Design and Operational Challenges Associated with Managed Lanes

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Editor's Note: This article is based on the presentation "Active Management 101: Techniques for Making Managed Lanes Work," given at the IBTTA Annual Meeting & Exhibition in Dallas, Texas, in September 2006.

Transportation agencies today face the growing challenges of traffic congestion coupled with real limitations to major freeway expansion. Rising construction costs, right-of-way constraints, and environmental and societal impacts all hinder freeway expansion as a way to address growing travel needs in congested urban areas. As a result, transportation officials are exploring the use of "managed lanes" to address mobility needs in freeway corridors, particularly as a way to offer travel choices on congested facilities where major expansion has limited feasibility.

The managed-lanes concept, which is gaining interest in the United States, employs operational strategies that manage travel demand and potentially improve transit and other forms of ride sharing. These operational aspects combine with unique design elements to improve the efficiency of freeway facilities. These same design and operations features, however, involve some unique conditions. With little on-the-ground experience, toll operators may need general guidance in developing effective managed-lane projects.

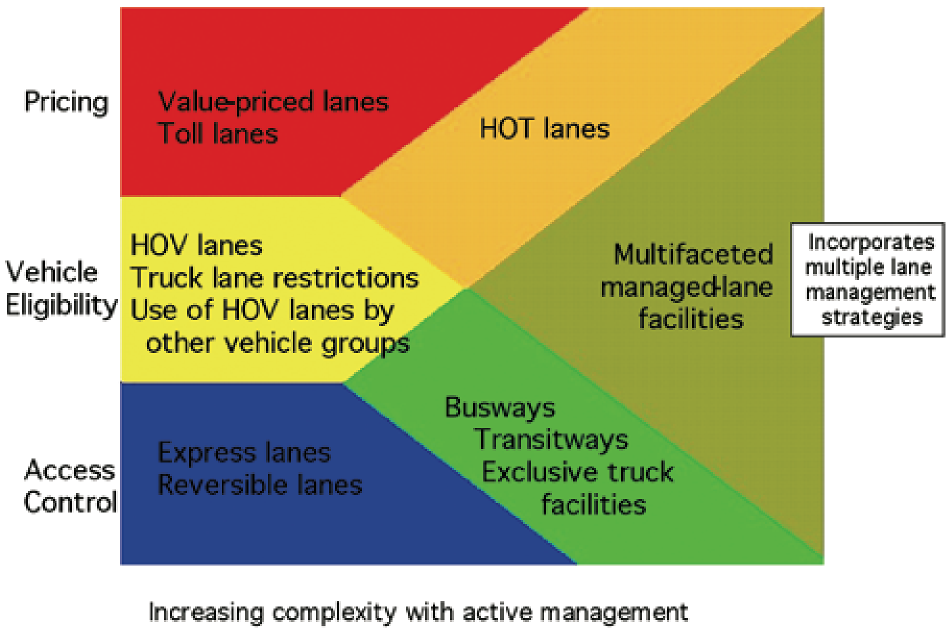
The information presented below is based largely on the Texas Department of Transportation's comprehensive managed-lanes research program, which is supporting the development of more than a dozen projects in Texas's major metropolitan areas.

Defining "Managed Lanes"

The term "managed lanes" is increasingly being recognized in the transportation profession, although it has different meanings depending upon the agency. In some agencies, managed lanes are commonly thought of as high-occupancy toll (HOT) lanes—facilities that employ pricing and vehicle eligibility requirements to maintain free-flow conditions while providing high-occupancy vehicle (HOV) preference. In other agencies, a broader definition of managed lanes is customary in which various management tools and techniques are combined to improve freeway efficiency and meet certain corridor and community objectives. This broader definition includes HOV lanes, HOT lanes, express toll lanes, and exclusive-use lanes such as bus-only or truck-only lanes.

Figure 1 illustrates the potential lane-management applications that fall into this broader definition of managed lanes. On the left of the diagram are applications of a single lane-management strategy: pricing (varying pricing by the level of congestion in the lanes), vehicle

Figure 1: Managed-Lane Strategies



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eligibility (allowing certain vehicles access to the lanes), and access control (limiting physical access to the lanes). Moving to the right through the diagram, the graphic illustrates more-complicated managed-lane facilities that blend one or more of these strategies. The more a particular facility blends different strategies—and the more it does so by time of day, day of week, or minute by minute—the more operational flexibility it seeks and the greater the technical challenges of implementing the project.

