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16. Abstract Texas cities are currently considering the managed lane concept for major freeway projects. As a new concept of operating freeways in a flexible and possibly dynamic manner, the managed lane concept has a limited experience base, thereby creating a knowledge vacuum in emerging key areas that are critical for effective implementation. Complicating the effort is the rapid progress of several freeway improvement projects in Texas in which managed lane operations are proposed. The operational experience both in Texas and nationally for managed lanes is minimal, particularly for extensive freeway reconstruction projects. The managed lane projects currently in existence involve retrofits of existing freeway sections within highly fixed access, geometric, and operational configurations, and established eligibility considerations. There are few projects in operation from which to draw experiential data on the implementation of managed lane freeway sections with complex or multiple operational strategies, including variations in eligible vehicle user groups by time of day. The <i>Managed Lanes Handbook</i> was developed for the Texas Department of Transportation (TxDOT) to help the staff make informed planning, design, and operational decisions when considering managed lanes facilities for its jurisdiction. This document presents the critical research results obtained over the five years of the related research project. The research is presented in a usable format, providing a clear, concise, and step-wise approach to planning, designing, operating, and enforcing a managed lanes facility. It also refers the user to other pertinent documents that provide additional detailed information on various aspects of managed lanes.					
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HANDBOOK

Report 0-4160-24

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Texas Department of Transportation
and the
Federal Highway Administration**

**Research conducted by
Texas Transportation Institute
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Disclaimer

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Executive Summary

Many Texas cities are considering the managed lanes concept for major freeway expansion projects. As a new operating strategy that incorporates flexible and potentially dynamic lane use, managed lanes have a very limited experience base from which to draw guidance. The operational experience in both Texas and nationally for managed lanes is minimal, particularly for extensive freeway reconstruction projects. Most operating projects are characterized by retrofit approaches for existing HOV lanes that have highly fixed access, geometric, and operational configurations. As a result of the limited experiential base, effective implementation of new managed lanes is hindered by a knowledge vacuum in emerging key areas of development, design, and operation.

To address this knowledge gap, the Texas Department of Transportation (TxDOT) undertook a five-year research study to explore the complex and interrelated issues associated with the safe and efficient operation of managed lanes. Over 20 different aspects of planning, designing and operating managed lanes were explored during the study. From those research efforts this *Managed Lanes Handbook* was developed, which brings together implementation guidance from the individual research tasks conducted as part of the larger study effort.

The *Managed Lanes Handbook* is a practical and easy-to-use reference for transportation professionals at all levels and with a variety of backgrounds. Policy makers can also use the handbook to review the key elements associated with various aspects of managed lanes projects. The topics covered in the handbook represent a full range of topics that are of interest to practitioners:

- ◆ Critical Issues and Key Resources
- ◆ Planning Managed Lanes Facilities
- ◆ Legislative Issues
- ◆ Public Outreach
- ◆ Funding and Financing Managed Lanes
- ◆ Managed Lanes Weaving, Ramp, and Design Issues
- ◆ Decision-Making Needs and Traffic Control Devices for Managed Lanes
- ◆ Enforcement Issues for Managed Lanes
- ◆ Incident Management for Managed Lanes
- ◆ Interim Use during Construction, Special Events, and Emergencies
- ◆ Staffing and Training for Managed Lanes

- ◆ Monitoring and Evaluating Managed Lanes Facility Performance
- ◆ Interoperability Issues on Managed Lanes Facilities

This *Managed Lanes Handbook* offers guidance based on a handful of field implementations of managed lanes and pricing projects, along with micro-simulation tools to replicate some of the more complex scenarios envisioned for Texas facilities. As such, the handbook should be considered a living document that provides practitioners with information based on a snapshot in time. While the managed lanes research program has offered TxDOT direct guidance for application in current project development, the program has also identified new challenges and areas for further exploration. Of particular interest are the second generation projects that are incorporating managed lanes as a mobility strategy that encompasses a broad range of operational possibilities, challenges, and complexities. Each of the new challenges pose tough questions that have not been tackled in the projects currently in operation. As more of these projects are put into operation and as more of the research gaps are addressed, the guidance provided by this handbook will undoubtedly evolve over time.

Chapter 1 – Guide to the Managed Lanes Handbook

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Section 1 – Overview

A viable method for meeting mobility needs in Texas is the concept of “managed” lanes. This concept is growing in popularity across the country because managed lanes maintain free-flow travel speeds on designated lanes or facilities by providing controlled service to eligible groups of vehicles. These eligible user groups can vary by time of day or other factors depending on available capacity and the mobility needs of the community.

This handbook provides a comprehensive guide to developing policies for, planning, designing, implementing, marketing, operating, enforcing, evaluating, and monitoring managed lanes facilities. The *Managed Lanes Handbook* is a practical and easy-to-use reference for transportation professionals at all levels and with a variety of backgrounds. Policy makers can also use the handbook to review the key elements associated with various aspects of managed lanes projects.

This chapter provides a quick guide to the topics covered in the individual chapters and the format used throughout the handbook:

- ◆ **What Are Managed Lanes?** This section presents a general vision for managed lanes operational strategies that will be discussed in more detail later in the handbook.
- ◆ **Overall Conceptual Framework.** This handbook is based on an overall framework for the comprehensive development of managed lanes projects. This section briefly describes this framework and the interrelated process for project development.
- ◆ **Chapters at a Glance.** This section provides a quick guide to the major topics covered in each of the chapters in the handbook.
- ◆ **Chapter Format.** A common format is followed in the individual chapters to allow users to easily find topics of interest. This section highlights the major elements covered in each chapter.
- ◆ **Commonly Used Acronyms.** Numerous acronyms for managed lanes and other transportation terminology appear throughout the document. This section serves as a quick reference guide for those acronyms commonly used in the handbook.

Section 2 – What Are Managed Lanes?

The term “managed lanes” is ambiguous and can mean different things to different stakeholders in the transportation industry. One managed lanes facility might cater to commuters while another might provide preferred service to heavy trucks. The user groups they serve are a function of a region’s mobility needs and the policies of operating agencies. The broad meaning of managed lanes emphasizes their usefulness as a tool to enhance mobility.

TxDOT defines a managed lanes facility as one that increases freeway efficiency by packaging various operational and design actions. Lane management operations may be adjusted at any time to better match regional goals. But what are those operational and design actions? As illustrated in Figure 1-1, they include high-occupancy vehicle (HOV) lanes, value-priced lanes or high-occupancy toll (HOT) lanes, exclusive-use lanes such as bus or truck lanes, separation and bypass lanes, dual-use lanes, and lane restrictions.

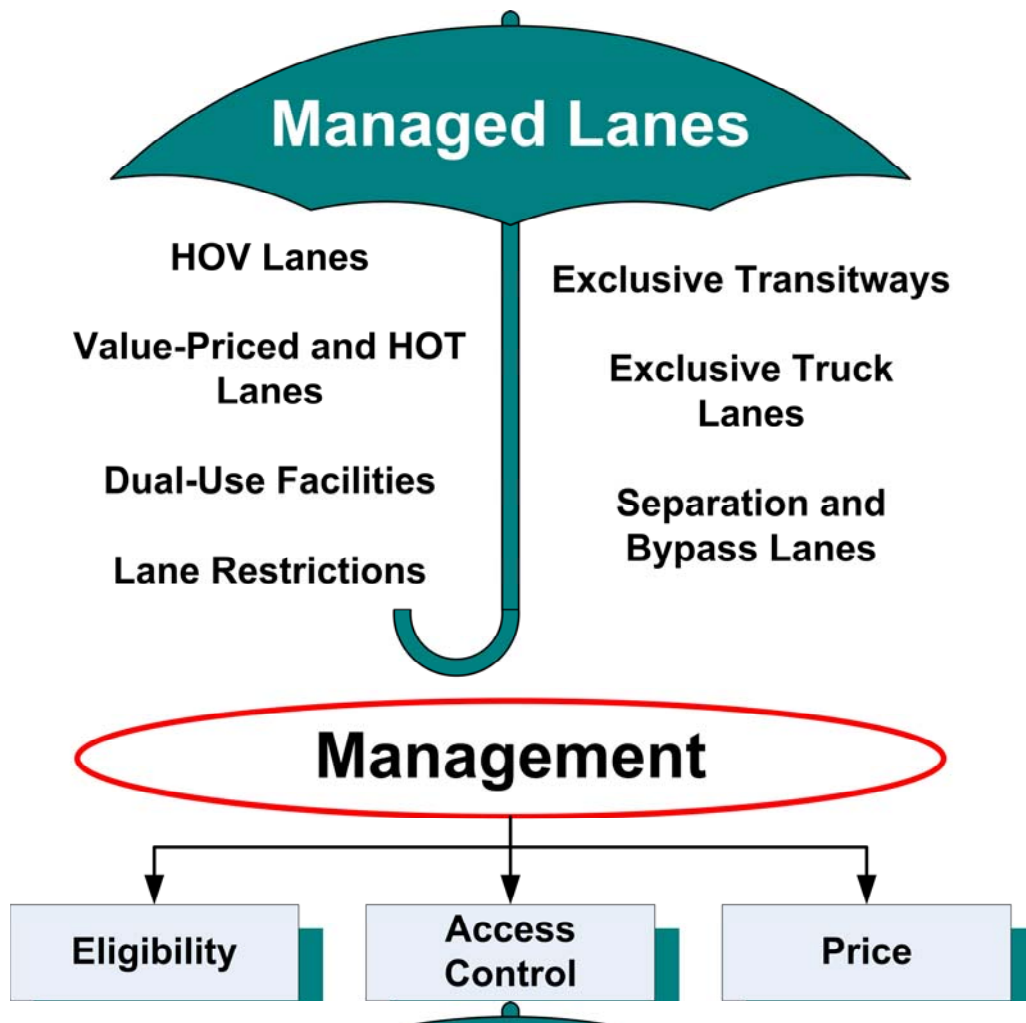


Figure 1-1. Managed Lanes Operational Strategies.

Typically, managed lanes facilities are a “freeway within a freeway” where a set of lanes within the freeway cross section is physically separated from general-purpose lanes. The intent is to incorporate a high degree of operational flexibility so that over time operations can be actively managed to respond to growth and changing needs. Also, the operation of and demand on the facility is managed using a combination of tools and techniques in order to continuously achieve an optimal condition, such as free-flow speeds, using one of three types of management: pricing, vehicle eligibility, and access control.

Section 3 – Overall Conceptual Framework

The process of developing a managed lanes project is complex and involves numerous steps. The type of users authorized to use a managed lanes facility plays a critical role in the feasibility, design, and operation of a managed lanes facility. A matrix of possible operating strategies for various eligible user groups can correlate eligibility decisions with realistic considerations for planning, designing, and operating a managed lanes facility.

This handbook was developed around a framework for supporting decisions related to the development of managed lanes projects. This framework depicts the sequential elements considered in implementing a managed lanes project. Features of the framework include the following:

- ◆ incorporation of financial goals, particularly those involving revenue generation, into the general policy framework;
- ◆ objective-based decision making in determining potential user groups and the use of pricing for demand management and/or revenue generation;
- ◆ the combination of vehicle user groups and operating strategy as the basis for determining design parameters for the project;
- ◆ the involvement of other agencies in the process, as well as multiple opportunities for public input;
- ◆ a strong link between design and operations in the development of schematic design; and
- ◆ a re-evaluation process if expected performance does not meet desired outcomes.

As the backbone of the *Managed Lanes Handbook*, this framework is the foundation of a user-friendly preliminary screening tool that helps users determine appropriate managed lanes operational strategies for a corridor at the sketch planning level. [Figure 1-2](#) illustrates this framework.

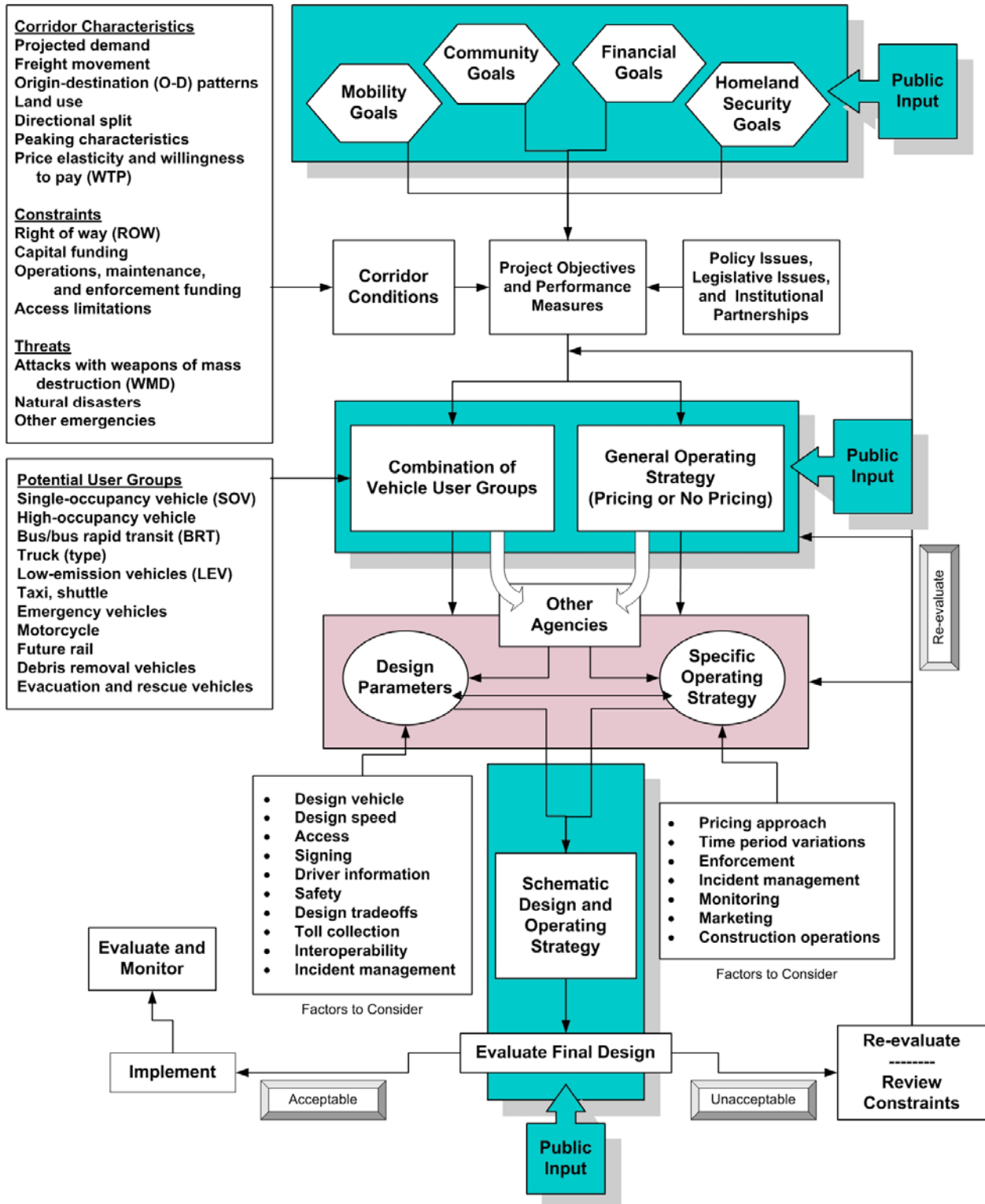


Figure 1-2. Overall Conceptual Framework.

Section 4 – Chapters at a Glance

The handbook is divided into the following 14 chapters. The titles of each chapter and the major topics covered are highlighted:

- ◆ **Chapter 1 – Guide to the Managed Lanes Handbook.** Provides a quick guide to the topics covered in the individual chapters, the format used throughout the handbook, and commonly used acronyms that appear in the handbook.
- ◆ **Chapter 2 – Introduction to Managed Lanes.** Discusses the definition of managed lanes, highlights the various types of managed lanes operational strategies, and gives examples of them.
- ◆ **Chapter 3 – Critical Issues and Key Resources.** Briefly discusses the critical issues associated with managed lanes, provides key resources the user can access for related information, and directs the user to subsequent chapters in the handbook that address these issues in more detail.
- ◆ **Chapter 4 – Planning Managed Lanes Facilities.** Provides guidance on planning managed lanes projects, including identifying goals, objectives, information and data needs, selection of operational strategies and users, institutional partnerships and agency roles, and public input and outreach.
- ◆ **Chapter 5 – Legislative Issues.** Provides a summary of legislation necessary to implement various managed lanes operational strategies, including HOV lanes, value-priced and HOT lanes, exclusive lanes, separation and bypass lanes, dual facilities, and lane restrictions.
- ◆ **Chapter 6 – Public Outreach.** Provides guidance on public outreach for managed lanes projects by helping determine messages to be communicated to the public, how they should be communicated, to whom they should be targeted, and the best approaches for communicating project goals and gaining acceptance.
- ◆ **Chapter 7 – Funding and Financing Managed Lanes.** Provides guidance on funding and financing managed lanes projects by highlighting the financial aspects of implementing managed lanes projects and the applicability of innovative financing techniques to various types of projects.
- ◆ **Chapter 8 – Managed Lanes Weaving, Ramp, and Design Issues.** Presents information on the basic elements of the geometric design considerations for managed lanes facilities, including cross sections and design considerations for terminal and access treatments.
- ◆ **Chapter 9 – Decision-Making Needs and Traffic Control Devices for Managed Lanes.** Addresses critical decision-making and traffic control device needs related to managed lanes facility planning and design.

- ◆ **Chapter 10 – Enforcement Issues for Managed Lanes.** Provides guidance on enforcement planning, enforcement considerations in design, automated enforcement technology, and enforcement considerations in operations.
- ◆ **Chapter 11 – Incident Management for Managed Lanes.** Provides guidance on incident management tools, techniques, policies, and procedures that can easily be applied to managed lanes facilities.
- ◆ **Chapter 12 – Interim Use during Construction, Special Events, and Emergencies.** Supports the development of interim use policies by providing guidance related to considerations for interim use, interim use criteria, implementation requirements for interim use, and planning for interim use.
- ◆ **Chapter 13 – Staffing and Training for Managed Lanes.** Identifies staffing needs related to operational options and specific training that might be required to ensure those staff are fully prepared to perform their duties to the satisfaction of both the agency and the customer.
- ◆ **Chapter 14 – Monitoring and Evaluating Managed Lanes Facility Performance.** Establishes a range of performance targets by facility type, and identifies and confirms the appropriateness of various performance monitoring and evaluation activities as specifically applied to managed lanes facilities.
- ◆ **Chapter 15 – Interoperability Issues on Managed Lanes Facilities.** Discusses the critical interoperability concerns for a managed lanes facility so that planners, designers, and operators can focus on these interactions and create a successful facility.
- ◆ **Appendix A – Preliminary Screening Tool.** Includes the strategy selection tool for use as a preliminary screening instrument for TxDOT project managers to help define the types of managed lanes strategies that would be conducive for a given corridor.
- ◆ **Appendix B – Position Paper for Policy Makers.** Provides sample text for a position paper on managed lanes geared toward policy makers.
- ◆ **Appendix C – Position Paper for Media and General Public.** Provides sample text for a position paper on managed lanes geared toward the media and the public.

Section 5 – Chapter Format

The individual chapters follow a common format. This section highlights the elements included in the individual chapters.

Table of Contents

A table of contents is provided at the start of each chapter, allowing users to easily find topics of interest.

Lists of Figures and Tables

Lists of figures and tables included in each chapter are provided for quick reference by the user.

Overview

Following the table of contents, an overview highlights the major topics covered in the chapter.

Specific Elements and Case Studies

The elements, issues, and activities related to the specific topic comprise the major portion of each chapter. Case study examples and information on specific projects are provided where appropriate.

References and Additional Information

The references used are provided at the end of each chapter.

Section 6 – Commonly Used Acronyms

AASHTO: American Association of State Highway and Transportation Officials

ADT: annual daily traffic

AVI: automatic vehicle identification

B/C: benefit/cost

BRT: bus rapid transit

Caltrans: California Department of Transportation

CBD: central business district

CCTV: closed circuit television

CHP: California Highway Patrol

CITE: Consortium for ITS Training and Education

CMS: changeable message sign

CO: carbon monoxide

CSS: context sensitive solutions

CV: coefficient of variation

DMS: dynamic message sign

DOT: department of transportation

DPS: Department of Public Safety

EMS: emergency medical services

EPS: electronic payment systems

EPA: Environmental Protection Agency

ETC: electronic toll collection

FAIR: fast and intertwined regular

FHWA: Federal Highway Administration

FTA: Federal Transit Administration

- GP:** general purpose
- HAR:** highway advisory radio
- HAZMAT:** hazardous materials
- HC:** hydrocarbon
- HCM:** *Highway Capacity Manual*
- HCTRA:** Harris County Toll Road Authority
- HOV:** high-occupancy vehicle
- HOT:** high-occupancy toll
- HOT START:** High Occupancy Toll Strategy Analysis Tool
- ILEV:** inherently low-emission vehicle
- ISTEA:** Intermodal Surface Transportation Efficiency Act of 1991
- ITE:** Institute of Transportation Engineers
- ITS:** intelligent transportation systems
- LEV:** low-emission vehicle
- LOS:** level of service
- LPR:** low power radio
- METRO:** Metropolitan Transit Authority of Harris County
- ML:** managed lane
- MPO:** metropolitan planning organization
- MUTCD:** *Manual on Uniform Traffic Control Devices for Streets and Highways*
- NCHRP:** National Cooperative Highway Research Program
- NEPA:** National Environmental Policy Act
- NHI:** National Highway Institute
- NHS:** National Highway System
- NJTA:** New Jersey Turnpike Authority

NO_x: nitrogen oxides

NTOC: National Transportation Operations Coalition

NTTA: North Texas Tollway Authority

O-D: origin-destination

OECD: Organisation for Economic Co-operation and Development

O/M: operations/maintenance

PMT: person miles traveled

PPD: passengers per day

PPDF: peak period distribution factor

PPUF: peak period utilization factor

RDM: *Roadway Design Manual*

ROW: right of way

SAFETEA-LU: Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users

SANDAG: San Diego Association of Governments

SIB: State Infrastructure Bank

SOV: single-occupancy vehicle

SSD: stopping sight distance

STAA: Surface Transportation Assistance Act

SUL: special use lane

TDM: traffic demand management

TEA-21: Transportation Equity Act for the 21st Century

TIFIA: Transportation Infrastructure Finance and Innovation Act

TRB: Transportation Research Board

TTA: Texas Turnpike Authority

TTI: Texas Transportation Institute

TMT: total miles traveled

TOT: truck-only toll

TxDOT: Texas Department of Transportation

USDOT: United States Department of Transportation

V/C: volume/capacity

VDOT: Virginia Department of Transportation

VHT: vehicle hours traveled

VMS: variable message sign

VMT: vehicle miles traveled

VOC: volatile organic compounds

VPD: vehicles per day

VPPP: Value Pricing Pilot Program

WMD: weapons of mass destruction

WSDOT: Washington State Department of Transportation

WTP: willingness to pay

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Section 1 – Overview

The increasing population growth in Texas has placed enormous demands on the transportation infrastructure, particularly the freeway systems. There is a growing realization that the construction of sufficient freeway lane capacity to provide free-flow conditions during peak travel periods cannot be accomplished in developed urban areas due to cost, land consumption, neighborhood impacts, environmental concerns, and other factors. Like other transportation agencies nationwide, the Texas Department of Transportation (TxDOT) is searching for methods to better manage traffic flow and thus improve the efficiency of existing and proposed networks.

A viable method for meeting mobility needs is the concept of “managed” lanes. Managed lanes maintain free-flow travel speeds on designated lanes or facilities by providing controlled service to eligible groups of vehicles, which can vary by time of day or other factors depending on available capacity and the mobility needs of the community.

Sections in this chapter cover:

- ◆ definition of managed lanes,
- ◆ managed lanes operational strategies,
- ◆ high-occupancy vehicle lanes,
- ◆ value-priced lanes and high-occupancy toll lanes,
- ◆ exclusive lanes,
- ◆ separation/bypass lanes,
- ◆ lane restrictions, and
- ◆ dual facilities.

Section 2 – Definition of Managed Lanes

As stated previously, the term “managed lanes” is ambiguous and can mean different things to different stakeholders in the transportation industry. One managed lanes facility might cater to commuters while another might provide preferred service to heavy trucks. The user groups they serve are a function of a region’s mobility needs and the policies of operating agencies. The broad meaning of managed lanes emphasizes their usefulness as a tool to enhance mobility.

TxDOT Definition

TxDOT defines a managed lanes facility as one that increases freeway efficiency by packaging various operational and design actions. Lane management operations may be adjusted at any time to better match regional goals.

Focus on Flexibility

This definition is very general, yet it reflects the complex and flexible nature of managed lanes. It allows each district across Texas to determine what “managed lanes” means for that jurisdiction. It respects the needs of the community without requiring the application of a specific strategy that does not meet those needs. It also encourages flexibility, realizing that the needs of a corridor, region, or district may change over time, thereby requiring a different managed lanes operational strategy or combination of multiple strategies.

Section 3 – Managed Lanes Operational Strategies

Managed lanes operational strategies include HOV lanes, value-priced lanes or HOT lanes, exclusive-use lanes such as bus or truck lanes, separation and bypass lanes, dual-use lanes, and lane restrictions. Managed lanes support increased efficiency of traffic on existing roadways and generally meet the following transportation systems management goals outlined in the *Guide for the Design of High Occupancy Vehicle Facilities (I)*, which were originally developed for HOV lanes:

- ◆ improve operating level of service for high-occupancy vehicles, both public and private, thereby maximizing the person-moving capacity of roadway facilities;
- ◆ provide fuel conservation;
- ◆ improve air quality by reducing pollution caused by delay and congestion; and
- ◆ increase overall accessibility while reducing vehicular congestion (I).

Variety of Terms

Strategies, terms, and acronyms are often used interchangeably to describe a particular managed lanes action or variation of a design without strict adherence to definitions. For example, what may be described by one jurisdiction as a high-occupancy toll lane is described by another jurisdiction as a value express lane. Meanwhile, a third entity might use the term value express lane for a totally different strategy. Within this handbook, the various strategies are defined for use in Texas, which may not necessarily coincide with traditional definitions for all areas of the country.

Managed Lanes Operational Strategies

The remainder of this chapter discusses the different types of managed lanes operational strategies and various operational issues related to their implementation, including:

- ◆ HOV lanes,
- ◆ value-priced and HOT lanes,
- ◆ exclusive lanes,
- ◆ mixed-flow separation/bypass lanes,
- ◆ lane restrictions, and
- ◆ dual facilities.

Section 4 – High-Occupancy Vehicle Lanes

HOV lanes are separate lanes that are restricted to vehicles with a specified occupancy and may include carpools, vanpools, and buses (2). They are designed to increase the person-moving capacity of the existing infrastructure (3). Most HOV facilities require that vehicles have two or more (2+) occupants to legally use the facility; however, some facilities require three or more (3+) occupants during peak travel times (4).

HOV lanes can be implemented on either arterials or freeways. When implemented on freeways, three types of facilities are used—separated roadway, concurrent-flow lanes, and contraflow lanes (1). Also, the separated roadway facility may be either a two-way facility or a reversible-flow facility.

Separated Two-Way HOV Lanes

The separated HOV facility is physically separated from main lanes or general-purpose lanes of the freeway with either a concrete barrier or a wide painted buffer. The lanes may be either two-way or reversible. Two-way separated HOV lanes usually consist of one lane in each direction, often have limited access, and may have their own direct ingress and egress treatments (3). Figure 2-1 illustrates a two-way, barrier-separated HOV lane in Los Angeles on IH-10 (El Monte). Note that in this segment of the facility, the two directions of flow are reversed so that the bus doors align with the center bus platforms (5).



Figure 2-1. IH-10 (El Monte) Two-Way, Barrier-Separated HOV Lane, Los Angeles, California (5).

The reversible lane is the most common type of separated lane HOV facility. As illustrated in [Figure 2-2](#), the reversible lane consists of a separated lane or lanes where the direction of travel changes by time of day. A reversible HOV lane typically operates as an inbound lane in the morning and reverses to an outbound lane in the afternoon. This flow reversal allows maximum use of the lane during peak hours.

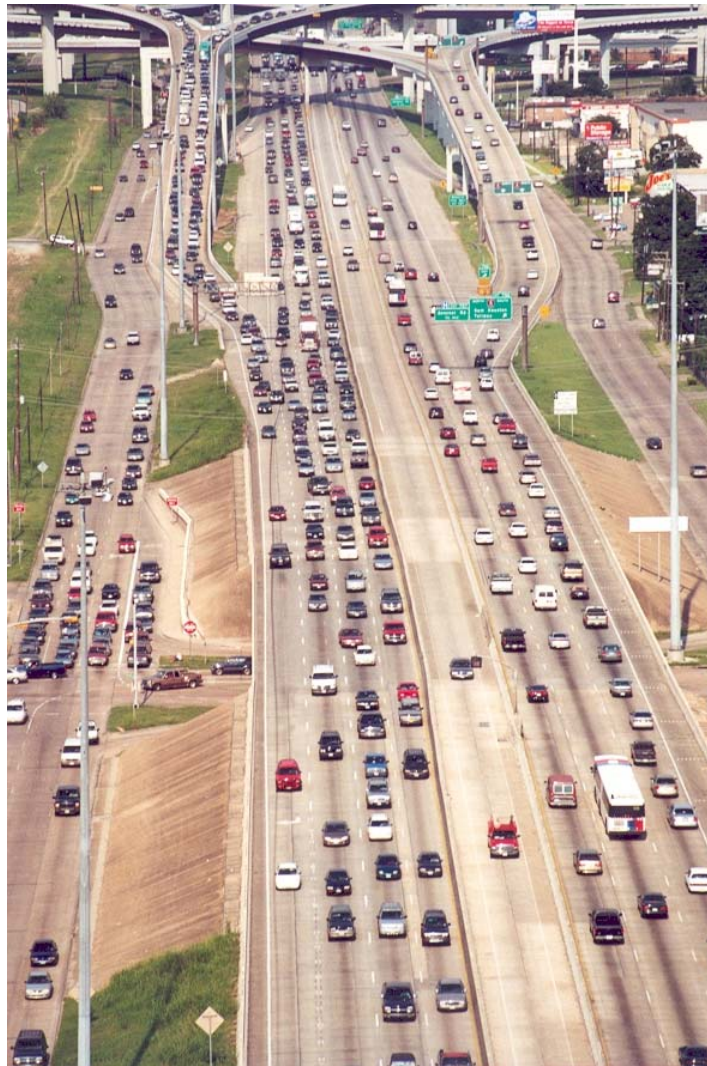


Figure 2-2. IH-10 (Katy) Reversible, Barrier-Separated HOV Lane, Houston, Texas.

Concurrent-Flow HOV Lanes

A concurrent-flow HOV lane is a freeway lane that flows in the same direction as the rest of traffic and is not physically separated from the main lanes of the freeway. Either a buffer or distinctive paint striping may separate the HOV lane from other traffic lanes. The lane, also referred to as a “diamond” lane, is often the inside lane of the roadway (3). This is the most common type of HOV lane. [Figure 2-3](#) illustrates a concurrent-flow HOV lane in each direction in the center of the roadway. In this example, the HOV lanes

are separated from the general-purpose lanes with a buffer that is marked with white striping.



Figure 2-3. IH-635 (LBJ) Concurrent-Flow, Buffer-Separated HOV Lane, Dallas, Texas.

Contraflow HOV Lanes

A contraflow HOV lane is a freeway lane in the off-peak direction of travel that is used for travel by vehicles in the peak direction. For example, an inbound lane is used for outbound travel from the downtown area during the afternoon peak period. The inside lane of the off-peak segment is normally the lane selected, and the lane is separated from off-peak traffic by some type of changeable or moveable barrier or physical treatment (2). Although buses primarily use this type of HOV lane, some contraflow lanes allow use by all multiple-occupant vehicles. [Figure 2-4](#) illustrates an early contraflow lane in Houston from the late 1970s that was originally only open to buses and authorized vanpools. A current contraflow HOV lane in operation in Atlanta on IH-75 is shown in [Figure 2-5](#) where the lanes are separated by a distinct pavement striping pattern.



Figure 2-4. IH-45 (North) Contraflow HOV Lane, Houston, Texas (5).



Figure 2-5. IH-75 Contraflow HOV Lane, Atlanta, Georgia (5).

Expectations and Constraints

The number of operating HOV lanes being proposed and implemented throughout North America is steadily increasing. This trend in popularity indicates that HOV lanes are a widely accepted strategy for addressing traffic mobility in metropolitan areas. However, HOV facilities are not appropriate for all situations, and each facility should be evaluated and monitored to ensure the facility is meeting the goals and expectations of the community (6). Expectations and objectives for a successful HOV lane include moving people, benefiting transit, and improving overall roadway efficiency. Constraints that may affect the successful implementation of strategies involving HOV lanes include adverse impact on general-purpose lanes, cost-effectiveness, public acceptance, and the environmental impact of implementation (2).

Section 5 – Value-Priced Lanes and High-Occupancy Toll Lanes

A HOT lane is an HOV lane that allows vehicles with lower occupancy to have access to the lane by paying a toll. Variations of HOT lanes are value-priced, value express, and fast and intertwined regular (FAIR) lanes, which may or may not be occupancy driven depending on the region or state. Value express lanes, as proposed by the Colorado Department of Transportation, are similar to HOT lanes (7). In most cases, value lanes and FAIR lanes are toll lanes. However, some jurisdictions use these terms to describe strategies similar to a HOT lane. Figure 2-6 shows the HOV and express toll lanes in operation on IH-15 in San Diego, California, where SOVs are tolled and HOV 2+ travel on the lanes for free.



Figure 2-6. IH-15 HOV/HOT Lanes, San Diego, California (5).

The idea behind HOT lanes is to improve the HOV lane utilization and sell unused lane capacity (2). For a HOT lane to be successful, the following assumptions should be present:

- ◆ HOT lanes should be incorporated with HOV lanes that are currently in existence or planned for construction.
- ◆ There must be recurring congestion where the HOT lanes could help drivers avoid congestion by paying a toll.
- ◆ HOT lanes cannot take away an existing main lane in order to be created.
- ◆ HOT lanes are not self-supporting (7).

The key to success for HOT lanes is to manage the number of vehicles to maximize the use of the HOV lane without exceeding capacity and creating congestion. One way to

manage a HOT lane is through the use of dynamic toll pricing. The toll is a variable toll that changes frequently, as often as every 5 minutes, with the price of the toll increasing with the level of congestion. As the toll increases, the number of motorists willing to pay the toll will decrease, thereby managing lane use (7).

Section 6 – Exclusive Lanes

The operational strategy of exclusive lanes provides certain vehicles, usually designated by vehicle type, an exclusive operational lane. The most common types of vehicles designated for this strategy are buses and large trucks. Buses are often given exclusive lanes to provide an incentive for riders by decreasing delay, whereas trucks are separated in an attempt to decrease the effects of trucks on safety and reduce conflicts by the physical separation of truck traffic from passenger car traffic.

It should be noted that until recently, very few truly exclusive facilities existed, and many of those facilities actually restricted trucks and/or buses to specified lanes and allowed other vehicles to use any lane (8). In recent years, a number of truly exclusive busways have been implemented in various metropolitan areas.

Exclusive Busways

A busway is a bus-only roadway that is separated from the rest of the traffic. The busway, which acts like a “surface subway,” allows buses to receive traffic signal preference, thus bypassing stoplights, or to cross over intersections on overpasses (9). Busways may be considered a cost-effective alternative to either subways or light rail and are being implemented by a number of cities. Advantages of busways include flexibility, self-enforcement, incremental development, low construction costs, and implementation speed (10). Figure 2-7 shows a busway in operation in Pittsburgh, Pennsylvania, constructed in various rail rights-of-way.



Figure 2-7. East Busway, Pittsburgh, Pennsylvania (5).

Exclusive Truck Lanes

The issue of increasing truck traffic is of vital concern to both traffic managers and the general public. Highway traffic operations are the “yardstick” by which the user measures the quality of the facility. The characteristics that matter most to the driver are speed of travel, safety, comfort, and convenience. As a result of increasing demand on highways, many transportation agencies have implemented a variety of strategies or countermeasures for trucks in an attempt to mitigate the effects of increasing truck traffic, including exclusive truck lanes.

For example, California operates a truck roadway on IH-5 in the Los Angeles area, as shown in [Figure 2-8](#). While passenger cars are allowed to use the facility, trucks are the primary users. This roadway is a segment of a controlled-access facility involving significant grades, so truck speeds are slower than free-flow speeds of passenger cars, especially in the northbound (uphill) direction. The truck roadway allows trucks to regain speed at the top of the hill before merging with other traffic.



Figure 2-8. IH-5 Truck Roadway, Los Angeles, California.

Feasibility studies regarding restrictions and exclusive lanes found that exclusive barrier-separated facilities were most plausible for congested highways where three factors exist: truck volumes exceed 30 percent of the vehicle mix, peak-hour volumes exceed 1800 vehicles per lane-hour, and off-peak volumes exceed 1200 vehicles per lane-hour ([11](#)).

Theoretically, truck facilities could have positive impacts on noise and air pollution, fuel consumption, and other environmental issues. Creating and maintaining an uninterrupted

flow condition for diesel-powered trucks will result in a reduction of emissions and fuel consumption when compared to congested, stop-and-go conditions. However, the creation of a truck facility may also shift truck traffic from more congested parallel roadways, thereby shifting the environmental impacts. There may also be increases in non-truck traffic on automobile lanes due to latent demand.

Section 7 – Separation/Bypass Lanes

The separation or bypass lane is a treatment for a specific section or segment of roadway. Several areas have successfully used this management strategy that often addresses a roadway segment that has a unique feature or characteristic, such as a weaving area, a significant grade, high percentage of truck traffic, and/or congestion. For example, weaving areas present an operational concern because the “crossing” of vehicles creates turbulence in the traffic streams. Trucks limit the visibility and maneuverability of smaller vehicles attempting to enter and exit the freeway system. An indication of the barrier effect is an over-involvement of trucks in weaving area crashes, rear-end collisions, and side collisions. Some studies have shown that this problem may be magnified when a differential speed limit is present (12, 13).

Figure 2-9 illustrates a ramp meter bypass lane in use in Minneapolis near downtown on IH-35 West near the IH-94 interchange. The purpose of this particular lane is to provide special priority to transit vehicles and allow them to bypass the ramp meters that control the two general-purpose lanes providing access to the freeway.



Figure 2-9. Ramp Meter Bypass Lane, Minneapolis, Minnesota (5).

Figures 2-10 and 2-11 show other uses of bypass lanes to provide priority access to identified user groups. Figure 2-10 illustrates the use of bypass lanes to provide priority for carpools and buses with three or more occupants approaching the toll plaza on the San Francisco/Oakland Bay Bridge. The bypass lanes provide a time savings for HOVs anywhere from 10 to 20 minutes during the morning peak period. Figure 2-11 shows how Seattle provides queue bypass lanes for HOVs at ferry landings, thereby reducing the wait time for HOVs during the peak travel period.



Figure 2-10. IH-80 Bay Bridge Queue Bypass, Oakland, California (5).



Figure 2-11. HOV Queue Bypass, Coleman Dock Ferry, Seattle, Washington (5).

A truck bypass facility exists on a section of northbound IH-5 near Portland, Oregon, at the Tigard Street interchange; it is similar to some of the California facilities. The bypass lane requires trucks to stay in the right lane, exit onto a truck roadway, and re-enter traffic downstream of the interchange. Passenger cars are also allowed to use the bypass

facilities. One reason this facility is needed is that a significant grade exists on the main lanes of IH-5. Without the truck roadway, larger vehicles would be forced to climb a grade and then weave across faster moving traffic that enters the main lanes from their right. The resulting speed differentials caused by trucks performing these maneuvers created operational as well as safety problems prior to the implementation of the bypass facility. Truck speeds are now typically 50 mph in the merge area; prior to implementation of the bypass lane, truck speeds were 20 to 25 mph. There were no specific cost data available for construction of the bypass lane (14).

IH-5 north of Los Angeles is a corridor with a very heavy volume of truck traffic. In the 1970s, the California Department of Transportation (Caltrans) built truck bypass lanes on IH-5 near three high-volume interchanges. The lanes were built to physically separate trucks from other traffic and to facilitate weaving maneuvers in the interchange proper. The first truck facility encompasses the section of IH-5 that includes the Route 14 and Route 210 interchanges. The other truck facilities are at Route 99 near Grapevine and at the interchange of Route 110 and IH-405. Although these facilities were built for trucks to bypass the interchanges, automobiles and other vehicles also use the lanes to avoid the weaving sections (14).

Section 8 – Lane Restrictions

Lane restrictions are management strategies that limit certain types of vehicles to specified lanes. The most common type of lane restriction addresses truck traffic. A large presence of trucks, both in rural and urban areas, can degrade the speed, comfort, and convenience experienced by passenger car drivers. Some states, to minimize these safety and operational effects, have implemented truck lane restrictions or have designated exclusive truck lane facilities. In 1986, the Federal Highway Administration asked its division offices to conduct a survey and report on experiences encountered by states with lane restrictions. This survey indicated a total of 26 states used lane restrictions. The most common reasons for implementing lane restrictions were:

- ◆ improved highway operations (14 states),
- ◆ reduced accidents (8 states),
- ◆ pavement structural considerations (7 states), and
- ◆ restrictions in construction zones (7 states).

Some states provided more than one reason for the restriction (15).

Section 9 – Dual Facilities

Dual facilities are managed lanes strategies that have physically separated inner and outer roadways in each direction. The inner roadway is reserved for light vehicles or cars only, while the outer roadway is open to all vehicles. The New Jersey Turnpike has a 35-mile segment that consists of interior (passenger car) lanes and exterior (truck/bus/car) lanes within the same right-of-way, as shown in [Figure 2-12](#). For 23 miles, the interior and exterior roadways have three lanes in each direction. On the 10-mile section that opened in November 1990, the exterior roadway has two lanes, and the interior roadway has three lanes per direction. Each roadway has 12-ft lanes and shoulders, and the inner and outer roadways are barrier separated. The mix of automobile traffic is approximately 60 percent on the inner roadways and 40 percent on the outer roadways ([14](#)).

These facilities, referred to as dual-dual segments, were implemented to relieve congestion. Other truck measures that have been implemented on the turnpike are lane restrictions and ramp shoulder improvements. The restriction implemented in the 1960s does not allow trucks in the left lane of roadways that have three or more lanes by direction. On the dual-dual portion of the turnpike from Interchange 9 to Interchange 14, buses are allowed to use the left lane. The resulting effect is that the left lane becomes a bus lane with the right lane(s) occupied by trucks. The New Jersey Turnpike Authority (NJTA) rates compliance for truck lane restrictions as high ([12](#)).

