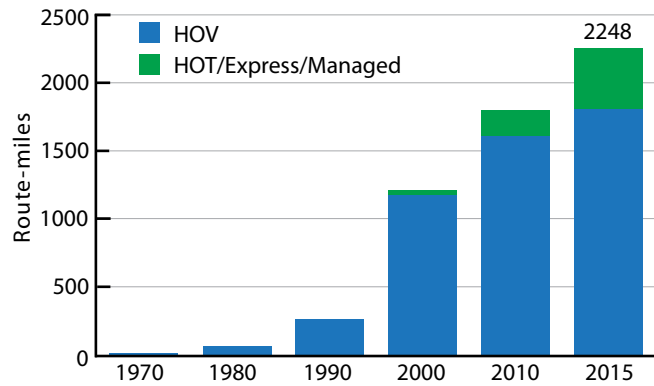


Appendix contributed by Oscar Slotboom*

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

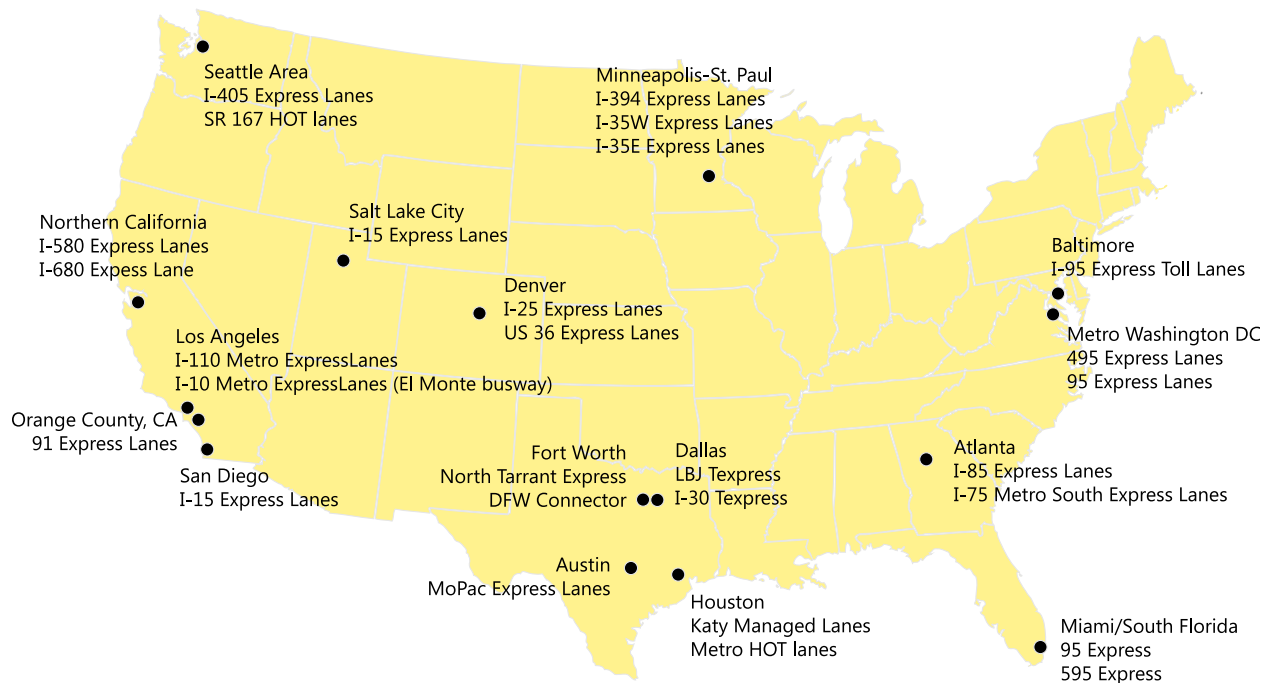


Data: Chuck Fuhs and Texas A&M Transportation Institute

A review of the nation's inventory of these managed lanes (including both HOV and HOT/express/managed) in 2016 provided the following findings²²

- 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.