Active Management and the Role of Variable Pricing

Lane-management strategies such as access control and vehicle eligibility have been used for decades to improve flow on freeways. The distinction between managed lanes and other traditional forms of lane management lies in the operating philosophy of "active management." Under this philosophy, an operating agency actively manages demand and available capacity on a facility to achieve predefined performance objectives. Those performance objectives can be specified in terms such as average speed, lane volume, travel-time savings, number of people moved, and revenue generated. For example, an operating agency may define an average operating speed of 50 miles (80 kilometers) per hour as a managed-lanes performance standard and apply lane-management strategies accordingly to avoid dropping below that threshold.

The role of variable pricing is critical to the premise of active management in the dynamic sense, as it is the only demonstrated method used on current U.S. HOT lanes for adjusting flow based on prevailing conditions in the lanes. Other lane-management strategies, such as HOV preference and access control, haven't been applied in the field on a dynamic, real-time basis as variable pricing has. Hence, priced managed lanes such as HOT lanes and express toll lanes (ETLs) are typically viewed as the most actively operated form of managed lanes now under development.

While priced managed lanes offer the greatest potential benefits for optimizing facility performance, they also pose the greatest risk, because of their limited application thus far in the United

LBJ Freeway in Dallas, Tex.
Courtesy Texas Transportation Institute

States from which to draw best practices. Several unique technical challenges influence the successful implementation of priced managed lanes, as outlined below.

Operating objectives. The first step in developing a priced managed-lanes project is to define the project's operating objectives. These objectives will guide all decisions regarding how the project is designed and operated.

Defining the project objectives is an element of the project development process, typically occurring during the preliminary engineering and environmental review, in which a high degree of public education and public discussion takes place on how the facility will operate and how any excess revenue will be used. Some of the questions the operating objectives should answer are:

- Who will be allowed to use the managed lanes?
- Who will receive toll exemptions or discounts?
- What kind of pricing schedule will be used: dynamic or fixed time-of-day pricing?
- What is the operating threshold and how is it defined (for example, operating speed)?
- What happens when the operating threshold is exceeded?
- How will price be communicated to motorists?
- Where will access to the managed lanes be allowed?
- Will the facility operate differently in peak versus off-peak periods?
- What is the policy for operating the facility in the event of a major incident or emergency situation?

An example of a policy that defines managed lanes on a regional basis is the Dallas–Fort Worth Managed Lanes Policy developed by the North Central Texas Council of Governments. Through public discussion and approval by its local policy board, the Dallas–Fort Worth region has devised a set of policies and criteria that helps guide the development of managed-lanes projects, particularly those involving private-sector involvement.

Lane separation. Managed lanes can be separated from adjacent general-purpose lanes using three general techniques: concrete barriers, painted buffers, or buffers with channelizers (such as plastic delineator sticks). A limited amount of research has been conducted on the trade-offs associated with these methods. One study conducted by the Texas Transportation Institute (TTI) to examine the effectiveness of concrete barriers versus painted buffers in the Dallas area received national media attention in 2005. The study evaluated barrier-separated and buffer-separated HOV lanes in the region and compared crash statistics before and after the HOV lanes were implemented. (An important side note to consider is that the HOV lanes without barriers are interim facilities and were incorporated into the existing freeway cross section with minimal shoulder and buffer widths.)

The study found a substantial increase in injury-causing (nonfatal) crash rates after HOV lane implementation on those facilities without physical barriers. Among the factors contributing to the increase were the level of traffic congestion, the reduced cross section, and the high speed differential between the HOV lanes and the adjacent general-purpose lanes. For all future HOV or managed lanes in Dallas, it was recommended that where a barrier is infeasible, a minimum 10-foot shoulder and 4-foot buffer should be used.

Some might conclude from this research that all barrierless facilities are unsafe, which was not the finding. The experience of the I-394 MnPASS project in Minnesota, for example, has shown that a HOT lane can operate successfully with a painted buffer. Determination of the appropriate lane-separation technique is project-specific and should involve a thorough review of the trade-offs associated with alternative treatments.

Access design. Vehicles may enter a managed-lanes facility at the beginning or, in most cases, at some point along the lane. Correspondingly, vehicles traveling the facility may exit at the end or at other egress locations. The type of access provided will depend on the nature of the managed lanes, the objectives of the project, land uses and origin–destination patterns in the corridor, available rights of way, and funding.