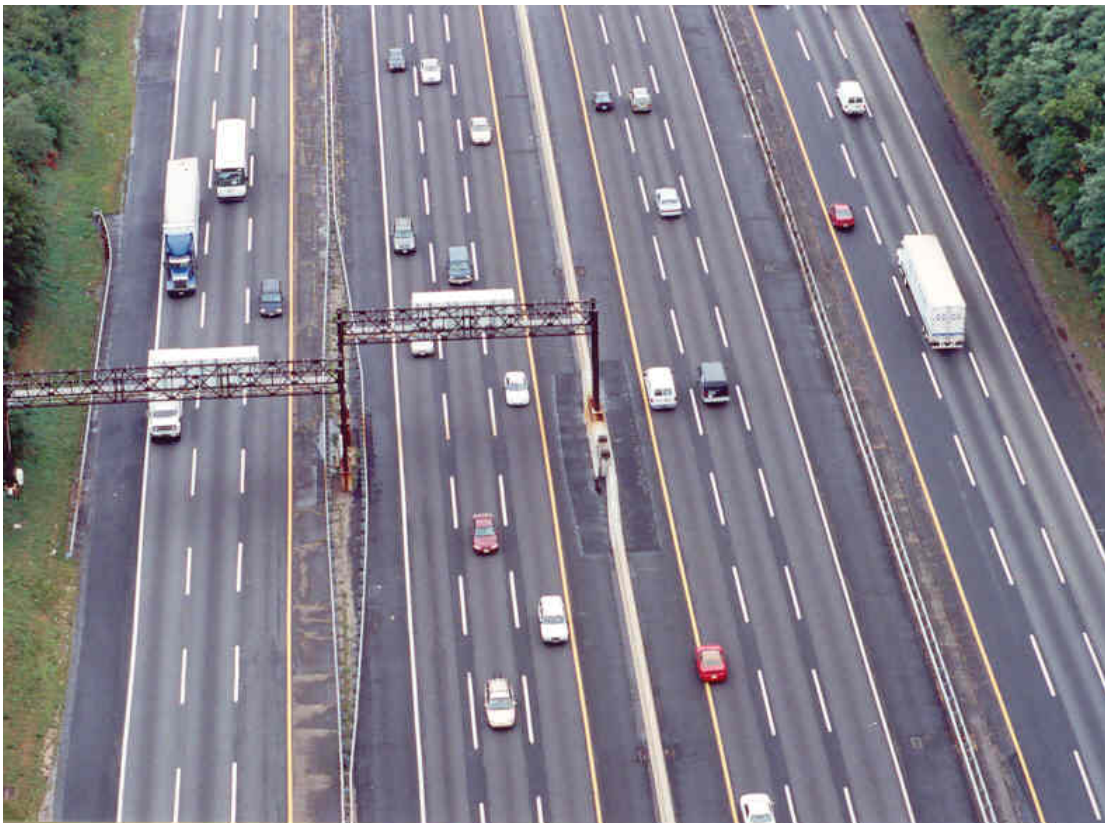


Figure 2-12. New Jersey Turnpike Dual Facility.

Section 10 – References

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12. S. Sirisoponsilp and P. Schonfeld. *State-of-the-Art Studies/Preliminary Work Scopes: Impacts and Effectiveness of Freeway Truck Lane Restrictions*. Transportation Studies Center, Maryland State Highway Administration, Baltimore, MD, 1988.

13. W. R. McCasland and R. W. Stokes. *Truck Operations and Regulations on Urban Freeways*. Report No. FHWA/TX-85/338-1F, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 1984.
14. P. Samuel. *How to “Build Our Way Out of Congestion” Innovative Approaches to Expanding Urban Highway Capacity*. RPPI Policy Study 250, Reason Public Policy Institute, Los Angeles, CA, 1999.
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Chapter 3 – Critical Issues and Key Resources

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Section 1 – Overview

This chapter briefly highlights critical issues associated with managed lanes, provides key resources the user can access for related information, and directs the user to the subsequent chapters in the handbook that address these issues in more detail.

Sections in this chapter cover:

- ◆ [planning managed lanes facilities](#);
- ◆ [legislative issues](#);
- ◆ [public outreach](#);
- ◆ [funding and financing managed lanes](#);
- ◆ [managed lanes weaving, ramp, and design issues](#);
- ◆ [decision-making needs and traffic control devices](#);
- ◆ [enforcement issues on managed lanes](#);
- ◆ [incident management for managed lanes](#);
- ◆ [interim use during construction, special events, and emergencies](#);
- ◆ [staffing and training for managed lanes](#);
- ◆ [monitoring and evaluating managed lanes facility performance](#); and
- ◆ [interoperability issues on managed lanes](#).

Section 2 – Planning Managed Lanes Facilities

The reality of improving the transportation infrastructure today is that agencies must function within environmental constraints. No longer may agencies plan transportation projects in a vacuum. Now, agencies must consider the environment in the planning of transportation projects, minimize the negative impacts of construction, and work to reduce transportation-related pollution in the process.

Agencies must demonstrate environmental stewardship and improve the environmental quality of their transportation decision making (1). Such stewardship, combined with environmental streamlining, helps address mobility and safety needs of the public while improving project delivery without compromising environmental protection (2). Managed lanes projects have the potential to improve mobility while reducing the increase in pollution and minimizing the impact on the environment.

Critical Issues

Planning and programming with managed lanes strategies in mind requires that agencies consider various planning-related issues from a slightly different perspective. Important steps in this process include needs identification, goals and objectives, correlation of those goals and objectives to operational strategies, and authorization and requirements determination.

Defining *vehicle user groups* for a managed lanes facility accomplishes an important step in the planning process. It helps in evaluating financing for the project, establishes the design vehicle used to control the geometrics of the facility design elements, offers insight into driver communication and signing needs, offers insight into potential enforcement opportunities and challenges, and provides a starting point for establishing a long-term “concept of operations,” where variations in user eligibility can be illustrated over time in order to maintain operational performance thresholds and communicate expected changes over time.

Environmental issues are concerns for most urban areas. One principal premise of HOV and HOT lanes are their potentially favorable impact on air quality and energy savings due to decreased fuel consumption. The actual quantification of these savings should be enhanced to strengthen policy arguments on the basis of environmental criteria (3). These aspects often make HOV and HOT lanes attractive to environmental groups.

Key Resources

The following documents are key resources for this topic in which users can find additional information and guidance beyond that which is presented in this handbook in [Chapter 4 – Planning Managed Lanes Facilities](#):

- ◆ G. Goodin and G. Fisher. *Decision Framework for Selection of Managed Lanes Strategies – Project Bulletin*. Bulletin No. 4160-21B, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2005,

<http://managed-lanes.tamu.edu/products/bulletins/4160-21B.pdf>, Accessed October 2005.

- ◆ G. Goodin and G. Fisher. *Decision Framework for Selection of Managed Lanes Facilities*. Report No. FHWA/TX-05/0-4160-21, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2005, <http://tti.tamu.edu/documents/0-4160-21.pdf>, Accessed February 2006.
- ◆ T. Collier and G. Goodin. *Managed Lanes: A Cross-Cutting Study*. Report No. FHWA-OP-05-037, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2004, http://ops.fhwa.dot.gov/freewaymgmt/managed_lanes/doc/crosscuttingstudy/index.htm, Accessed October 2005.
- ◆ B. Kuhn, D. Jasek, J. Carson, G. Fisher, G. Goodin, and T. Collier. *Developing Managed Lanes*. Report No. FHWA-HOP-05-032, Texas Transportation Institute, The Texas A&M University System, College Station, TX, to be published.
- ◆ *A Guide to Metropolitan Transportation Planning under ISTEA: How the Pieces Fit Together*. Report No. FHWA-PD-95-031, Federal Highway Administration and Federal Transit Administration, U.S. Department of Transportation, Washington, D.C., 1995.
- ◆ *Public Involvement Techniques for Transportation Decision-Making*. Report No. FHWA-PD-96-031, Federal Highway Administration and Federal Transit Administration, U.S. Department of Transportation, Washington, D.C., 1996.

Section 3 – Legislative Issues

It is critical that state or local jurisdictions be able to legally operate a roadway using a specific managed lanes operational strategy. State departments of transportation, including TxDOT, receive authorization regarding the operation of federal-aid highways from the United States government. Once the states receive this federal authorization, each state must establish authorization within its specific legal structure.

For an agency to successfully develop and operate managed lanes, the appropriate federal, state, and local legislation and/or policies need to be in place that allow for the design, operation, and enforcement of managed lanes under a variety of control scenarios. Furthermore, agencies likely need legal and regulatory flexibility to make appropriate operational and eligibility changes over time as conditions change.

The operation of different types of managed lanes may be sufficiently different from typical freeway operations that changes in legislation and/or regulations may be required. Appropriate legislation should be in place at both the federal and state levels to ensure their success and legality.

Critical Issues

Numerous federal and state laws are necessary so that operational agencies have the complete collection of options available to design, operate, and enforce managed lanes under a variety of control scenarios. Such federal and state statutes broaden the powers of the states and other transportation organizations and provide them with the tools they need to successfully implement managed lanes facilities in their jurisdictions in the most effective manner, thereby working to reduce congestion and enhance the mobility of their citizens. It is critical that *federal and state laws to authorize development* are in place for each managed lanes operational strategy under consideration.

Once a managed lanes facility is authorized and constructed, the agencies responsible for its operation must ensure that all legal pathways to effective operations are clear. These issues include the handling of violations, enforcement, and operational flexibility. Early consideration of the *legal implications of operational issues* can ensure that the facility operates smoothly and efficiently and can adapt to the regional needs in an effective manner.

Key Resources

The following documents are key resources for this topic in which users can find additional information and guidance beyond that which is presented in this handbook in [Chapter 5 – Legislative Issues](#):

- ◆ B. Kuhn and D. Jasek. *State and Federal Legislative Issues for Managed Lanes – Project Bulletin*. Bulletin No. 4160-8B, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2003,

<http://managed-lanes.tamu.edu/products/bulletins/4160-8B.pdf>, Accessed October 2005.

- ◆ B. Kuhn and D. Jasek. *State and Federal Legislative Issues for Managed Lanes*. Report No. FHWA/TX-02/0-4160-8, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2003, <http://tti.tamu.edu/documents/4160-8.pdf>, Accessed October 2005.
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- ◆ National Environmental Policy Act of 1969, Pub. L. 91-190, 42 U.S.C. 4321-4347, 1 January 1970, as amended by Pub. L. 94-52, 3 July 1975, Pub. L. 94-83, 9 August 1975, and Pub. L. 97-258, Sec. 4(b), 1982.
- ◆ 40 Code of Federal Regulation.
- ◆ *Federal-Aid Highway Occupancy Guidance on High Occupancy Vehicle (HOV) Lanes*. Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., FHWA website, <http://www.fhwa.dot.gov/operations/hovguide01.htm>, Accessed January 2005.
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- ◆ *Federal-Aid Highway Occupancy Guidance on High Occupancy Vehicle (HOV) Lanes*. Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., FHWA website, <http://www.fhwa.dot.gov/operations/hovguide01.htm>, Accessed January 2002.

Section 4 – Public Outreach

Public acceptance plays a critical role in the success of any project. Communicating a new product or concept can be challenging. Effective public outreach programs must consider the goals of the project and tailor the message to meet those goals. Several different techniques can be used to communicate with the public depending on the message that is to be delivered and the objectives. Likewise, a message may be tailored to particular audiences. It is important that the public, or the audience, be correctly defined. Audiences will depend on the nature or scope of the project and may change throughout the different phases of the project.

Many managed lanes projects around the country are under development; several have been implemented. Critical to the success of these projects are the project goals and the strategies agencies use to communicate these goals to the public. It is important to understand public perception and public interaction when a new and complex concept for managing travel demand is introduced.

Critical Issues

Public involvement is important as it serves as a method for communicating all aspects of the project, such as goals, objectives, operations, and revenue use.

Public education should be a consideration at the first stage of planning a project. All interested parties should be involved in the decision-making process, and efforts should be made to contact known stakeholders as well as non-traditional stakeholders who may have a vested interest in a project.

Identifying a *project champion* is also crucial to the success of a project. Research has found that projects that have been successfully implemented have had a strong advocate. This person can serve as a spokesperson in the education process.

Successful projects have *common messages* that have been well received by the public. These include information on choice, use of managed lanes as only one tool within a comprehensive plan, efficiency, operations, enforcement, revenue use, and transportation funding.

Key Resources

The following documents are key resources for this topic in which users can find additional information and guidance beyond that which is presented in this handbook in [Chapter 6 – Public Outreach](#):

- ◆ T. Collier and G. Goodin. *Marketing the Managed Lanes Concept – Project Bulletin*. Bulletin No. 4160-7B, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2002, <http://managed-lanes.tamu.edu/products/bulletins/4160-7B.pdf>, Accessed October 2005.

- ◆ T. Collier and G. Goodin. *Marketing the Managed Lanes Concept*. Report No. FHWA/TX-02/0-4160-7, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2002, <http://tti.tamu.edu/documents/4160-7.pdf>, Accessed October 2005.
- ◆ T. Collier and G. Goodin. *Managed Lanes: A More Efficient Use of the Freeway System: A Position Paper for Policy Makers*. Report No. FHWA/TX-02/4160-P1, Texas Transportation Institute, The Texas A&M University System, TX, 2002, <http://managed-lanes.tamu.edu/products/reports/4160-P1.pdf>, Accessed October 2005.
- ◆ T. Collier and G. Goodin. *Managed Lanes: A New Concept for Freeway Travel: A Position Paper for the Media*. Report No. FHWA/TX-02/4160-P2, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2002, <http://managed-lanes.tamu.edu/products/reports/4160-P2.pdf>, Accessed October 2005.
- ◆ Pacific Rim Resources in collaboration with Parsons Brinckerhoff, Inc., and HS Public Affairs. *Managed Lanes Public Opinion Research – Draft*. Prepared for Washington State Department of Transportation, Seattle, WA, 2001.
- ◆ Wilbur Smith Associates. *I-15 Congestion Pricing Project, Task 3-B, Market Research and Program Promotion Plan*. Prepared for San Diego Association of Governments, San Diego, CA, 1996.
- ◆ Urban & Transportation Consulting and Parsons Brinckerhoff Quade & Douglas. *Colorado Value Express Lanes Feasibility Study Round One Focus Groups, Public Involvement and Outreach Summary Report No. 1, Rev. 1.1*. Prepared for the Colorado Department of Transportation Region 6 Planning and Environmental Section, Denver, CO, 2000.
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Section 5 – Funding and Financing

How to fund transportation projects, in general, and managed lanes projects, in particular, is an issue that TxDOT officials must grapple with daily. The unique operating strategies on managed lanes facilities offer opportunities for innovative financing techniques that are new and untried in the transportation arena.

The key to successful implementation of a managed lanes project will be matching the desires and needs of the community with specific project goals. Financing can be accomplished in a number of ways, be it tolling, a special transportation tax, pricing, revenue bonds, a number of different kinds of loans, commercial vehicle fees, or tourist fees. The goals of the region and the local agencies developing the managed lanes project will determine the candidate methods for financing that should be explored further. Successful projects will find mechanisms that balance those goals with financing criteria.

Critical Issues

It is also important to *distinguish “funding” from “financing.”* Typically, transportation agencies will have a project in the long-term planning process. Whether or not that project is realized will depend on available funding. Therefore, a project in development may be implemented when or if monies (i.e., funding) become available. Ultimately, all projects need a source of funding whether it be grants, taxes, special assessments, or toll revenues.

The key to developing a successful project is to identify the project goals and *match the financing to the purpose.* In an effort to ease this burden on transportation departments, the federal government has made available many new techniques for financing and funding projects. For the most part these new methods can be divided into two categories, cash management tools and credit enhancement and/or investment tools.

Key Resources

The following documents are key resources for this topic in which users can find additional information and guidance beyond that which is presented in this handbook in *Chapter 7 – Funding and Financing Managed Lanes*:

- ◆ T. Collier and G. Goodin. *The Funding and Financing of Managed Lanes Projects – Project Bulletin*. Bulletin No. 4160-9B, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2002, <http://managed-lanes.tamu.edu/products/bulletins/4160-9B.pdf>, Accessed October 2005.
- ◆ T. Collier and G. Goodin. *The Funding and Financing of Managed Lanes Projects*. Report No. FHWA/TX-02/0-4160-9, Texas Transportation Institute,

The Texas A&M University System, College Station, TX, 2002,
<http://tti.tamu.edu/documents/4160-9.pdf>, Accessed October 2005.

- ◆ *Innovative Finance Primer*. Report No. FHWA-AD-02-004, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 2002.

Section 6 – Managed Lanes Weaving, Ramp, and Design Issues

Engineers should consider several elements, criteria, and controls in the design process. In many cases, right-of-way limitations and roadway constraints may make it difficult to meet all desirable design standards. Many groups have an interest in how a facility is designed and operated, and these interests may require compromises during the testing phase.

Unless a facility is being developed as part of a new project or major reconstruction of an existing facility, some compromise in design may need to be considered. To accommodate the fact that using desirable design elements may not always be realistic, this chapter includes information on both desirable and reduced design features. The desirable criteria include all the preferred design elements. Desirable designs generally reflect those associated with a permanent or new facility and meet American Association of State Highway and Transportation Officials (AASHTO) and other standards.

Designs with reduced features reflect the inability to meet the desirable criteria due to lack of available rights-of-way or other significant limitations. Reduced designs do not reflect those associated with permanent facilities, and consideration of reduced designs should be given on a case-by-case basis based on sound engineering practices. The reduced values presented in this chapter are not intended as a standard of practice, and practitioners should use desired values whenever practical.

Critical Issues

The *design and operational components* of a managed lanes facility must be considered simultaneously. Right-of-way constraints will normally dictate the extent of design that is possible. A full design requires fewer operational treatments. When reduced design standards are implemented, the operations component of the managed lanes development becomes increasingly important.

The physical and operating characteristics of eligible vehicles will influence the design of managed lanes facilities. Standard and articulated buses, as well as carpools and vanpools, are often part of the allowed vehicle mix on these types of facilities. The *design vehicles* should be used to control the geometrics of the different managed lanes facility design elements.

In most cases, the *design speed* of managed lanes will be the same as that used on the adjacent general-purpose lanes. However, there may be limited instances where the design speed of the managed lanes is lower than the adjacent general-purpose lanes, due to the geometrics of the managed lanes facility or other limitations. The designated design speed of the facility should relate to the maximum speed the facility is expected to accommodate. Further, the design speed should accommodate the vast majority of users (e.g., the anticipated 85th percentile speed).

These three primary geometric design issues impact all aspects of a managed lanes facility, including additional general geometric considerations (i.e., horizontal and

vertical clearance, stopping sight distance, superelevation, cross slope, minimum turning radius, horizontal and vertical curvature, and gradients), cross sections by facility type, and terminal and access treatments.

Key Resources

The following documents are key resources for this topic in which users can find additional information and guidance beyond that which is presented in this handbook in *Chapter 8 – Managed Lanes Weaving, Ramp, and Design Issues*:

- ◆ S. Venglar, D. Fenno, S. Goel, and P. Schrader. *Managed Lanes – Traffic Modeling – Project Bulletin*. Bulletin No. 4160-4B, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2002, <http://managed-lanes.tamu.edu/products/bulletins/4160-4B.pdf>, Accessed October 2005.
- ◆ S. Venglar, D. Fenno, S. Goel, and P. Schrader. *Managed Lanes – Traffic Modeling*. Report No. FHWA/TX-02/0-4160-4, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2002, <http://tti.tamu.edu/documents/4160-4.pdf>, Accessed October 2005.
- ◆ K. Fitzpatrick, M. Brewer, and S. Venglar. *Managed Lane Ramp and Roadway Design Issues – Project Bulletin*. Bulletin No. 4160-10B, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2003, <http://managed-lanes.tamu.edu/products/bulletins/4160-10B.pdf>, Accessed October 2005.
- ◆ K. Fitzpatrick, M. Brewer, and S. Venglar. *Managed Lane Ramp and Roadway Design Issues – Project Bulletin*. Report No. FHWA/TX-03/4160-10, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2003, <http://tti.tamu.edu/documents/4160-10.pdf>, Accessed October 2005.
- ◆ Texas Transportation Institute; Parsons Brinckerhoff Quade & Douglas, Inc.; and Pacific Rim Resources. *NCHRP Report 414: HOV Systems Manual*. Transportation Research Board, National Research Council, Washington, D.C., 1998.
- ◆ C. Fuhs. *High-Occupancy Vehicle Facilities: A Planning, Design, and Operation Manual*. Parsons Brinckerhoff, Inc., New York, NY, 1990.
- ◆ *A Policy on Geometric Design of Highways and Streets*. American Association of State Highway and Transportation Officials, Washington, D.C., 2001.
- ◆ *Texas Roadway Design Manual*. Revised April 2002, Texas Department of Transportation, Austin, TX, http://www.manuals.dot.state.tx.us/dynaweb/coldesig/rdw/@Generic__BookView, Accessed August 2002.

- ◆ *Guide for High-Occupancy Vehicle (HOV) Facilities.* American Association of State Highway and Transportation Officials, Washington, D.C., 2005.
- ◆ *Guide for the Design of Park-and-Ride Facilities.* American Association of State Highway and Transportation Officials, Washington, D.C., 2005.

Section 7 – Decision-Making Needs and Traffic Control Devices

An implied goal of the managed lanes concept is to offer additional choices to motorists on a section of freeway. These choices can vary by time of day or possibly in response to changing traffic conditions on either the managed lanes or the other general-purpose lanes in the corridor or region. The extent to which travelers can and will accommodate such operational flexibility hinges on getting the right information to travelers, at the right time, and in the right format so that they can make effective decisions pertaining to their trip. There are great differences among drivers in terms of their ability to read, comprehend, and react to traffic control devices. The challenge for designers is to find the design and placement of traffic control devices that serve the most users of the roadway.

Some users of managed lanes will make decisions prior to the start of their trip. However, others may make such decisions en route to their destination. The information needed to support such decisions must be safely and effectively interwoven with that information required for motorists to safely control, guide, and navigate their vehicles into and along the managed lanes. To further complicate matters, this information must often also be interwoven with similar control, guidance, and navigation information required for motorists operating in adjacent general-purpose lanes. Obviously, in such a complex information environment the potential for information conflicts and overload exists. How, where, and when such conflicts and overload can occur, as well as what can be done to help alleviate these conditions, are critical for successful managed lanes facilities.

Critical Issues

Early planning for traffic control devices is important from the perspective of *initial and ongoing costs*. For example, initial costs of communicating information to the driver may include the cost of right-of-way; structures; dynamic message signs and their accompanying power and communications; designing, fabricating and installing static signs including any lane closures required; and pavement markings including standard lane striping plus any horizontal signs and symbols required or desired to augment guide or warning information contained in the signs. Ongoing costs may include maintenance of signs and markings, communications fees, maintenance of power supplies, and maintenance of other electronic components of dynamic message signs.

Early consideration of *driver information needs as a function of managed lanes strategy* will assure that an operating scheme is not implemented which requires overly complex signs. For example, 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 slow speeds, and in most cases stopping completely, it is safe to present this large amount of information. But with electronic toll collection at high speed, it becomes dangerous to overload drivers with complex toll rules.

Applying appropriate principles to *sign design* can help reduce driver workload and confusion on managed lanes facilities. Principles such as positive guidance, information spreading, and coding (with color, banners, or symbols) can help immensely in this regard. Additionally, consistent route naming and numbering is a fundamental issue for wayfinding, addressing, map making, and reference markers. It is especially critical for existing roads, or parts of roads, that are being expanded with managed lanes facilities.

In addition to operating strategies, planners also need to consider *the impact of traffic control devices on geometric design*. Access points that violate driver expectancy, such as left exits, will require good advance signing. Buffer-separated facilities pose a particular problem because there is often insufficient clearance in the median for adequately sized signs.

Key Resources

The following documents are key resources for this topic in which users can find additional information and guidance beyond that which is presented in this handbook in *Chapter 9 – Decision-Making Needs and Traffic Control Devices for Managed Lanes*:

- ◆ S. Schrock, G. Ullman, A. Williams, and S. Chrysler. *Identification of Traveler Information and Decision-Making Needs for Managed Lane Users – Project Bulletin*. Bulletin No. 4160-13B, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2004, <http://managed-lanes.tamu.edu/products/bulletins/4160-13B.pdf>, Accessed October 2005.
- ◆ S. Schrock, G. Ullman, A. William, and S. Chrysler. *Identification of Traveler Information and Decision-Making Needs for Managed Lane Users*. Report No. FHWA/TX-04/0-4160-13, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2004, <http://tti.tamu.edu/documents/0-4160-13.pdf>, Accessed October 2005.
- ◆ S. Chrysler, A. Williams, S. Schrock, and G. Ullman. *Traffic Control Devices for Managed Lanes – Project Bulletin*. Bulletin No. 4160-16B, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2004, <http://managed-lanes.tamu.edu/products/bulletins/4160-16B.pdf>, Accessed October 2005.
- ◆ S. Chrysler, A. Williams, S. Schrock, and G. Ullman. *Traffic Control Devices for Managed Lanes*. Report No. FHWA/TX-04/0-4160-16, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2004, <http://tti.tamu.edu/documents/0-4160-16.pdf>, Accessed October 2005.
- ◆ *Manual on Uniform Traffic Control Devices for Streets and Highway, 2003 Edition*. Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 2003, <http://mutcd.fhwa.dot.gov/>, Accessed October 2005.

- ◆ H. Lunenfeld and G. J. Alexander. *A User's Guide to Positive Guidance (3rd Edition)*. Report No. FHWA-SA-90-017, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 2003.

Section 8 – Enforcement

A managed lanes facility requires effective enforcement policies and programs to operate successfully. Enforcement of vehicle-occupancy requirements, use by authorized vehicles, or proper toll collection is critical to protecting eligible vehicles' travel-time savings and safety. Visible and effective enforcement promotes fairness and maintains the integrity of the managed lanes facility to help gain acceptance among users and non-users.

Successful enforcement of managed lanes requires appropriate application of available resources. Various enforcement strategies exist concerning the amount of enforcement required to ensure that the rules and regulations of managed lanes are maintained. This amount ranges from continuous enforcement to the simpler process of self-enforcement. A review of the various enforcement practices across the country indicates that there are multiple variations for the enforcement of managed lanes with varying levels of success.

Critical Issues

Planning for enforcement of managed lanes is tied to the goals and objectives of the individual project, which determines the operating strategy and user groups. Once an operating strategy for the lanes is defined (i.e., type of managed lanes facility, allowable user groups, toll exemptions or discounts, designated access points by user group, etc.), the agencies involved in developing the project can determine what characteristics determine compliance.

Traditional enforcement on managed lanes requires the specific *design treatment* known as dedicated enforcement areas. These areas are usually located immediately adjacent to the managed lanes facility and allow enforcement personnel to monitor the facility, pursue violators, and apprehend violators to issue appropriate citations. However, recent advances in automated enforcement technology may lower the number of dedicated enforcement areas needed in the future, thereby shifting the focus of design to proper placement of electronic equipment.

The *role of technology* for managed lanes enforcement is growing at an ever-increasing rate. For many years, intelligent transportation system (ITS) technologies have been available for use in monitoring roadways as part of various traffic demand management (TDM) programs. Early detection and quick response times have been vital for incident management and effective use of emergency services. Such advances are the precursor for the use of technology in monitoring and providing enforcement of managed lanes facilities.

Enforcement and operations of a managed lanes facility are intertwined. The role of an HOV lane enforcement program is to ensure that operating requirements, including vehicle-occupancy levels, are maintained to protect eligible vehicles' travel time savings, discourage unauthorized vehicles, and maintain a safe operating environment. Visible and effective enforcement maintains the integrity of the HOV facility and can promote public acceptance.

Key Resources

The following documents are key resources for this topic in which users can find additional information and guidance beyond that which is presented in this handbook in *Chapter 10 – Enforcement Issues for Managed Lanes*:

- ◆ A. Cothron, D. Skowronek, and B. Kuhn. *Enforcement Issues on Managed Lanes – Project Bulletin*. Bulletin No. 4160-11B, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2003, <http://managed-lanes.tamu.edu/products/bulletins/4160-11B.pdf>, Accessed October 2005.
- ◆ A. Cothron, D. Skowronek, and B. Kuhn. *Enforcement Issues on Managed Lanes*. Report No. FHWA/TX-03/0-4160-11, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2003, <http://tti.tamu.edu/documents/4160-11.pdf>, Accessed October 2005.
- ◆ Texas Transportation Institute; Parsons Brinckerhoff Quade & Douglas, Inc.; and Pacific Rim Resources. *NCHRP Report 414: HOV Systems Manual*. Transportation Research Board, National Research Council, Washington, D.C., 1998.

Section 9 – Incident Management

Much has been documented regarding traffic incident management for general-purpose lanes on controlled-access highways. Incident management for general-purpose lanes and for managed lanes share many of the same goals; consequently, many of the techniques, policies, and procedures are the same for facilities of both categories.

Among the various principles for incident management for general-purpose facilities, perhaps the most important is the development, and maintenance, of relationships between key individuals from each of the involved agencies. While it may not be uncommon for the heads of agencies (e.g., local and state law enforcement, local and state transportation departments, transit agency, etc.) to meet periodically during the normal course of events, this type of interaction cannot take the place of familiarity and healthy working relationships among operations staff members from these and other critical agencies. In addition to working relationships, another characteristic of successful incident management programs is the use of various types of agreements, including mutual-aid agreements, hold-harmless agreements, wreckage clearance policies, etc.

These and various other elements of incident management programs are common to successfully minimizing non-recurring congestion due to freeway incidents in general-purpose lanes. These elements are also common to incident management programs for managed lanes facilities. However, the unique features of various types of managed lanes introduce additional aspects to incident management.

Critical Issues

The incident response team roles (e.g., police, fire, emergency medical services, traffic operations, etc.) for the managed lanes team are usually filled by the same agencies as for the general-purpose lanes; however, because different agencies can have different goals, this is not always the case. In these circumstances, the negative potentials within these scenarios can be mitigated through *multi-agency cooperation* that includes mutual aid agreements, hold-harmless agreements, quick clearance policies, abandoned vehicle policies, post-incident briefings, shared information, etc.

Communications to the public regarding the clearance of an incident in the managed lanes should be delivered quickly, just as with messages regarding the beginning of the incident. Incident management for managed lanes should include coordinating statements to the media through a designated incident response team member, e.g., state department of transportation public information officer.

Depending on the specific financial details of a managed lanes facility, it may be that the cost of *pre-positioning tow trucks*, or other response vehicles, is offset by the more rapid response to an incident. The consideration of deploying pre-positioned tow trucks is an issue of travel time reliability and the resultant beneficial impact on toll revenues.

When incident response teams arrive at a scene where a one-lane incident is sufficiently severe, it may require that a second lane be closed to create a *safe work area* in which the team can maneuver. How this is handled depends on where the incident occurs and the design of the managed lanes facility.

Where managed lanes are separated from general-purpose lanes by a barrier, *access to an incident*, when congestion levels are high and speeds are slow, can be achieved via traveling on the shoulders. Where the best route to an incident scene is via the lanes on the opposite side of the barrier from the incident, emergency response vehicles can benefit from the use of emergency access points in the barrier.

A *diversion plan* should be developed by all the relevant parties, including all the agencies on the incident response team. Typically this team should include the state department of transportation, state law enforcement, transit authority, incident response team, fire department, hazardous materials team, freeway service patrols, emergency medical services, local government traffic engineering, towing companies, medical examiner, the designated agency's public information office, etc.

Key Resources

The following documents are key resources for this topic in which users can find additional information and guidance beyond that which is presented in this handbook in *Chapter 11 – Incident Management for Managed Lanes*:

- ◆ A. Ballad. *Incident Management for Managed Lanes – Project Bulletin*. Bulletin No. 4160-17. Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2004, <http://managed-lanes.tamu.edu/products/bulletins/4160-17B.pdf>, Accessed October 2005.
- ◆ A. Ballad. *Incident Management for Managed Lanes*. Report No. FHWA/TX-05/0-4160-17. Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2004, <http://tti.tamu.edu/documents/0-4160-17.pdf>, Accessed October 2005.
- ◆ PB Farradyne. *Traffic Incident Management Handbook*. Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., November 2000, <http://ops.fhwa.dot.gov/OpsSecurity/AltRoutePlans.htm>. Accessed March 2004.
- ◆ K. P. Hoppers. Opening HOV Lanes to General Traffic during Major Incidents and Severe Weather Conditions. August 1999, <http://swutc.tamu.edu/Reports/Compendiums/Compendium1999.pdf>, Accessed August 2004.

- ◆ W. M. Dunn, Jr., R. A. Reiss, and S. P. Latoski. *NCHRP Synthesis of Highway Practice 279: Roadway Incident Diversion Practices*. Transportation Research Board, National Research Council, Washington, D.C., 1999.



Section 10 – Interim Use

Managed lanes will largely function under their intended standard operating procedures, derived from goals and objectives set earlier in the planning process. However, certain conditions, such as construction or maintenance activities, special events, major incidents, or emergencies, may require interim use of the facilities.

Because interim use of managed lanes may detract from the facilities' intended use and performance related to mobility and congestion, reliability, accessibility, safety, environmental impact, system preservation, or organizational efficiency; carefully crafted interim use policies, developed in the planning stages, should guide decisions for the short-term use of managed lanes.

Critical Issues

During unusual conditions, managed lanes may be opened to all traffic regardless of time-of-day, vehicle occupancy, or vehicle type restrictions. Several issues need to be examined when considering this option of *suspending restrictions*. Bottlenecks may form at the terminus of the managed lane, which may reduce capacity and offset any potential benefits. Confusion may result because not all motorists may be familiar with managed lanes facilities; public awareness prior to interim use is needed to ease confusion. The beginning and end of the managed lanes interim use period must be clearly defined and relayed to the motoring public so that the managed lanes can return to standard operating procedures. Furthermore, dropping time-of-day, vehicle occupancy, or vehicle type limitations sets a precedent for similar actions in the future, which may compromise managed lanes compliance during standard operation and increase the need for enforcement (4, 5).

Either singularly or in combination with the suspension of time-of-day, vehicle occupancy, or vehicle type restrictions, tolls can be temporarily suspended during periods of interim use. Historically, agencies have *suspended toll collection* during emergencies to increase capacity and reduce bottlenecks created by the toll collection process. Automated toll collection technologies have largely addressed the potential for bottlenecks at toll plazas, but this strategy still provides an alternative when no suitable alternative routes exist and motorists would be forced to pay tolls (4, 5). To invoke this practice, cooperative agreements should be established with the toll authority prior to implementation. As with other restriction suspensions, temporary toll suspension sets a precedent for similar actions in the future and may result in motorist pressure to suspend tolls when conditions do not warrant such action.

Key Resources

The following documents are key resources for this topic in which users can find additional information and guidance beyond that which is presented in this handbook in [Chapter 12 – Interim Use during Construction, Special Events, and Emergencies](#):

- ◆ J. Carson. *Strategies for Interim Use of Managed Lanes – Project Bulletin*. Bulletin No. 4160-22B, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2005, <http://managed-lanes.tamu.edu/products/bulletins/4160-22B.pdf>, Accessed October 2005.
- ◆ J. Carson. *Strategies for Interim Use of Managed Lanes*. Report No. FHWA/TX-05/0-4160-22, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2005, <http://tti.tamu.edu/documents/0-4160-22.pdf>, Accessed February 2006.
- ◆ K. Hoppers. *Opening HOV Lanes to General Traffic during Major Incidents and Severe Weather Conditions*. Department of Civil Engineering, Texas A&M University, College Station, TX, 1999.
- ◆ G. L. Ullman, N. D. Trout, and R. Collins. *Transportation Management for Major Emergencies*. Texas Transportation Institute, The Texas A&M University System, College Station, TX, 1993.
- ◆ R. A. Reiss and W. M. Dunn, Jr. *Freeway Incident Management Handbook*. Report No. FHWA-SA-91-056, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 1991.
- ◆ G. L. Ullman, N. D. Trout, and T. Urbanik II. *Synthesis of Traffic Management for Major Emergencies*. Report 1231-1, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 1991.

Section 11 – Staffing and Training

Managed lanes facilities present many new challenges to the agency or agencies responsible for their operation. The potential complexities associated with user groups and operational options will require agencies to have an appropriate number of qualified staff to ensure adequate oversight of operations and to ensure satisfactory customer service to the users. It is important to identify those staffing needs related to operational options and specific training that might be required to ensure agency staff are fully prepared to perform their duties to the satisfaction of both the agency and the customer. Additionally, it is important to understand the roles of job positions within the framework of managed lanes, the competencies required of those positions, and accessibility to appropriate training, education, and technical assistance to ensure these needs are met.

Critical Issues

A number of *skill sets or knowledge bases* exist that should be met within an organization operating a managed lanes facility to ensure smooth operations. These skill sets include contract management and supervision, customer service relations, accounts handling, traffic operations management, incident management, and public relations and marketing.

For agencies operating managed lanes facilities, skilled personnel should be identified within the agencies. Otherwise appropriate personnel should receive training for the start-up of operations, or appropriate personnel should be secured through outsourcing.

Key Resources

The following documents are key resources for this topic in which users can find additional information and guidance beyond that which is presented in this handbook in *Chapter 13 – Staffing and Training for Managed Lanes*:

- ◆ B. Ullman and D. Jasek. *Staffing and Training Needs for Managed Lanes Facilities – Project Bulletin*. Bulletin No. 4160-20B, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2005, <http://managed-lanes.tamu.edu/products/bulletins/4160-20B.pdf>, Accessed February 2006.
- ◆ B. Ullman and D. Jasek. *Staffing and Training Needs for Managed Lanes Facilities*. Report No. FHWA/TX-06/0-4160-20, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2005, <http://tti.tamu.edu/documents/0-4160-20.pdf>, Accessed February 2006.
- ◆ National Highway Institute (NHI) website, <http://www.nhi.fhwa.dot.gov/>, Accessed August 2005.
- ◆ Consortium for ITS Training and Education (CITE) website, <http://www.citeconsortium.org/>, Accessed August 2005.

- ◆ Institute of Transportation Engineers (ITE) website, <http://www.ite.org/>, Accessed August 2005.
- ◆ Northwestern University Center for Public Safety website, <http://server.traffic.northwestern.edu/>, Accessed August 2005.

Section 12 – Monitoring and Evaluating Managed Lanes Facility Performance

A successful performance monitoring and evaluation program generally comprises six indistinct and overlapping steps (6):

- ◆ setting goals and objectives that reflect the program or system’s desired performance and are consistent with agency or regional priorities;
- ◆ identifying appropriate performance measures to accurately evaluate attainment of the goals and objectives;
- ◆ identifying required data and sources to support calculation of the performance measures;
- ◆ defining appropriate evaluation methods within the constraints of data availability and staff training;
- ◆ defining an appropriate schedule for ongoing, periodic monitoring of the system; and
- ◆ reporting the results in a usable and easily understood format.

Successful performance monitoring and evaluation activities support an agency’s provision of day-to-day services, direct facility and administrative management decisions, and guide short- and long-range planning efforts.

Critical Issues

Successful *goals and objectives* for managed lanes projects should:

- ◆ be measurable and quantifiable, adequately describing changes in operation;
- ◆ consider performance at the system, project, agency, regional, or statewide level and involve the public, local business interests, elected officials, and agency personnel;
- ◆ drive the data to be collected, not be driven by data availability;
- ◆ consider qualitative (i.e., related to customer satisfaction) goals; and
- ◆ prioritize conflicting goals (i.e., system preservation goals may require an increase in maintenance expenditures while agency efficiency goals seek to minimize maintenance costs).

Performance measures should be:

- ◆ limited in number to prevent data collection and analytical requirements from overwhelming an agency's resources or decision makers;
- ◆ simple and understandable with consistent definitions and interpretations to address the needs of a wide-ranging audience, while still achieving the required precision, accuracy, and detail to facilitate system or program improvement;
- ◆ easily captured either automatically using various technologies or manually with minimal manual data entry and processing to produce usable results;
- ◆ sensitive to change and able to adequately capture observed changes in system or program performance;
- ◆ consistent with staff skills (simplistic evaluation methods with accurate results are preferred over advanced methods that may be erroneous if staff are not adequately trained);
- ◆ consistent in timeframe with decision-making needs, ranging from real time to long term; and
- ◆ geographically appropriate with decision-making needs, ranging from corridor-specific to region-wide, statewide, or even nationwide.

Three general categories of *data* are generally collected to support transportation facility performance monitoring and evaluation: facility use and performance data (i.e., traffic volumes, travel times, and delay); staffing and resource allocation and use data; and event and incident data, including location, duration, and nature.

Evaluation activities may range from a simplistic analysis of quantitative measures to produce descriptive or inferential statistics to any number of more comprehensive, robust analyses related to capacity and level of service, simulation, before-after effects, or alternatives selection. Capacity analysis and simulation are appropriate for ongoing system monitoring, while before-after and alternatives analyses are more appropriate for evaluation prior to or following implementation.

The audience for performance monitoring and evaluation *information* is broad but can be effectively categorized by jurisdictional levels.

Key Resources

The following documents are key resources for this topic in which users can find additional information and guidance beyond that which is presented in this handbook in [Chapter 14 – Monitoring and Evaluating Managed Lanes Facility Performance](#):

- ◆ J. Carson. *Monitoring and Evaluating Managed Lanes Facility Performance – Project Bulletin*. Bulletin No. 4160-23B, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2005, <http://managed-lanes.tamu.edu/products/bulletins/4160-23B.pdf>, Accessed February 2006.
- ◆ J. Carson. *Monitoring and Evaluating Managed Lanes Facility Performance*. Report No. FHWA/TX-06/0-4160-23, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2005, <http://tti.tamu.edu/documents/0-4160-23.pdf>, Accessed February 2006.
- ◆ D. Bracewell, T. Sayed, and A. Shalaby. “High Occupancy Vehicle Monitoring and Evaluation Framework.” *Transportation Research Record 1682*, Transportation Research Board, National Research Council, Washington, D.C., 1999, pp. 38-45.
- ◆ G. Daniels and W. R. Stockton. “Cost-Effectiveness of High-Occupancy Vehicle Lanes in Texas.” *Transportation Research Record 1711*, Transportation Research Board, National Research Council, Washington, D.C., 2002, pp. 1-5.
- ◆ *Evaluation Guidelines for BRT Demonstration Projects*. Federal Transit Administration, Washington, D.C., 2002.
- ◆ A. Gan and S. Jo. *Operational Performance Models for Freeway Truck-Lane Restrictions*. Florida Department of Transportation, Tallahassee, FL, 2003.
- ◆ F. R. Hanscom. “Operational Effectiveness of Truck Lane Restrictions.” *Transportation Research Record 1281*, Transportation Research Board, National Research Council, Washington, D.C., 1990, pp. 119-126.
- ◆ *Highway Capacity Manual*. Transportation Research Board, National Research Council, Washington, D.C., 2000.
- ◆ Texas Transportation Institute; Parsons Brinckerhoff Quade & Douglas, Inc.; and Pacific Rim Resources. *NCHRP Report 414: HOV Systems Manual*. Transportation Research Board, National Research Council, Washington, D.C., 1998.
- ◆ T. Shaw. *NCHRP Synthesis 311: Performance Measures of Operational Effectiveness for Highway Segments and Systems*. Transportation Research Board, National Research Council, Washington, D.C., 2003.