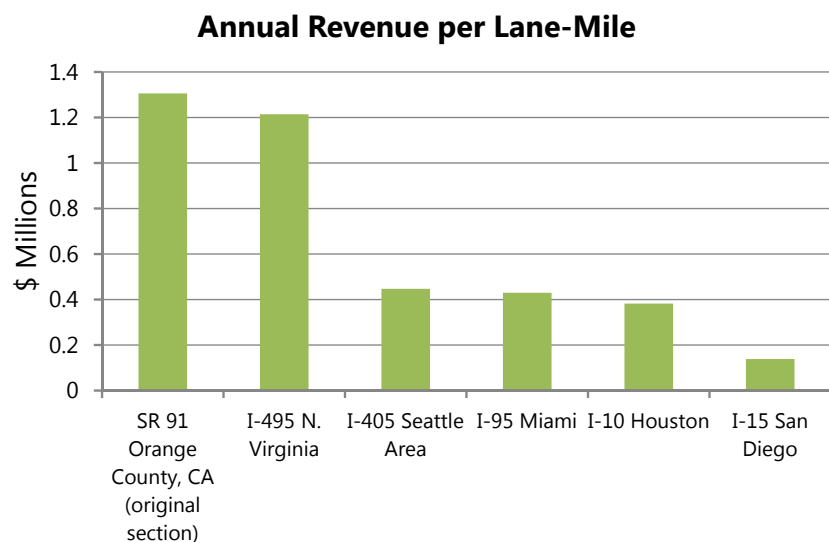
* Oscar Slotboom is author of the books *Houston Freeways, A Historical and Visual Journey* (2003) and *Dallas-Fort Worth Freeways, Texas-Sized Ambition* (2014). He operates the web sites HoustonFreeways.com and DFWFreeways.com.

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

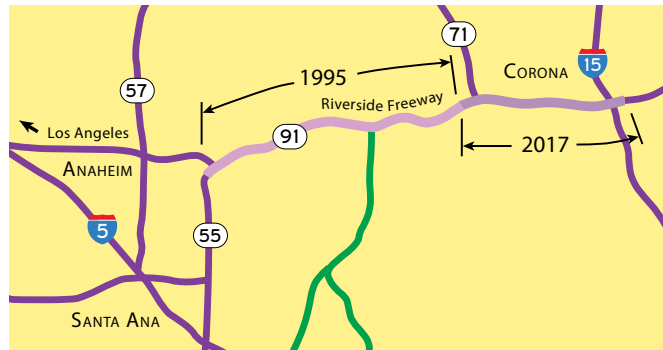
The first managed lanes in the USA, and the most financially successful

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

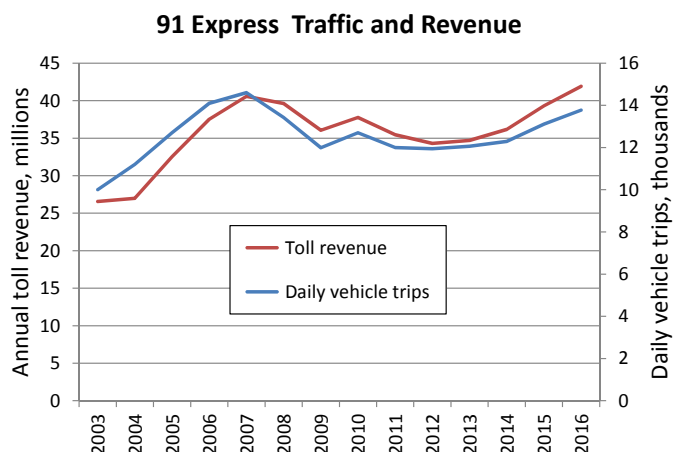
In the early 2000s traffic congestion on the regular lanes of SR 91 remained a serious issue, but non-complete clauses in the toll agreement prevented improvement to the regular lanes until 2030. To eliminate the non-complete clause, the Orange County Transportation Authority in 2002 agreed to purchase 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.

California 91, Orange County, California



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



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

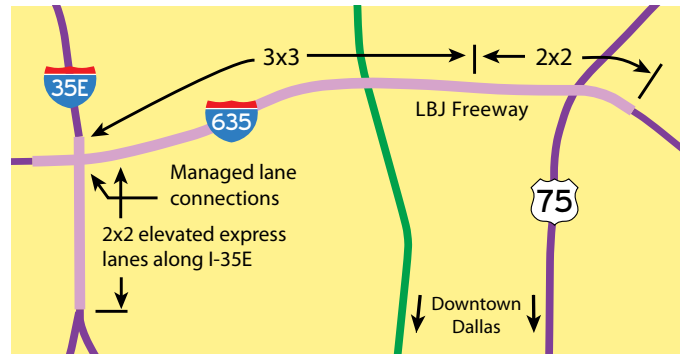
Interstate 635 Lyndon B. Johnson Freeway, Dallas, TX

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.

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



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



The managed lanes are underneath the Interstate 635 main lanes. Elevated express lanes along Interstate 35E.