In most cases, the same geometric criteria should be applied as would be used for a freeway ramp. Grade-separated access ramps are desirable and should be considered when the anticipated volume

I-15 managed lanes, San Diego
Courtesy San Diego Association of Governments

Katy Freeway, Houston, Tex.
Courtesy Texas Transportation Institute

attempting to access a managed-lanes facility exceeds 275 vehicles per hour. These ramps are especially beneficial where high volumes are anticipated or where additional time savings and operational efficiencies can be gained from their use.

The use of at-grade access treatments, also sometimes referred to as slip ramps or midstream access, are less optimal than direct access ramps unless the operational integrity of the managed lanes and general-purpose lanes can be maintained. Relatively long, 2- to 3-mile (3.2- to 4.8-kilometer) spacings between access points for the general-purpose lanes may allow for successful weaving maneuvers for at-grade access treatments.

The Texas Department of Transportation (TxDOT) comprehensive managed-lanes research program examined weaving distances through more than 2,000 simulation model runs and recommended various minimum weaving distances between managed lanes and freeway ramps. For example, under heavy congestion, a weaving distance per lane of 900 feet (275 meters) is suggested, which equates to approximately one-half mile for a vehicle to enter at a freeway ramp and cross three general-purpose lanes to enter a managed lane.

Another design consideration for at-grade access treatments is the length of the access opening. Recent TxDOT research evaluated more than 8,300 videotaped vehicle access maneuvers on five facilities that included both HOV and HOT lanes. The objective of the research was to develop guidelines for allowing intermediate access to and from buffer-separated toll lanes. The result was the recommendation of a minimum opening length of 1,300 feet (396 meters), with 1,500 feet (457 meters) the optimal length. The study also revealed some interesting findings about the way drivers behave when accessing these facilities, the risks they take, and how the openings are occasionally used for passing slow vehicles.

Signage and driver information. Variable tolls based on occupancy or time of day with dynamic pricing based on current conditions can result in complex toll schedules. Conventional toll roads often have a full menu of prices posted at toll plazas. With vehicles moving at slower speeds, and in most cases completely stopped, it is safe to present this large amount of information. But with multifaceted managed lanes using electronic toll collection at high speed, it becomes dangerous to overload drivers with complex toll rules in addition to information on allowable vehicles, number of occupants, hours of operation, method for electronic toll payment, access points, and travel time saved.

Providing adequate information for managed-lane users can be a challenge in a freeway environment that may already be overwhelmed with visual clutter. Some of the techniques that can be used to improve communication to users of managed lanes are as follows:

- Use banners, plaques, symbols, or color to differentiate signs with managed-lane information from other freeway signage.
- Place managed-lane signs on their own structures, distinct from freeway signage structures, to visually separate information for managed-lane users.
- Early in the development process, define the primary users of the managed lanes and design for them specifically. For example, if the facility is designed for familiar drivers who are daily users, they would need to know only current traffic conditions and would need relatively little information about specifics such as the location of access points or hours of operation.

For the complex operations posed by managed lanes, planners may have to accept that "one big sign" is not appropriate. With a subscription-based system of users, it is possible to communicate to subscribers through the mail or other means the basic geometric and operations information that wouldn't then be necessary to convey on a sign. Designers, meanwhile, should pay close attention to managed-lanes signage early on in the process to strike a balance between providing enough information (including the type of transponder users need) and providing too much.

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Enforcement. Enforcement of managed lanes involves four elements:

- Verification of proper toll collection;
- Confirmation of use by authorized vehicles (for example, certain-size vehicles may be disallowed);
- Enforcement of motor vehicle laws and traffic regulations (including those pertaining to speeding and illegal

buffer crossings); and

- Compliance with vehicle-occupancy requirements.

Automated enforcement of proper electronic toll payment has been proven possible through violation enforcement systems (VES) technology. Enforcement of use by authorized vehicles and adherence to traffic regulations, meanwhile, can be performed by periodic, random law enforcement patrols. The enforcement of vehicle-occupancy requirements as specified on HOT lanes, however, poses the greatest challenge of all of the managed-lane enforcement tasks.

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Transportation agencies enact toll exemptions or discounts for carpools in managed lanes for a number of reasons: The managed lanes are an adaptation of existing HOV lanes; HOV/HOT lanes are an important component of meeting federal requirements for regional air-quality conformity; or regional policy objectives dictate increasing the average vehicle occupancy. The challenge to enforcing toll-exempt or toll-discounted carpools, whether they're two- or three-person carpools, is that the task requires a visual verification of the number of people in the vehicle. Counting the number of occupants in a vehicle can be complicated by the availability of a vantage point for the observer, the location of rear occupants, a high vehicle-traveling speed, tinted windows, and inclement weather or lighting (dawn/dusk) conditions.