Section 13 – Interoperability

Bringing a managed lanes facility to completion is a complex process of planning, design, and daily operation. Once complete, these ongoing operations may include management, enforcement, incident detection, revenue collection, maintenance, and more. Often, a managed lanes facility is crosscutting, not only in the use of multiple operating concepts to achieve goals, but also in the involvement of multiple agencies and vehicle user groups.

These types of relationships all point to a level of interaction heretofore unseen for most roadways. In essence and indeed in practice, while it may serve special user groups, a managed lanes facility becomes an integral part of the transportation system. A typical statement is that the facility must be interoperable with other facilities in the transportation system. In the case of managed lanes, the facility must act in concert with the adjacent infrastructure to accomplish mobility goals.

Critical Issues

Interoperability within the context of managed lanes can exist at *three levels*: at the agency level, at the facility level, and/or at the equipment level. As a result of the complex interactions that can occur between many aspects of the managed lanes facility, other facilities, and the agencies responsible for their design and operation, interoperability is a key concept to address in the managed lanes concept.

Planning and traffic control device interoperability are critical to success. By addressing system integration or interoperability needs at the planning level, agency partners can work together to ensure that a managed lanes facility satisfies the regional mobility goals. Furthermore, traffic control device interoperability should focus on the consistency of information being provided to the motorist.

Key Resources

The following documents are key resources for this topic in which users can find additional information and guidance beyond that which is presented in this handbook in [Chapter 15 – Interoperability Issues on Managed Lanes Facilities](#):

- ◆ R. Brydia and S. Song. *Interoperability Issues on Managed Lanes Facilities – Project Bulletin*. Bulletin No. 4160-18B, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2004, <http://managed-lanes.tamu.edu/products/bulletins/4160-18B.pdf>, Accessed October 2005.
- ◆ R. Brydia and S. Song. *Interoperability Issues on Managed Lanes Facilities*. Report No. FHWA/TX-05/0-4160-18, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2004, <http://tti.tamu.edu/documents/0-4160-18.pdf>, Accessed October 2005.

- ◆ *Linking Regional Planning and Operations for Effective ITS Deployment Proceedings*. Federal Highway Administration, Federal Transit Administration, and Volpe National Transportation System Center, Washington, D.C., 1996.
- ◆ M. Miller and A. Lam. *Institutional Aspects of Multi-agency Transit Operations*. California PATH Research Report UCB-ITS-PRR-2003-18, California Partners for Advanced Transit and Highways, Berkeley, CA, 2003.
- ◆ B. Christie and S. Proper. *ITS Standards Implementation – Interoperability Issues and Solution*. ITS America 12th Annual Meeting, Long Beach, CA, 2002.

Section 14 – References

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2. FHWA's Vital Few Environmental Goal – Environmental Stewardship and Streamlining, 2002. FHWA website, <http://environment.fhwa.dot.gov/strmlng/vfovervw.htm>, Accessed December 2004.
3. National Environmental Policy Act of 1969, Pub. L. 91-190, 42 U.S.C. 4321-4347, 1 January 1970, as amended by Pub. L. 94-52, 3 July 1975, Pub. L. 94-83, 9 August 1975, and Pub. L. 97-258, Sec. 4(b), 1982.
4. G. L. Ullman, N. D. Trout, and R. Collins. *Transportation Management for Major Emergencies*. Texas Transportation Institute, The Texas A&M University System, College Station, TX, 1993.
5. S. D. Wohlschlaeger and G. L. Ullman. *Catalog of Transportation Management Activities for Major Emergencies*. Report 1231-2, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 1991.
6. Neudorff, Louis G., Jeffrey E. Randall, Robert Reiss and Robert Gordon. *Freeway Management and Operations Handbook*. FHWA-OP-04-003. Federal Highway Administration, Washington D.C., 2003.

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Section 1 – Overview

The highway system in the United States is a critical component of American life. It provides extensive and flexible personal mobility to American citizens and efficient freight movement to support the domestic economy (1). Both of these services are impacted by investment and location decisions made by governmental entities across the country in their planning processes.

A variety of factors may interfere with this system’s ability to provide these services. These factors include, but are not limited to, an increase in travel by users, congestion, and environmental and financial constraints. For example, the growth in vehicle miles traveled (VMT) continues to outpace lane mile growth across the country. In 2002, the VMT for highway travel in the United States was nearly 3 trillion miles (2). Between 1993 and 2000, the VMT increased by 2.7 percent annually while the number of lane miles in the United States only grew by 0.2 percent annually during the same time period (2). This growth in travel places a strain on a transportation system that is already overburdened. This strain is especially felt in freight transportation. It is expected that freight tonnage will nearly double by the year 2020, with even higher numbers at key ports of entry, along major corridors, and along primary intermodal connectors and related hubs (1). Managed lanes projects have the potential to better utilize existing facilities and reduce the impact of this increase in travel.

Congestion in urban areas in the United States is increasing. It occurs on more roads during longer parts of the day, delaying more travelers every year (3). The “rush hour” grows longer and costs Americans dearly in the form of delay, increased fuel consumption, lost productivity, and related crashes. In 1999 alone, more than \$72 billion was wasted in time and fuel consumption (4). Such congestion interferes with daily life, and any method to alleviate it, such as managed lanes projects, can help reduce its impact on productivity.

The reality of improving the transportation infrastructure today is that agencies must function within environmental constraints. No longer may agencies plan transportation projects in a vacuum. Now, agencies must consider the environment in the planning of transportation projects, minimize the negative impacts of construction, and work to reduce transportation-related pollution in the process. Reinforcing this direction is the Federal Highway Administration’s strategic plan, which highlights the importance of protecting and enhancing the natural environment and communities affected by highway transportation (5). Agencies must demonstrate environmental stewardship and improve the environmental quality of their transportation decision making (6). Such stewardship, combined with environmental streamlining, helps address mobility and safety needs of the public while improving project delivery without compromising environmental protection (7). Managed lanes projects have the potential to improve mobility while reducing the increase in pollution and minimizing the impact on the environment.

Sections in this chapter cover:

- ◆ [planning and programming](#),

- ◆ preliminary design, and
- ◆ environmental considerations.

Section 2 – Planning and Programming

Needs Identification

The purpose of the strategy selection tool is to provide a preliminary screening instrument for TxDOT project managers that helps define the types of managed lanes strategies that would be conducive for a given corridor. The screening tool is based on the upper elements in the flow diagram shown in the outlined box in Figure 4-1. It is a simple tool that primarily relies on the defined objectives for the improvements in defining the potential operating strategies.

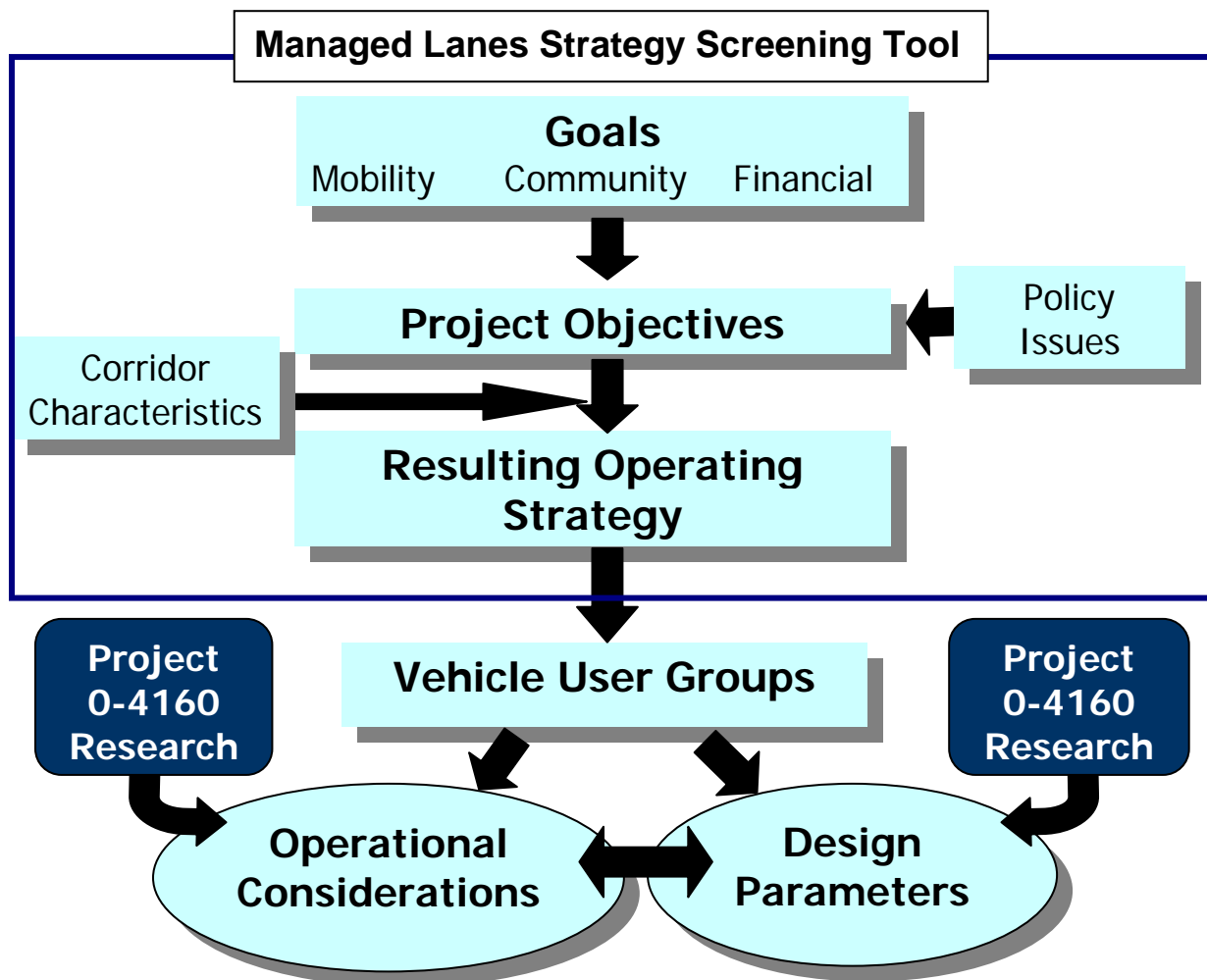


Figure 4-1. Flow Diagram Showing Elements of the Decision Process Incorporated into the Strategy Selection Tool.

The managed lanes strategy screening tool was created to facilitate the decision-making process by identifying potential managed lanes scenarios to implement. The program incorporates many different calculations made to determine the best possible scenario based upon the objectives chosen by the user. It is important to note that it is a very quick and simple tool to be used early in the planning process to help sort possible managed lanes operating scenarios. Other screening tools offer further refinement of potential strategies, such as the High Occupancy Toll Strategy Analysis Tool (HOT START) developed for TxDOT Project 0-4898. That particular tool evaluates the use of HOT lanes in HOV corridors, either through adapting existing HOV lanes or by building HOT lanes instead of HOV lanes in corridors where HOV lanes are planned. As an illustration, if the managed lanes strategy screening tool identifies HOV and HOT as strong candidate strategies, the analyst may consider using the HOT START tool to further refine the decision.

The flow diagram shown in [Figure 4-2](#) illustrates the steps the managed lanes strategy screening tool uses to develop a list of candidate strategies. The program itself has four critical steps in determining the appropriate scenario to advocate: the choice of objectives, weighting of the objectives (optional), the constraints, and the processing of the final solution.

The remaining portion of this section describes the methodology and underlying assumptions used in the program.

Goals and Objectives for Managed Lanes

The overall goals for the implementation of managed lanes can be divided into three distinct groups: mobility goals, community goals, and financial goals. First, the mobility goals of managed lanes are focused upon such wide topics as demand and accessibility. These goals are characterized as mobility goals because they aim to improve the mobility of the facility or system in question. The second category of goals is the community goals. Community goals are generally defined as goals that aim to help maintain or improve the local community based on the interests of its constituents. Financial goals, much like their name implies, are goals that aim to address the financial realities of infrastructure expansion with limited funding and the financing methods by which an agency pursues the development of projects. [Table 4-1](#) highlights different mobility, community, and financial goals that may be associated with managed lanes.

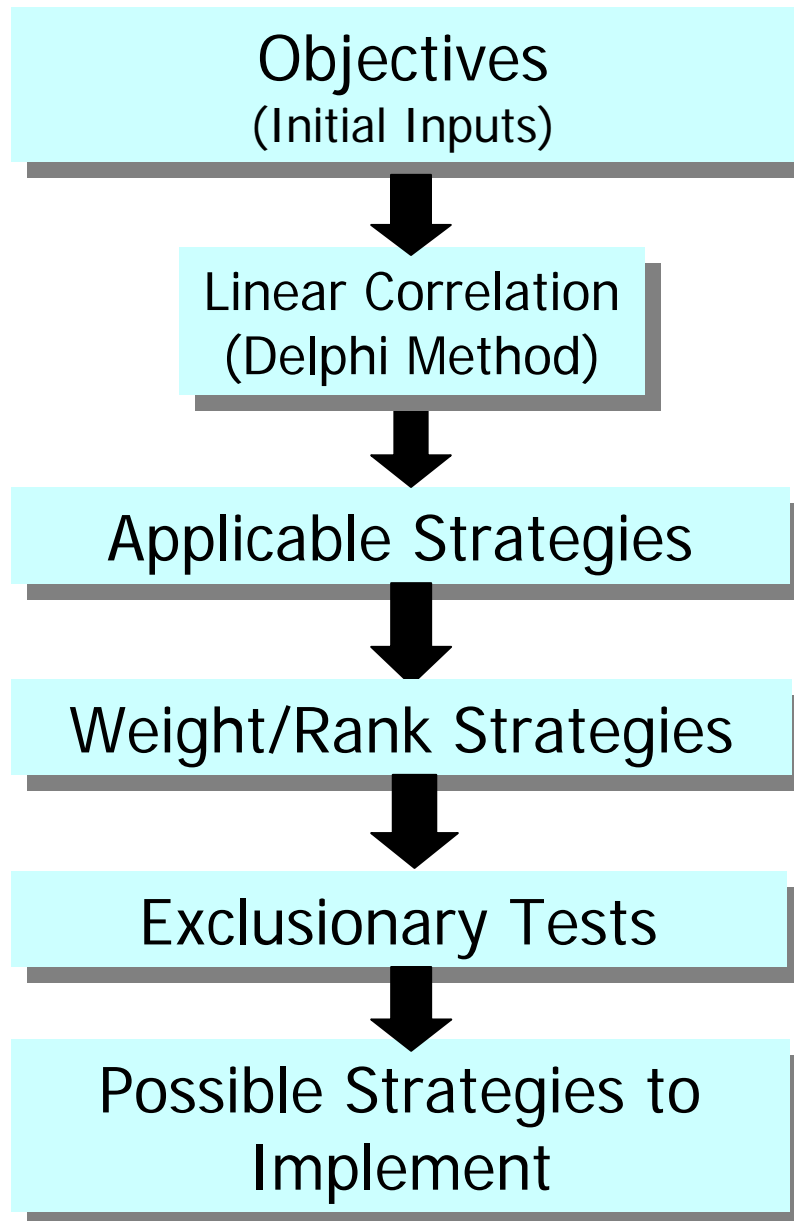


Figure 4-2. Flow Diagram for Managed Lanes Strategy Screening Tool.

Table 4-1. Possible Managed Lanes Goals.

Category of Goal	Possible Goals
Mobility Goals	<ul style="list-style-type: none"> • Provide a transportation system that can handle current and future demand • Increase mobility and accessibility by offering travel options • Provide additional facility capacity • Optimize existing managed lanes capacity • Provide congestion relief • Modify travel demand • Enhance alternative modes • Improve accessibility
Community Goals	<ul style="list-style-type: none"> • Improve the safety of corridor travel • Minimize environmental impacts • Preserve neighborhoods • Maintain land-use patterns
Financial Goals	<ul style="list-style-type: none"> • Develop transportation improvements that are financially self-sustaining

The overall goals of various managed lanes can be linked to individual objectives they are trying to achieve. [Table 4-1](#) lists potential project goals. The corresponding objectives listed in [Table 4-2](#) were developed over the course of the research project through literature review and meetings with TxDOT staff.

Table 4-2. Typical Project Objectives for Managed Lanes.

Goal	Typical Project Objectives
Provide a transportation system that can handle current and future demand	Increase vehicle-carrying capacity Increase person-carrying capacity Increase goods-carrying capacity Maintain or improve level of service (LOS) Reduce travel time
Increase mobility and accessibility by offering travel options	Provide travel alternatives Improve express bus service Encourage transit-oriented development Fund new transit and managed lanes improvements
Provide additional facility capacity	Increase vehicle-carrying capacity Increase person-carrying capacity Increase goods-carrying capacity Maintain or improve LOS
Optimize existing managed lanes capacity	Increase vehicle-carrying capacity Increase person-carrying capacity Increase goods-carrying capacity Maintain or improve LOS
Provide congestion relief	Increase vehicle-carrying capacity Increase person-carrying capacity Reduce travel time Provide travel alternatives Reduce peak-period vehicle trips Encourage transit-oriented development
Modify travel demand	Provide travel alternatives Reduce peak-period vehicle trips
Enhance alternative modes	Provide travel alternatives Improve express bus service Provide transmodal connectivity and accessibility encourage transit-oriented development
Improve accessibility	Provide transmodal connectivity and accessibility
Improve the safety of corridor travel	Minimize traffic crashes involving large trucks
Minimize environmental impacts	Provide travel alternatives Improve express bus service Improve air quality from mobile sources Address environmental justice concerns
Preserve neighborhoods	Provide transmodal connectivity and accessibility Address environmental justice concerns Encourage transit-oriented development
Maintain land-use patterns	Provide transmodal connectivity and accessibility Address environmental justice concerns Encourage transit-oriented development
Develop transportation improvements that are financially self-sustaining	Fund new transit and managed lanes improvements Produce enough revenue to cover operations/maintenance (O/M) and enforcement Produce enough revenue to cover debt service Provide private investment profit

User Input of Objectives in Screening Tool

Initially, the program gathers the input from the user in the form of objectives a user would like to see addressed. This is done by a series of check boxes for which the user can select the appropriate objectives. There are 19 objectives available for the user to select for the screening tool. The list of the possible objectives follows:

1. Increase vehicle-carrying capacity.
2. Increase person-carrying capacity.
3. Increase goods-carrying capacity.
4. Maintain free flow speeds.
5. Maintain or improve the LOS.
6. Reduce travel time.
7. Increase trip reliability.
8. Provide travel alternatives.
9. Reduce peak-period vehicle trips.
10. Improve express bus service.
11. Provide transmodal connectivity and accessibility.
12. Minimize traffic crashes involving large trucks.
13. Improve air quality from mobile sources.
14. Address environmental justice concerns.
15. Encourage transit-oriented development.
16. Fund new transit and managed lanes improvements.
17. Produce enough revenue to cover O/M and enforcement.
18. Produce enough revenue to cover debt services.
19. Provide private investment return on investment.

Correlation of Objectives to Strategies

From the list of objectives provided in [Table 4-2](#), various objectives can be related to different managed lanes strategies. [Table 4-3](#) shows the various objectives (on the right) and how they can relate to the different strategies (on the left). Presented in the table are seven different managed lanes strategies and potential objectives to be achieved by them. This relationship between the objectives and the strategies is based on a web-based survey of practitioners and experts. Electronic mailing lists of professionals involved in managed lanes were used to solicit respondents, including the Project 0-4160 managed lanes listserv and the Transportation Research Board (TRB) Managed Lanes Joint Subcommittee mailing list. The survey is provided in [Appendix A](#). Twenty-nine responses were received. A linear correlation, or Delphi Method, was used to analyze input from experts and form a direct linear correlation between objectives and strategies. Their answers were aggregated, and the results from their input form the determination used to relate the two sets. The researchers asked the experts about how each objective (taken in isolation) can be fulfilled by the strategies. The results were used by the researchers to combine different objectives to find the best strategy or strategies for achieving the composite objective.

Table 4-3. Managed Lanes Strategies and Associated Objectives.

Managed Lanes Strategy	Objectives
<p>Express Toll Lanes</p> <p>Separated lanes with limited access where all vehicles pay a toll</p>	<p>Increase vehicle-carrying capacity Reduce travel time Provide travel alternatives Fund new transit and managed lanes improvements Produce enough revenue to cover O/M and enforcement Produce enough revenue to cover debt service Provide private investment profit</p>
<p>HOV Lanes</p> <p>Lanes that only allow vehicles that meet or exceed a required number of occupants</p>	<p>Increase vehicle-carrying capacity Increase person-carrying capacity Reduce travel time Increase trip reliability Provide travel alternatives Reduce peak-period vehicle trips Improve express bus service Improve air quality from mobile sources Address environmental justice concerns Encourage transit-oriented development</p>
<p>Express Lanes</p> <p>Separated lanes with limited access</p>	<p>Increase vehicle-carrying capacity Reduce travel time Provide travel alternatives</p>
<p>Exclusive Transitways</p> <p>Lanes or roadways which are meant to exclusively serve buses</p>	<p>Increase person-carrying capacity Reduce travel time Increase trip reliability Provide travel alternatives Reduce peak-period vehicle trips Improve express bus service Provide transmodal connectivity and accessibility Improve air quality from mobile sources Address environmental justice concerns Encourage transit-oriented development</p>
<p>Exclusive Truck Lanes</p> <p>Dedicated lanes in which only large trucks are permitted</p>	<p>Increase vehicle-carrying capacity Increase goods-carrying capacity Maintain free-flow speed Reduce travel time Minimize traffic crashes involving large trucks</p>
<p>Truck Restricted Lanes</p> <p>Lanes of the roadway in which large trucks are restricted</p>	<p>Maintain free-flow speed Maintain or improve LOS Minimize traffic crashes involving large trucks</p>
<p>HOT Lanes</p> <p>HOV lanes that allow vehicles that do not meet the occupancy requirement to use the lanes for a fee or toll.</p>	<p>Increase vehicle-carrying capacity Increase person-carrying capacity Maintain free-flow speed Reduce travel time Improve express bus service Improve air quality from mobile sources Address environmental justice concerns Encourage transit-oriented development Fund new transit and managed lanes improvements Produce enough revenue to cover O/M and enforcement Produce enough revenue to cover debt service Provide private investment profit</p>

Weighting of Objectives

Once a user has determined the appropriate objectives, the values for those rows are summed into a master row, hereafter referred to as “the values.” After this step has been completed, the user has the opportunity to “weight” objectives.

The purpose of weighting objectives is to place greater importance upon some of the objectives, while diminishing the importance of others. The option to weight objectives is initially hidden. In order to weight the objectives, the user must enable the weighting process. This option is hidden from the user by default because any choices made in this option will affect the initial array of data created by the experts. Changing the array data, while useful in many circumstances, must be done carefully.

Once the user has enabled the weighting process, he or she is presented with a list of the options he or she had selected earlier in the process (Figure 4-3). Next to each of the objectives is a box describing the choices the user can make for that objective. The options are: Important (the default value), Less Important, and Higher Importance.

If the user leaves the default value selected (Important), no changes are made to the data array linking the importance with the objectives. However, if the user selects “Less Important,” the values for the objective in the data array are divided in half. Likewise, if the user selects a higher level of importance for an objective, the objective values in the array are doubled in value.

Increase Vehicle Carrying Capacity	Important	⬇
Increase Person Carrying Capacity	Important	⬇
Increase Goods Carrying Capacity	Important	⬇
Increase Trip Reliability	Important	⬇
Improve Express Bus Service	Important	⬇
Encourage Transit Oriented Development	Important	⬇
Produce Enough Revenue to Cover Debt Services	Important	⬇

Figure 4-3. Weighting Screen.

By weighting the objectives themselves, the user is able to place more emphasis upon specific objectives, thereby allowing them to have a much more fine-tuned result. If the user does not choose to weight the objectives, the default values (given above) are used.

Corridor Considerations

There are other considerations, besides that of goals and strategies, which must be considered before determining the appropriate type of managed lanes to pursue. Not all of the goals and objectives can adequately define all of the possible real-world

environments in which managed lanes are to be constructed. The list of other considerations is in [Table 4-4](#) below, with brief definitions of the other considerations.

Table 4-4. Corridor Considerations in Strategy Selection.

Corridor Condition	Characteristic
Physical constraints	Physical constraints, including cross-section limitations, right-of-way restrictions, and access limitations may impact the type of strategy that can be used.
Truck characteristics	Level and type of truck traffic, safety considerations, and availability of alternative truck routes may have an effect on the choice of strategy.
Origin-destination patterns	The selection of a managed lanes strategy may depend on the origin-destination patterns in the corridor.
Land use	Related to origin-destination patterns, the land use (existing and future) may have a bearing on the appropriate managed lanes strategy to implement.
Price elasticity and willingness to pay	Price elasticity and WTP help quantify the role of value pricing in the corridor and the funding available for improvements.
Funding	Capital funding refers to the initial cost of the project and may exclude possible strategies due to cost and related funding availability. Operations funding refers to the ongoing management, maintenance, and enforcement of the facility.

Exclusionary Tests

After the user has selected the objectives that he or she feels are important, the user is then presented with a list of constraints that must be provided to rule out possible managed lanes scenarios from being provided to the user at the conclusion of the program. There are 20 general constraints, which are directly tied to the seven possible managed lanes strategies.

The constraint questions are listed below:

1. Is there currently enough right-of-way within the existing or proposed development to add a lane in each direction?
2. Is there currently enough right-of-way within the existing or proposed development to add two additional lanes?
3. Do other corridors in the region currently have HOV lanes?
4. What percentage of crashes is caused by trucks?
5. Is the route currently a hazardous materials (HAZMAT) route?
6. How long is the proposed managed lanes facility?
7. Do you expect to recover operating costs and more than 10 percent of capital costs from revenue generated by the facility?
8. What percentage of peak-period traffic is freight?
9. What type of drivers use the roadway most often?
10. What type of trucks use the roadway?

11. Are there currently truck restricted lanes on the corridor?
12. Is the corridor a trucking route?
13. Are there parallel alternative truck routes nearby?
14. Does the proposed route serve a major activity center?
15. What is the congestion index for the roadway in question?
16. What is the median family income in the corridor?
17. What is the average number of vehicles per household in the corridor?
18. Besides buses, is there another form of mass transit in the corridor?
19. How many buses will use these managed lanes per day?
20. Is there political opposition to toll roads in your city?

Once the user enters the constraints section, a queue is formed using all of their previous answers. The queue has a list of all the possible strategies to implement along with values associated with each strategy. The data for the queue come directly from the above mentioned steps (choosing the objectives and weighting the objectives). The constraints section takes the values in the queue and lowers the values depending upon the user's answers to the various constraints.

The viability of the strategies is largely based in the initial section of the program where the objectives are matched to the strategies. The corridor constraints function only excludes the possibilities based upon responses to the constraint questions. So, depending upon the inputs a user makes initially when choosing the objectives, applicable strategies are identified using the data gleaned from the expert survey.

The reason there are constraints is that the strategies advocated by the experts were too close in some fields, most notably truck traffic and financial considerations. So, the constraints were identified to separate the possible strategies to determine whether or not trucks should be advocated or not, and also tolling or not. Essentially, the answers given by the experts were too similar (points wise) for strategies that were very different (hypothetically, truck lane restrictions and HOVs, which are very different). Therefore, the constraints are put into place to determine which one should be given as an appropriate answer.

The constraints can be configured to be absolute or lenient. If the "strict" constraints are selected, a much more strict method of reducing the values in the queue is implemented (thereby eliminating more possible strategies). However, if the "lenient" constraints are selected, a managed lanes strategy will not necessarily be eliminated due to constraints alone. Although it will be pushed down in the queue of appropriate strategies to implement, the values will not be as low as with the strict interpretation. The algorithm developed to filter the constraints is then run on the possible strategies, eliminating those that do not meet the basic criteria for use in the corridor.

These scores are then totaled for each of the strategies and are parsed by an algorithm (which takes into account if the constraints should be interpreted loosely or not). The remaining sum for each strategy is then divided by the sum gathered in the objective stage to determine the appropriate strategies to implement.

Results from the Strategy Selection Tool

The final screen presented to the user takes all of the input and offers three strategy options and their scoring. This task takes the values associated with the objectives and totals the values to determine which possible scenario best meets the criteria of the user. The constraints are then applied depending upon the user's preference (lenient or strict), and the final array is completed containing all the possible strategies listed in order of acceptability. After this step is complete, the answers are then displayed to the end user for approval. Next to each possible strategy is the final queue value for that particular strategy. This "score" is used to determine the placement in the queue and can vary drastically in number between 200 and 1.

Project Authorization and Requirements Determination

Perhaps one of the more critical and fundamental components of any managed lanes project is the ability for a state or local jurisdiction to legally operate a roadway using a specific managed lanes operational strategy. State departments of transportation receive authorization regarding the operation of federal-aid highways from the U.S. government. Once the states receive this federal authorization, each state must establish authorization within its specific legal structure.

Numerous federal and state laws are necessary so that operational agencies have the complete arsenal of options available to design, operate, and enforce managed lanes under a variety of control scenarios. Such federal and state statutes broaden the powers of states and other transportation organizations and provide them with the tools they need to successfully implement managed lanes facilities in their jurisdictions in the most effective manner, thereby working to reduce congestion and enhance the mobility of their citizens. *Chapter 5 – Legislative Issues* in this handbook provides a brief discussion of federal and state laws, either existing or needed, to authorize and govern the various lane management strategies.

Section 3 – Preliminary Design

Defining User Groups

Once an operating strategy or multiple operating strategies are identified, defining vehicle user groups for a managed lanes facility is the next important step in the managed lanes development process for several reasons:

- ◆ It helps in evaluating financing for the project if non-paying or exempt users are identified.
- ◆ It establishes the design vehicle used to control the geometrics of the facility design elements.
- ◆ It offers insight into driver communication and signing needs, especially if the user group can be categorized as a familiar, semi-familiar, or non-familiar user.
- ◆ It offers insight into potential enforcement opportunities and challenges.
- ◆ It provides a starting point for establishing a long-term “concept of operations,” where variations in user eligibility can be illustrated over time in order to maintain operational performance thresholds and communicate expected changes over time. This is illustrated in [Figure 4-4](#), which shows how one HOT lane facility over time is expected to modify operations – both in terms of who can use the HOT lane and who will be tolled (8).

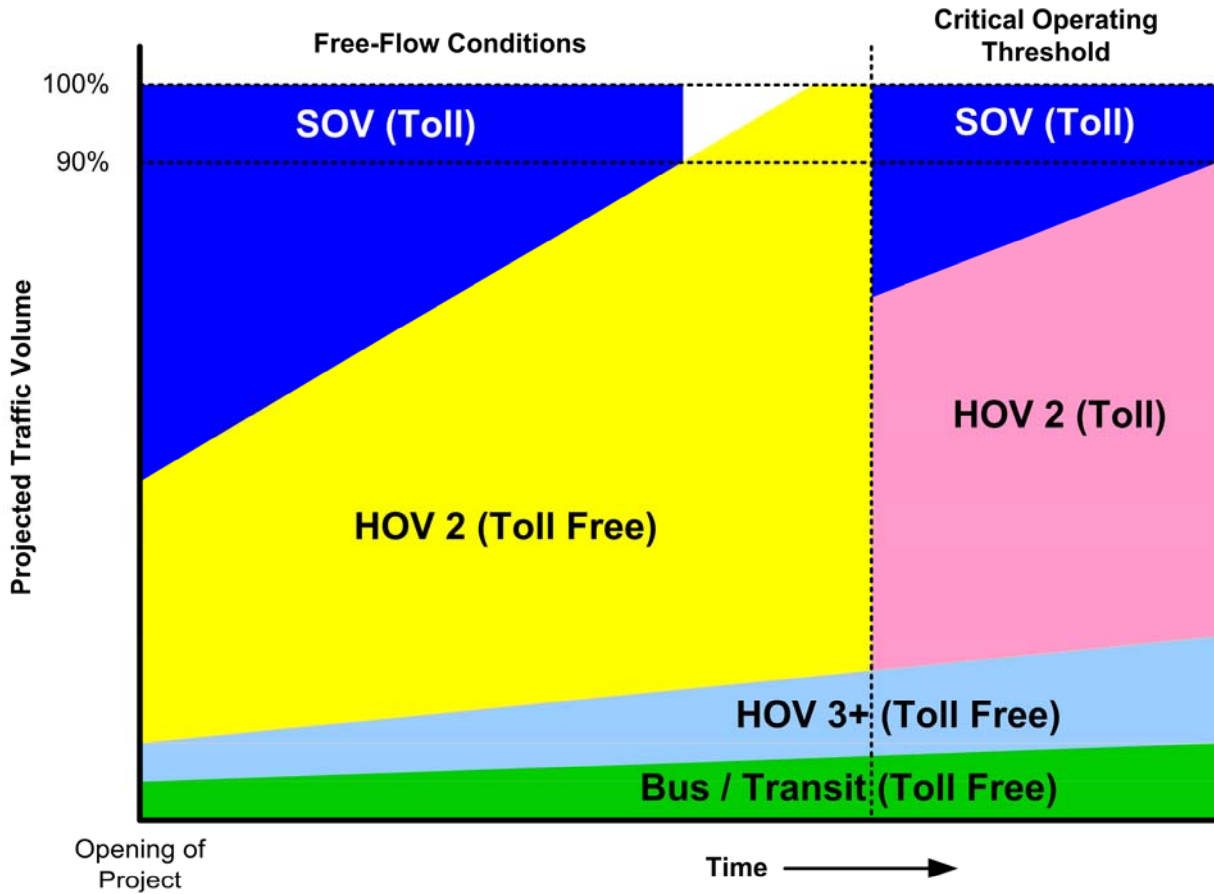


Figure 4-4. Life Cycle of a Facility (8).

Table 4-5 depicts the seven operational strategies and candidate user groups for each strategy. There are several issues to keep in mind when defining potential user groups for a project:

- ◆ The table below has a broad definition of “trucks.” The objectives and characteristics of each individual facility will have to be carefully examined to determine if trucks should be included and the type of truck allowed (single unit versus semi-trailer, for example).
- ◆ There may be a desire to incorporate rail as a future component of a managed lanes envelope. As such, design criteria should reflect the stricter vertical and horizontal criteria for rail vehicles and associated bridge loadings.
- ◆ “Emergency vehicles” include not only on-duty police, fire, and emergency medical vehicles, but also vehicles necessary to respond to threats such as natural disasters or terrorist attacks. This would include debris removal vehicles and evacuation/rescue vehicles.

Table 4-5. Potential Vehicle User Group Scenarios.

Managed Lanes Strategy	Potential Vehicle User Groups	
	Tolled	Non-tolled
Express Toll Lanes	SOV HOV Trucks LEV Taxi/Shuttle Motorcycle	Bus/BRT Emergency Vehicles
HOV Lanes		HOV Bus/BRT LEV Taxi/Shuttle Motorcycle Emergency Vehicles
HOT Lanes	SOV Trucks	HOV Bus/BRT LEV Taxi/Shuttle Motorcycle Emergency Vehicles
Express Lanes (Non-tolled)		All Vehicle User Groups
Exclusive Transitways		Bus/BRT
Exclusive or Dedicated Truck Lanes		Trucks
Truck Restricted Lanes		All Vehicle User Groups Except Trucks

Public Opinion

Societal and public opinion regarding the implementation of a managed lanes strategy may be the single most important nonoperational factor in a facility’s success or failure. Unfavorable public opinion can result in either the curtailment or cancellation of projects or provide a preconceived notion of the effectiveness of a strategy that may affect future projects. A marketing strategy and public education campaign are therefore paramount for successful implementation of any managed lanes strategy.

Public involvement and a successful marketing program are critical to HOV projects and their success. In addition to helping the community and public understand the purpose of the project, a successful public education campaign will increase utilization of the facility (9). Poorly thought out strategies combined with insufficient public education can lead to implementation problems.

HOT lanes also pose some potential public relations challenges, even though they improve utilization of existing HOV lanes. For example, the Maryland Department of

Transportation Value Pricing Study found that public acceptance depends on the type of pricing implemented and the quality of the alternatives available. When drivers have an on-the-road choice of travel options and routes and new innovative alternatives expand the public's choice, the public opinion of HOT or value-priced lanes increases (10).

Generally speaking, bus ridership has declined in many cities since the middle of the last century. Public acceptance of the use of buses as a viable transportation alternative is paramount to a quality multi-modal transportation plan (11). Shen et al. found that public acceptance hinged on education about the advantages of busways, including flexibility, self-enforcement, incremental development, low construction costs, and implementation speed, as well as the provision of passenger improvements in comfort, economy, travel time, and quality of service (12).

The most significant obstacle to exclusive truck facilities may be public opinion. In the reserved capacity feasibility study by Trowbridge et al., an attitudinal study of motorists and the general public examined opinions regarding the use of HOV lanes by trucks (13). The response by the general public indicated considerable resistance to any strategy that was perceived as a special benefit to truck traffic. However, it should be noted that the general public was favorable to truck lane restrictions. Individual comments included responses (19 percent) that trucks were unable to maintain constant speed or traveled at different speeds. Some individuals (13 percent) viewed trucks as dangerous or unsafe (13).

The Organisation for Economic Co-operation and Development (OECD) report on truck roads (14) verified that exclusive truck lanes would be unpopular with the general public. Public acceptance of a facility depends on whether individuals find the facility useful. In the case of an exclusive truck road, people living near the facility do not perceive a direct benefit and may oppose the facility. Once again, although public opinion is negative toward exclusive facilities, the public generally favors the restriction of trucks to specific lanes (14). This acceptance of restrictions is consistent with public input on the Capital Beltway truck lane restrictions. In this specific case, public opinion was so favorable that lane restrictions were maintained even though there was no indication of improved traffic operations or a reduction of crashes (14, 15, 16).

Perhaps one of the most critical components of the transportation planning process is public involvement. Without it, the plan and its related projects do not necessarily reflect the goals and objectives of the region and its residents, increasing the risk of opposition to efforts to improve the transportation system. The investment in the transportation system has far-reaching effects, and involving the general public and all affected stakeholders in this decision-making process helps ensure that the impacts of that investment are sufficiently considered (17).

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) requires that a metropolitan planning organization (MPO) have a formal public involvement process that is broad in its reach and responsive in its efforts. Various techniques for establishing communication, sharing information, gathering feedback, and enhancing participation of the public include but are not limited to the following:

- ◆ public meetings, briefings, and hearings;
- ◆ conferences, workshops, and retreats;
- ◆ key person interviews, focus groups, and public opinion surveys;
- ◆ on-line services and hotlines; and
- ◆ video, telephone, and other media effort (18).

When considering managed lanes strategies as part of the transportation plan, public involvement is especially critical and even includes a comprehensive public education component (19). The problem lies with the fact that people tend to be unfamiliar with the concept of managed lanes. The MPO must thoroughly communicate the concept and the various potential strategies it might include. Also, the MPO should include all aspects of managed lanes in their education effort, such as goals, objectives, operations, and potential revenue use, when considering it for the transportation plan. For example, while the public is familiar with some examples of pricing to manage demand, many do not see the government's role in this endeavor. Research has shown that in focus groups, individuals are more supportive of the concept after they are shown examples of successful projects and how they operate.

With such a public involvement process, an MPO can ensure that all of the social, economic, and environmental consequences of transportation investment decisions are considered. Furthermore, it ensures that those decisions are in accord with the region's land-use plans, have the broad support of the community, and work to meet its needs, goals, objectives, interests, priorities, and values (17).

It goes without saying that public and agency input is critical to the planning process. As illustrated in Figure 4-5, this input should be part of every step in the regional planning process. Without it, the plan and its related projects do not necessarily reflect the goals and objectives of the region and its residents, increasing the risk of opposition to efforts to improve the transportation system. An MPO should engage the public and other stakeholder groups by establishing communication, sharing information, gathering feedback, and enhancing their participation in the planning process.

The managed lanes concept complicates this involvement process by generating a need for public education. The MPO must thoroughly communicate the concept and the various potential strategies it might include. Also, the MPO should include such aspects of managed lanes as goals, objectives, operations, and potential revenue use, when considering them for the transportation plan. Public involvement can help ensure that an MPO considers all of the social, economic, and environmental consequences of their transportation investment decisions. It gains buy-in from the public and develops an environment of cooperation and collaboration with participating stakeholders that can smooth the way for project development in the future.

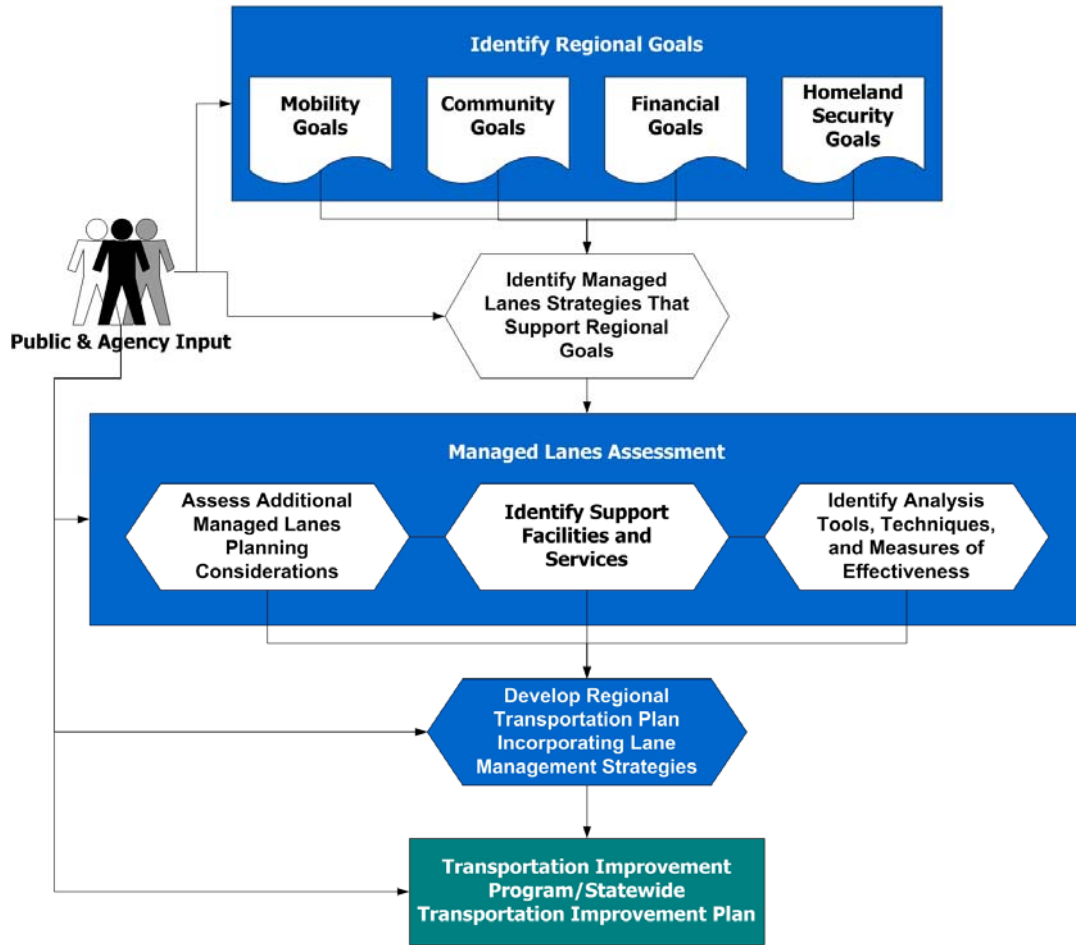


Figure 4-5. The Regional Context and Managed Lanes.