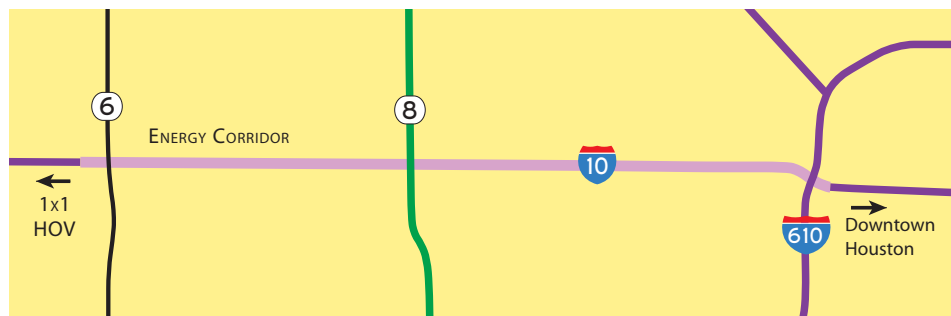
Katy Managed Lanes

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.

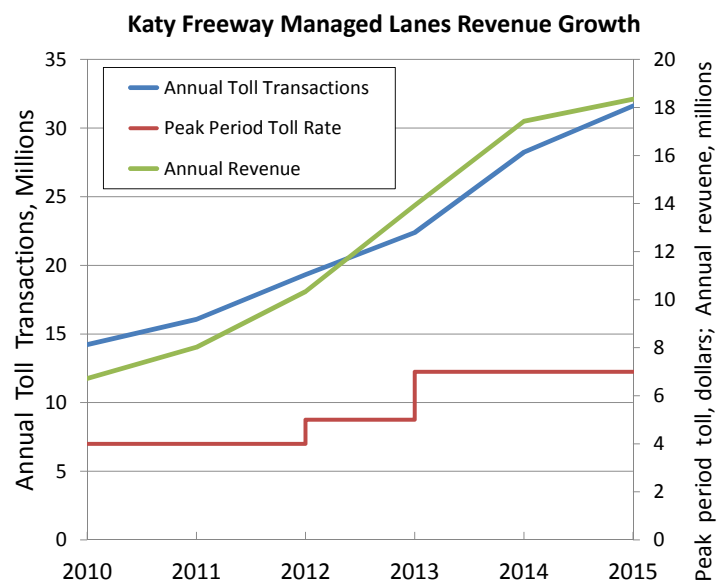
The managed lanes have been a success, running at capacity during peak periods, with the freeway among the busiest in the United States with 375,000 vehicles per day at its busiest point in 2015.³⁰ The Katy Freeway serves Houston's Energy Corridor, with its concentration of employers in the oil and gas industry, and the sprawling western suburbs.



2016 Data²⁹

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



Data: Harris County Toll Road Authority annual reports²⁸

95 Express Lanes

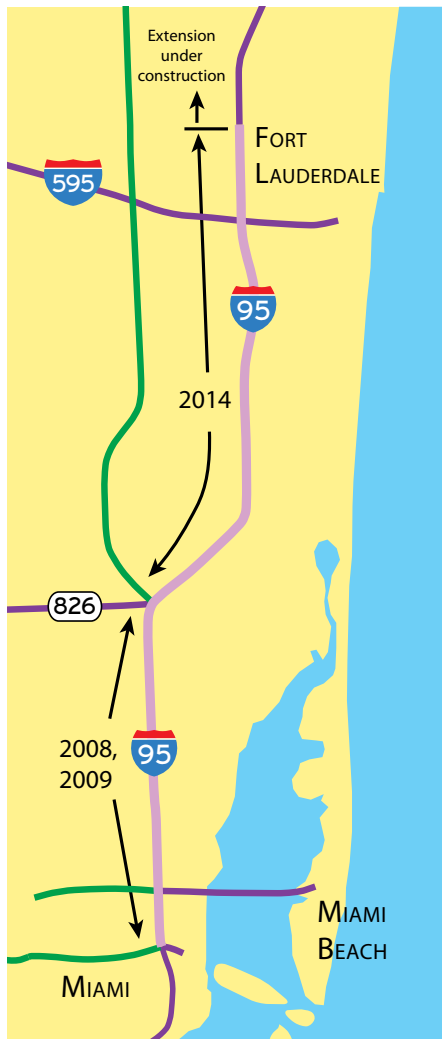
Interstate 95, Miami to Fort Lauderdale, Florida

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

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

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



95 Express Traffic and Revenue

