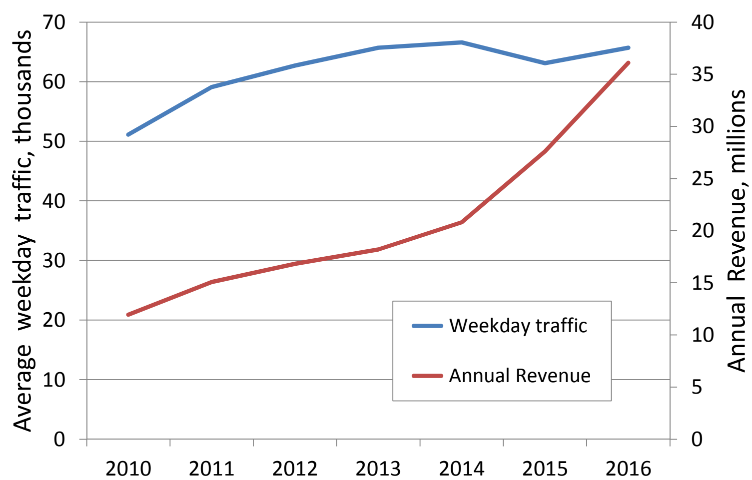
Opened	Phase 1, 10 miles: 2008-2009 Phase 2, 14 miles: 2014
Lanes	mostly 2x2 with some 1x1 sections
Length	24 miles
Cost	$234 million
Financing	Public
Design	Low standards with no shoulder, narrow lanes and narrow pylon separation
Objective	SOV alternative, carpooling
Toll Policy	Real-time dynamic

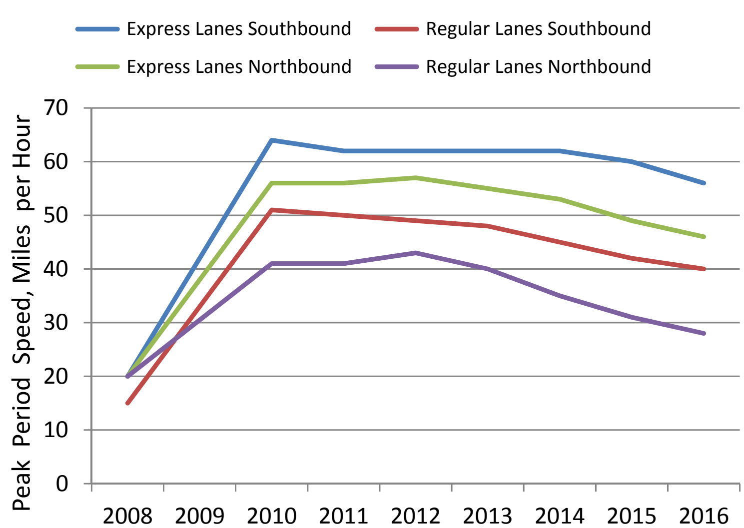
The 1x1 HOV lane facility on Interstate 95 in South Florida was converted to 2x2 managed lanes by making the interior shoulder a traffic lane and narrowing the existing regular lanes. The regular and managed lanes are separated by a thin strip of pylons, which have required high maintenance. Usage is high with 33% of total traffic using the managed lanes at peak periods, and use averaging 25% on weekdays and 19% on weekends.[31]

After the initial opening, the 95 Express Lanes reported huge improvements in average peak period traffic speeds. Prior to the express lanes, peak period speeds averaged 20 mph in both directions of the HOV lanes, 15 mph in the regular southbound lanes, and 20 mph in the regular northbound lanes. After the express lanes opened, speeds improved to 62 mph in the southbound express lanes, 56 mph in the northbound express lanes, 51 mph in the southbound regular lanes, and 41 mph hour in the northbound regular lanes. However, these gains have diminished (see chart) with the regular southbound lanes at 40 mph and the regular northbound lanes at 28 mph in 2016.[32]



95 Express Traffic and Revenue





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