Geometric Design

Agencies and engineers should consider several elements, criteria, and controls when planning for managed lanes projects. In many cases, right-of-way limitations and roadway constraints may make it difficult to meet all desirable design standards. While specific design issues are addressed in the project development process, they may impact the feasibility of managed lanes operational concepts and particular projects at the planning level. Many groups have an interest in how a facility is designed and operated, and these interests may require compromises (20). Table 4-6 lists groups and agencies with interests in how managed lanes facilities are designed.

Unless a facility is being developed as part of a new project or major reconstruction of an existing facility, some compromise in design may need to be considered. Designs with reduced features reflect the inability to meet the desirable criteria due to lack of available rights-of-way or other significant limitations. Reduced designs do not reflect those associated with permanent facilities, and consideration of reduced designs should be given on a case-by-case basis based on sound engineering practices (20).

Table 4-6. Agencies and Groups Involved in Designing Managed Lanes Facilities (Adapted from 2I).

Agency or Group	Potential Roles and Responsibilities
State Department of Transportation	<ul style="list-style-type: none"> • Overall project management responsibilities with freeway projects • Supporting role if transit agency is lead on projects in separate rights-of-way • Responsible for design of facilities on freeways • Staffing of multi-agency or multi-division team
Transit Agency	<ul style="list-style-type: none"> • Overall project management on busways in separate rights-of-way • Supporting role with facilities on freeways • Design facility or assist with design • Staffing multi-agency team or participating on team
Trucking Industry	<ul style="list-style-type: none"> • Provide information on trucking origins and destinations • Training of drivers on facility use for trucks
Toll Authority	<ul style="list-style-type: none"> • Introduce tolling technologies • Revenue generation • Pre-operational testing
State and Local Police	<ul style="list-style-type: none"> • Assist with design, especially enforcement elements • Participate on multi-agency team
Metropolitan Planning Organization	<ul style="list-style-type: none"> • Assist in facilitating meetings and multi-agency coordination • Ensure that projects are included in necessary planning and programming documents • Assist with design of projects • May have policies relating to facility design
Rideshare Agency	<ul style="list-style-type: none"> • Assist with design of projects • Participate on multi-agency team
Local Municipalities	<ul style="list-style-type: none"> • Assist with design of projects • Coordinate with local managed lanes facilities • Participate on multi-agency team
Federal Agencies (Federal Highway Administration [FHWA] and Federal Transit Administration [FTA])	<ul style="list-style-type: none"> • Funding support for facility design • Technical assistance • Possible approval of design or steps in design process • Participate on multi-agency team
Other Groups	<ul style="list-style-type: none"> • Emergency medical services (EMS), fire, and other emergency personnel • Tow truck operations • Businesses • Neighborhood groups • Judicial system – state and local courts
<p>Note: Depending on an area’s institutional relationships, the roles may be different.</p>	

The design and operational components of a managed lanes facility must be considered simultaneously. Right-of-way constraints will normally dictate the extent of design that is possible. A full design requires fewer operational treatments. When reduced design standards are implemented, the operations component of the managed lanes development becomes increasingly important and should be incorporated if reduced design features are used. Reduced designs must be decided by each local area and situation and be acceptable to FHWA, FTA, department of transportation (DOT), transit agency, city, and others with a stake in the facility (20).

During project design, agencies must engage in even more detailed planning and design to ensure all aspects of managed lanes operational strategies are considered and assessed for a particular facility. The following sections describe the components of the initial project design steps illustrated in Figure 4-5.

Design Parameters

As discussed above, design parameters directly impact project design. Careful consideration of these issues at the facility level can help ensure that the managed lanes operational strategy is effective in meeting the goals and objectives for the corridor, enhance operational flexibility, and optimize use over the life of the project. These parameters include, but are not limited to, the following:

- ◆ design vehicle,
- ◆ design speed,
- ◆ access,
- ◆ signing,
- ◆ driver information,
- ◆ safety,
- ◆ design tradeoffs,
- ◆ toll collection,
- ◆ interoperability, and
- ◆ incident management.

The careful consideration of these factors when planning a facility is necessary to ensure viability. Previous discussion of these design issues highlights their importance and the need for their consideration in project development.

Specific Operating Strategy(ies)

After identifying and assessing the design parameters and additional managed lanes considerations for a facility, the MPO and stakeholder groups need to assess the specific operating strategy(ies) for a facility. The factors to consider in this assessment include, but are not limited to, the pricing approach, time period variations and their impact on hours of operation, enforcement issues, incident management, evaluation and monitoring, marketing, and operations during construction. After careful assessment of all of these issues, the agencies can identify the most appropriate strategy or combination of strategies for a facility.

The *geometric design* of a facility should be considered simultaneously with its operational components. As discussed earlier, constraints such as right-of-way can dictate the design and may limit the types of feasible operational treatments. Optimal designs may be a challenge, and the careful consideration of all aspects of the design is critical to the overall utilization and success of a managed lanes facility. Planning and project development with the specific design parameters noted in the *Design Parameters* section is important to ensure that target user groups and operational strategies are optimized for a facility.

Section 4 – Environmental Considerations

Environmental issues are concerns for most urban areas. Congestion requires vehicles to move more slowly, thereby worsening noise and pollution levels. Vehicles moving in a free-flow traffic environment generate a minimum amount of exhaust pollution, and fuel consumption is minimized. Traveling the same mileage under congested conditions results in significantly increased pollution levels and fuel consumption. One principal premise of HOV and HOT lanes is that they can have a favorable impact on air quality and energy savings due to decreased fuel consumption. The actual quantification of these savings should be enhanced to strengthen policy arguments on the basis of environmental criteria (22). These aspects often make HOV and HOT lanes attractive to environmental groups.

It should be noted, however, that environmental groups may also oppose the implementation of HOV or HOT lanes because of increased land usage or expanding vehicle capacity of the roadway (23). Busway lanes are also generally thought to have a favorable impact on mobility, resulting in air quality improvement, energy savings due to decreased fuel consumption, and a reduction in the growth rate of vehicle miles of travel.

Truck restrictions and exclusive truck facilities also have potential to improve air quality.

The European Conference of Ministers of Transport held a special conference on the environment in 1989 (24). The reports presented at the conference discussed various concerns regarding environmental damage caused by traffic and traffic congestion. The conference compared the pollution due to trucks versus automobiles. One conclusion reached was that given the current state of traffic, a 10 percent reduction in traffic congestion for trucks would result in a significant decrease in environmental pollution, whereas a 10 percent decrease in traffic congestion for automobiles would be inconsequential (25).

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Chapter 5 – Legislative Issues

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Section 1 – Overview

It is critical that state or local jurisdictions be able to legally operate a roadway using a specific managed lanes operational strategy. Is legislation a roadblock to managed lanes implementation? State departments of transportation, including TxDOT, receive authorization regarding the operation of federal-aid highways from the United States government. Once the states receive this federal authorization, each state must establish authorization within its specific legal structure. In Texas, the state legislature passes laws that authorize the Texas Transportation Commission to operate federal-aid and all other state roadways in accordance with the statutes.

For an agency to successfully develop and operate managed lanes, the appropriate federal, state, and local legislation and/or policies need to be in place that allow for the design, operation, and enforcement of managed lanes under a variety of control scenarios. Furthermore, agencies likely need legal and regulatory flexibility to make appropriate operational and eligibility changes over time as conditions change.

The operation of different types of managed lanes may be sufficiently different from typical freeway operations that changes in legislation and/or regulations may be required. Appropriate legislation should be in place at both the federal and state levels to ensure their success and legality. The following sections provide a brief description of each managed lanes operational strategy and a discussion of the federal laws and Texas statutes that authorize and govern its operation.

Sections in this chapter cover:

- ◆ [legality of managed lanes operational strategies](#), and
- ◆ [operational issues](#).

Section 2 – Legality of Managed Lanes Operational Strategies

Numerous federal and state laws are necessary so that operational agencies have the complete collection of options available to design, operate, and enforce managed lanes under a variety of control scenarios. Such federal and state statutes broaden the powers of the states and other transportation organizations and provide them with the tools they need to successfully implement managed lanes facilities in their jurisdictions in the most effective manner, thereby working to reduce congestion and enhance the mobility of their citizens. The following sections provide a brief description of each managed lanes operational strategy and a discussion of federal and state laws, either existing or needed, to authorize and govern its operation.

Managed Lanes

Legislation currently in place at the national level is sufficient to enable states to establish all types of managed lanes facilities discussed herein on the Interstate Highway System, on state and county highways, and on local streets. Regulations regarding operational changes are also in place to guide states in the creation and long-term operation of such facilities. However, the term “managed lanes” is not recognized as a formal definition in the legislation. Thus, to ensure that the concept of managed lanes becomes a commonly accepted description of particular operational strategies for transportation facilities, a definition for managed lanes needs to be included in the legislation. Additionally, states need to define the term “managed lanes” and include the term in the authorizing and other appropriate legislation that addresses such facilities

HOV Lanes

Various federal codes, guidelines, and legislation currently authorize the creation and operation of HOV lanes (1, 2, 3, 4, 5). Additionally, the United States Department of Transportation (USDOT) provides guidance to states on the Federal-Aid Highway Program as it pertains to HOV lanes (6). This document provides states with background information, the federal policy position regarding HOV lanes, and conditions under which proposed operational changes to existing HOV lanes are subject to federal review.

The State of Texas provides the Texas Transportation Commission with the authority to designate and TxDOT the authority to finance, designate, design, construct, operate, or maintain dedicated HOV lanes on any multi-lane highway on the state highway system (7). This statute also allows TxDOT to authorize motorcycles or low-emissions vehicles to use an HOV lane regardless of the number of occupants (8), unless such action would be in violation of federal regulations or impair the ability of TxDOT to acquire federal transit funds.

A point of concern is the discrepancy in providing authorization for inherently low-emission vehicles (ILEVs) to use HOV lanes. This authorization is provided at the federal level in the Transportation Equity Act for the 21st Century (TEA-21) with ILEVs being those vehicles certified in Title 40, Code of Federal Regulations (9). However,

FTA policy disallows agencies from allowing ILEVs to use HOV lanes funded with FTA dollars. Since the number of ILEVs currently in operation in the United States is extremely small, their impact on HOV systems is virtually undetectable at this time. However, it is reasonable to expect that the number of ILEVs will grow steadily as more vehicle manufacturers design them and offer them for purchase. Thus, federal legislation and regulations need to establish a consistent policy regarding the use of HOV lanes by ILEVs to prevent confusion in the future.

An emerging issue of concern is whether states should allow hybrid vehicles with only one occupant to use HOV lanes. This trend is an outgrowth of the allowance of ILEVs on HOV lanes. In 2000, Virginia began to exempt hybrid vehicles from the occupancy requirements for the state's HOV lanes (10). In 2001, Arizona requested FHWA to allow hybrids to use their HOV lanes, but a Policy Memorandum released in December of that year stated that hybrid vehicles do not qualify as ILEVs because their engines have fuel vapor emissions. FHWA's position was that allowing them to use HOV lanes with only one occupant is a violation of the federal code and Environmental Protection Agency (EPA) regulations (11). The California Assembly passed a bill in 2004 allowing hybrid vehicles to use the state's HOV lanes (12), but the bill has yet to go into effect pending approval from Congress (13).

In addition to FHWA's interpretation of the federal code as it relates to hybrid vehicles, the general concern regarding hybrid use of HOVs is the increased congestion and delay they may cause to the lanes themselves. The number of hybrid vehicles on the road is steadily increasing, and carpoolers in Virginia are beginning to notice an increase in single-occupant hybrids on the HOV lanes, resulting in an increase in congestion on their daily commutes (14). The reauthorization bill passed by Congress allows states to permit such vehicles to use HOV facilities if they pay a toll for that use. They also have the ability to limit or discontinue allowing their use if their presence degrades the operation of the facility (15).

States need legislative authority to design, construct, operate, or maintain dedicated HOV lanes on any multi-lane highway on the state highway system. The objective of providing this authority could be to help relieve traffic congestion or to serve some other purpose necessary and beneficial to the citizens of the state. Furthermore, state laws should consistently mirror the federal policy regarding the use of HOV lanes by ILEVs, whatever that policy might be. Once the issue of allowing hybrids on HOV lanes is resolved in Congress, states should mirror that policy appropriately.

Value-Priced and HOT Lanes

ISTEA specifically authorized the creation of up to five congestion pricing pilot programs, no more than three of which could implement tolls on the interstate system (16). TEA-21 modified and enhanced the congestion pricing program in several ways, including the renaming of the program to value pricing, increasing the number of projects to 15, and allowing tolling on any of the programs established under this act (17). TEA-21 also established the Interstate System Reconstruction and Rehabilitation Pilot Program, which authorizes states to collect tolls on an interstate facility for the purposes

of reconstructing or rehabilitating that corridor if it could otherwise not be maintained or improved (18). However this program is limited to three projects, each located in a different state.

Texas statutes authorize TxDOT to charge a toll for the use of one or more lanes of a state highway facility, including an HOV lane (19). Therefore, TxDOT is able to participate in the federal value-pricing program, which it has done with the HOT lane pilot programs on the Katy (IH-10) and Northwest (US 290) Freeways in Houston.

For this operational strategy to become a widespread feature of HOV lanes in the United States, support for a larger and more permanent program was needed at the federal level. The reauthorization bill passed by Congress takes this more mainstream approach to value pricing by allowing states to toll SOVs using HOV facilities, provided that the tolls vary in price according to the time of day or traffic level to managed congestion or improve air quality (15). State statutes should also authorize transportation agencies to implement value-priced or HOT-lanes as directed by federal regulations.

Exclusive Lanes

Until recently, very few truly exclusive facilities existed in the United States, and many of those facilities actually restricted trucks and/or buses to specified lanes and allowed other vehicles to use any lane (20). In recent years, a number of truly exclusive busways have been implemented in various metropolitan areas, often as a cost-effective alternative to either subways or light rail. The advantages of this alternative are flexibility, self-enforcement, incremental development, low construction costs, and implementation speed. At the federal level, any exclusive facility designated for buses would fall under the jurisdiction of laws governing HOV lanes and related transit facilities. The same jurisdiction would be applicable at the state level as well. Thus, if a state has the authority to implement HOV lanes, then it also could implement exclusive lanes for buses.

The issue of increasing truck traffic is of vital concern to both traffic managers and the general public. Highway traffic operations are the “yardstick” by which the user measures the quality of the facility. Theoretically, truck facilities could have positive impacts on noise and air pollution, fuel consumption, and other environmental issues. Creating and maintaining an uninterrupted flow condition for diesel-powered trucks will result in a reduction of emissions and fuel consumption when compared to congested, stop-and-go conditions. However, the creation of a truck facility may also shift truck traffic from more congested parallel roadways, thereby shifting the environmental impacts of that traffic. An increase in non-truck traffic on automobile lanes may also occur due to latent demand.

Any exclusive facility designated for buses falls under the jurisdiction of the laws governing HOV lanes and related transit facilities. Regarding exclusive facilities for trucks, regulations at the federal level specify only that no state may deny reasonable access to heavy vehicles either to or from any facility on the Interstate Highway System (21). Texas statutes allow the Texas Transportation Commission to designate and

TxDOT to finance, design, construct, operate, or maintain one or more lanes of a state highway facility as exclusive lanes (22), particularly for the purpose of enhancing safety, mobility, or air quality. Additionally, these lanes may be tolled under certain circumstances, and these exclusive lanes can be designated for different classes of motor vehicles (23).

Separation and Bypass Lanes

As with exclusive facilities, any separation or bypass facility designated for HOVs, buses, trucks, or other special-use groups would fall under the jurisdiction of the aforementioned federal laws governing their operation. Any separation or bypass facility designated for buses or HOVs in Texas would fall under those laws governing HOV lanes. Once again, Texas has appropriate statutes that would govern the establishment of separation or bypass facilities for various classes of motor vehicles.

Dual Facilities

Dual facilities are managed lanes strategies that have physically separated inner and outer roadways in each direction. The inner roadway is reserved for light vehicles or cars only, while the outer roadway is open to all vehicles. For example, the New Jersey Turnpike has a 35-mile segment that consists of interior (passenger car) lanes and exterior (truck/bus/car) lanes within the same right-of-way. Any managed lanes facility using the dual operational concept falls under the jurisdiction of the federal and state laws governing the specific strategies used by the operating entity, such as HOV, HOT, trucks, etc. As with the federal laws, any managed lanes facility using the dual operational concept in Texas falls under the jurisdiction of the state laws governing the specific strategies used by the operating entity. Therefore, any specific legislation regarding dual facilities is not necessary.

Lane Restrictions

Lane restrictions are a management strategy that limits certain types of vehicles to specified lanes. The most common type of lane restriction addresses truck traffic. A large presence of trucks, both in rural and urban areas, can degrade the speed, comfort, and convenience experienced by passenger car drivers. Some states, to minimize these safety and operational effects, have implemented truck lane restrictions. At the federal level, the regulation noted under exclusive facilities applies to lane restrictions in that no state may deny reasonable access to heavy vehicles either to or from any facility on the Interstate Highway System (21).

Texas state statutes authorize municipalities, counties, and TxDOT to establish lane restrictions on facilities on certain portions of the designated state highway system (24, 25). As shown in the Texas statutes, the wording of such legislation should be such that select vehicles are allowed to use more than one lane of a facility. Such wording can help reduce the likelihood that the motor carrier community will not support the restrictions. Moreover, allowing full-time restrictions is critical to maximizing the effectiveness of

lane restrictions on mobility. All state-level legislation should be written such that it does not violate the aforementioned federal regulations regarding motor carrier transport.

Section 3 – Operational Issues

Once a managed lanes facility is authorized and constructed, the agencies responsible for its operation must ensure that all legal pathways to effective operation are clear. These issues include the handling of violations, enforcement, and operational flexibility. Early consideration of these issues can ensure that the facility operates smoothly and efficiently and can adapt to the regional needs in an effective manner. The following sections highlight the legislative and/or regulatory issues surrounding these operational issues.

Managed Lanes Violation

To date, no state legislation exists that specifically prohibits unauthorized use of managed lanes facilities per se, with the exception of legislation regarding the failure or refusal to pay toll charges on a HOT lane facility (26). Legislation regarding violations in the use of such facilities is traditionally enacted at the county or local level. For example, in Houston, the Metropolitan Transit Authority of Harris County (METRO) enforces the HOV lanes within the city limits under a City of Houston ordinance (27). Where the HOV lane system operates beyond the city limits, officers ticket violators for disregarding official traffic control devices regulating vehicle occupancy within the HOV lane. Enforcement of the HOT lane restrictions is handled in a similar manner. Similar arrangements exist in other cities across Texas.

With traditional tolled facilities, regulations are in place regarding failure to pay a toll. While the Texas Turnpike Authority (TTA) currently does not operate a toll road, it has the power to prosecute violators under the law (28). Regional mobility authorities have the power in Section 361.003 of the Texas Transportation Code to construct, maintain, and operate turnpike projects in a region within Texas (29). The code grants regional mobility authorities the same powers as the Texas Turnpike Authority, including that of prosecuting violators. Furthermore, in Dallas, the North Texas Tollway Authority (NTTA) enforces its facilities under state regulations governing regional tollway authorities and failure or refusal to pay tolls (30). Likewise, the Harris County Toll Road Authority (HCTRA) in Houston enforces the toll facilities under state laws addressing non-payment of tolls on turnpikes in specific counties (31).

Law enforcement personnel, acting on behalf of transportation agencies, can issue citations for managed lanes violations through a number of legislative and legal channels. Depending on the operating strategy in place, managed lanes violators can receive citations for violating state statutes, county laws, or municipal ordinances. As noted previously, Texas has all of the necessary legislation in place to govern managed lanes violations. However, states just beginning to develop managed lanes projects in significant numbers might benefit from having one single law cover all operating strategies on a statewide level. Thus, to remain consistent with the recommendation that “managed lanes” be incorporated into the authorization of congestion mitigation projects and facilities, states should draft legislation that addresses the violation of any managed lanes facility in operation within the state.

Enforcement

Enforcement of managed lanes, like the enforcement of all traffic laws, is handled through a combination of state regulations and local ordinances, so long as those laws do not conflict with any federal regulations governing the operation of federal-aid highways. To enforce managed lanes facilities within a state, the operating entity needs to ensure that the appropriate traffic-related laws are in place prior to operation and that the state, county, municipal, or toll authorities have adequate jurisdiction to employ or contract with law enforcement personnel to enforce appropriate state, county, or municipal laws governing the unlawful use of their respective managed lanes facilities, including any legislation that may be provided for the statewide violation of managed lanes. If such laws are in place, then any current or future managed lanes project could be enforced with the current code and without further changes to state statutes.

In Texas, the Texas Highway Patrol, part of the Traffic Law Enforcement Division of the Department of Public Safety (DPS), is responsible for “patrolling and supervising more than 200,000 miles of rural highways in Texas” (32). The authority of DPS is granted through the Texas Government Code. The agency is empowered to enforce the laws protecting the public safety, and state troopers are charged with the duties of enforcing the traffic laws on rural Texas highways (33). Furthermore, TxDOT is directed to cooperate with and assist DPS in the “enforcement of state laws concerning public safety” (34).

At the county level, the state empowers county peace officers to “enforce state laws that regulate the operation of a motor vehicle on a highway, street, or alley” (35). Therefore, these officers have the power to enforce any state law governing managed lanes within their jurisdictions.

Municipalities in Texas have the necessary powers to enforce traffic laws as well. For example, peace officers in municipalities are empowered by the Texas Local Government Code (36) and have the powers and jurisdiction granted to a peace officer by the Code of Criminal Procedure (37). Moreover, TxDOT can enter into agreements with municipalities to give them the authority to “provide for the location, relocation, improvement, control, supervision, and regulation of a designated state highway in the municipality” (38).

Other entities with the power to enforce traffic-related laws include transit authorities, regional mobility authorities, and tollway authorities. In Texas, various chapters of the Texas Transportation Code governs transit authorities (39, 40, 41, 42, 43). Under these codes, certain transit authorities are allowed to commission and hire peace officers, who are responsible for enforcing traffic laws and investigating traffic incidents that occur in the transit authority system (44, 45). Additionally, if a transit authority serves an area in which the principal municipality has more than 1.5 million residents (currently only Houston fits this description), sworn peace officers of the authority have all the “powers, privileges, and immunities of peace officers in the counties in which the transit authority system is located, provides services, or is supported by a general sales and use tax” (46). However, it is important to note that while transit peace officers in Houston have this

authority, the city does not typically rely on them for all primary control on state highways within the municipal boundaries.

Toll authorities – including the TTA (47), regional tollway authorities (48), and county authorities (49) – enforce operations depending on their type of authority. For example, NTTA contracts with DPS for enforcement, while HCTRA has county law enforcement personnel enforce its facilities. In both cases, enforcement of these toll facilities may be handled electronically through the use of technologies that photograph the license plates of violators, thereby fining the owner of the vehicle for violating the applicable state law governing the failure to pay tolls on specific facilities.

Automated enforcement is a controversial issue in the United States. The most common application of this enforcement technique is at signalized intersections, but it has yet to become mainstream in the arena of managed lanes. For tolling purposes, automated enforcement is feasible since the presence or lack of a transponder or failure to pay is easy to detect. However, any managed lanes facility that has vehicle occupancy as an operational strategy presents unique enforcement challenges that cannot be readily resolved with current automated technology. Furthermore, legislative action at the state level may be necessary to decriminalize the violation of managed lanes facilities to authorize the use of such technologies in the future (50).

Operational Changes

Over time, an operating agency may need to change the operational strategy of a managed lanes facility to better meet the changing needs of the region. The FHWA has guidelines for the operation of HOV lanes, specifically when federal actions might be needed if a “proposed significant operational change can be reasonably expected to affect a specific HOV lane or portions of the regional HOV system, which were funded or approved by FHWA” (51). Texas has no specific regulations regarding operational changes to any type of managed lanes facility, though changes to existing HOV facilities would have to follow federal guidelines as noted above.

An important feature of managed lanes is the flexibility to change the operational strategy of the facility to better meet the goals of the region it serves. This feature allows the operating entity to adapt the facility to maximize the benefits to its users and the impact on the transportation system as a whole. One example in particular that may create a challenge is allowing hybrid vehicles to use HOV lanes. Allowing hybrid vehicles with one occupant to use HOV lanes may, in the future, increase congestion on managed lanes to the extent that operations deteriorate. Thus, states would need to establish the authority to make operational changes when deemed appropriate, including disallowing certain vehicle classes to preserve operational integrity.

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Chapter 6 – Public Outreach

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Section 1 – Overview

Public acceptance plays a critical role in the success of any project. Communicating a new product or concept can be challenging. Effective public outreach programs must consider the goals of the project and tailor the message to meet those goals. Several different techniques can be used to communicate with the public depending on the message that is to be delivered and the objectives. Likewise, a message may be tailored to particular audiences. It is important that the public, or the audience, be correctly defined. Audiences will depend on the nature or scope of the project and may change throughout the different phases of the project.

Many managed lanes projects around the country are under development; several have been implemented. Critical to the success of these projects are the project goals and the strategies agencies use to communicate these goals to the public. It is important to understand public perception and public interaction when a new and complex concept for managing travel demand is introduced.

This chapter provides guidance on public outreach for managed lanes projects by helping determine:

- ◆ What messages about managed lanes should be communicated to the public, and how do they relate to the goals of the project?
- ◆ How should the messages be communicated?
- ◆ Who are the target audiences?
- ◆ What are the best approaches for communicating project goals and gaining acceptance?

Section 2 – Common Messages for Communicating the Managed Lanes Concept

Communicating a complex concept, such as managed lanes, to the public can be very challenging. Additionally, there are no facilities in operation that encompass the complete range of managed lanes strategies. Not having a tangible project to point to as an example makes the task even more difficult.

Pricing in particular, and other operational actions in general, can be used as mechanisms to regulate demand on a managed lanes facility. When coupled with a comprehensive transportation plan, the strategies can be very effective. Studies indicate that when certain factors (such as severe congestion) are present and prevalent issues (such as revenue use, toll collection, and long-range planning) are addressed, the likelihood of a project's success increases.

Public Involvement

Public involvement has become an important step in the project planning process. However, when considering a managed lanes project, public involvement must go one step further and include a more comprehensive public education component. In this regard, public education differs from public involvement in that people are unfamiliar with the concept. It must be thoroughly communicated, and it must include all aspects of the project, such as goals, objectives, operations, and revenue use. While the public is familiar with some examples of pricing to manage demand, many do not see the government's role in this endeavor. Research has shown that in focus groups, individuals are more supportive of the concept after they are shown examples of successful projects and how they operate.

Public Education

Public education should be a consideration at the first stage of planning a project. All interested parties should be involved in the decision-making process, and efforts should be made to contact known stakeholders as well as non-traditional stakeholders who may have a vested interest in a project. These groups may include the trucking industry, environmental groups, alternative fuel proponents, or energy conservation groups. By involving representatives from all affected and potentially affected groups, an education process is cultivated that carries through all the stages of the project. This effort also prevents the spread of misinformation and capitalizes on the interaction between different groups.

Research has shown that public education can alleviate concerns about the equity of a project. Pricing projects have been seen as unfair to economically disadvantaged groups when originally presented to the public. However, after a project and its operation are explained, many of the equity questions disappear. Additionally, studies of managed lanes use indicate that users represent a fairly even distribution of economic and social groups.

Project Champion

Identifying a project champion is also crucial to the success of a project. Research has found that projects that have been successfully implemented have had a strong advocate. This person can serve as a spokesperson in the education process.

Although transportation agency representatives or local elected officials might seem the most likely candidates to move a project to public acceptance, the mistrust of politicians and governmental agencies may require a champion to emerge from elsewhere. Public opinion of elected officials and other politicians will help discern whether or not an elected official can effectively communicate the managed lanes project message. Therefore, it is important to involve as many potential stakeholders as possible because a champion may arise from any group. For instance, Portland formed a citizen's committee to explore pricing. The MPO felt that since pricing was such a controversial issue, a citizen's committee would provide a more credible and independent voice to the general public.

Common Messages

After a project champion has been identified and the public education process begins, the key messages of the project need to be communicated to the general public. Successful projects have common messages that have been well received by the public. These include:

- ◆ **Choice.** Research has shown that the public does not perceive pricing as inequitable when it is presented as a choice for commuters (1). The education process is key to communicating this message.
- ◆ **Tool.** The public may perceive a project that utilizes pricing concepts as a short-term solution. Messages should emphasize that it is only one tool that works with a comprehensive plan.
- ◆ **Efficiency.** Typically the public does not understand how underutilized an HOV lane may be. When shown that pricing maximizes available capacity, the pricing concept is more acceptable.
- ◆ **Operations.** People want to know how the proposed operational strategy will work. Presenting examples of successful projects and how they operate helps facilitate understanding and support. Examples are particularly helpful in areas where there are no HOV lanes or toll roads. Motorists need assurances that toll collection will not impede travel that is already congested because they may be unfamiliar with electronic toll collection.
- ◆ **Enforcement.** Enforcement is especially important in areas that currently operate HOV lanes because enforcement preserves the integrity of the HOV lane. The

traveling public wants to know that if they pay for a premium service, others will not be allowed a “free ride.”

- ◆ **Revenue use.** From the outset of the project, the managing agency must clearly define how it plans to use the revenue. Successful projects have targeted the money for improvements in a corridor where the project is occurring. Public opinion research indicates that people are evenly split on whether to use revenue for transit improvements or to fund roadway projects (2). Additionally, as part of the ongoing public information, managing agencies need to highlight improvements that are made with the revenue.

- ◆ **Transportation funding.** Research has shown that the public is unaware of how transportation projects are funded (2). Messages should focus on the funding shortfall and show pricing as a means to raise revenue for projects that might otherwise not be funded. This scenario reinforces the idea that a pricing project is a management tool in a comprehensive plan that will impact the entire region.

Section 3 – Outreach to Policy Makers

[Appendix B](#) provides sample text for a position paper on managed lanes geared toward policy makers. Intended to provide TxDOT’s statewide perspective on managed lanes, the paper provides an effective means of communicating information about managed lanes, how managed lanes may be operated, the benefits of managed lanes, where successful projects have been implemented, and what TxDOT is planning for Texas.

Policy makers can use this text to help articulate the concept of managed lanes as a means to achieve statewide mobility goals. Their position can then be further refined to match regional and community objectives. By communicating the concept, TxDOT can begin to build consensus to utilize an available tool to maximize efficiency of the transportation network and provide options for the traveling public.

It is important to note that each region of the state will have different goals for the region or for a particular corridor. It is important for policy makers to tailor the message of managed lanes and its concepts to match these goals. Focus groups, telephone interviews, and surveys are methods that should be employed in areas around the state to gauge public perception prior to project implementation. The results from this input will be invaluable in defining the message for the public. Communicating a clear, concise message to the intended audience will help achieve consensus to formulate policy. A full-color version of this document is available online at http://managed-lanes.tamu.edu/products/brochures/4160-5-P1-Policy_Brochure.pdf (2).

Section 4 – Outreach to the Media and General Public

Appendix C provides sample text for a position paper on managed lanes geared toward the media and the public. The paper provides the media with a statewide perspective on managed lanes and identifies the benefits of managed lanes, how the lanes may be operated, where successful projects have been implemented, and what TxDOT has planned for Texas.

The information presented is designed for use by editorial boards, news and television reporters, magazine editors, and news directors. It can be developed into a brochure-like product that conveys the information in a manner that will be easily understood, utilizing graphics where applicable. The result will provide a medium through which a common message may be communicated. A full-color version of this document is available online at http://managed-lanes.tamu.edu/products/brochures/4160-6-P2-Media_Brochure.pdf (3).

Certain activities should be considered when using this information to address the local audience:

- ◆ Develop a supplemental information sheet that includes local plans and resources for more information, such as the following websites:
 - <http://www.sandag.cog.ca.us/>,
 - <http://www.valuepricing.org>,
 - <http://www.fhwa.dot.gov////////policy/13-hmpg.htm>,
 - <http://www.valuelanes.com/>, and
 - <http://www.wsdot.wa.gov/regions/northwest/Traffic/ExpressLanes/>.
- ◆ Refine terminology. The term “managed lanes” represents many different types of facilities and operating strategies. TxDOT has determined that “managed lanes” will be the terminology used at the state level. Other, more marketable names could be developed and used at the local level. Possible considerations include flex lanes, express lanes, value lanes, or fast lanes. The name selected for a region could be developed through a public involvement process.

Section 5 – References

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Chapter 7 – Funding and Financing Managed Lanes

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Section 1 – Overview

Even with the apportionment from the federal government, TxDOT each year expects to fund only a fraction of needed projects. How to fund transportation projects, in general, and managed lanes projects, in particular, is an issue that TxDOT officials must grapple with daily. The unique operating strategies used with managed lanes facilities offer opportunities for innovative financing techniques that are new and untried in the transportation arena.

Many of the managed lanes projects under development in Texas will incorporate a user fee structure to obtain the desired operating characteristics. The fact that a project has a dedicated revenue stream makes it a more likely candidate for non-traditional funding. Additionally, these projects may attract private-sector investment.

The key to successful implementation of a managed lanes project will be matching the desires and needs of the community with specific project goals. Financing can be accomplished in a number of ways, be it tolling, a special transportation tax, pricing, revenue bonds, a number of different kinds of loans, commercial vehicle fees, or tourist fees. The goals of the region and the local agencies developing the managed lanes project will determine the candidate methods for financing that should be explored further. Successful projects will find mechanisms that balance those goals with financing criteria.

This chapter provides guidance on funding and financing managed lanes projects. It highlights the financial aspects of implementing managed lanes projects and the applicability of innovative financing techniques to various types of projects.

The sections in this chapter cover:

- ◆ [the challenge of funding and financing managed lanes](#), and
- ◆ [funding and financing methods](#).

Section 2 – The Challenge

Beginning with ISTEA, the federal government has responded to the growing gap between funding and need. ISTEA created a loan program whereby states could lend federal funds to toll projects. This legislation permitted certain toll revenue expenditures to serve as credit in meeting the required non-federal matching funds.

In 1994, FHWA launched an important initiative that asked states to identify barriers to project funding and financing. The program was designated TE-045 since it was a “test and evaluation” program. The program identified new techniques to leverage federal monies and provided for more flexibility in receiving and using federal funds.

Later, the National Highway System Designation Act of 1995 (NHS) codified many of the innovations of the TE-045 program and went much further to close the gap. This act established a State Infrastructure Bank (SIB) Pilot Program, broadened the use of federal aid in retiring the costs of debt financing, expanded the types of commitments available to meet the non-federal matching requirements, and increased the federal matching ratio for toll projects.

TEA-21 attempts to provide even more flexibility in funding and financing major projects. TEA-21 continued the SIB program and provided for more flexibility in meeting the non-federal match requirements. TEA-21 also enacted the Transportation Infrastructure Finance and Innovation Act (TIFIA) to provide \$10.6 billion in credit assistance to major projects of national importance.

Texas Responds

It is evident that states and the federal government must work together to meet the demands for an effective, safe, and reliable transportation system. Much of this legislation puts control of projects into the hands of local decision makers. Many innovative financing measures are ideally suited to managed lanes projects. A basic understanding of the programs will enable decision makers to pursue financing that is most appropriate to a particular project. Additionally, many of these strategies may be used in tandem with other strategies.

Funding versus Financing

It is also important to distinguish “funding” from “financing.” Typically, transportation agencies will have a project in the long-term planning process. Whether or not that project is realized will depend on available funding. Therefore, a project in development may be implemented when or if monies (i.e., funding) become available. Ultimately, all projects need a source of funding whether it be grants, taxes, special assessments, or toll revenues.

Conversely, financing refers to the methodology used to secure funding. In this scenario a need for a project is identified, and often a project can be developed to match types of financing that may be available. An innovative financing approach can offer more

flexibility than the traditional payment-reimbursement method that is most often used for transportation projects. Likewise, innovative financing methods for new transportation solutions can spur an infusion of funding from non-traditional sources such as private-sector investment. Not only do financing techniques identify possible alternative funding sources, they often result in project acceleration. Critical projects may be advanced sooner than would be possible under the old process, sometimes by as much as 20 years.

Successful Projects

The key to developing a successful project is to identify the project goals and match the financing to the purpose. Managed lanes, which typically involve a toll component, are being used more as a public policy tool as opposed to considering tolls as solely a financing mechanism. Managed lanes utilize various operating scenarios to maximize the operational efficiency of a facility. This makes a managed lanes facility inherently more risky to investors. Typically, investors will want to have some assurances that the debt service will be paid and that rate covenants will be maintained. Therefore, the question becomes, “What is being managed?” Again, this relates to the goal of the project. Is the facility being managed to increase high-occupancy vehicle usage? Is the facility being managed to increase transit use? Is the facility being managed to decrease single-occupant vehicle use? Is the facility being managed to provide an incentive to alternate-fuel vehicles? Or is the facility being managed to maximize revenue generation?

Each of these questions must be answered when considering the financing for a managed lanes facility. Additionally, the relative importance of each answer must be weighed because the project goals may seek to do all of these things and more. The answers and the weight of each will determine the best route of financing. Each facet must work together to assemble a financing package that will result in a financially feasible project. The goals of the project will determine the type of cost-benefit analysis used in assessing the potential performance of a project.

Each of the financing mechanisms described in the chapter attempt to enhance the financial feasibility of a particular project. They can be combined and structured to receive the most possible benefits in the most cost-effective manner.

The U.S. Department of Transportation has achieved tremendous advances in making large, complex projects, such as managed lanes projects, more feasible. It has developed numerous programs to capitalize on all available resources. It has made leveraging federal monies more accessible.

Section 3 – Funding and Financing Methods

New Techniques

In addition to the traditional pay-as-you-go method of reimbursement, many new funding and financing techniques exist today. Often managed lanes projects are large, complex projects. This may require the state department of transportation to obligate funds for several years before a project even begins. As a result other projects may be pushed back even further in the funding pipeline.

In an effort to ease this burden on transportation departments, the federal government has made available many new techniques for financing and funding projects. For the most part these new methods can be divided into two categories: cash management tools and credit enhancement and/or investment tools. A detailed explanation of each of the financing mechanisms is available on the Internet at <http://tti.tamu.edu/documents/4160-9.pdf>. Figure 7-1 below graphically represents how some of the funding mechanisms may be used for different types of projects. The shaded area indicates that managed lanes projects can encompass each of the three broad categories.

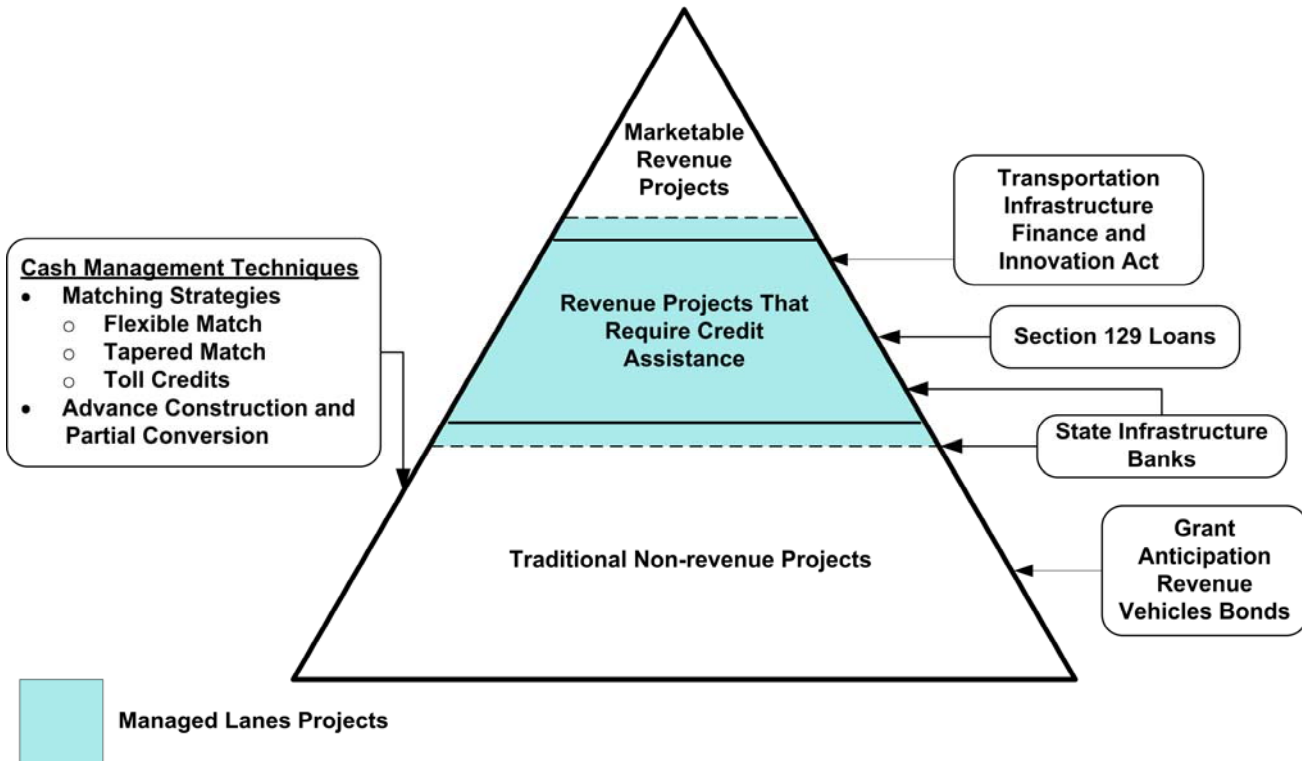


Figure 7-1. Funding and Financing Strategies (Adapted from *1*).

As the pyramid indicates, most projects fall into the traditional non-revenue category. These are projects that will require typical grant funding for their implementation. The top of the pyramid represents the very small percentage of projects that can be marketable revenue projects on a stand-alone basis. These are the types of projects that are able to show revenues that provide the level of debt coverage necessary to obtain investment grade ratings and sell sufficient debt to fully finance a project. These projects are typically developed on high-volume corridors where user fees support maintenance and operations of the facility as well as the debt service on the initial capital costs.

The middle section of the pyramid is most likely where a managed lanes project would fit. Often these projects are substantial undertakings that will require leveraging monies from every available source. Ideally, the projects are attractive to private investors, so some risks shift from public entities to the capital market. A project needs a tremendous amount of agency cooperation to guide it through the development process. Every effort should be made to include any and all interested parties from the earliest stages of project planning. Not only does this foster a collaborative attitude, but it may also help identify potential financing sources and investment opportunities.