Because this function can't reliably be automated using current technology, enforcing requirements for carpool preferences through visual inspection can be costly. If desired, a revenue stream from the managed lanes can be dedicated to enforcing occupancy requirements if carpool preference is an important project objective. Several options are available for such enforcement until automated methods catch up. Some are design related, such as separating the carpools from other vehicles by providing inspection lanes at tolling points or at low-speed access ramps. This permits the counting of occupants and the use of a separate, human toll reader to credit the carpool for its trip.

Other occupancy-enforcement strategies entail adopting more policy and regulatory approaches that impose stiff fines for violations or that set up systems for credits through ride-share matching programs. Additional solutions involve equipping law enforcement officers with technology such as cruiser-mounted toll readers and hand-held PDAs. Such tools can let officers check a vehicle's toll status and occupancy, whether the officers are stationary or are patrolling the facility. Because agencies are expected to continue pursuing HOV preferences to meet air-quality requirements, near-infrared imaging technology and in-vehicle airbag-sensing devices for occupancy verification will likely advance.

Traffic management and toll integration. The philosophy of active management requires a continual monitoring of the managed-lanes facility so that appropriate action can be taken to manage demand. As a system, actively managed lanes entail more than a variable-pricing piece; they involve all of the traffic operations functions of the managed-lanes facility working together cohesively to achieve optimum performance. This includes integrating functions such as incident management, emergency use, signage operations, enforcement, transit operations, and, potentially, general-purpose–lane operations into the overall system and defining the data and information flow necessary for implementing and operating an actively managed facility. For example, real-time data such as minute-by-minute traffic volumes, travel times, and speeds can be collected in the field to support functions such as establishing dynamic price variations by identifying breakdowns in flow, providing driver information related to time savings and traffic snarls ahead, and calculating and communicating bus arrival times.

As discussed earlier, pricing can be a primary strategy for active management. Setting the variable toll rates is part science and part art and depends on factors such as the configuration of the facility (access and bottleneck points, single versus dual lanes) in addition to willingness-to-pay data for one's market. The pricing algorithm—and the type of data supporting it—should derive from the project objectives. Is the algorithm based on maintaining a certain speed in the managed lanes? On achieving a specified travel-time savings for the managed lanes? The objective the agency is trying to achieve will dictate how and what data should be collected to establish the price.

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Development of a "concept of operations" (ConOps) for the managed-lanes system is the means by which all operations functions are described and data flow is defined. This formal document, prepared by the managed-

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lanes operator, provides a user-oriented view of how the managed-lanes system intends to operate. It lays out an integrated corridor management (ICM) approach and the associated strategies and operations. In essence, the ConOps presents the findings from the system conception stage, laying out the ICM approach, explaining how things are expected to work once the system is in operation, and identifying the responsibilities of the various agencies or stakeholders who will make it happen.

The Future of Managed Lanes

There is much more to be learned about the techniques for making managed lanes work. From the research side, work continues in Texas and at the federal level in several areas to bridge the gap between concept and reality. These include:

- The role of carpool preference in managed lanes;
- Truck toll lanes;
- Intermediate at-grade access design parameters;
- Field verification of weaving distances for intermediate at-grade access;
- The application of managed-lane strategies to freeway ramps;
- Guidance for signage and traffic control devices;
- Occupancy-verification technologies;
- Lane-separation techniques; and
- Network and system implications of managed lanes.

Additionally, a host of active management strategies is on the horizon in the United States, as identified through the Federal Highway Administration's recent Managed Lanes European Scan Tour. The FHWA team visited four countries—Germany, Denmark, the Netherlands, and England—to observe and assess programs related to proactive operation of their highway facilities. The results of the tour revealed a more holistic approach to freeway congestion management through the use of strategies such as speed harmonization, temporary shoulder use, junction control, and dynamic signage and rerouting.

With more than 40 managed-lanes projects under development in 12 U.S. states, managed lanes hold promise for bringing together multiple mobility strategies and offering travel choices in our most congested urban freeway corridors. As projects are developed and implemented and as the concept evolves over time, there is more to be learned through research and practice that will enhance the success of future projects.

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