These methods may be used alone or in concert with one another to finance a project. Each is designed to offer more flexibility in an effort to make projects more feasible and to get them implemented sooner. The effect of these efforts has been the ability to leverage state and federal funds.

Summary

There are an array of innovative funding and financing strategies that can be used to accelerate projects and/or make them financially feasible. The strategies may be used alone or in tandem with one another, and can greatly enhance the viability of a project.

As noted previously, the financing mechanism chosen should reflect the goals of the community and the objective of the project. Different programs will offer different benefits at different costs.

Section 4 – References

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Section 1 – Overview

This chapter presents information on the basic elements of the design of managed lanes facilities including appropriate design values and cross sections. The sections address the most frequently encountered design issues but do not attempt to address every possible design unique to the specific situation. Additional discussions on issues associated with high-occupancy vehicle facilities are contained in the *HOV Systems Manual (I)*.

This chapter discusses the following issues:

- ◆ [geometric considerations for managed lanes facilities](#),
- ◆ [cross sections for managed lanes facilities](#), and
- ◆ [design considerations for terminal and access treatments](#).

Section 2 – Geometric Considerations for Managed Lanes Facilities

Overview

Engineers should consider several elements, criteria, and controls in the design process. In many cases, right-of-way limitations and roadway constraints may make it difficult to meet all desirable design standards. Many groups have an interest in how a facility is designed and operated, and these interests may require compromises during the testing phase. [Table 8-1](#) lists groups and agencies with interests in how managed lanes facilities are designed.

Unless a facility is being developed as part of a new project or major reconstruction of an existing facility, some compromise in design may need to be considered. To accommodate the fact that using desirable design elements may not always be realistic, this chapter includes information on both desirable and reduced design features. The desirable criteria include all the preferred design elements. Desirable designs generally reflect those associated with a permanent or new facility and meet AASHTO and other standards.

Designs with reduced features reflect the inability to meet the desirable criteria due to lack of available rights-of-way or other significant limitations. Reduced designs do not reflect those associated with permanent facilities, and consideration of reduced designs should be given on a case-by-case basis based on sound engineering practices. The reduced values presented in this chapter are not intended as a standard of practice, and practitioners should use desired values whenever practical.

The design and operational components of a managed lanes facility must be considered simultaneously. Right-of-way constraints will normally dictate the extent of design that is possible. A full design requires fewer operational treatments. When reduced design standards are implemented, the operations component of the managed lanes development becomes increasingly important. For each cross section shown throughout this chapter, operational treatments should be incorporated if the reduced design cross-section values are used. [Table 8-2](#) lists examples of the operational treatments needed for full and reduced designs on managed lanes. Reduced designs must be decided by each local area and situation and be acceptable to FHWA, FTA, DOT, transit agency, city, and others with a stake in the facility.

**Table 8-1. Agencies and Groups Involved in Designing Managed Lanes Facilities
(Adapted from 2).**

Agency or Group	Potential Roles and Responsibilities
State department of transportation	<ul style="list-style-type: none"> • Overall project management responsibilities with freeway projects • Supporting role if transit agency is lead on projects in separate rights-of-way • Responsible for design of facilities on freeways • Staffing of multi-agency or multi-division team
Transit agency	<ul style="list-style-type: none"> • Overall project management on busways in separate rights-of-way • Supporting role with facilities on freeways • Design facility or assist with design • Staffing of multi-agency team or participating on team
Trucking industry	<ul style="list-style-type: none"> • Provide information on trucking origins and destinations • Training of drivers on facility use for trucks
Toll authority	<ul style="list-style-type: none"> • Introduce tolling technologies • Revenue generation • Pre-operational testing
State and local police	<ul style="list-style-type: none"> • Assist with design, especially enforcement elements • Participate on multi-agency team
Metropolitan planning organization	<ul style="list-style-type: none"> • Assist in facilitating meetings and multi-agency coordination • Ensure that projects are included in necessary planning and programming documents • Assist with design of projects • May have policies relating to facility design
Rideshare agency	<ul style="list-style-type: none"> • Assist with design of projects • Participate on multi-agency team
Local municipalities	<ul style="list-style-type: none"> • Assist with design of projects • Coordinate with local managed lanes facilities • Participate on multi-agency team
Federal agencies (FHWA and FTA)	<ul style="list-style-type: none"> • Funding support for facility design • Technical assistance • Possible approval of design or steps in design process • Participate on multi-agency team
Other groups	<ul style="list-style-type: none"> • EMS, fire, and other emergency personnel • Tow truck operations • Businesses • Neighborhood groups • Judicial system – state and local courts
<p>Note: Depending on an area’s institutional relationships, the roles may be different.</p>	

Table 8-2. Operational Treatments Needed for Full and Reduced Design Standards (Adapted from 1).

Design Standards	Level of Operational Treatments	Example Operational Treatments
Full	Low	<ul style="list-style-type: none"> • Minimal enforcement • Visual detection by police, bus operators, motorist assistance patrols, or agency personnel • Calls from motorists using cellular telephones • Reports from roadside call boxes • Information from commercial traffic reporters • Flow metering not required • Consistent speed limit
Reduced	High	<ul style="list-style-type: none"> • Items noted above for full standards • Automatic vehicle identification (AVI) or inductance loop detectors for vehicle detection • Closed-circuit television cameras • Full advanced transportation management systems or integrated transportation management systems • Dedicated tow trucks with limited turning radius for narrow managed lane width • Changeable message signs (CMSs) • Entry ramp metering • Significant enforcement effort • Lower speed limits at constricted points

The following sections describe the various design and control criteria that designers should consider with managed lanes facilities. The design vehicle criteria are presented first, followed by a discussion of design driver criteria, design speed, and roadway alignment elements.

Design Vehicle

The physical and operating characteristics of eligible vehicles will influence the design of managed lanes facilities. Standard and articulated buses, as well as carpools and vanpools, are often part of the allowed vehicle mix on these types of facilities. Table 8-3 lists the dimensions for these vehicle types. The typical dimensions and turning radii for design vehicles are included in the AASHTO *Green Book* (3), and values are also included in the National Cooperative Highway Research Program (NCHRP) *HOV Systems Manual* (1). Designers should use these dimensions, which will also accommodate vanpools and carpools, to assist with the design of managed lanes projects on freeways.

The designer can use the AASHTO *Green Book* templates in determining turning paths, lateral and vertical clearances, bus stops, and other elements associated with a project. The design process should also account for the path of the vehicle overhang beyond the outside turning radius.

The design vehicles should be used to control the geometrics of the different managed lanes facility design elements. Acceleration and deceleration lanes and corner radii should be based on a bus or other large design vehicle, while alignment geometry should be based on the stopping sight distance of a passenger car driver, which is lower to the ground. Larger design vehicles are not usually used in alignment design because the higher eye height of their drivers allows them to see objects from a longer distance. Larger design vehicles, however, should be used for vertical alignment design when sight restrictions occur on long downgrades. In these situations, the speed of a bus may exceed that of a passenger car (2).

If the managed lane will be used for general-purpose vehicles during off-peak periods or during incident management situations, consider using a semitrailer truck as the design vehicle (e.g., WB-67). Further, for these situations and/or when the facility will be opened to truck traffic, it is important to ensure that the entire facility, including all ingress/egress locations and horizontal curvature, is designed for the semitrailer truck design vehicle.

Table 8-3. Managed Lanes Facility Vehicle Dimensions (Adapted from 3).

Design Vehicle Type (Symbol)	U.S. Customary (ft)							Metric [m]						
	Ht.	Width	Length	Overhang		Wheelbase		Ht	Width	Length	Overhang		Wheelbase	
				Front	Rear	WB ₁	WB ₂				Front	Rear	WB ₁	WB ₂
Passenger Car (P)	4.25	7	19	3	5	11	--	1.3	2.1	5.8	0.9	1.5	3.4	--
Van	6.5	7.5	17.0	2.5	4.0	10.5	--	2.0	2.3	5.2	0.7	1.2	3.2	--
Inter-city Bus ¹ (Bus-40 or Bus-12)	12.0	8.5	40	6	6.3*	24	3.7	3.7	2.6	12.2	1.8	1.9*	7.3	1.1
Inter-city Bus ¹ (Bus-45 or Bus-14)	12.0	8.5	45	6	8.5*	26.5	4.0	3.7	2.6	13.7	1.8	2.6*	8.1	1.2
City Transit Bus ¹ (City-Bus)	10.5	8.5	40	7	8	25	--	3.2	2.6	12.2	2.1	2.4	7.6	--
Articulated Bus ¹ (A-Bus)	11.0	8.5	60	8.6	10	22.0	19.4	3.4	2.6	18.3	2.6	3.1	6.7	5.9
Interstate Semitrailer Truck ² (WB-67 or WB-20**)	13.5	8.5	73.5	4	4.5-2.5*	21.6	43.4-45.4	4.1	2.6	22.4	1.2	1.4-0.8*	6.6	13.2-13.8

¹Exact dimension may vary by bus manufacturer.
²Managed lanes facilities may allow truck vehicles, and the proper design vehicle should be selected.
*Overhang is measured from the back axle of the tandem axle assembly.
**Design vehicle with 53 ft [16.2 m] trailer as grandfathered in with 1982 Surface Transportation Assistance Act (STAA).

Design Speed

In most cases, the design speed of managed lanes will be the same as that used on the adjacent general-purpose lanes. However, there may be limited instances where the design speed of the managed lanes is lower than the adjacent general-purpose lanes, due to the geometrics of the managed lanes facility or other limitations. The designated design speed of the facility should relate to the maximum speed the facility is expected to accommodate. Further, the design speed should accommodate the vast majority of users (e.g., the anticipated 85th percentile speed).

The TxDOT *Texas Roadway Design Manual (RDM)* states that the design speed of freeways should reflect the desired operating conditions during non-peak hours (4). Table 8-4 lists the desirable and minimum design speeds. Table 8-5 summarizes the design speeds associated with various types of managed lanes as reported in the NCHRP *HOV Systems Manual (1)*. This information provides general ideas of potential design speeds; however, the design speed for a specific facility should consider the anticipated user groups, the use of on-line and off-line stations, gradients, and local conditions.

Table 8-4. Design Speed for Controlled Access Facilities (Adapted from TxDOT RDM Table 3-17, 4).

U.S. Customary (mph)			Metric [km/h]		
Facility	Desirable	Minimum	Facility	Desirable	Minimum
Mainlanes – Urban	70	50	Mainlanes – Urban	110	80
Mainlanes – Rural	70	70	Mainlanes – Rural	110	110

Table 8-5. Examples of Typical Design Speeds for Managed Lanes Facilities (Adapted from 1).

U.S. Customary (mph)			Metric [km/h]		
Types of Managed Lanes	Typical Design Speed		Types of Managed Lanes	Typical Design Speed	
	Reduced	Desirable		Reduced	Desirable
Barrier separated	50	70	Barrier separated	80	110
Concurrent flow	50	60	Concurrent flow	80	100
Contraflow	30	50	Contraflow	50	80

There should be a definite relationship between the design speed on a ramp or direct connection and the design speed on the intersecting highway or frontage road. According to the *RDM*, ramp connections should be designed to enable vehicles to leave and enter the traveled way of a freeway at no less than 50 percent (70 percent usual, 80 percent desirable) of the freeway design speed, and the design speed of the ramp should not be less than the design speed on the intersecting frontage roads (4). Ramp connections for HOV lanes should be designed at approximately 70 percent of the mainline design speed, or nominally in the 35 to 50 mph [55 to 80 km/h] speed range. This criterion is applicable to elevated flyover ramps and connecting drop ramps with local streets.

At-grade access locations may use this criterion if dedicated weave lanes are provided, or they may be designed at a higher speed based on the specific location and operating characteristics of the freeway through lanes (2).

Horizontal Clearance

For horizontal clearances, 5 ft [1.5 m] is the desired clearance; however, as a minimum, at least a 2-ft [0.6 m] lateral clearance should be provided to adjacent barriers, signing columns, or other obstructions for both managed lanes and general-purpose traffic lanes. Exceptions to this minimum should be considered only in temporary situations, such as construction or reconstruction of a facility where speeds are reduced or for very short distances where other options do not exist.

Vertical Clearance

The TxDOT *Texas Roadway Design Manual* states that all controlled access highway grade separation structures should provide a 16.5-ft [5 m] minimum vertical clearance over the usable roadway (4). Structures over the mainlanes of interstate or controlled-access highways must meet the minimum vertical clearance requirement except within cities where the 16.5-ft [5 m] vertical clearance is provided on an interstate loop around the particular city. In some locations, the height of the tallest vehicle anticipated to operate in the managed lanes facility is used to determine the vertical clearance. As discussed previously, buses are usually the tallest vehicle using a managed lane and are commonly used to determine the vertical clearance. If the managed lane will include trucks, the vertical clearance of the truck design vehicle may govern (see Table 8-3). In the case of managed lanes on freeways, the standard of 16.5 ft [5 m] used for the adjacent freeway lanes will also be used for the managed lane (3). In situations of restricted vertical clearance, a minimum of 14.5 ft [4.4 m] is acceptable per the AASHTO *Green Book*, which includes an allowance of 6 inches [0.15 m] in anticipation of future resurfacing (3,5). This may also be an issue where an overcrossing road is widened; the cross slope on the wider road can result in reduced clearance at the edges of the roadway.

Stopping Sight Distance

The design of a managed lanes facility should provide adequate stopping sight distance (SSD) for all vehicle types (e.g., bus, truck, van, car) using the facility. Due to the driver's eye height, the automobile is usually used as the design vehicle for determining stopping sight distance. TxDOT's *Roadway Design Manual* should be used in determining stopping sight distances for various travel speeds. Table 8-6 lists the SSD values adopted by TxDOT in July 2001. The stopping sight distances should be checked if barriers are used since they may restrict the available sight distances (2).

Table 8-6. Stopping Sight Distance (Adapted from TxDOT RDM Table 2-1, 4).

U.S. Customary					Metric				
Design Speed	Brake Reaction Distance	Braking Distance on Level	Stopping Sight Distance		Design Speed	Brake Reaction Distance	Braking Distance on Level	Stopping Sight Distance	
			Calculated	Design				Calculated	Design
(mph)	(ft)	(ft)	(ft)	(ft)	[km/h]	[m]	[m]	[m]	[m]
30	110.3	86.4	196.7	200	50	34.8	28.7	63.5	65
35	128.6	117.6	246.2	250	60	41.7	41.3	83.0	85
40	147.0	153.6	300.6	305	70	48.7	56.2	104.9	105
45	165.4	194.4	359.8	360	80	55.6	73.4	129.0	130
50	183.8	240.0	423.8	425	90	62.6	92.9	155.5	160
55	202.1	290.3	492.4	495	100	69.5	114.7	184.2	185
60	220.5	345.5	566.0	570	110	76.5	138.8	215.3	220
65	238.9	405.5	644.4	645	120	83.4	165.2	248.6	250
70	257.3	470.3	727.6	730	130	90.4	193.8	284.2	285
75	275.6	539.9	815.5	820					
80	294.0	614.3	908.3	910					

Note: Brake reaction distance predicated on a time of 2.5 sec; deceleration rate 11.2 ft/sec² [3.4 m/sec²].

Superelevation

Superelevation rates on managed lanes must be applicable to curvature over a range of design speeds. Designers must give consideration to the higher center of gravity for buses, vans, and trucks, which will result in superelevations slightly higher than otherwise justified (5). Table 8-7 presents recommended superelevation rates for managed lanes.

Table 8-7. Recommended Managed Lanes Superelevation Rates (Adapted from 5, 6).

U.S. Customary			Metric		
Managed Lanes Design Speed (mph)	Maximum Superelevation, <i>e</i> (ft/ft)		Managed Lanes Design Speed [km/h]	Maximum Superelevation, <i>e</i> [m/m]	
	Allowable	Desirable		Allowable	Desirable
40 - 50	0.06	0.04	70 - 80	0.06	0.04
50 - 70	0.06	0.04	80 - 110	0.06	0.04

Cross Slope

The cross slope of a managed lanes facility should generally follow the adjacent freeway, which is commonly 2 percent. However, for a facility located in a median that straddles the crown of the roadway, it is acceptable to crown the facility with a 2 percent crossfall

to either side if drainage requirements permit (an example is shown in Figure 8-1). For typical sections with five or more lanes, the uniform cross slope of 2 percent may not be sufficient and the outside lane(s) cross slope may require modification. For concurrent-flow facilities, the designer should extend the existing crossfall of the freeway mainlanes. Reversing cross slope (i.e., creating a cross-slope break of greater than 4 percent) except along extremely wide buffer or barrier alignments is not desirable since it can affect driver expectations when crossing the buffer at designated access points and possibly degrade operational performance.

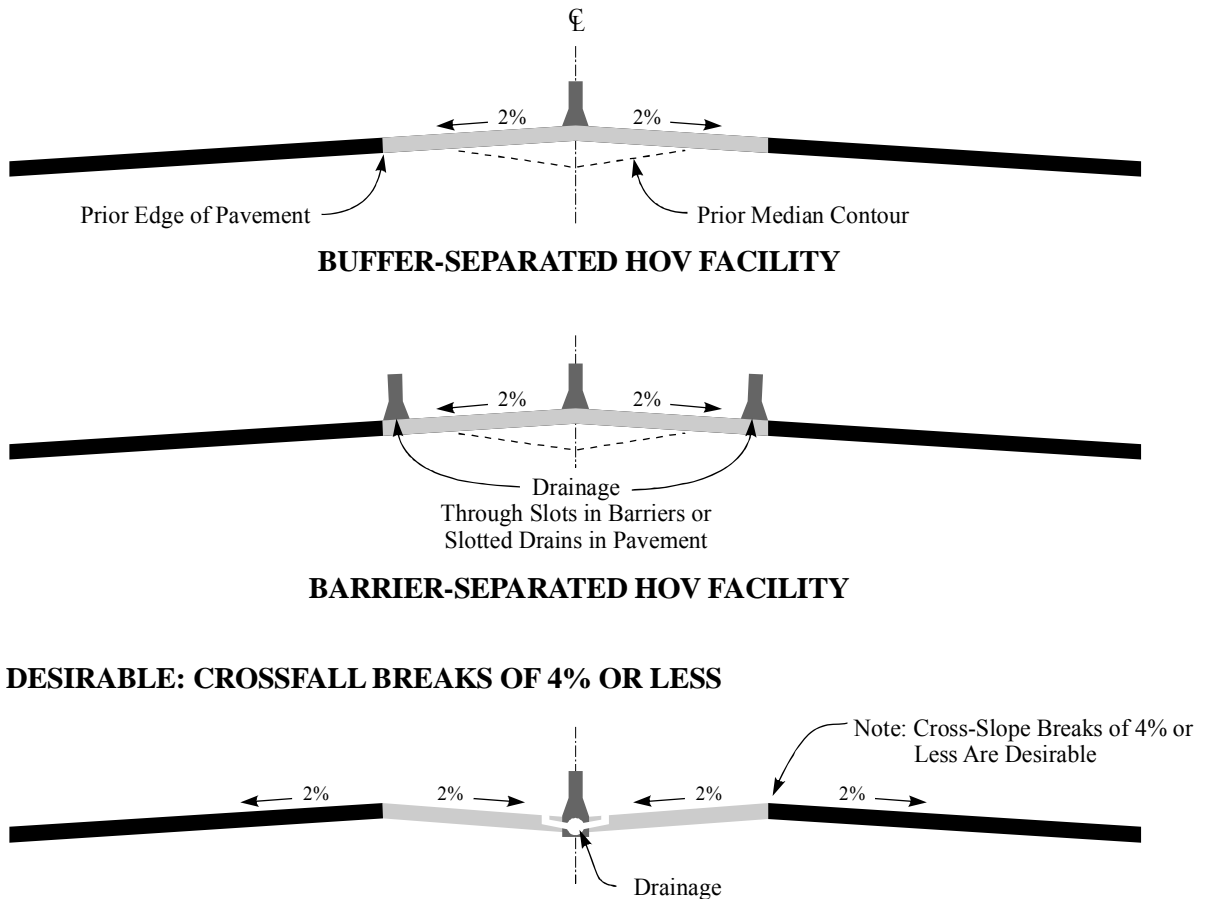


Figure 8-1. Cross-Slope Alternatives for Median Retrofit Projects (Adapted from 6).

Minimum Turning Radius

Generally, a 50-ft [15.2 m] minimum radius (inner wheel path) is considered desirable at low speeds (10 mph [16 km/h]); this will accommodate most urban transit buses. For a radius below this value, the designer should consider the possibilities of a compound curve or approach and departure tapers to avoid increasing the outside radius and causing vehicle overhang. This condition is likely to be encountered at managed lanes ramp intersections with local streets and possibly at ramp intersections with the mainlane

facility. These recommended radii might differ if the managed lanes facility is designed to accommodate semitrailers (2).

Horizontal Curvature

The horizontal alignment of a managed lanes facility should be designed to ensure that all design vehicles, including buses and semitrailers, if applicable to the managed lanes facility design, may safely negotiate all curves. Table 8-8 presents desirable and reduced radii for horizontal curves on managed lanes. Values for minimum radii for horizontal curvature should be used only where the cost of incorporating desirable radii is inconsistent with the benefits (1, 2, 5).

Managed lanes on curves should provide additional lateral width for maneuvering and for the overhang of various parts of a bus. Table 8-9 recommends pavement widening for managed lanes for various horizontal curve radii and design speeds. Likewise, ramps on curves must also have sufficient width to accommodate the bus wheel path and allow passing of stalled vehicles. Recommended pavement widths for travel lane(s) are given for both single- and multiple-lane operations and varying ramp radii. Designers should consider providing extra lane width on curves to accommodate semitrailers on a full- or part-time basis (1, 2, 5).

Table 8-8. Recommended Minimum Radii for Managed Lanes Horizontal Curvature (Adapted from 3).

U.S. Customary			Metric		
Design Speed (mph)	Radii (ft)		Design Speed [km/h]	Radii [m]	
	Reduced ¹	Desirable ²		Reduced ¹	Desirable ²
45	600	660	70	175	195
50	760	835	80	230	250
55	965	1065	90	305	335
60	1205	1340	100	395	435
65	1485	1660	110	500	560
70	1820	2050	120	665	775
75	2215	2510	130	830	950
80	2675	3060			

¹Reduced radii are obtained from the *Green Book* (3), pages 160 and 161, with $e_{\max} = 8$ percent.

²Desirable radii are obtained from the *Green Book* (3), pages 158 and 159, with $e_{\max} = 6$ percent.

**Table 8-9. Pavement Widening Recommended for Horizontal Curvature
(Adapted from 2).**

Managed Lanes Mainline									
U.S. Customary					Metric				
Design Speed (mph)	Pavement Widening for Single-Lane, One-Way Curve with Radius of (in ft):				Design Speed [km/h]	Pavement Widening for Single-Lane, One-Way Curve with Radius of [in m]:			
	500	750	1000	2000		150	230	305	610
40	2.0	1.0	1.0	0.0	70	0.6	0.3	0.3	0.0
50	N/A	1.5	1.0	0.5	80	N/A	0.5	0.3	0.2
60	N/A	N/A	1.0	0.5	100	N/A	N/A	0.3	0.2
70	N/A	N/A	N/A	N/A	110	N/A	N/A	N/A	N/A

Managed Lanes Ramps									
U.S. Customary					Metric				
Ramp Type	Pavement Widening for Curve with Radius of (in ft):				Ramp Type	Pavement Widening for Curve with Radius of [in m]:			
	100	250	500	1000		30.5	76	152	305
Single lane, one way	8	6	4	2	Single lane, one way	2.4	1.8	1.2	0.6
Multiple lanes, one way	6	4	3	2	Multiple lanes, one way	1.8	1.2	0.9	0.6

Note: Allowances are for roadways only and do not include the need for shoulders.

Vertical Curvature

Managed lanes on freeways typically follow the existing vertical curvature of the facility. For busways and managed lanes facilities on separate rights-of-way or new construction, K-factors are used to determine the necessary vertical curvature and are determined by applicable design speeds. For design on independent facilities outside the freeway right-of-way, K-factors (distance divided by the percentage change in algebraic difference of grades) should be used to calculate the recommended minimum length of vertical curvature. These calculations assume a driver eye height of 3.5 ft [1080 mm] (passenger cars being the most critical vehicles), object height of 2.0 ft [0.6 m], parabolic curvature, and the presence of fixed-source lighting for an urban environment. Table 8-10 presents recommended K-factors for the length of the managed lanes vertical curves over a range of design speeds and both crest and sag conditions (3). K-factors for sag vertical curvature based on comfort are about 50 percent of that required to satisfy the headlight sight distance requirement for the normal range of design conditions (3). Therefore, it is important that fixed-source lighting exists along the managed lanes facility to apply the sag vertical curvature values in these tables. If the fixed-source lighting does not exist or is not adequate, the headlight sight distance requirement should be used in the design of the sag vertical curvature.

Table 8-10. Vertical Curve Criteria (K-Factors) for Managed Lanes Facilities (Adapted from 3).

U.S. Customary				Metric			
Design Speed (mph)	Minimum Length (ft)	Minimum K-Factors (ft/Percent Change in Algebraic Difference of Gradients)		Design Speed [km/h]	Minimum Length [m]	Minimum K-Factors [m / Percent Change in Algebraic Difference of Gradients]	
		Crest Stopping	Sag Comfort			Crest Stopping	Sag Comfort
70	225	247	181	110	70	74	55
60	200	151	136	100	60	52	45
50	150	84	96	80	50	26	30
40	125	44	64	70	45	17	23
30	100	19	37	50	30	7	13

Note: Length of curve is three times the design speed (see *Green Book (3)*, page 280).

Gradients

Recommended gradients should reflect current AASHTO practice to ensure both safety and uniformity of operation along with the capabilities of the vehicles authorized on the managed lanes facility. Consideration must be given to maximum and minimum grades. [Table 8-11](#) indicates desirable and maximum grades to be used on managed lanes mainlanes and connecting ramps. Values exceeding the recommended maximum may be considered in special or extreme situations only. The designer can enhance operation by providing flatter grades of adequate length at starting and stopping locations. The maximum length of grade should be such that vehicles are not slowed by more than 10 mph [16 km/h] considering the length and percentage of the grade.

A minimum longitudinal grade of 0.35 percent is controlled by the need to provide adequate drainage and to prevent water retention (i.e., ponding) on the roadway surface. For median facilities retrofitted at grade, the minimum grade follows the existing freeway gradient (2, 5).

Table 8-11. Recommended Maximum Grades.

Facility Type	Grade		
	Freeway Level ¹	Freeway Rolling ¹	HOV Maximum ²
Mainline (70 mph [110 km/h])	3 percent	4 percent	5 percent
Ramp (40 mph [65 km/h])	Preferably limited to 4 percent ¹		5 percent

¹See *Texas Roadway Design Manual (4)*.
²See *High-Occupancy Vehicle Facilities (2)* and *Guide for High-Occupancy Vehicle (HOV) Facilities (6)*.

Summary of Managed Lanes Mainline Design Guidelines

Table 8-12 provides a summary of alignment and other typical factors controlling the design for mainline managed lanes facilities.

Table 8-12. Summary of Managed Lanes Mainline Design Criteria
(Adapted from 2, 3, 5, 6).

Design Speed	U.S. Customary		Metric	
	Desirable	Reduced	Desirable	Reduced
	70 mph	50 mph	110 km/h	80 km/h
Alignment				
Stopping Distance	730 ft	425 ft	220 m	130 m
Horizontal Curvature (Radius)	2050-2345 ft 0.04 ft/ft	835-930 ft 0.06 ft/ft	560-635 m 0.04 m/m	250-280 m 0.06 m/m
Maximum Superelevation				
Rate of Vertical Curvature	247	84	74	26
Crest, k	181	96	55	30
Sag, k				
Gradients				
Maximum (%)	4	5	4	5
Minimum (%)	0.5	0.5	0.3	0.3
Clearance				
Vertical	16.5 ft	14.5 ft	5 m	4.4 m
Lateral	4 ft	2 ft	1.2 m	0.6 m
Lane Width				
Travel Lanes	12 ft	11 ft	3.6 m	3.4 m
Cross Slope				
Maximum	0.020 ft/ft	0.020 ft/ft	0.020 m/m	0.020 m/m
Minimum	0.015 ft/ft	0.015 ft/ft	0.015 m/m	0.015 m/m
Turning Radius Minimum	N/A	N/A	N/A	N/A
Superelevation: Depends on curve radii and design speed (0.10 ft/ft [0.10 m/m] maximum).				

Section 3 – Cross Sections for Managed Lanes Facilities

This section describes desirable and reduced cross sections for managed lanes facilities. As with all components of the development of managed lanes facilities, the cross section must consider the operation and enforcement of the facility.

Design Considerations for Exclusive Freeway Managed Lanes

Exclusive freeway managed lanes are physically separated from the adjacent freeway general-purpose lanes by a barrier or wide buffer. There are two types of exclusive freeway management lanes:

- ◆ two way and
- ◆ reversible.

Reversible facilities may be designed as single-lane or multiple-lane facilities. As with other types of managed lanes facilities, standards from AASHTO, FHWA, and local agencies should be used to guide the design process.

Exclusive Two-Way Managed Lanes Facilities

Exclusive two-way facilities are lanes constructed within the freeway right-of-way that are physically separated from the general-purpose freeway lanes and are used exclusively as managed lanes for all, or a portion, of the day. Concrete barriers are generally used to physically separate the managed lanes facility from the general-purpose freeway lanes.

Exclusive facilities often have limited access points and may include direct ramps and other exclusive ingress and egress treatments. The general design approach is similar to a normal freeway design with the addition of a barrier or wide buffer between the managed lanes facility and the general-purpose lanes. The following design components should be considered with an exclusive two-way managed lanes facility. The forthcoming revision to the TxDOT *Roadway Design Manual* (anticipated January 2006) includes an example cross section.

- ◆ **Median component.** Opposing-direction managed lanes are normally separated from each other by a median barrier. AASHTO and federal guidelines should be used to design the median barrier (7).
- ◆ **Lane component.** Exclusive two-way managed lanes facilities should have 12-ft [3.6 m] travel lanes. Designers should consider narrower lane widths only in special circumstances or for short distances due to limited right-of-way.
- ◆ **Lane separation component.** Barrier can be provided as the separation treatment. Lateral clearance will also need to be provided adjacent to the general-purpose lanes with this approach.

- ◆ **Cross-section design summary.** Enforcement, drainage, site distance, and the need for passing and emergency access should also be considered in determining the sectional width.
- ◆ **Design tradeoffs.** Table 8-13 shows an example ordered list of adjustments that may be made to the cross-section design of a two-way barrier-separated managed lanes when there is limited right-of-way. Operational treatments should be considered prior to using a reduced design cross section. Table 8-13 is only an example; the designer must consider each facility and consult with all involved agencies to decide what will be approved.

Table 8-13. Example Design Tradeoffs for Two-Way Barrier-Separated Managed Lanes Facilities (Adapted from 6).

Ordered Sequence	Cross-Section Design Change
First	Reduce total design envelope to 42 ft [12.6 m] according to the middle schematic of Figure 8-2 with 2 ft [0.6 m] offset to middle barrier.
Second	Reduce freeway left lateral clearance to no less than 2 ft [0.6 m]. Reduce left managed lanes lateral clearance to no less than 2 ft [0.6 m].
Third	Reduce freeway right lateral clearance (shoulder) from 10 ft [3.0 m] to no less than 8 ft [2.4 m].
Fourth	Reduce managed lanes width to no less than 11 ft [3.4 m]. (Some agencies prefer reversing the fourth and fifth steps when buses or trucks are projected to use the managed lanes facility.)
Fifth	Reduce selected mixed-flow lane widths to no less than 11 ft [3.4 m]. (Leave at least one 12-ft [3.6 m] outside lane for trucks).
Sixth	Reduce freeway right lateral clearance shoulder from 8 ft [2.4 m] to no less than 4 ft [1.2 m].
Seventh	Convert barrier shape at columns to a vertical face.

Exclusive Reversible Managed Lanes Facility

The second type of exclusive managed lane treatment is a reversible lane or lanes. Like a two-way facility, this approach involves a lane (or lanes) within the freeway right-of-way that is (are) physically separated from the general-purpose freeway lanes and is (are) used exclusively by eligible vehicles for all or a portion of the day. Trucks may also be eligible users of the facility.

Exclusive reversible managed lanes facilities usually operate inbound toward the central business district (CBD) or other major activity center in the morning and outbound in the afternoon. Daily reconfiguration is required with reversible facilities. This often includes opening gates to the lanes in the morning, closing the lanes to inbound traffic, reopening the lanes in the reverse direction of travel in the afternoon, and closing the lanes in the evening. Either manual or automated techniques may be used to open and close reversible managed lanes facilities. The forthcoming revision to the TxDOT *Roadway Design Manual* (anticipated January 2006) includes an example cross section.

Table 8-14 shows an example of an ordered list of adjustments that may be made to the cross-section design of a reversible barrier-separated managed lane when there is limited right-of-way. As noted in the cross-section figures, the operational allowances described in Table 8-2 should be considered prior to using reduced design cross sections. Table 8-14 is only an example; the designer must consider each facility and consult with all involved agencies to decide what will be approved.

Table 8-14. Example Design Tradeoffs for Reversible-Flow Managed Lanes Facilities (Adapted from 6).

Ordered Sequence	Cross-Section Design Change
First	Reduce single-lane managed lane envelope to no less than 20 ft [6.1 m], or two-lane envelope to no less than 36 ft [11.0 m].
Second	Reduce freeway left lateral clearance to no less than 2 ft [0.6 m].
Third	Reduce freeway right lateral clearance (shoulder) from 10 ft [3.0 m] to no less than 8 ft [2.4 m].
Fourth	Reduce managed lane width to no less than 11 ft [3.3 m]. (Some agencies prefer reversing fourth and fifth steps when buses are projected to use the managed lanes facility.)
Fifth	Reduce selected general-purpose lane widths to no less than 11 ft [3.3 m]. (Leave at least one 12-ft [36 m] outside lane for trucks.)
Sixth	Reduce freeway right lateral clearance shoulder from 8 ft [2.4 m] to no less than 4 ft [1.2 m].
Seventh	Convert barrier shape at columns to a vertical face.

Design Considerations for Concurrent-Flow Managed Lanes

Concurrent-flow managed lanes are defined as freeway lanes in the same direction of travel, not physically separated from the general-purpose traffic lanes, and designated for exclusive use by eligible vehicles for all or a portion of the day. A few facilities are open only to buses, allowing transit vehicles to bypass specific bottlenecks.

Concurrent-flow lanes are usually, although not always, located on the inside lane or shoulder. Pavement markings are a common means used to separate these lanes. Unlimited ingress and egress may be allowed with a concurrent-flow managed lanes facility, but specific access points are preferred for enforcement purposes. The forthcoming revision to the TxDOT *Roadway Design Manual* (anticipated January 2006) includes an example cross section.

Concurrent-flow managed lanes facilities are often developed by retrofitting an existing freeway cross section. For example, the inside shoulder or center median may be converted to an additional lane, or the freeway right-of-way may be expanded and a managed lane added.

Table 8-15 shows an example ordered list of adjustments that may be made to the cross-section design of a concurrent-flow managed lanes facility when there is limited right-of-way. As noted in the cross-section figures, the operational allowances described in Section 2 should be considered prior to using reduced design cross sections. Table 8-15 is only an example; the designer must consider each facility and consult with all involved agencies to decide what will be approved.

Table 8-15. Example Design Tradeoffs for Concurrent-Flow Managed Lanes Facilities (Adapted from 6).

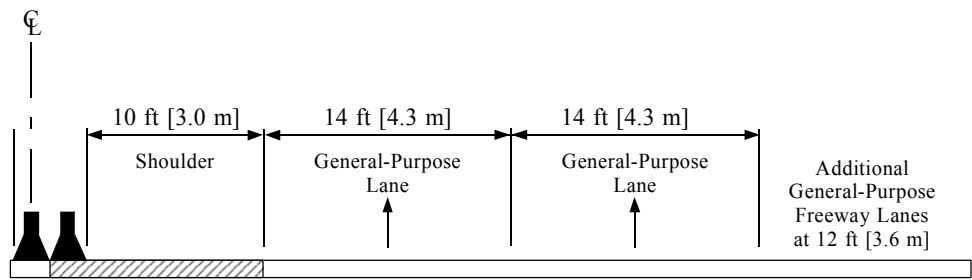
Ordered Sequence	Cross-Section Design Change
First	Reduce managed lanes design envelope.
Second	Reduce freeway right lateral clearance (shoulder) from 10 ft [3.0 m] to 8 ft [2.4 m].
Third	Reduce managed lane width to no less than 11 ft [3.3 m]. (Some agencies prefer reversing third and fourth steps when buses are projected to use the managed lanes facility.)
Fourth	Reduce selected mixed-flow lane widths to no less than 11 ft [3.3 m]. (Leave at least one 12-ft [3.6 m] outside lane for trucks.)
Fifth	Reduce freeway right lateral clearance (shoulder) from 8 ft [2.4 m] to no less than 4 ft [1.2 m].
Sixth	Transition barrier shape at columns to vertical face or remove buffer separation between the managed lanes and mixed-flow lanes.

Design Considerations for Freeway Contraflow Managed Lanes

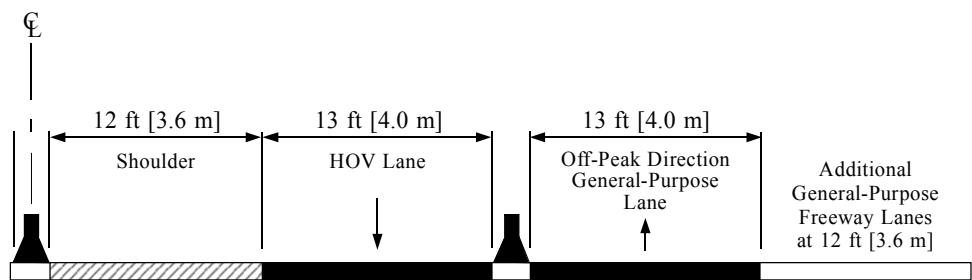
Contraflow managed lanes borrow a lane from the off-peak direction of travel for use by eligible vehicles in the peak direction. Contraflow managed lanes should be considered only in cases where there is a high directional split, where capacity exists in the off-peak direction of travel, and where the facility can be designed and operated safely. Since contraflow facilities involve traffic operating in opposing directions on the same side of a freeway, safety for both managed lanes and general-purpose traffic should be a critical element in the design process.

Contraflow managed lanes have two somewhat unique design elements. The first is the treatment used to separate the lane from the general-purpose traffic operating in the opposite direction of travel. The other is the access to and from the lane. The separation treatments and other lane design elements are highlighted in this section. Section 4 of this chapter discusses access treatments.

Figures 8-2 and 8-3 provide examples of cross sections for contraflow managed lanes facilities using both types of treatments.



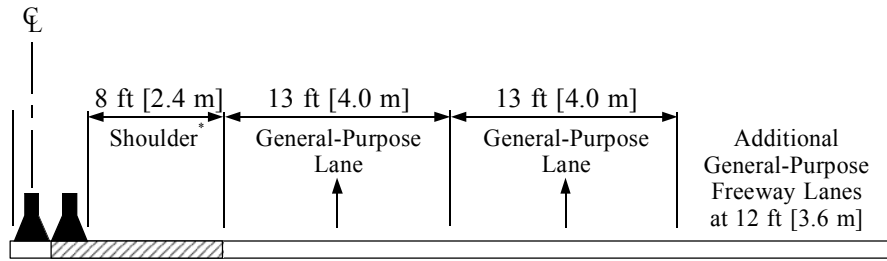
DESIRABLE* (NON-OPERATING) MOVEABLE BARRIER SEPARATED



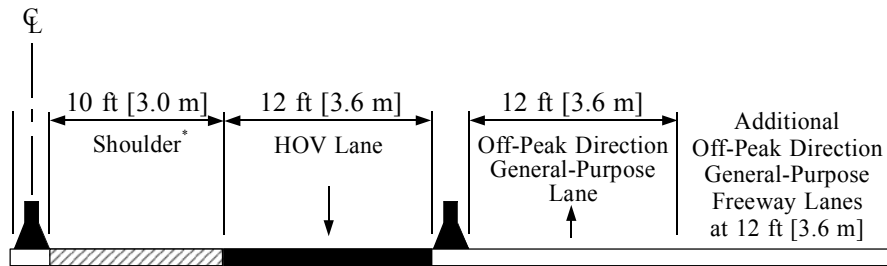
DESIRABLE* (OPERATING) MOVEABLE BARRIER SEPARATED

* Enforcement of this facility is performed at the ends and access locations.

Figure 8-2. Desirable Cross Sections for Contraflow Managed Lanes (Adapted from 6).



MINIMUM* (NON-OPERATING) MOVEABLE BARRIER SEPARATED



MINIMUM* (OPERATING) MOVEABLE BARRIER SEPARATED

* Operational treatments should be incorporated if the minimum design cross section is used or no continuous shoulder exists. The minimum cross section should be used as an interim project or over short distances. Increased enforcement and incident management programs should be implemented to successfully operate the facility.

(Suggested operational treatments are listed in [Table 8-2](#).)

Figure 8-3. Reduced Cross Sections for Contraflow Managed Lanes (Adapted from 6).

Section 4 – Design Considerations for Terminal and Access Treatments

Overview

This section examines the design elements for different types of terminal and access treatments associated with managed lanes facilities. Vehicles may enter a managed lanes facility at the beginning of, or in most cases, at some point along the lane.

Correspondingly, vehicles traveling the facility may exit a facility at the end or at other egress locations. The type of access provided will depend on the nature of the managed lanes facility, the objectives of the project, land uses in the corridor, available rights-of-way, and funding. The designer should follow these general guidelines for the design of access treatments:

- ◆ Where possible, the same geometric criteria should be applied as would be used for a freeway ramp, including locally recognized entrance and exit standards.
- ◆ Sight distance is particularly critical due to the proximity of barriers to ramp lane alignments. Where practical, removal of barrier-mounted glare screens or slight adjustments in striping alignment may be necessary within the ramp envelope to accommodate the proper design speed.
- ◆ For at-grade access with the adjacent freeway lanes, designated outlets should be strategically positioned so as to minimize erratic weaving to reach nearby freeway exits.
- ◆ Locate access/egress points associated with street access away from intersections that are operating at or near the traffic capacity.
- ◆ Vehicles entering the managed lanes facility should be required to make an overt maneuver to enter the lane. A freeway lane should not end at a managed lanes entrance; the freeway lane should be moved laterally and the managed lanes entrance located out of the normal path of travel.
- ◆ Managed lanes ramps should provide adequate space for possible metering, storage, and enforcement.
- ◆ If direct ramps are not included in an initial project design, provisions should be made so that the ramps can be added later.
- ◆ Adequate advance signing should be provided.
- ◆ Pavement markings should emphasize the mainline (possibly through use of skip stripe markings across the diverging exit ramp).
- ◆ Safety lighting should be applied for all access locations using the same warrants applied for urban freeway entrance and exit ramps.

Selecting Ramp Type

All aspects of managed lanes design must be considered in light of the operation and enforcement of the facility. Full standards for access include direct ramps to park-and-ride facilities or local streets with barrier-separated facilities. When general-purpose exit and entrance ramps are spaced relatively far apart (2 to 3 miles [3.2 to 4.8 km]), concurrent-flow facilities with at-grade entrance and exit ramps may be acceptable. Difficult weaving patterns may be created at the weaving sections of concurrent-flow facilities when traffic volumes entering and/or exiting the managed lanes facility are high at an at-grade access point.

Multi-lane managed lanes facilities may be necessary for large demands. The fundamental design of these facilities should follow the same geometric criteria for freeway ramps with locally recognized entrance and exit standards. For maximum travel time savings and trip reliability benefits, the facility should be located where the primary critical volume and/or mode of travel is most congested. Direct access and direct connections of managed lanes facilities provide the best accommodation for multi-lane geometrics.

[Table 8-16](#) provides guidelines for selecting ramp types. Each type of ramp will be described in the following discussion.

Table 8-16. Guidelines for Selecting Ramp Type (Adapted from 2).

Objective	Type of Ramp ¹			
	T-Ramp or Drop Ramp with Park-and-Ride Lot or Transit Station	T-Ramp or Drop Ramp with Street	Flyover Ramp	At-Grade Slip Ramp with Freeway
Frequent spacing (< 3 miles [4.8 km])	+	0	-	0
Maximize bus travel time savings	+	0	0	0
User mix requirements				
Buses only	+	+	+	+
Buses and other eligible vehicles	+	+	+	+
Primarily carpools and vanpools	+	+	+	+
Potential conflict with general-purpose traffic	+	+	+	0
Enforceability	+	+	0	-
Traffic regulation capability ²	+	+	+	-
Capital cost	0	0	-	+
High vehicle volumes (> 400 vph)	-	+	+	Terminations + Intermediate sites -
Low vehicle volumes (< 400 vph)	+	+	-	+
High ramp design speed (> 35 mph [60 km/h])	-	-	+	+
Low ramp design speed (< 35 mph [60 km/h])	+	+	N/A	-
Retrofit compatibility with exiting freeway	0	+	0	+
Flexibility to modify later	-	-	-	+
+ = favorable 0 = neutral, often depends on the design or site specifics - = not favorable N/A = not applicable ¹ Not included are busway street intersections used for low-volume, bus-only operation in separate right-of-way. ² Assumes use of meters to regulate entering flow of vehicles.				

Design Speed

There should be a definite relationship between the design speed on a ramp or direct connection and the design speed on the intersecting highway, frontage road, or street to a park and ride. The TxDOT *Texas Roadway Design Manual* states that all ramps and connections should be designed to enable vehicles to leave and enter the traveled way of the freeway at no less than 50 percent (70 percent usual, 85 percent desirable) of the

freeway’s design speed (4). Table 8-17 shows guide values for ramp/connection design speed. The design speed for a ramp should not be less than the design speed on the intersecting facility. AASHTO’s *A Policy on Geometric Design of Highways and Streets* provides additional guidance on the application of the ranges of ramp design speed shown in Table 8-17 (3).

Table 8-17. Guide Values for Ramp/Connection Design Speed as Related to Highway Design Speed (Adapted from TxDOT RDM Table 3-20, 4).

(Desirable based on $e_{max} = 6\%$)

Highway Design Speed	U.S. Customary (mph)					Metric [km/h]			
	50	55	60	65	70	80	90	100	110
Ramp* Design Speed:									
Upper Range (85%)	45	48	50	55	60	70	80	90	100
Mid-range (70%)	35	40	45	45	50	60	60	70	80
Lower Range (50%)	25	28	30	30	35	40	50	50	60

*Loops: Upper and middle range values of design speed generally do not apply. The design speed on a loop is usually 40 km/h [55 m] minimum radius. Particular attention should be given to controlling superelevation on loops due to the tight turning radii and speed limitations.

Direct Access Ramps

Grade-separated or direct-access ramps are desirable and should be considered when the anticipated volume attempting to access a managed lanes facility exceeds 275 veh/hr. They provide access for eligible vehicles where high vehicle volumes are anticipated or where additional time savings and operational efficiencies can be gained. Direct access ramps are usually found with exclusive managed lanes, but they may be used with any type of lane, and they may be used at the start, end, or intermediate locations along a managed facility. Direct connections can be the most efficient means of managing conflicting movements at locations where there is substantial congestion and they facilitate enforcement.

A variety of managed lanes ramp alignments exist. Examples of direct-access connections include:

- ◆ T-ramps,
- ◆ drop ramps,
- ◆ flyover ramps, and
- ◆ Y-ramps.

The exact design of these types of facilities will depend on the nature and design of the managed lane and the adjacent roadway or facility and available right-of-way. The following information provides design examples for these types of access treatments.

T-Ramps and Drop Ramps

The name of T-ramps and drop ramps reflect the fact that this type of direct access ramp looks like the letter “T” and the ramp “drops” from the managed lane to the freeway, local roadway, park-and-ride lot, or other facility. These access treatments are usually used with barrier-separated exclusive managed lanes, but they may also be considered with other types of managed lanes facilities. Figure 8-4 shows an example T-ramp design from a reversible-flow managed lane to a park-and-ride lot or arterial street. Figure 8-5 presents a schematic of the managed lanes acceleration lane, deceleration lane, and taper lengths for a T-ramp.

Table 8-18 shows the recommended acceleration and deceleration lane lengths for managed lanes for providing access with a T-ramp. The lengths shown are based upon acceleration and deceleration rates for single-unit buses of 2 mph/s [3.2 km/h/s] and 2.5 mph/s [4 km/h/s], respectively, on a level grade. The effective reduction for the length of a deceleration lane on an upgrade is approximately 5 percent for every 1 percent positive grade (8). The effective reduction for the length of acceleration lane on a downgrade is approximately 10 percent for every 1 percent negative grade. These guidelines are restricted to gradients of 6 percent or less and lengths of grade of 1000 ft [300 m] or less (6).

Table 8-18. Recommended Acceleration/Deceleration Lane Lengths for T-Ramps (Adapted from 8).

U.S. Customary					Metric				
Mainlane Managed Lanes Speed	Managed Lanes Entering Speed ¹	Length of Acceleration/Deceleration Lane	Length of Taper ²	Rec. Total Length	Mainlane Managed Lanes Speed	Managed Lanes Entering Speed ¹	Length of Acceleration/Deceleration Lane	Length of Taper ²	Rec. Total Length
(mph)	(mph)	(ft)	(ft)	(ft)	[km/h]	[km/h]	[m]	[m]	[m]
35	25	250	170	420	60	40	75	50	130
40	30	400	190	590	65	50	120	60	180
45	35	700	210	910	70	55	210	65	275
50	40	975	230	1205	80	65	300	70	365
55	45	1400	250	1650	90	70	425	75	505
60	50	1900	270	2170	100	80	580	80	660
65	55	2400	280	2680	105	90	730	85	815
70	60	3000	290	3290	110	100	915	90	1000

¹Bus speed at end of taper
²Usual desirable taper is 50:1; minimum taper is 20:1.

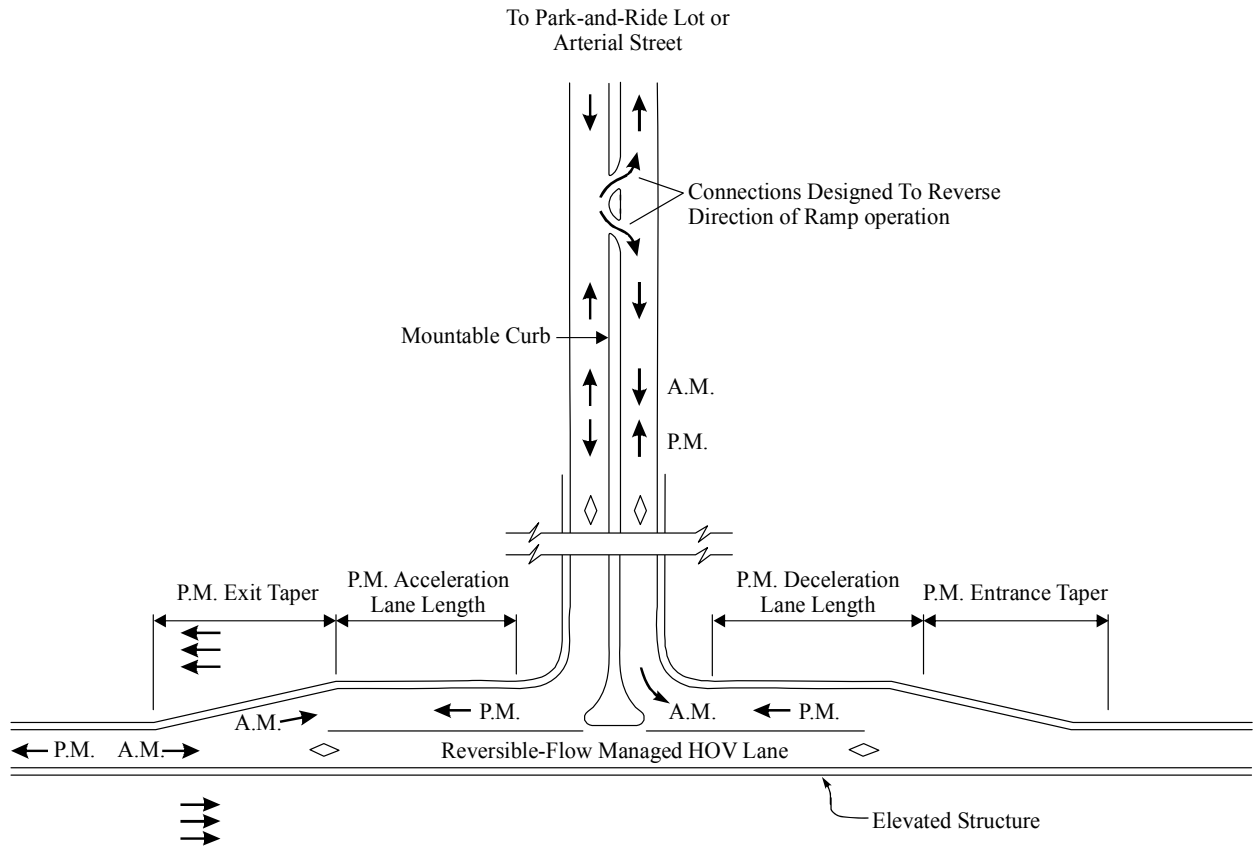


Figure 8-4. Typical T-Ramp for Reversible Managed Lanes Facility (Adapted from 1).

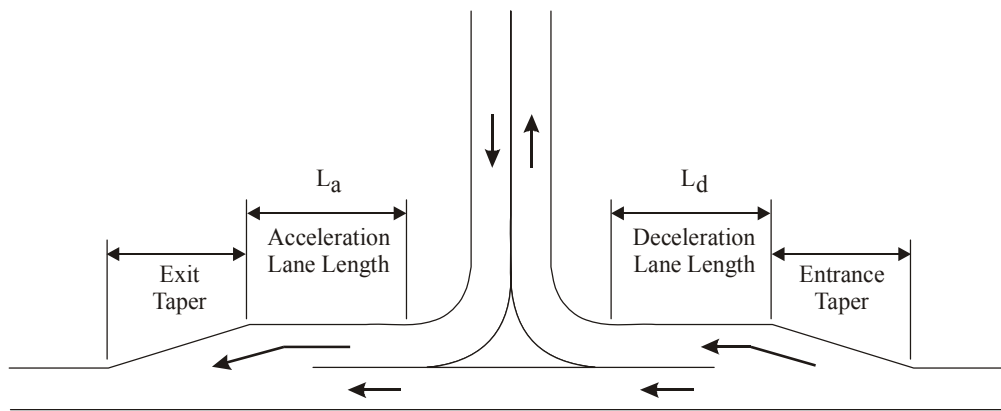


Figure 8-5. Managed Lanes Acceleration Lane, Deceleration Lane, and Taper Lengths (Adapted from 8).

Figure 8-6 shows a schematic of the morning and afternoon operations on a T-ramp crossover at a transit center. Figure 8-7 shows a schematic of an alternate T-ramp treatment. Entering traffic from the T-ramp merges downstream from the elevated section.

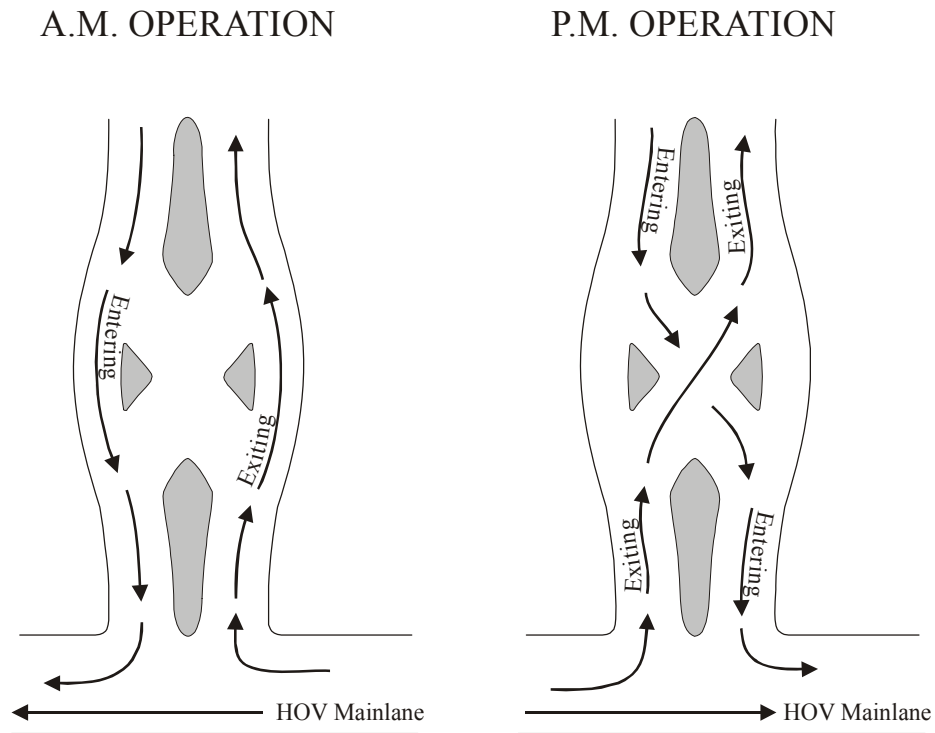
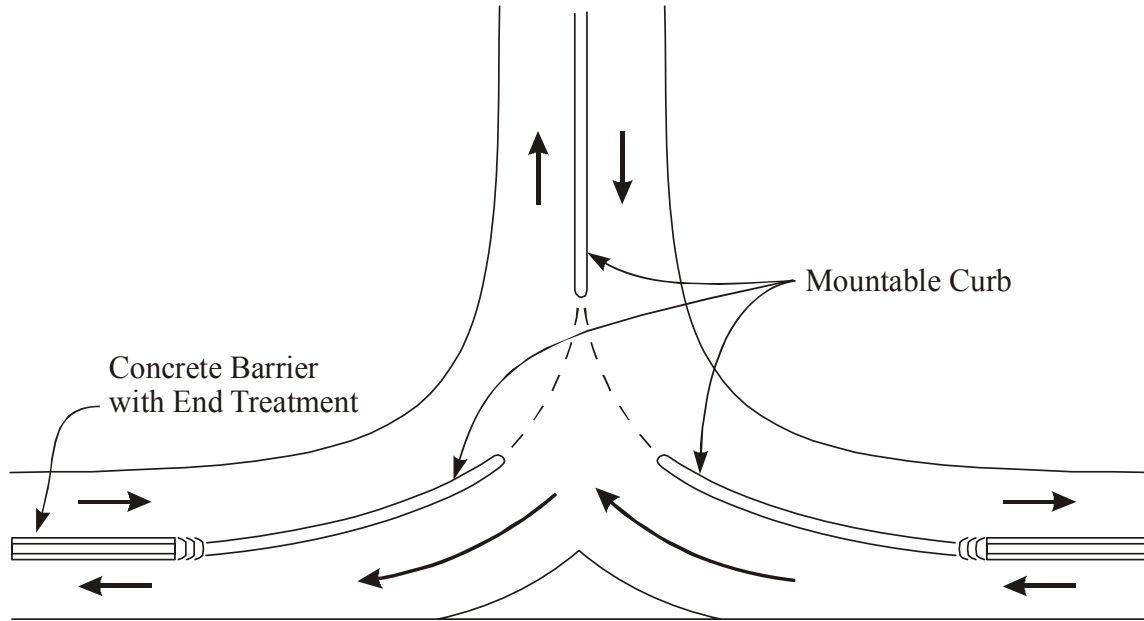


Figure 8-6. Schematic of Morning and Afternoon Operation on T-Ramp Crossover.



(Through traffic handled at ground level)

Figure 8-7. T-Ramp Design for Entrance/Exit Only (Adapted from 9).

Figure 8-8 shows a drop lane that provides access to a two-lane reversible-flow HOV lane facility. Figure 8-9 shows a two-way drop ramp. The upper schematic is for a barrier separation on the ramp and provides for an enforcement area for entering vehicles. The lower schematic provides for an enforcement area on the ramp in a buffered area.

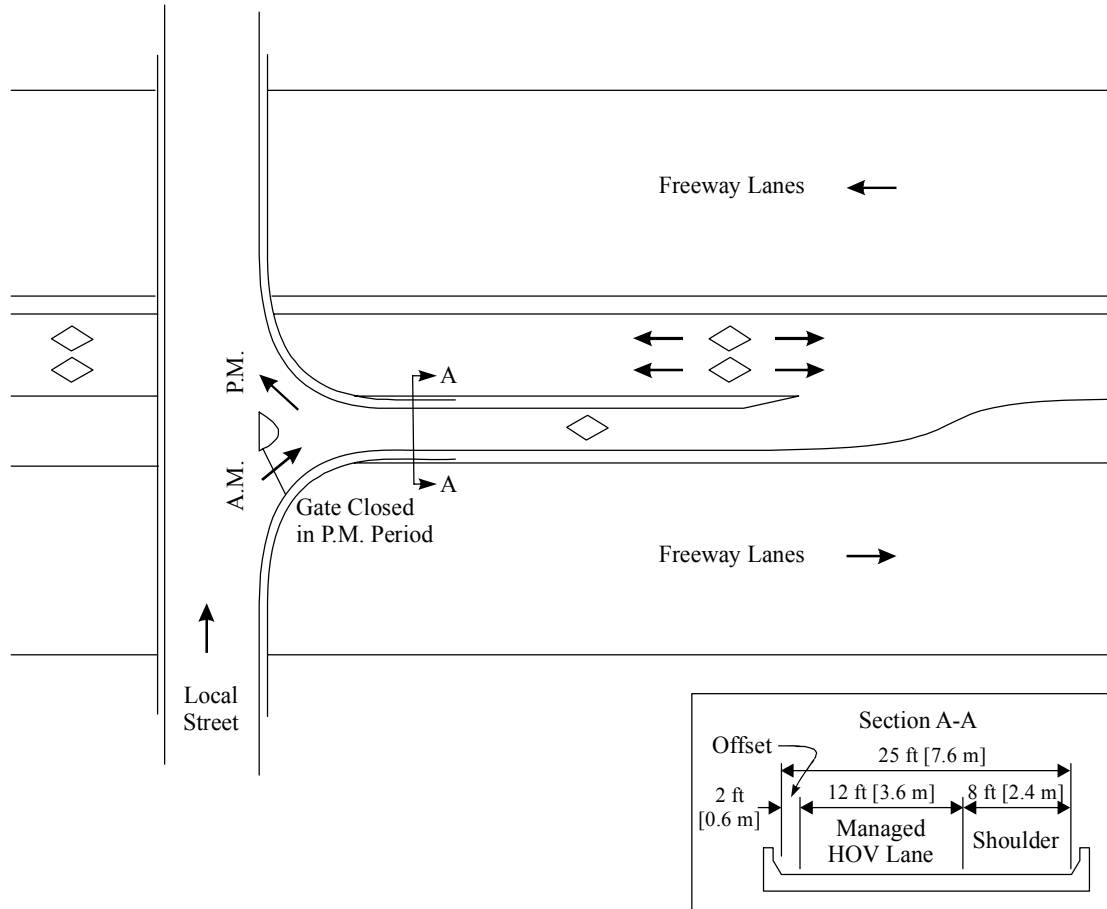
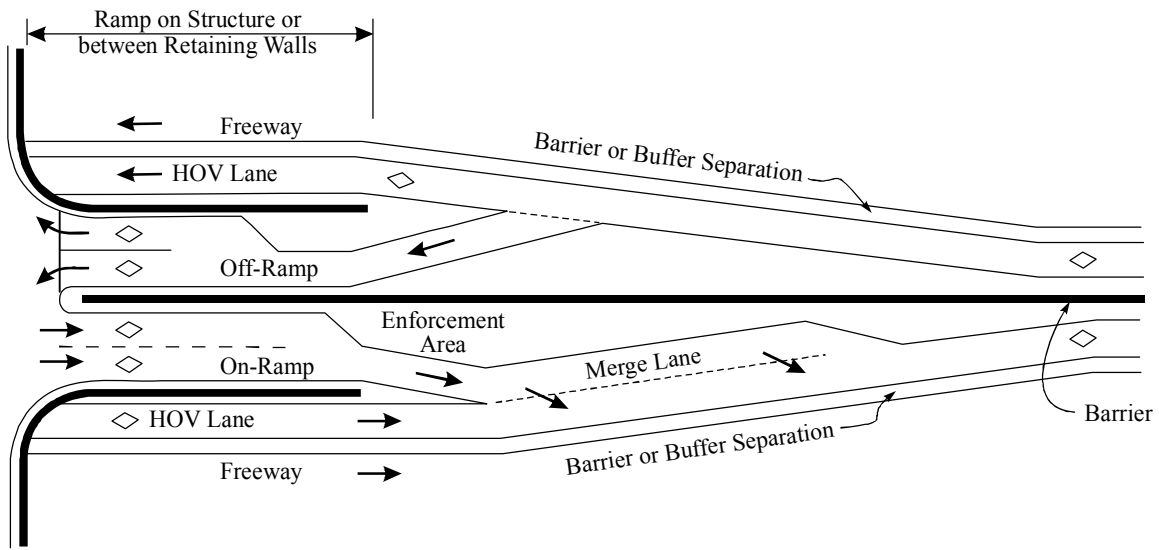
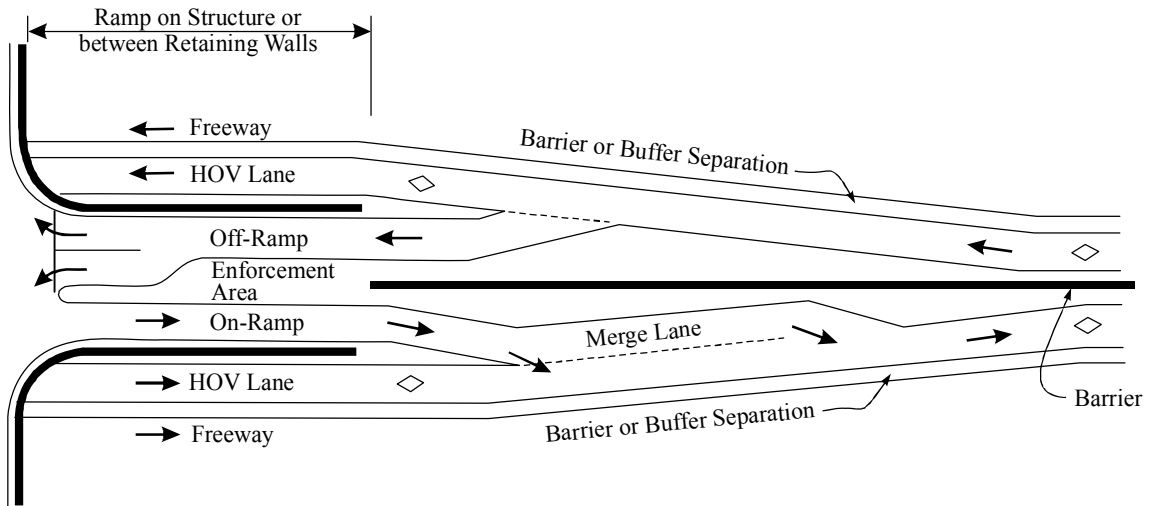


Figure 8-8. Drop Ramp Providing Access to a Two-Lane Reversible-Flow Managed Lanes Facility (Adapted from 2).



BARRIER SEPARATION ON RAMP



NO BARRIER SEPARATION ON RAMP

Figure 8-9. Two-Way Drop Ramp (Adapted from 2).

The following elements should be considered in the design of drop or T-ramps:

- ◆ **Design speed.** The design speed for the drop or T-ramp should be based on the characteristics of the individual project. However, the managed lanes mainlane should not be adversely affected by the ramp design speed. Designers must provide acceleration and deceleration lanes along the facility in order to help ensure the safe and efficient operation of the managed lanes facility.
- ◆ **Shoulder.** Designers should provide a shoulder for each direction of travel. If a full shoulder cannot be provided, other approaches may be used. A center barrier should be considered with two-way ramps, especially if high volumes of carpools and vanpools are projected to use the facility.
- ◆ **Cross section.** A cross section of 22 to 25 ft [6.7 to 7.6 m] is desirable for a single direction or reversible-flow drop or T-ramp. The desirable cross section for a two-way ramp is 45 ft [13.7 m] for two 12-ft [3.6 m] lanes, two 4-ft [1.2 m] shoulders, and a 10-ft [3.0 m] buffer between the opposing lanes. A reduced cross-section width of 38 ft [11.6 m] for a two-way ramp may be considered in certain instances where low speeds are anticipated.

Flyover and Y-Ramps

This ramp design accommodates high-speed, high-volume access to and from a managed lanes facility. The function of a flyover ramp is to provide direct, high-speed connections between the managed lanes facility and the general-purpose freeway lanes, park-and-ride lot, or other roadway. A variety of design treatments can be used with flyover ramps. [Figure 8-10](#) shows a schematic of a flyover ramp that provides access to a single-lane reversible-flow managed lane. [Figure 8-11](#) shows a flyover ramp to a single-lane reversible-flow facility at its terminus. [Figure 8-12](#) shows a flyover ramp (Y-ramp) from a two-lane reversible facility, and [Figure 8-13](#) illustrates flyover ramps. Finally, [Figure 8-14](#) illustrates a flyover ramp terminus for a buffer-separated HOV lane.

If possible, the cross section for a flyover ramp should be similar to the managed lanes mainlane design. Based on this objective, the cross section for a flyover ramp should be in the range of 22 to 28 ft [6.7 to 8.5 m] per direction, or 44 to 56 ft [13.4 to 17.1 m] total with a reduced cross section of 20 to 22 ft [6.1 to 6.7 m].

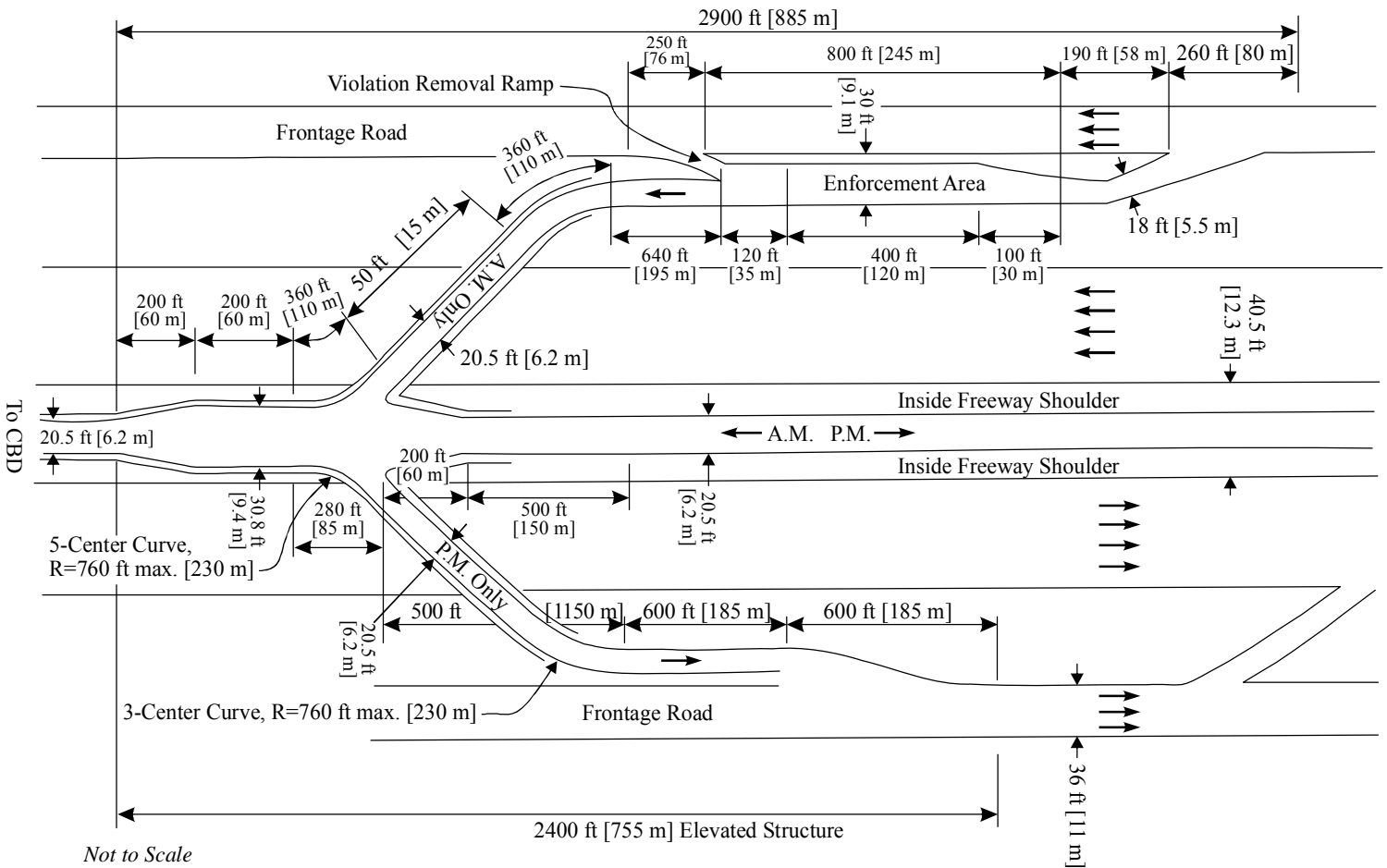


Figure 8-10. Flyover Ramp to Single-Lane Reversible-Flow Managed Lane (Adapted from 2).

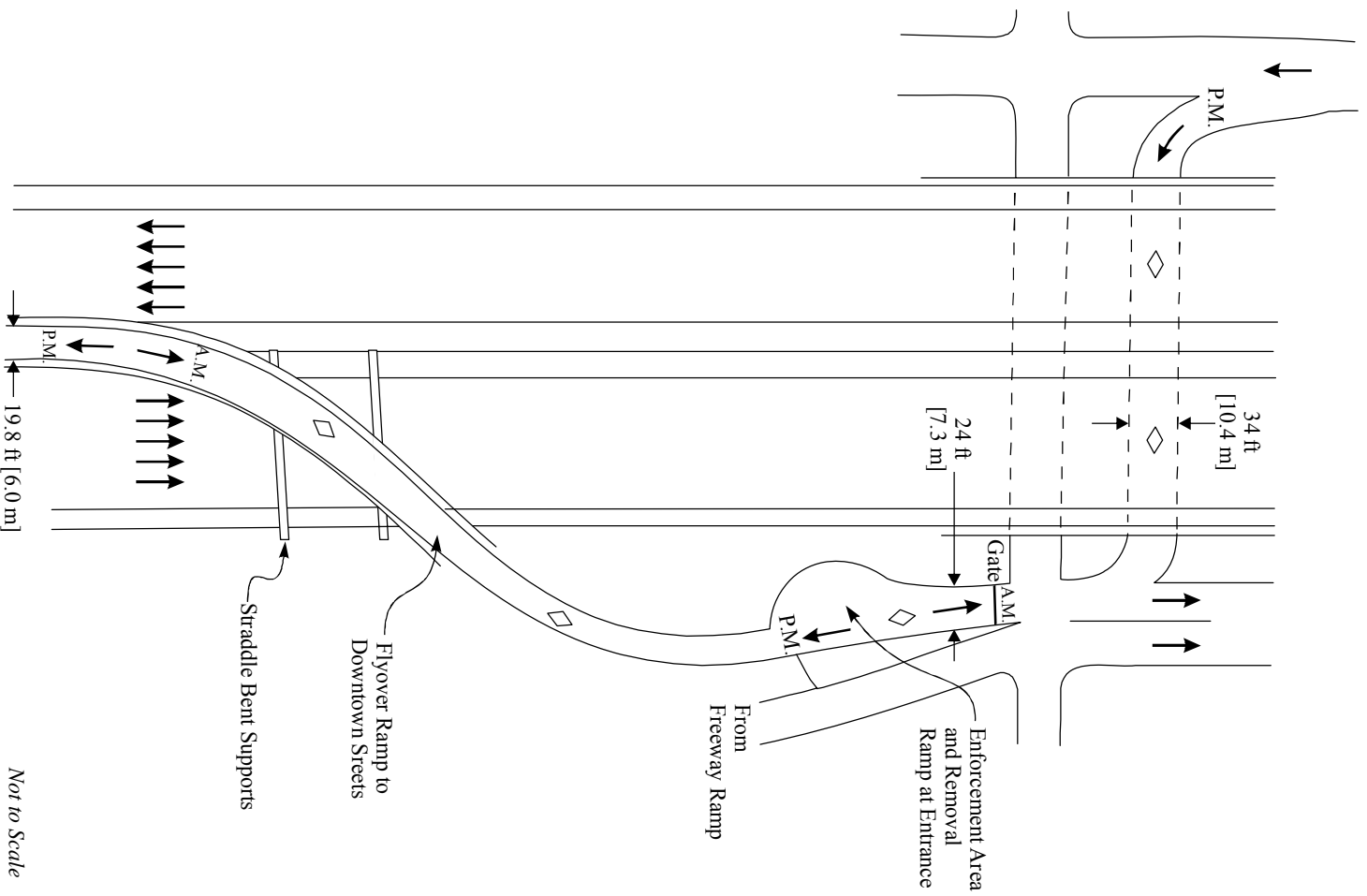


Figure 8-11. Example of a Flyover Ramp Used at Terminus of Managed Lane (Adapted from 2).

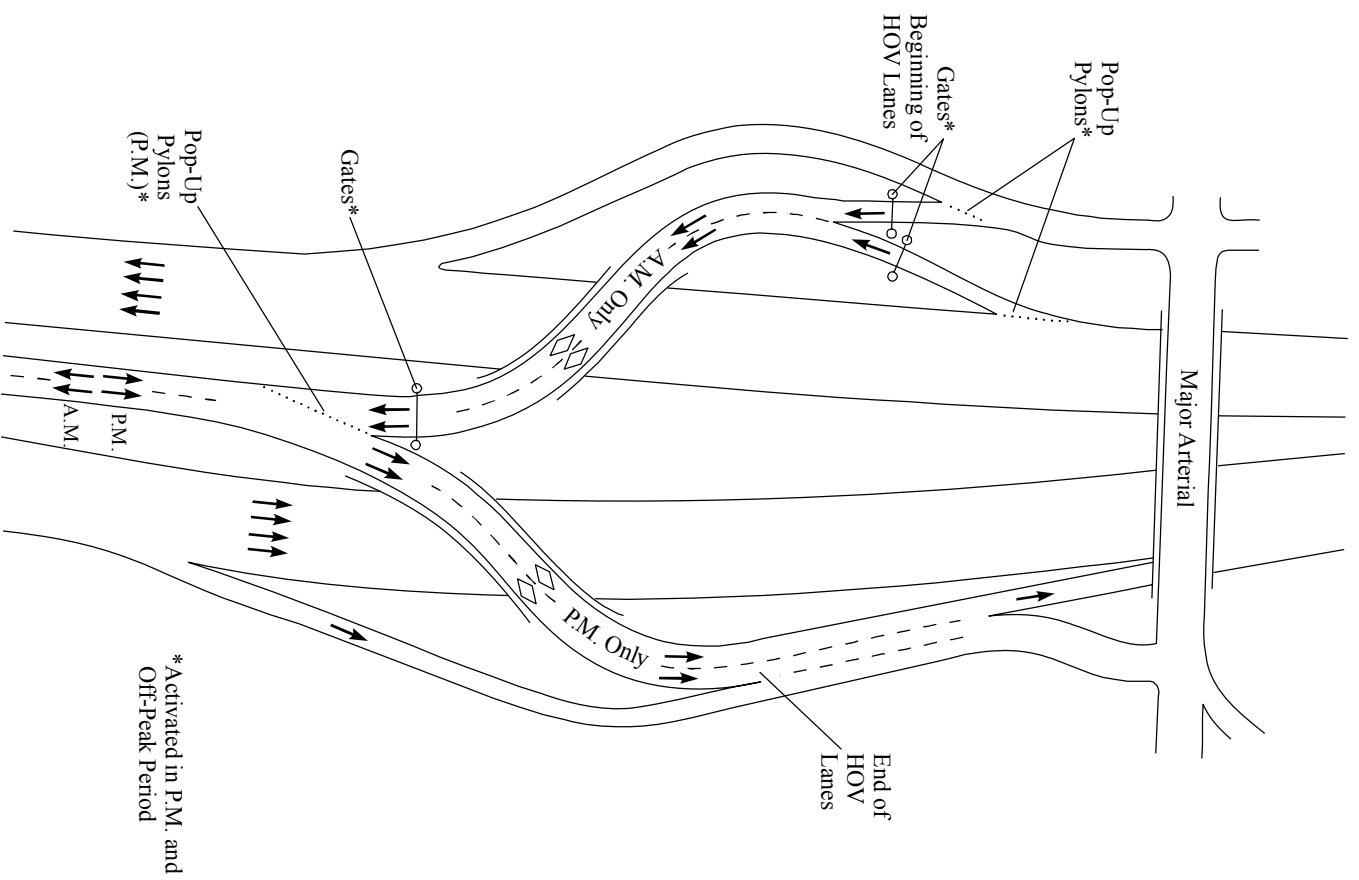


Figure 8-12. Flyover Ramp (Y-Ramp) for a Two-Lane Reversible Managed Lane (Adapted from 2).

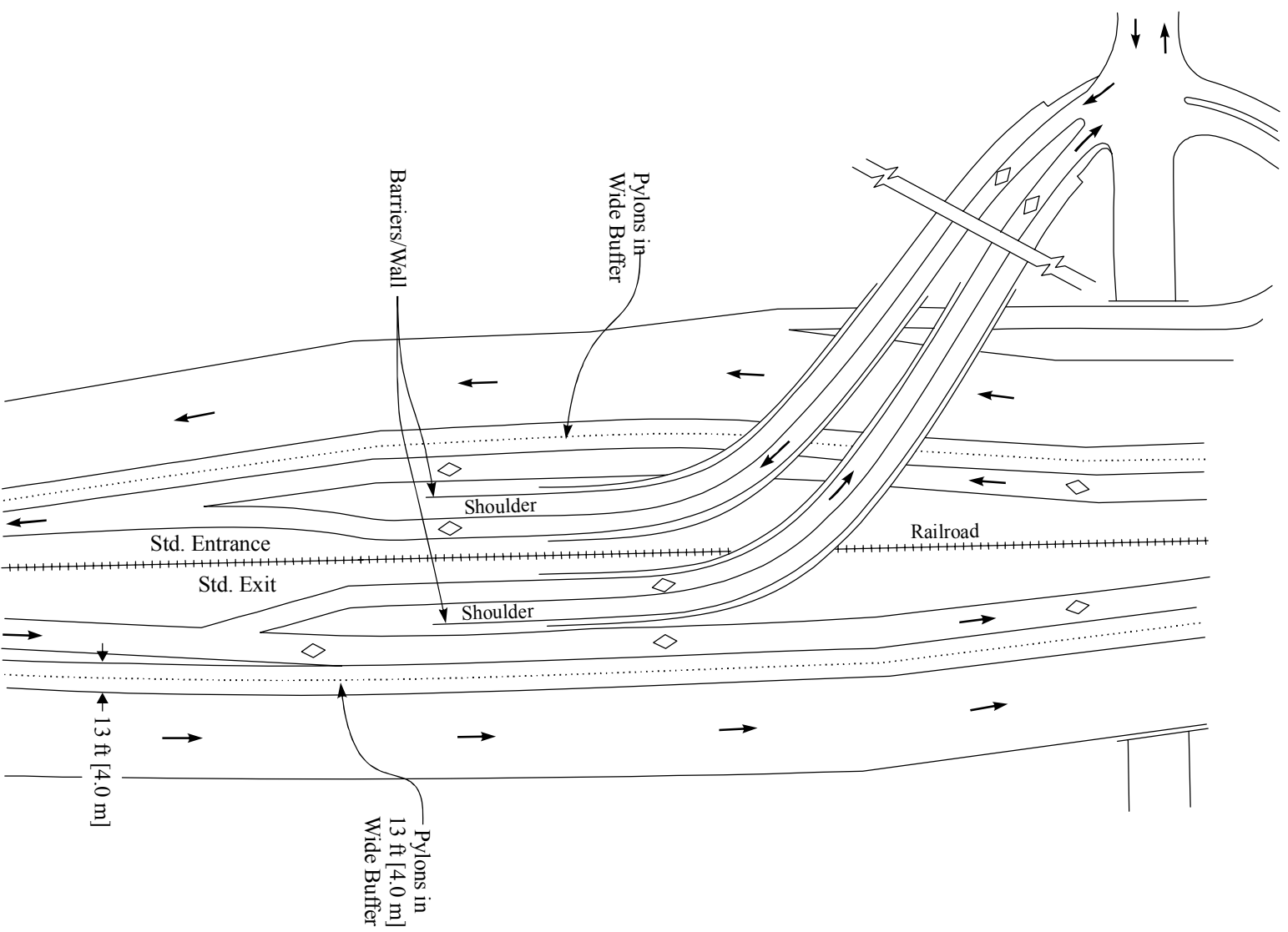


Figure 8-13. Two-Way Flyover Ramp from Managed Lane (Adapted from 2).

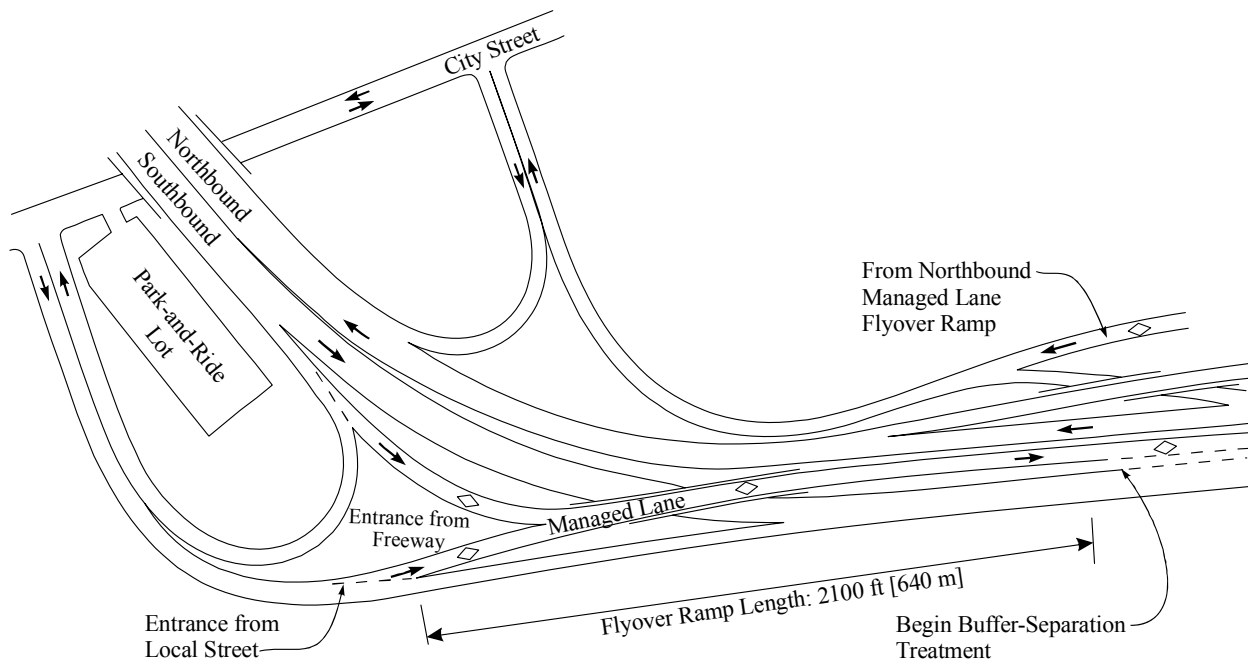


Figure 8-14. Flyover Ramp Terminus for a Buffer-Separated Managed Lane (Adapted from 2).

Managed-Lane-to-Managed-Lane Connection

The development of a coordinated managed lanes system may include linking managed lanes on multiple freeways. Although freeway-to-freeway managed lanes connections can have major benefits in terms of travel time savings and improved operating efficiencies, they represent a significant capital cost. The need for this type of facility should be considered during the planning process. Elements that may be considered in this analysis include high levels of eligible vehicle demand, safety and operational enhancements, and cost. For example, research on weaving volumes and their effects on speeds recommended that direct connect ramps be considered when the anticipated entrance volume to (or exit from) the managed lane is 400 veh/h (10).

The design of managed-lane-to-managed-lane connections is similar to a general-purpose freeway-to-freeway ramp. The same design speeds, geometrics, cross sections, and other design elements used with a normal freeway-to-freeway ramp should be applied with a freeway-managed-lane-to-freeway-managed-lane connection. Figure 8-15 provides an example of a layout for this type of facility.

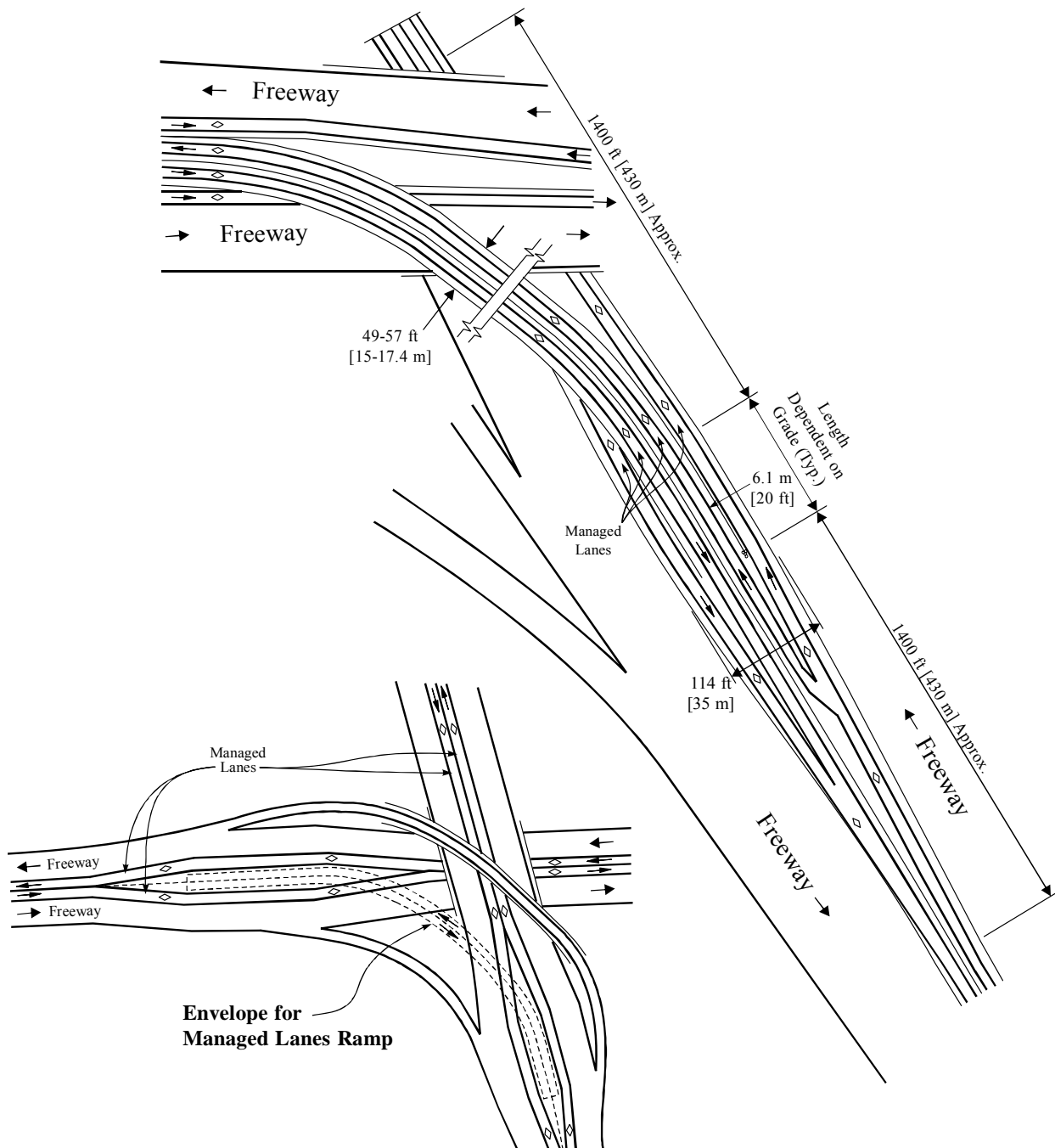


Figure 8-15. Illustration of Managed-Lane-to-Managed-Lane Ramp (Adapted from *1*).

At-Grade Access

At-grade access represents the most commonly used treatment with concurrent-flow managed lanes. There are two main types of approaches: unrestricted or unlimited (continuous) access, and restricted or limited access. For peak-only operations with no buffer treatment, continuous access is recommended; the managed lane is easily converted to a general-purpose lane at other times. Conversely, full-time operation and restricted access are desirable for lengthy commute periods (typically between 6 to 11 hours of congestion) and short off-peak traffic hours. For a 24-hour operation with a buffer treatment, limited access locations are recommended.

Continuous access allows eligible vehicles to enter and leave the lane at any point. No weave, acceleration, or deceleration lane is provided. The paint striping used to separate the general-purpose and the managed lanes, along with signing and pavement markings, should all indicate that access can occur at any point. The unlimited access concept is frequently used in projects where no buffer separates the managed lane and the general-purpose lanes.

Restricted or limited access regulates the locations where vehicles can enter and leave a managed lane. In most cases, the same section accommodates both movements. In some situations, however, only ingress or egress may be allowed. No special weave, acceleration, or deceleration lane is typically provided. An opening or merge area of 1300 to 1500 ft [400 to 460 m] is desirable. [Figure 8-16](#) illustrates a schematic for a buffer-separated option with and without a weave lane.

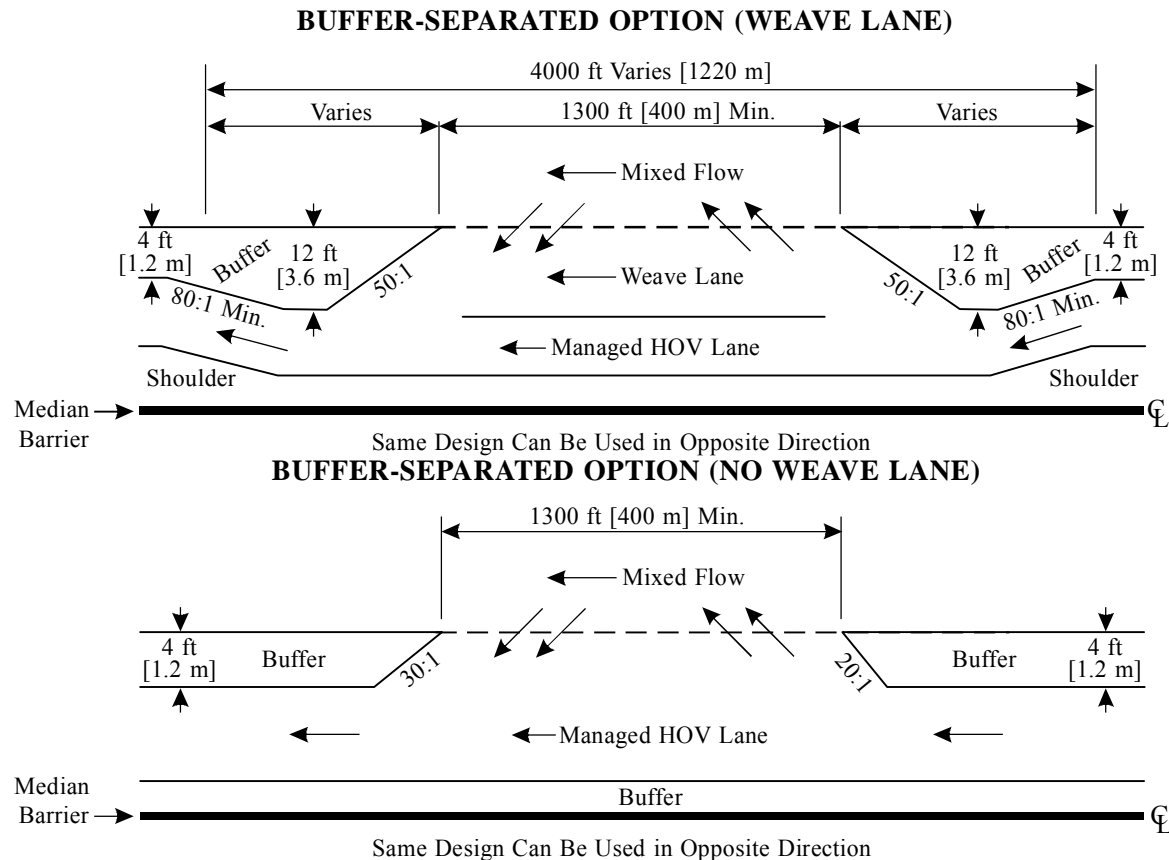


Figure 8-16. Buffer-Separated Intermediate Access with and without Weave Lane (Adapted from 1).

When using at-grade access, consider the volumes in the general-purpose lanes that will be merging with the managed lanes facility vehicles. Relatively long 2- to 3-mile [3.2 to 4.8 km] spacings between access points for the general-purpose lanes may allow for successful weaving maneuvers for at-grade access treatments; however, the use of at-grade access treatments are less preferred than direct access treatments unless the operational integrity of the managed lanes facility and general-purpose lanes will not diminish. Adequate enforcement for the concurrent managed lanes facility must also be provided.

Figure 8-17 shows the termination of a managed lane as a “free” lane to the inside. Recent research in Texas determined weaving distances for managed lanes cross-freeway maneuvers (9). Table 8-19 lists these weaving distances.

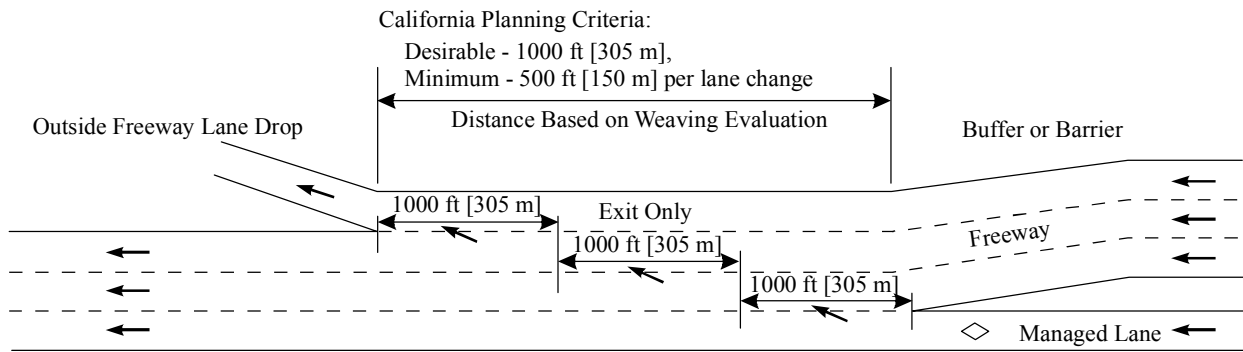


Figure 8-17. Termination of Managed Lane as a “Free” Lane to Inside (Adapted from 2).

Table 8-19. Weaving Distances for Managed Lanes Cross-Freeway Maneuvers (9).

Design Year Volume Level	Allow up to 10 mph (16 km/h) Mainlane Speed Reduction for Managed Lanes Weaving?	Intermediate Ramp (between Freeway Entrance/Exit and Managed Lanes Entrance/Exit)?	Recommended Minimum Weaving Distance per Lane ft (m)
Medium (LOS C or D)	Yes	No	500 (153)
		Yes	600 (183)
	No	No	700 (214)
		Yes	750 (229)
High (LOS E or F)	Yes	No	600 (183)
		Yes	650 (198)
	No	No	900 (275)
		Yes	950 (290)

Note: The provided weaving distances are appropriate for freeway vehicle mixes with up to 10 percent heavy vehicles; higher percentages of heavy vehicles will require increasing the per-lane weaving distance. The value used should be based on engineering judgment, though a maximum of an additional 250 ft (76 m) per lane is suggested.

Slip Ramps

Slip ramps are used with barrier-separated facilities. The first step when determining access locations on barrier-separated facilities is to determine whether grade-separated (direct access) or slip ramps are best. If the location of the proposed access is a terminal point at the outer end of the lane, it may be appropriate to use a slip ramp. If the access location is intermediate, or if it is a high-volume or high-bus activity area, it may not be appropriate to use a slip ramp. One benefit of slip ramps is that they provide for ingress or egress but not for both movements at the same location, eliminating the need to weave traffic both directions. Figure 8-18 illustrates an at-grade intermediate access for a single-lane reversible-flow HOV lane facility. If an entrance ramp is also necessary at a location where an exit is provided, the designer should provide the exit first and then the entrance to avoid the creation of a bottleneck on the general-purpose lanes where there is no location for vehicles to pass.

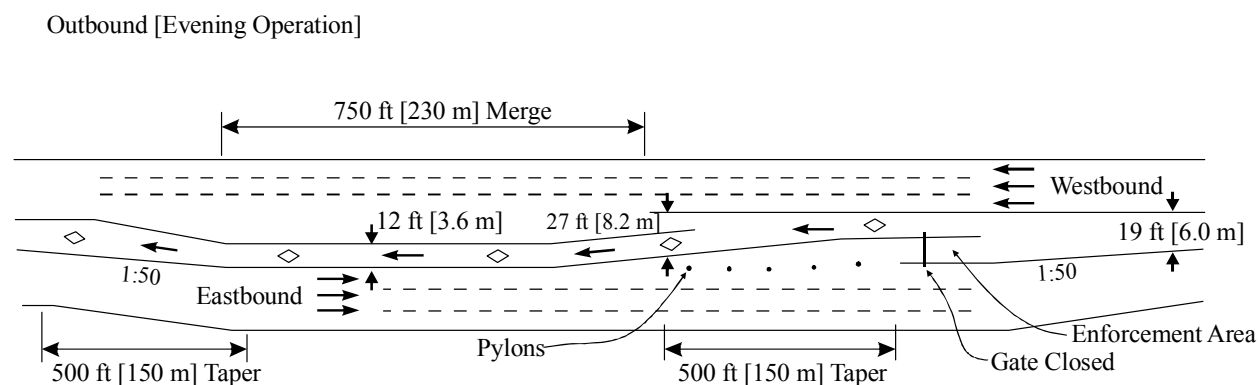
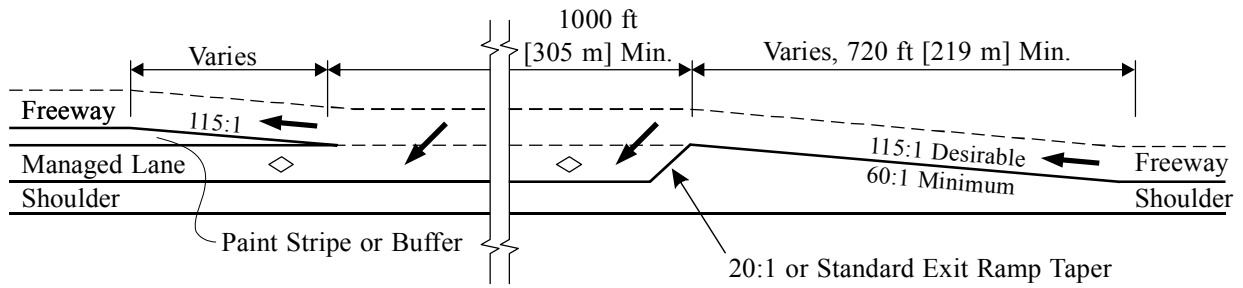


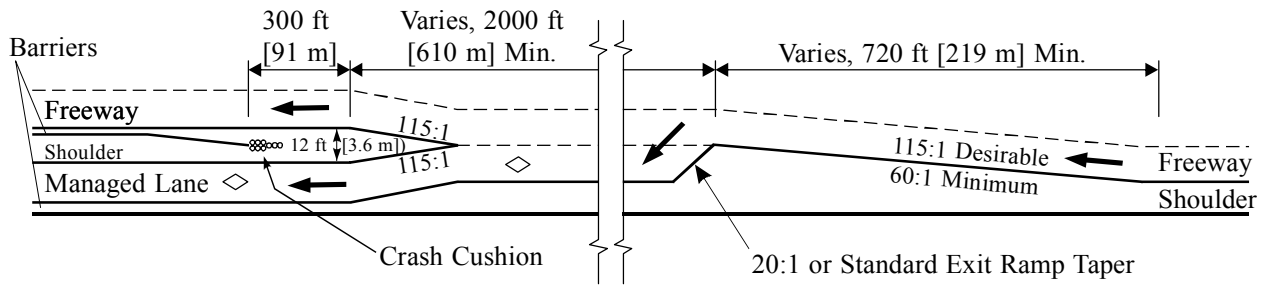
Figure 8-18. Intermediate Slip Ramp for Barrier-Separated Single-Lane Reversible-Flow Managed Lanes Facility (Adapted from 2).

Figures 8-19 and 8-20 provide examples of entrance and exit terminal locations with slip ramps, respectively. Another example of a slip ramp is anticipated for the forthcoming *Roadway Design Manual* revision (estimated release is January 2006).

At the termination of a managed lane, continuing the lane as a general-purpose lane is recommended. If the managed lanes volumes do not exceed 1000 veh/h, a merge area of approximately 1500 ft [460 m] downstream of the slip ramp may be acceptable, but effects on the general-purpose lanes should be checked. Signing at the entrance to a managed lanes facility is essential. In all cases, signing should be located at least 1 mile [1.6 km] in advance of the entry point. It should also be noted that the merge tapers in design are desirably 115:1 with a minimum of 50:1, and diverge tapers are desirably 50:1 with a minimum of 20:1. Entrances to the managed lanes facility shall be designed as lane changes to prevent motorists from entering the facility unintentionally.

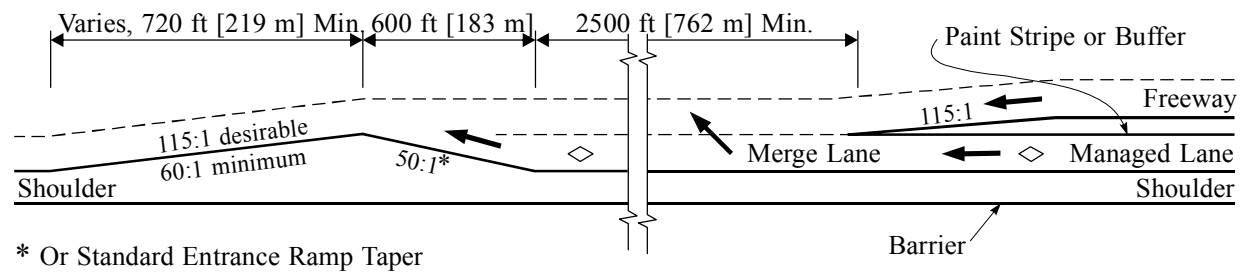


Example of Entrance to Concurrent-Flow Managed Lane

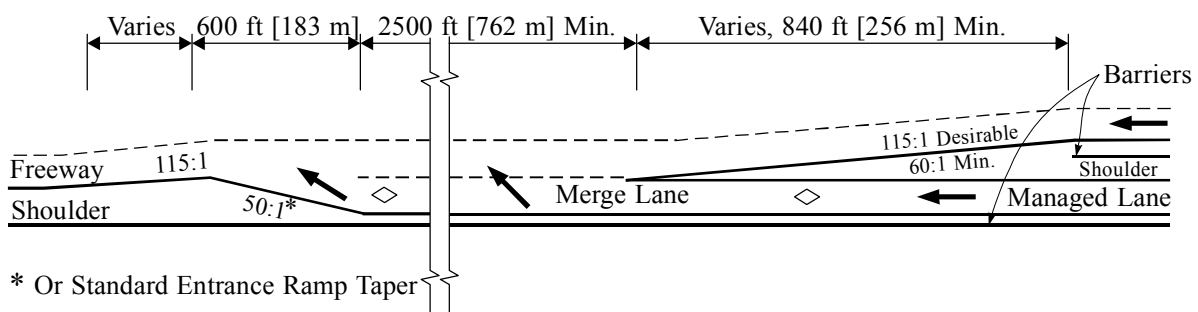


Example of Entrance to Barrier-Separated Managed Lane

Figure 8-19. Example of Layouts for Managed Lanes Entry Terminal with Slip Ramps (Adapted from 1).



Example of Exit from Concurrent-Flow Managed Lane



Example of Exit from Barrier-Separated Managed Lane

Figure 8-20. Example of Layouts for Managed Lanes Exit Terminal with Slip Ramps (Adapted from I).

Figure 8-21 illustrates an at-grade slip ramp to a two-lane reversible-flow HOV lane with the use of gates for traffic control. Figure 8-22 shows the origin of a contraflow lane within a freeway interchange with an enforcement area. The schematic in Figure 8-23 shows a terminus with morning and afternoon termination of the contraflow facility. Figure 8-24 illustrates another design of a terminus of a contraflow facility.

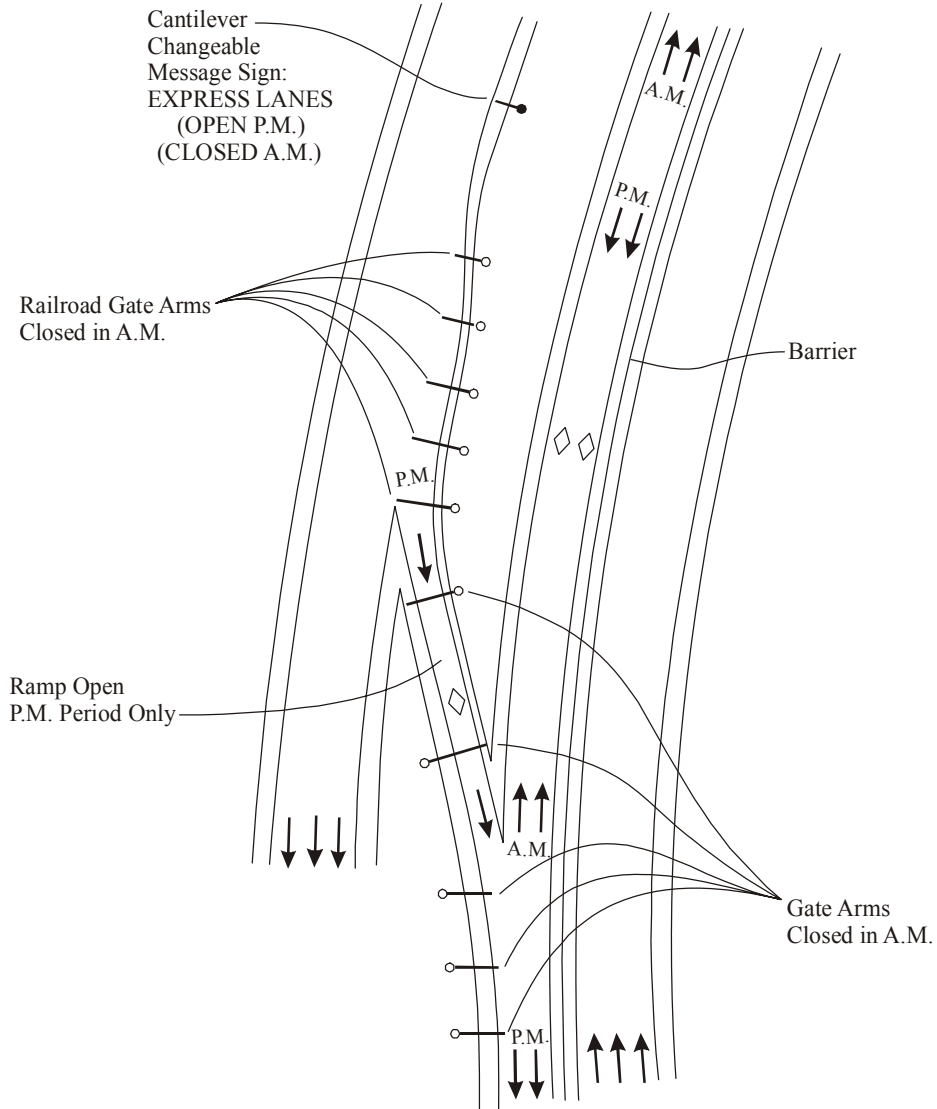


Figure 8-21. At-Grade Slip Ramp to Two-Lane Reversible-Flow Managed Lane (Adapted from 2).

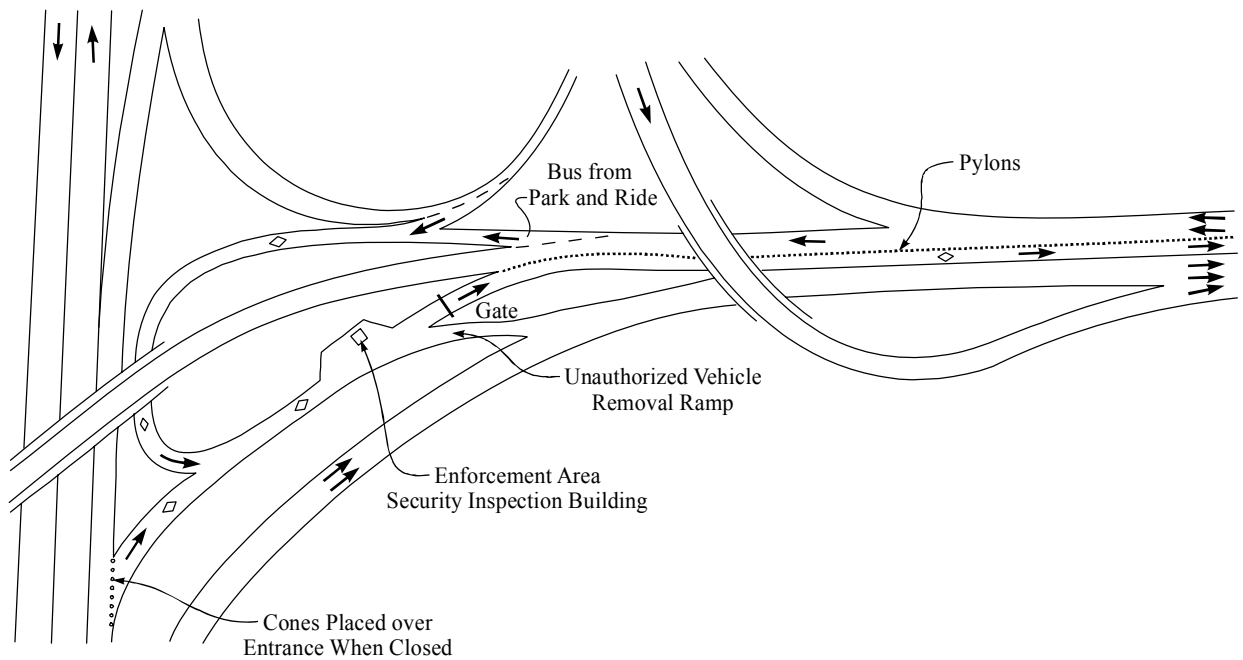


Figure 8-22. Origin of Contraflow within a Freeway Interchange (Adapted from 2).

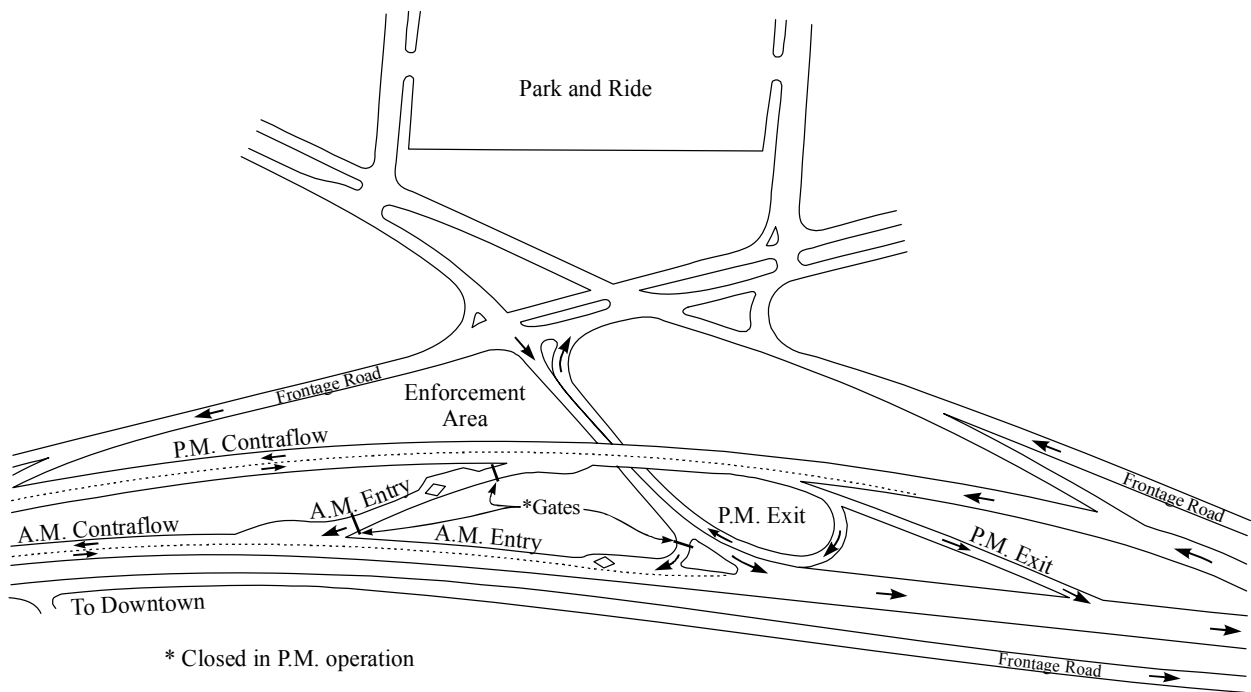


Figure 8-23. Morning Origin and Afternoon Termination of a Contraflow Facility.

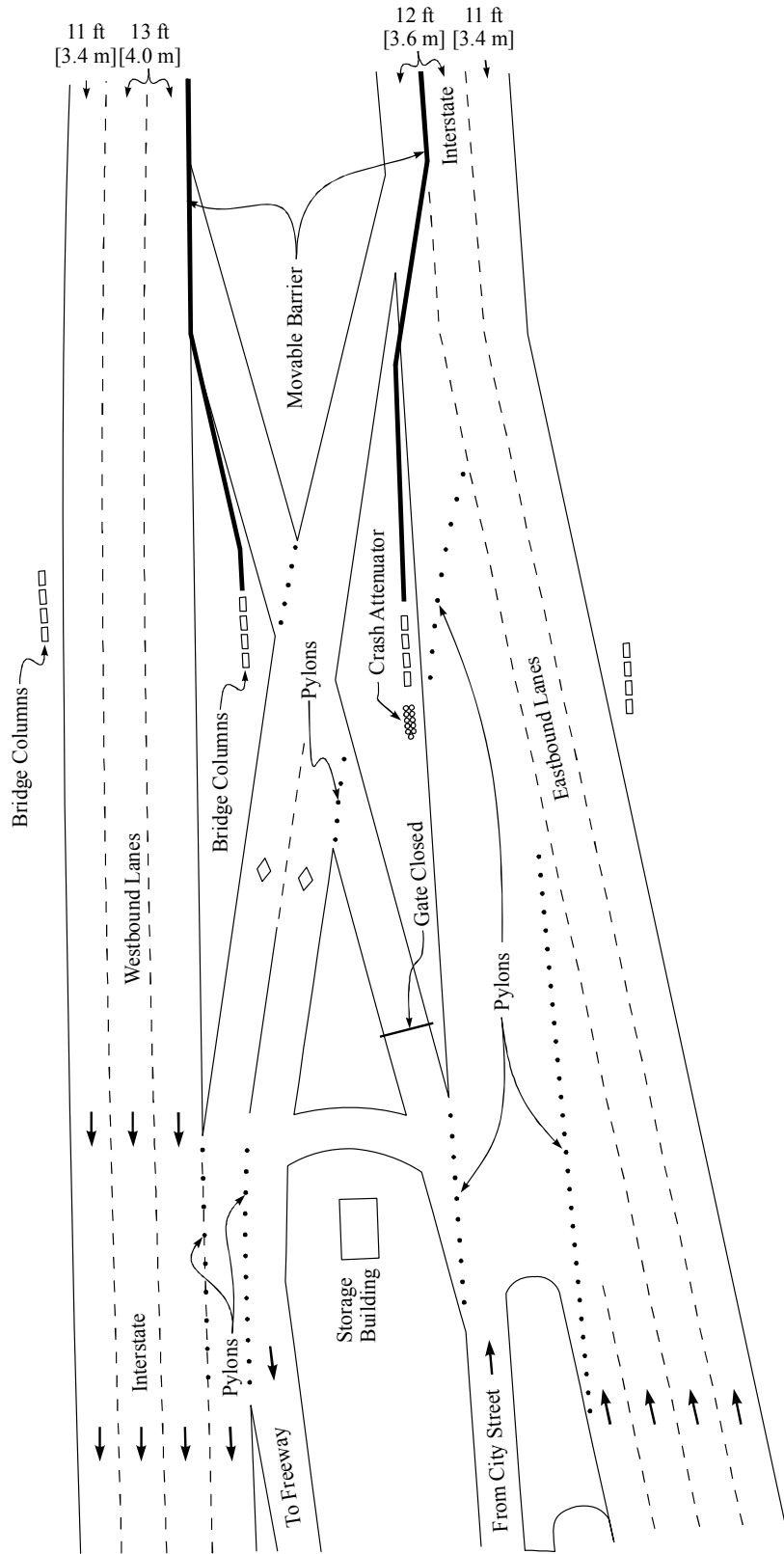


Figure 8-24. Downtown Terminus of Contraflow Facility (Adapted from 11).

Design Considerations for Bypass Lanes at Ramp Meters

Metering traffic on entrance ramps can improve the overall level of service on a freeway by regulating the flow of traffic and by dispersing the platoons of vehicles that typically enter a freeway during the peak periods. Ramp metering may also discourage drivers from using a freeway for a short-distance trip that can be more effectively served on the local street system.

Providing managed lanes users with a way to bypass the queues that can form at ramp meters, especially during the peak hours, can help encourage greater use of carpools, vanpools, and buses. Bypass ramps for eligible vehicles may be used in conjunction with a freeway managed lane, or they may be provided as stand-alone treatments on freeways that do not have managed lanes.

Two general types of treatments usually used with bypass lanes at metered freeway entrance ramps are:

- ◆ an additional lane as part of the existing ramp and
- ◆ a separate lane for eligible vehicles around the meter.

Figure 8-25 shows layouts of each type of bypass lane. The text that follows highlights the design elements associated with these treatments.

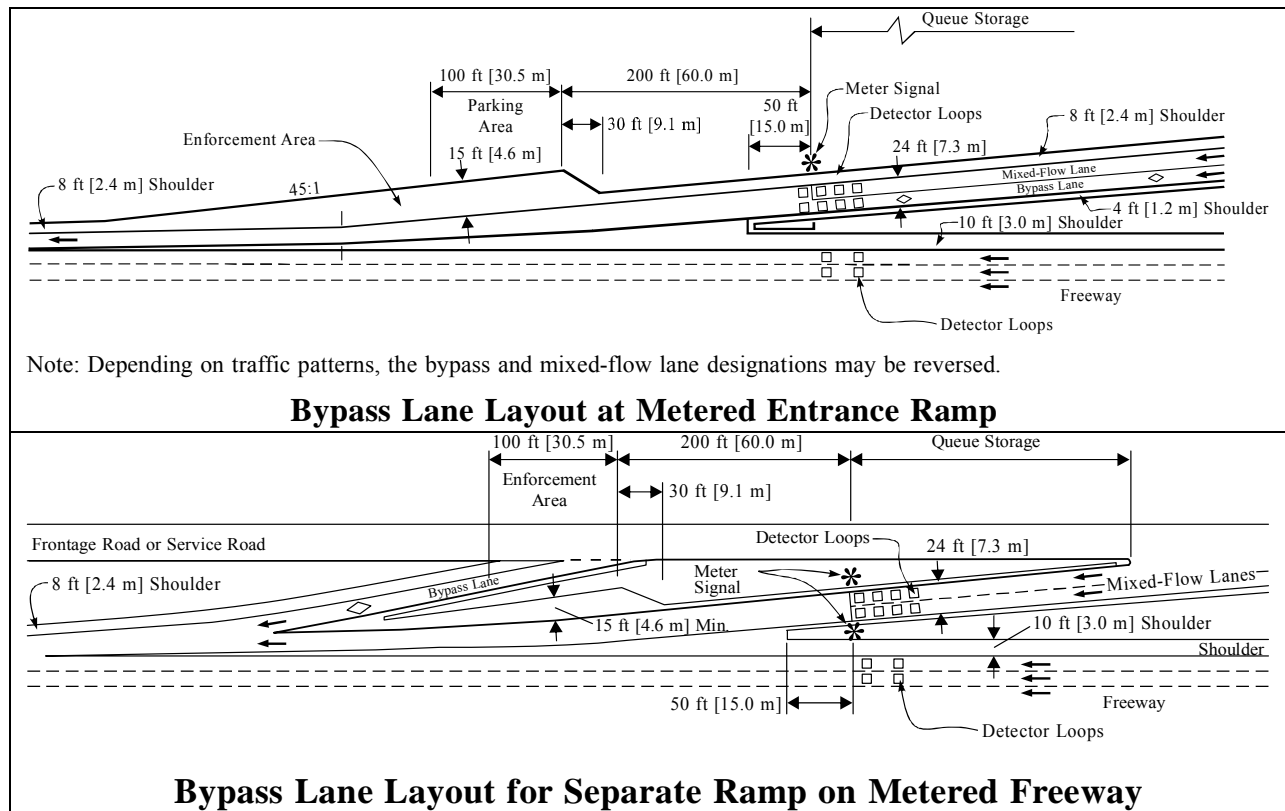


Figure 8-25. Example of Layouts for Bypass Lane at Metered Freeway Entrance Ramp (Adapted from 1).

Bypass Lane on Exiting Ramp

As shown in the upper schematic of [Figure 8-25](#), one approach is a lane for eligible vehicles directly adjacent to the general-traffic lane. A lane width of 12 ft [3.6 m] with ramp shoulders is recommended. However, adequate space within the existing freeway alignment or additional rights-of-way may not be available to meet these criteria. As a result, narrowing the lane to 10 to 11 ft [3.0 to 3.4 m] and dropping the shoulder may be considered in some cases. A distance of 300 ft [91 m] from the meter to the freeway is also recommended to allow the eligible vehicles to merge with the ramp traffic.

The striping detail should use a solid line to separate the eligible vehicle lane from the general-traffic lane. A painted buffer or mountable curb may also be considered to provide further separation. The length of the bypass lane will depend on the length of the ramp and the location of the meter. As a general guide, the bypass lane should be long enough to allow eligible vehicles to avoid the queue in the general-purpose lane.

A bypass lane can be located on either the left or right side of the existing general-purpose ramp lane. Right-side placement is preferred for enforcement purposes and high

bus volumes; however, the design must have sufficient provision to prevent vehicles queued at the meter from blocking the bypass lane.

In a few cases, the freeway entry ramp may have two general-purpose lanes with a third lane for eligible vehicles only. The same lane width of 12 ft [3.6 m] is preferred in these cases although modifications may be needed based on local conditions.

Separate Entrance Ramp

An alternative for providing eligible vehicles with preferential treatment is to provide a separate entrance ramp. The design of these ramps should also follow state guidelines on freeway entrance ramps. As in the previous case, the eligible vehicle ramp and the general-purpose ramp should merge into a common acceleration lane prior to entering the freeway. It is also desired that separate bypass lanes be located downstream of the general-purpose ramp. In some cases, the eligible vehicle lane may also be metered, although at a faster rate, to ensure a smooth flow of traffic. Enforcement areas should be provided with either type of bypass treatment. [Figure 8-25](#) shows the location and general design of enforcement areas.

Location of Bypass Lane

The exact location and design of bypass lanes at a metered freeway ramp will depend on location conditions and site-specific elements. Bypass lanes should be considered only at ramps with high volumes of current or projected eligible vehicle levels. Further, the design of the existing ramp, the location of the ramp meter, the availability of needed rights-of-way, ramp volumes, and the local street system should all be considered in the design of a bypass lane.

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Section 1 – Overview

An implied goal of the managed lanes concept is to offer additional choices to motorists on a section of freeway. These choices can vary by time of day or possibly in response to changing traffic conditions on either the managed lanes or the other general-purpose lanes in the corridor or region. The extent to which travelers can and will accommodate such operational flexibility hinges on getting the right information to travelers, at the right time and in the right format so that they can make effective decisions pertaining to their trip. There are great differences among drivers in terms of their ability to read, comprehend, and react to traffic control devices. The challenge for designers is to find the design and placement of traffic control devices that serve the most users of the roadway.

Some users of managed lanes will make decisions prior to the start of their trip. However, others may make such decisions en route to their destination. The information needed to support such decisions must be safely and effectively interwoven with that information required for motorists to safely control, guide, and navigate their vehicles into and along the managed lanes. To further complicate matters, this information must often also be interwoven with similar control, guidance, and navigation information required for motorists operating in adjacent general-purpose lanes. Obviously, in such a complex information environment the potential for information conflicts and overload exists. How, where, and when such conflicts and overload can occur, as well as what can be done to help alleviate these conditions, are the focus of this chapter.

Managed lanes facilities may present drivers with unfamiliar access, geometries, and operating rules. Conveying information concerning these features requires effective use of standard and novel traffic control devices. As managed lanes facilities continue to evolve, new operational strategies and geometric designs may require new traffic control devices. The current federal *Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD)* contains information on preferential lanes, spread across several different sections (1). The Texas *MUTCD* offers guidance on HOV and other preferential lanes in sections on regulatory signs and pavement markings (2).

Designers and operators of managed lanes facilities must consider traffic control device needs early in the planning process. The initial costs of communicating with drivers includes the right-of-way for signing and supporting structures, the cost of the structures, the cost of dynamic message signs and accompanying power and communications, the cost of designing, fabricating, and installing static signs including any lane closures required, the cost of pavement markings including standard lane striping plus any horizontal signs and symbols required or desired to augment guide or warning information contained in the signs. The ongoing costs of communications include maintenance of signs and markings, communications fees such as monthly cell phone charges for wireless networks, and maintenance of power supplies and other electronic components of dynamic message signs.

Beyond the cost of traffic control, early consideration of driver information needs in the planning process will assure that an operating scheme is not implemented that requires

overly complex signs. 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 slow speeds, and in most cases stopping completely, it is safe to present this large amount of information. But with electronic toll collection at high speed, it becomes dangerous to overload drivers with complex toll rules. For such complex operations, planners may have to accept that “one big sign” is not appropriate. With a subscription-based system, it is possible to communicate with subscribers through the mail or other means, in order to provide the full toll schedule off-road. With a wider audience, other methods of presenting the information must be considered such as the use of multiple, sequential signs. Or, a small amount of information which applies to the largest number of users, such as the minimum toll for a passenger vehicle, could be presented. Other mechanisms, such as two-way transponders, which would present information in-vehicle, are on the horizon and may lessen the need for numerous traffic control devices in the future.

In addition to operating strategies, planners need to consider traffic control devices in the geometric design as well. Access points that violate driver expectancy, such as left exits, will require good advance signing. Buffer-separated facilities pose a particular problem because there is often insufficient clearance in the median for adequately sized signs.

Sections in this chapter cover:

- ◆ [information principles](#),
- ◆ [the information assessment process](#), and
- ◆ [traffic control device principles for managed lanes](#).

Section 2 – Information Principles

MUTCD's Principles of Traffic Control Devices

The current *MUTCD* provides five basic requirements for an effective traffic control device and stresses that these guidelines be given primary consideration when selecting the devices (1). The requirements for each device are that it should:

- ◆ fulfill a need;
- ◆ command attention;
- ◆ convey a clear, simple meaning;
- ◆ command respect from road users; and
- ◆ give adequate time for proper response.

The manual also states:

Design, placement, operation, maintenance, and uniformity are aspects that should be carefully considered in order to maximize the ability of a traffic control device to meet the five requirements listed in the previous paragraph. Vehicle speed should be carefully considered as an element that governs the design, operation, and placement, and location of various traffic control devices.

Positive Guidance

Positive guidance is a principle that combines highway/traffic engineering with human factors methods to produce a highway information system matched to driver attributes and situational demands (3). Drivers gather information from many sources, including tactile vibrations through the vehicle, auditory input of road noise, and predominantly visual input of the roadway ahead. According to the positive guidance model, all of this information is processed at three different levels of control actions. As depicted in [Figure 9-1](#), the most important of these is the control level, which relates to the physical operation of the vehicle. A higher level of control is required for guidance of the vehicle, which relates to the safe speed and lane choice for the vehicle. Finally, above that is the navigation level of control, in which the driver chooses the route to get from the trip origin to the trip destination. When a driver is overloaded with information, the driver actively sheds the information load by ignoring the navigational level in order to maintain the physical control of the vehicle and keep from colliding with another vehicle or other hazard.



Figure 9-1. Levels of the Driving Task (3).

A procedure based on positive guidance principles was developed to serve as a technique to assess countermeasure for known traffic problem locations. These locations are identified through high-accident frequencies, motorist complaints, and other methods. One of the key facets of positive guidance is the acknowledgment that humans have limits on their ability to scan, process, and react to information as part of their driving activities. The principles of positive guidance have been used in the traffic engineering community for almost 30 years.

Evaluating a location with the positive guidance procedure requires evaluation of eight steps:

1. site definition,
2. problem description,
3. hazard identification,
4. hazard visibility assessment,
5. expectancy violation determination,
6. information load analysis,
7. information needs specification, and
8. current information system evaluation.

The last three steps are of interest for this research, and they are discussed in further detail in the following sections.

Information Load Analysis

When using positive guidance to improve an existing roadway location, the information load is determined by a drive-through of the site. This drive-through can be performed using planning documents before construction. For each potential traffic control device location, the following factors should be considered:

- ◆ adjacent land use,
- ◆ traffic volume,
- ◆ traffic speed,
- ◆ the required driving task,
- ◆ the amount and location of any hazards,
- ◆ sight distance,
- ◆ violations of what typical drivers were expecting, and
- ◆ the clutter and complexity of the information (3).

There are methods other than drive-throughs that may be valid for determining information load. Current methods for determining the information load of as-yet-unbuilt facilities include information load models (4) and testing using driving simulators (5,6). This process was merely intended to get the engineer conducting the site investigation to determine locations where a relatively large amount of information is presented to drivers.

Information Needs Specification

Positive guidance also helps traffic engineers understand that not all information is needed at all locations. When a driver is far upstream from a decision point, such as a managed lanes entrance or exit, there is little information required by the driver. As the driver approaches the decision point, more information is required for the driver to understand that there may be maneuvering required, that other drivers may be maneuvering in that area, and that there may be alternate paths that drivers can select. As the driver reaches the location, little information other than speed and implementation information is needed since the driver should be focused on acting on the path choice he or she made. After the decision point, the information needs are reduced to minimal guidance information.

Drivers receive information both from their own background knowledge and from traffic control devices. Required information may come from:

- ◆ signing information about laws and regulations,
- ◆ signing about hazard warnings,
- ◆ speed advisories,
- ◆ surrounding traffic behavior,
- ◆ advance guide signs,
- ◆ roadway geometric information, and
- ◆ previous experience by the driver about the area (3).

Current Information System Evaluation

In the final step of the positive guidance process, a comparison is made between the information needed and the information actually provided. If there is a deficiency in the traffic control plan (either from information that is not provided or not legibly provided, or if too much information is provided at a specific location), then steps are recommended to remedy the specific problem.

Adding missing information is obviously a fairly straightforward process. However, if too much information is present at the specific location, one of two steps is recommended. First, the information being presented is analyzed to identify if some of the information is superfluous, and if so that material is removed from the roadway. If no superfluous material is present, then attempts should be made to spread the information farther upstream or downstream from the location as appropriate.

Overload

As previously discussed, when drivers are loaded with too much information to process at one time, they “load shed” as a way of coping. Drivers will focus on that information that they believe will successfully help them traverse the immediate section of roadway ahead, and they will not process higher level information such as navigational or general information signing. To date, it has been difficult to quantify how much is too much information for a traveler to accommodate. Several factors come into play, including the type and content of information, traffic and environmental conditions, and the alertness and information processing ability of the driver.

Driver Reaction to Overload

Under most driving situations, overload is not a factor since driving is usually undemanding (7). But as information demand increases, drivers need to spend more and more energy attending to and processing that information. Pietrucha states this process succinctly:

In the simplest situation, the driver has to perform only vehicle control tasks and has little problem attending to and processing information on traffic signs. However, as driving becomes more complex or conditions outside the vehicle degrade and obscure the visual cues needed for vehicle control, the driver's attention becomes focused on these other tasks, and attending to certain types of traffic signing becomes less important. As the driving task becomes more complex or conditions degrade further, the task load increases and becomes progressively difficult for the driver to handle. (7)

Messer, Mounce, and Brackett researched driver expectancies on rural roadways to determine how drivers reacted to unexpected events (8). The researchers found that when drivers were surprised by unexpected geometric features, there was an increased probability of potentially unsafe driving decisions. While the surprise might shock a person into an unwise physical reaction, it is also likely that a portion of this reaction comes from an inability to process the information that is presented. In the information overload context, when the critical information of an unexpected geometric feature is presented, a driver may be slow to react because of the slow information processing time. This is consistent with previous research indicating that it takes drivers longer to detect and react to events that are unexpected (9). This basis is also recognized in current engineering design policies (10).

Attempts to Quantify Information Overload Conditions

In 2003, the Transportation Research Board published NCHRP Report 488, titled *Additional Investigations on Driver Information Overload*. The goal of the authors of that report was to “develop a model of driver information load for freeway applications and to translate that model into a practical tool so traffic and safety professionals could analyze information load” (4). In essence, that research was intended to provide a way of quantifying the amount of information presented to drivers, at least as presented on freeway guide signs. To accomplish this, the researchers attempted to identify information dissemination problems, limitations of human processing in short time intervals, and the amount of information presented on freeway guide signs.

The researchers of the NCHRP report developed a methodology for quantifying the driver mental workload of a given highway guide sign by quantifying the units of information that are presented by various types of signing, as well as the information provided from roadway geometric configurations. In order to manipulate the measure of complexity of a particular sign, the user can input a complexity rating on the sign that would increase the quantified workload value. Workload for a given sign was also designed to be dependent on the distance between the sign and the observation point. Attempts to apply this methodology to managed lanes facilities have not been successful because there is no mechanism in the model to identify particular information intended for particular lanes (11). While the concepts of information overload described in this report certainly apply to managed lanes, the specific model cannot accommodate managed lanes at this time.

Driver Decision Models

Pain, Knapp, Hostetter, and Mace examined how drivers make a decision to use a managed lanes facility in a report published in 1982 (12). At that time, these types of special lanes were referred to as special use lanes (SULs), and consisted primarily of HOV lanes, some bus-only lanes, and toll facilities. As part of their work, the researchers developed a driver decision-making paradigm for the process of how a driver makes the decision of whether or not to enter a managed lane or SUL. This paradigm is presented in Figure 9-2.

Conceptual Driver Models Regarding Managed Lanes Use

Because managed lanes facilities represent a tremendous number of design options and operational strategies that influence traveler information requirements, an exhaustive accounting of all possible combinations would prove unwieldy and have limited benefit to practitioners. Therefore, several examples of typical interactions between driver familiarity and common managed lanes facilities are provided as instructional illustrations of information requirements for these facilities and how the requirements change as a function of driver familiarity.

Types of Drivers

One of the more important considerations that arose from this assessment process is the recognition that managed lanes information needs are also highly dependent upon traveler experience and other individual factors. Certainly, not all of the information needed to make an informed decision must come from the highway agency in terms of information dissemination devices (overhead and shoulder-mounted static signs, overhead and shoulder-mounted dynamic message signs, pavement markings, etc.); some of the information required is internal to each individual driver, such as the perceived value of time and the level of comfort with entering a barrier-separated facility. Other information, such as geometric features or specific sign locations and content, can be learned over time through repeated trips through a corridor. Drivers experienced with a particular roadway would also be likely to have some expectations of typical traffic conditions during their trips, including speed and congestion at different times of day as well as areas where additional attentional demand is required such as at interchanges with weave areas. A driver who has been through a specific corridor before could likely be considered to need to acquire less information and will rely more heavily on information stored in the driver's mind.

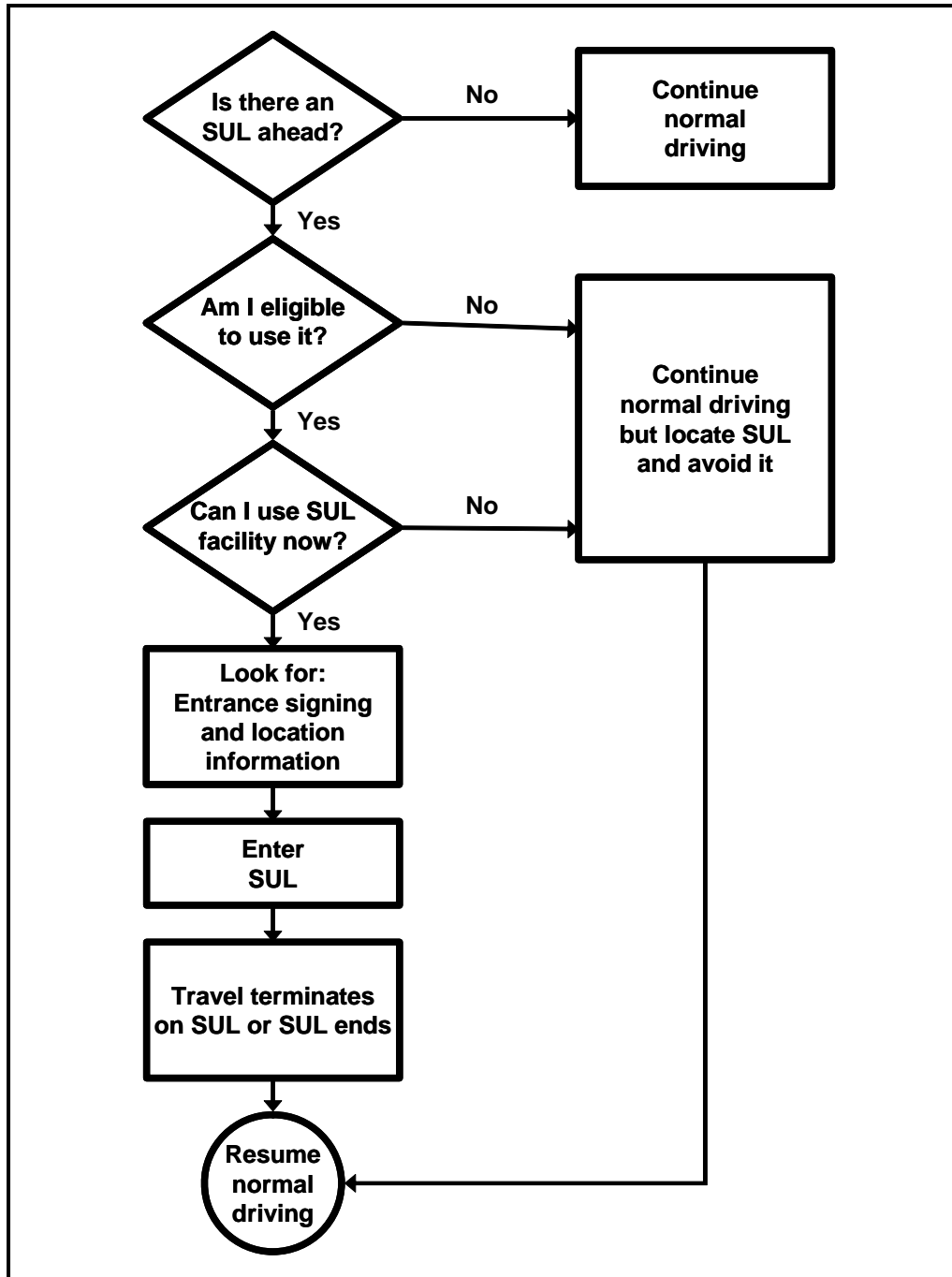


Figure 9-2. Driver Decision-Making Paradigm for Special Use Lanes (12).

Researchers developed a general classification of drivers who might reasonably be confronted with the decision of whether or not to enter a managed lane. At one extreme is the unfamiliar driver, in the middle is what is called a semi-familiar driver, and at the other extreme is the very familiar driver. While it should be stated plainly that the entire driving population would fill the continuum between the extremes of a completely unfamiliar driver and a completely familiar driver, the three examples presented are for planning considerations and are considered examples of the wider distribution of drivers. The general classifications of the types of drivers are detailed in the following sections.

Several assumptions were made in the development of these example drivers. First, an unfamiliar driver was considered to be a driver that knew very little about the specific managed lanes facility or managed lanes in general. Unfamiliar drivers should not, however, be assumed to be bad drivers or novice drivers in the sense of their ability to drive. Rather, it is just that this driver would not know much about the managed lanes facility or managed lanes in general. Likewise, familiar drivers should not be assumed to be expert drivers; they merely know much more about the details of the managed lanes facility in question.

Unfamiliar Driver. An unfamiliar driver has little or no experience on the roadway in question. In the extreme case, this driver may have never driven on this particular roadway before, may not be aware that a managed lanes facility is ahead, and may not have encountered managed lanes of this type before. In order to make an informed decision on the proper path to take, this driver would need to acquire all of his or her knowledge from the roadway environment en route (or have researched the potential use of the facility beforehand). This type of driver would need the highest amount of information presented to him or her, and would be at highest risk of experiencing information overload from the information presented, particularly at locations where control and guidance tasks are more severe. A conceptual example of an unfamiliar driver is shown in [Figure 9-3](#).

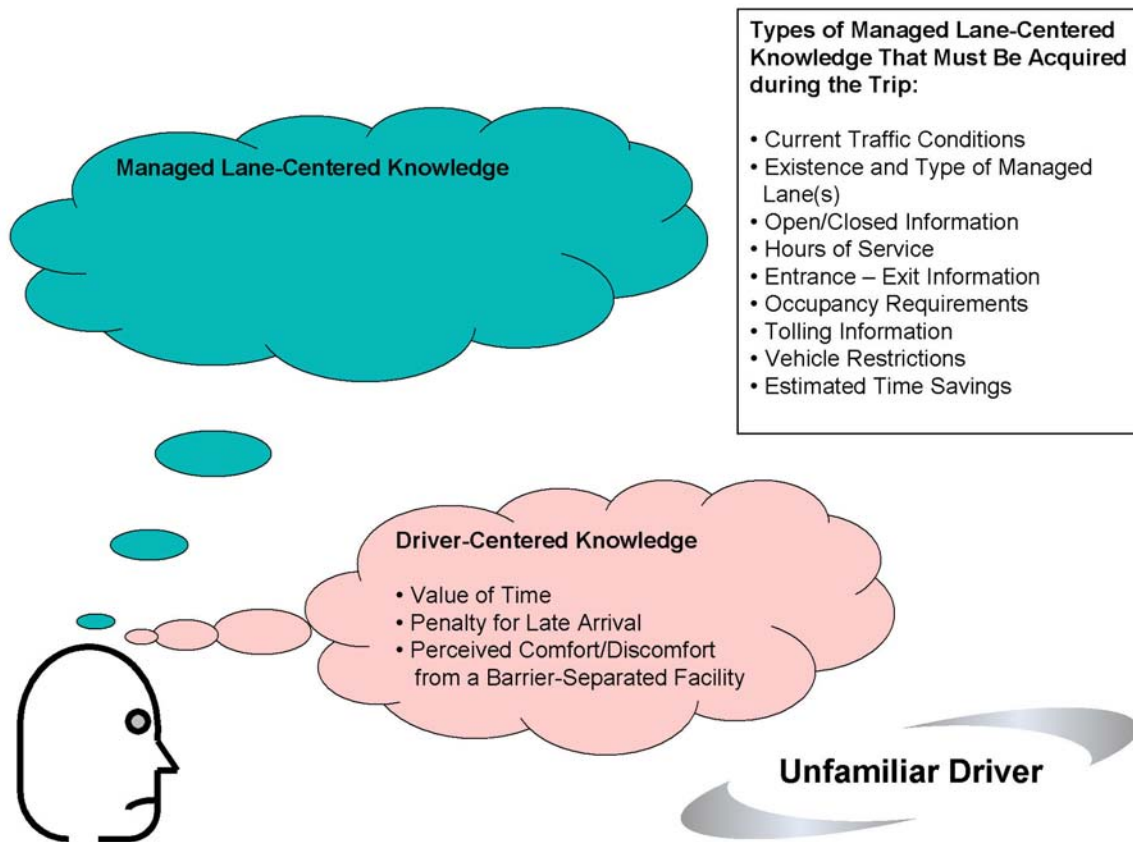


Figure 9-3. Example of an Unfamiliar Driver’s Managed Lanes Knowledge Base.

Semi-familiar Driver. A semi-familiar driver is one who fits between the other classifications. This driver could be considered one who has occasionally used the facility, or one who may have driven on the general-purpose lanes adjacent to the managed lanes and is considering using the managed lanes for the first time. This driver would know some information, such as geometry, speed, and direction of the roadway, but may need to determine additional information, such as tolling information and potential time savings en route. Depending on the type and amount of information needed by this type of driver, the amount of information that must be acquired from the roadway could be extensive and could result in a driver who is overloaded with information. The specific information needed would likely vary widely between drivers. A conceptual example of a semi-familiar driver is shown in [Figure 9-4](#).

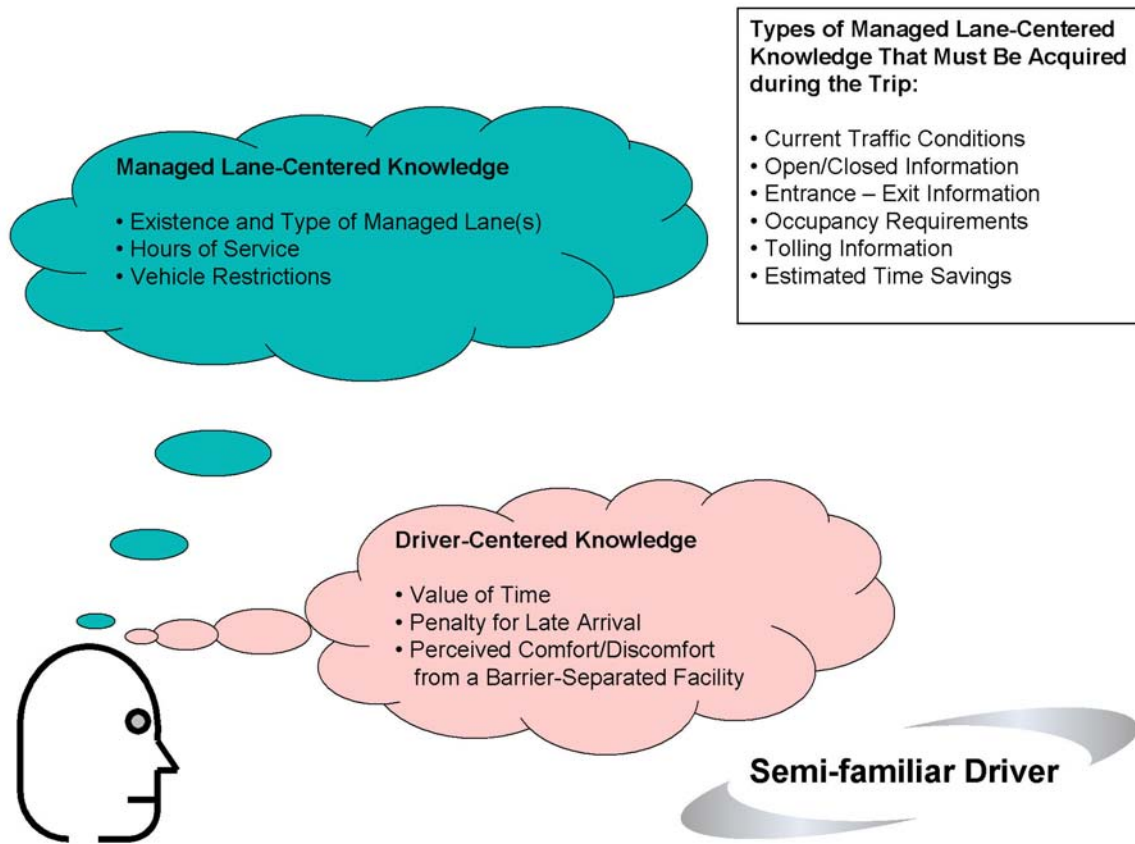


Figure 9-4. Example of a Semi-familiar Driver’s Managed Lanes Knowledge Base.

Familiar Driver. The familiar driver can be considered one who is intimately acquainted with the roadway in question. This driver may be a daily user, such as a commuter who drives the route daily at the same time. Alternatively, this may be a driver who is an experienced driver in a general sense, who may have extensive knowledge of other managed lanes, and who has taken the effort to learn about this managed lanes facility prior to the trip. This driver would need relatively little information about the geometry of the roadway and little signing information. In fact, in the extreme case, this type of driver could successfully maneuver through the route in question without even looking at a single sign, hearing a radio broadcast, reviewing a navigational aid, etc. This group of drivers would be least likely to be burdened with information overload. A conceptual example of a familiar driver is shown in [Figure 9-5](#).

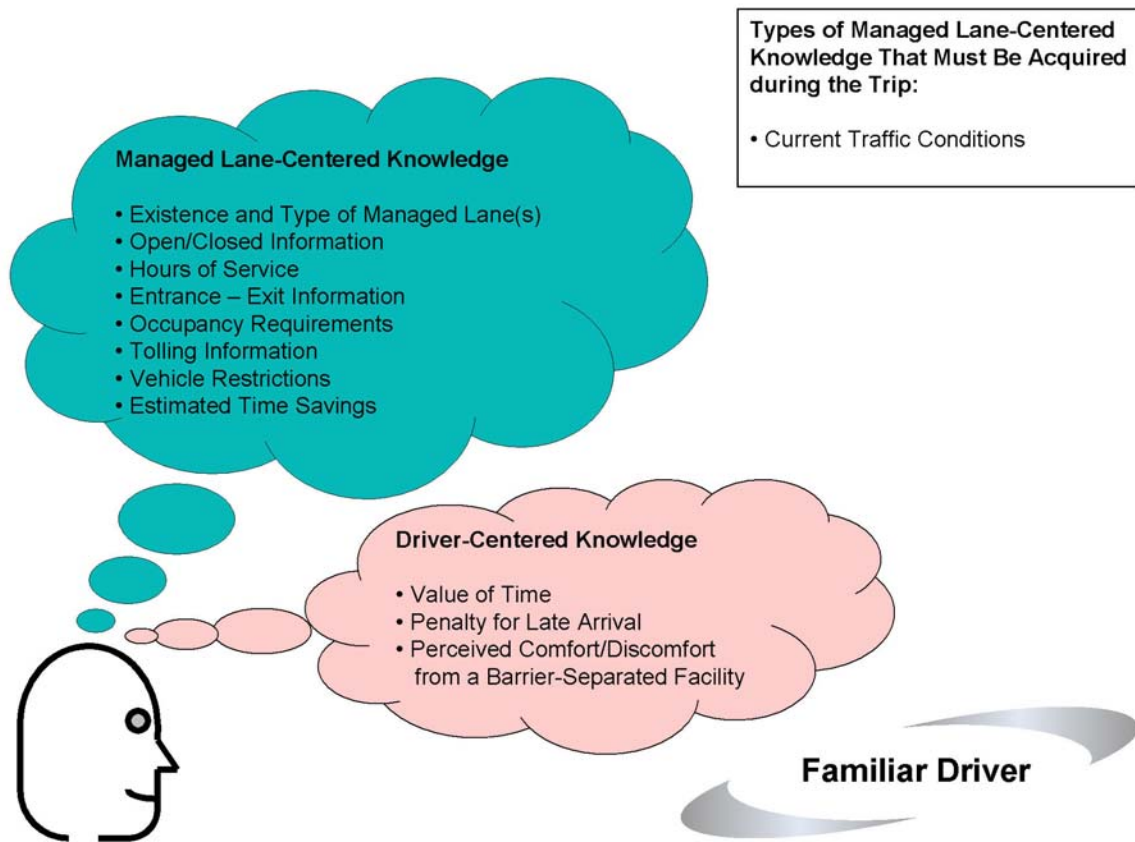


Figure 9-5. Example of a Familiar Driver’s Managed Lanes Knowledge Base.

Section 3 – Information Assessment Process

Driver Information Needs

The [previous section](#) can be a useful starting point, in that it correctly identified that the decision to use a managed lanes facility is a multi-step process, and it also implied that in order to make a properly informed decision, the driver must be able to take in several different types of pertinent information. However, the specific informational units needed at each point were not included in that initial effort. Therefore, TTI researchers expanded upon that paradigm to generate a list of information that drivers would likely need. This information is presented in [Table 9-1](#).

Table 9-1. Information Needs for Managed Lanes Decision-Making Process.

General Information Category	Types of Information That May Be Needed
Managed Lanes Information	<ul style="list-style-type: none"> • Type of managed lanes (HOV, fixed toll, variable toll, transit only, some combination of these) • What vehicles are allowed • Hours of operation • Open/closed information • Entrance information • Managed lanes final destination • Intermediate exit locations for the managed lanes • Toll structure (if any) • Required method of payment (if any) • Penalty for improper use
Traffic Condition Information	<ul style="list-style-type: none"> • Current traffic congestion in general-purpose lanes • Presence of incidents in either general-purpose or managed lanes • Estimated time savings for use of managed lanes
Vehicle Information	<ul style="list-style-type: none"> • Proper number of occupants • Presence of transponder or cash (if required) • Specific prohibitions on certain vehicles (trucks, towed trailers, etc.)
Driver Information	<ul style="list-style-type: none"> • Need to save time • Penalty for late arrival at destination • Desire to spend the money for a toll • Perceived value of time • Comfort level with barrier-separated facilities • Comfort level with concurrent-lane facilities if there is a large speed differential between managed lanes and general-purpose lanes

This information list is highly dependent on the specific managed lanes design and operational strategy, and thus these needs would not likely exist at all facilities. For example, information regarding tolls or payment methods would not apply at a facility that is only for HOV traffic. This information is needed in addition to the other

information drivers must access and use to operate their vehicle, such as speed limits, geometric changes, and the flow of traffic immediately surrounding the driver. The information categories are defined below:

- ◆ **Entrance information.** This category includes information such as how a driver can enter the managed lanes facility and subsequent entrance information. Information such as whether this is the only chance for a driver to enter the managed lanes or whether subsequent opportunities exist downstream can be useful in helping a driver make an informed decision.
- ◆ **Exit information.** Being able to understand potential exit points will help a driver better understand if the managed lanes could be useful in completing his or her trip, and if it would require a longer driving distance than would be the case if he or she remained in the general-purpose lanes.
- ◆ **Hours of service.** For some managed lanes facilities that are only open certain times of day, this type of information would typically be the hours that the facility is open. This is also true for managed lanes that reverse direction at different times of day.
- ◆ **Incident management information.** This type of information includes real-time information on the presence of any downstream crashes or other unexpected delays in either the managed lanes or the general-purpose lanes.
- ◆ **Occupancy requirements.** This category includes the minimum number of occupants that must be in a vehicle in order to properly use the managed lanes. This information is typically related to HOV or HOT facilities.
- ◆ **Open/closed information.** This information is similar to hours of service but may be simplified to only show “OPEN” or “CLOSED” with no other information such as when and how long the facility will be open or closed.
- ◆ **Time savings.** Time savings is the amount of time less that it takes to reach the terminal destination of the managed lanes (such as “downtown” for example) when using the managed lanes instead of the general-purpose lanes.
- ◆ **Tolling information.** This information may be fixed, or it may vary by time of day in an attempt to shift some drivers from peak times to off-peak times.
- ◆ **Travel time.** The total amount of time it takes to travel to a downstream location using either the managed lanes or the general-purpose lanes. An example of this is the message “23 MINUTES TO DOWNTOWN” displaying real-time information on a DMS sign.
- ◆ **Type of managed lanes.** This type of information helps drivers understand if they are even eligible to use the managed lanes. Examples include “BUS ONLY LANE,” “TOLL LANE,” or “HOV LANE.”

- ◆ **Vehicle restrictions.** If certain vehicles are not allowed into the managed lanes, this should be conspicuously displayed to prevent confusion. Common examples of restricted vehicles on existing managed lanes facilities include trucks, vehicles with trailers, and wide loads.

User Familiarity Role in the Managed Lanes Traveler Information Assessment Process

As described above, user familiarity has a significant influence upon traveler information needs for a managed lanes facility. Over time, such familiarity often reduces the need for certain types of information such as where to enter a facility, what legal and financial requirements exist for entry, where exits are located, etc. The most familiar users of a facility could reasonably be expected to travel the facility successfully even without any external sources of information, but completely unfamiliar drivers need to acquire virtually all their information from the roadway signs or other information sources.

While common practice for general-purpose lanes and all other roadways requires the highway agency to plan for the completely unfamiliar driver, a review of the informational requirements listed in [Table 9-1](#) and [Figure 9-6](#) suggests that it may not always be possible to accommodate this type of driver for all types of managed lanes scenarios. In other words, an operating agency may choose to design the facility (and the information system supporting it) for “familiar users.” However, if such a decision is made, focus must turn toward ensuring that unfamiliar users are not misled or confused into using the managed lanes when they do not wish to do so.

The interaction between driver familiarity and information requirements implies that information requirements should be considered early in the managed lanes design process, as choices are being made regarding ingress and egress points, types of tolling facility, and type and amount of vehicle occupancy adjustments to accommodate. [Table 9-2](#), [Table 9-3](#), and [Table 9-4](#) can help guide practitioners in considering which facility types require more en route information than other facilities, and highlight the types of information that should be considered (at least in general terms) in the managed lanes design process. These tables reiterate that different user groups require different information. One noteworthy point from [Table 9-4](#) is that more complex managed lanes facilities (such as variable-priced HOT lanes) require even familiar drivers to acquire a substantial amount of en route information. If this cannot be effectively accommodated into the overall information system via static and dynamic signing, other mechanisms such as the mobile Internet, two-way transponder communications, or other in-vehicle communications with the motorists may be necessary.

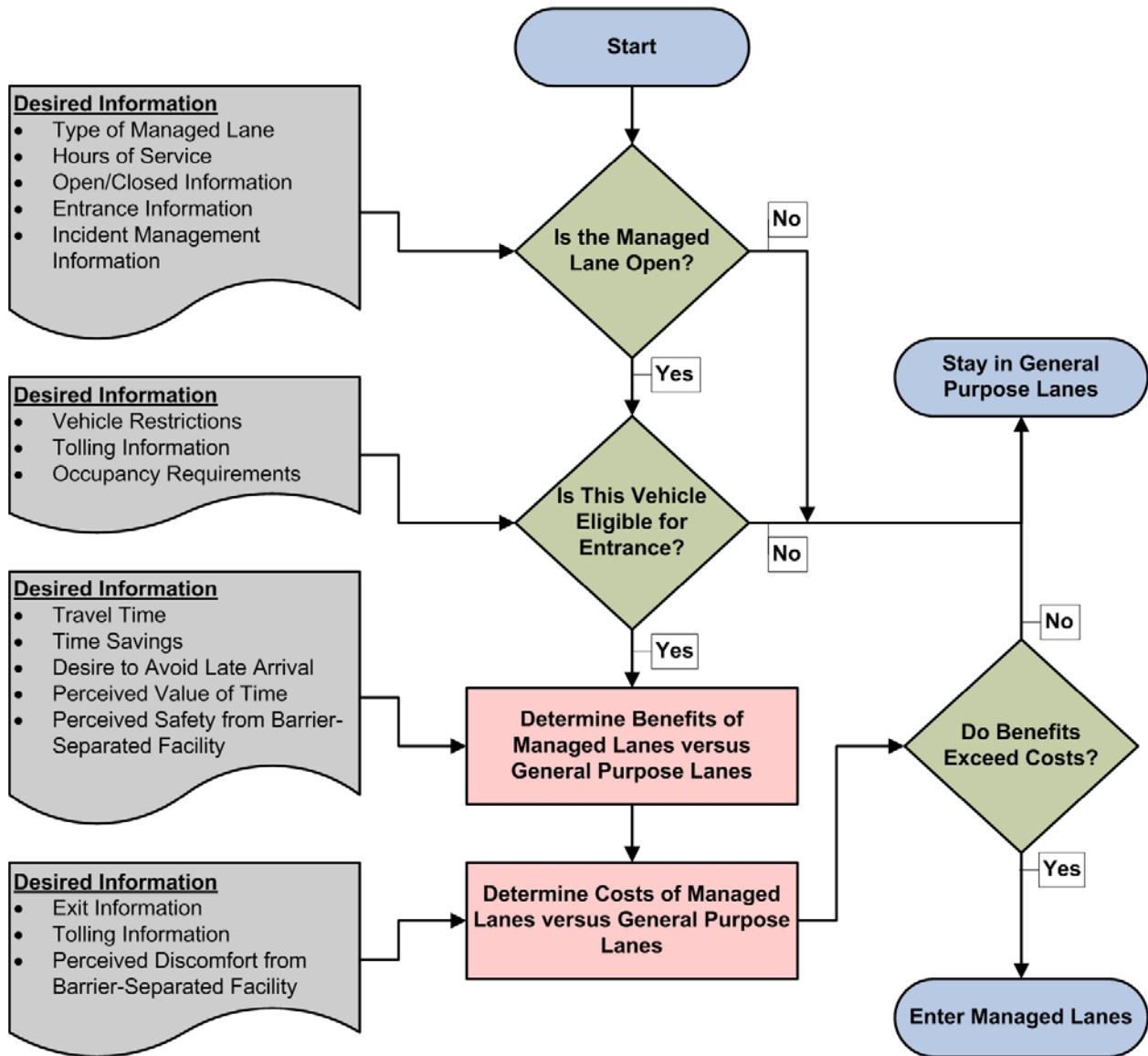


Figure 9-6. Conceptualized Model of Decision Whether or Not to Access Managed Lanes.

Table 9-2. Typical Information Needs for HOV Lane Users.

Driver Type	HOV Lanes	
	Concurrent Flow	Barrier Separated
Unfamiliar Drivers	<ul style="list-style-type: none"> • Entrance Information • Hours of Service and/or Open/Closed Information • Incident Information • Occupancy Requirements • Travel Time and/or Time Saving • Vehicle Restrictions 	<ul style="list-style-type: none"> • Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Occupancy Requirements • Travel Time and/or Time Saving
Semi-familiar Drivers	<ul style="list-style-type: none"> • Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Occupancy Requirements 	<ul style="list-style-type: none"> • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Occupancy Requirements • Travel Time and/or Time Saving
Familiar Drivers	<ul style="list-style-type: none"> • Incident Information • Occupancy Requirements • Travel Time and/or Time Saving 	<ul style="list-style-type: none"> • Incident Information • Occupancy Requirements • Travel Time and/or Time Saving

Note: The information categories shown in this table are typical examples shown merely for illustrative purposes. It is entirely likely that specific managed lanes facilities may exhibit different information-dissemination needs and/or capabilities.

Table 9-3. Typical Information Needs for Toll Lane Users.

Driver Type	Toll Lanes	
	Static Pricing or Pricing That Changes by Time of Day	Dynamic Pricing
Unfamiliar Drivers	<ul style="list-style-type: none"> • Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Tolling Information • Travel Time and/or Time Saving • Vehicle Restrictions 	<ul style="list-style-type: none"> • Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Tolling Information • Travel Time and/or Time Saving • Vehicle Restrictions
Semi-familiar Drivers	<ul style="list-style-type: none"> • Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Tolling Information • Travel Time and/or Time Saving 	<ul style="list-style-type: none"> • Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Tolling Information • Travel Time and/or Time Saving • Vehicle Restrictions
Familiar Drivers	<ul style="list-style-type: none"> • Hours of Service and/or Open/Closed Information • Incident Information • Travel Time and/or Time Saving 	<ul style="list-style-type: none"> • Hours of Service and/or Open/Closed Information • Incident Information • Tolling Information • Travel Time and/or Time Saving

Note: The information categories shown in this table are typical examples shown merely for illustrative purposes. It is entirely likely that specific managed lanes facilities may exhibit different information-dissemination needs and/or capabilities.

Table 9-4. Typical Information Needs for HOT Lane Users

Driver Type	Toll Lanes	
	Static Pricing or Pricing That Changes by Time of Day	Dynamic Pricing
Unfamiliar Drivers	<ul style="list-style-type: none"> • Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Occupancy Requirements • Tolling Information • Travel Time and/or Time Saving • Vehicle Restrictions 	<ul style="list-style-type: none"> • Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Occupancy Requirements • Tolling Information • Travel Time and/or Time Saving • Vehicle Restrictions
Semi-familiar Drivers	<ul style="list-style-type: none"> • Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Occupancy Requirements • Tolling Information • Travel Time and/or Time Saving 	<ul style="list-style-type: none"> • Entrance Information • Exit Information • Hours of Service and/or Open/Closed Information • Incident Information • Occupancy Requirements • Tolling Information • Travel Time and/or Time Saving • Vehicle Restrictions
Familiar Drivers	<ul style="list-style-type: none"> • Hours of Service and/or Open/Closed Information • Incident Information • Travel Time and/or Time Saving 	<ul style="list-style-type: none"> • Hours of Service and/or Open/Closed Information • Incident Information • Tolling Information • Travel Time and/or Time Saving

Note: The information categories shown in this table are typical examples shown merely for illustrative purposes. It is entirely likely that specific managed lanes facilities may exhibit different information-dissemination needs and/or capabilities.

Section 4 – Traffic Control Device Principles for Managed Lanes

Information Spreading

Sign placement is a difficult issue for managed lanes facilities. The *MUTCD* provides somewhat confusing information as to when signs should be placed overhead, on the right shoulder, or on the left-side median barrier. Particularly for concurrent-flow facilities with limited access areas, conflicting information regarding distances to exit points for the managed lanes and general-purpose lanes may exist. In these situations, it is critical that signing displays be designed so as to clearly separate the information for the managed lanes from that intended for the general-purpose lanes. In general, overhead signs are often preferable on freeways because they are visible to all lanes and will not be blocked by large vehicles. Overhead signs, however, can be extremely expensive to install and often require lane closures for maintenance activities. A common practice is to erect a large sign structure that spans the full width of the roadway. Guide signs for general-purpose and managed lanes are then all placed on the same structure. Separate cantilevers rather than full-span sign structures are preferred to separate this information. If separate cantilevers are not possible, managed lanes signs should be as far left as possible, preferably with a noticeable gap between them and signs for the general-purpose lanes.

Right-shoulder ground mounting is generally more cost effective, except in cases of very limited right-of-way. For managed lanes facilities that use the right shoulder or right lane, this is an appropriate location for the signs. For median or left-lane facilities, however, it is not recommended to place signs on the right shoulder. The *MUTCD* makes no statements concerning which side of the road to place ground-mounted signs. All of the figures for managed lanes use illustrate all signs as being on the left side of the road, for left-side managed lanes.

Unfortunately, placing the sign on the left side of the road poses problems for facilities with a narrow median or concrete barrier separating two carriageways. The *MUTCD* does make allowances for these situations with limited lateral clearance in Section 2E.59 (1). It provides an option to skew signs up to 45 degrees for signs that are 72 inches or less in width in order to fit within the barrier width.

The *MUTCD* can be difficult to interpret regarding ground-mounted and overhead signs. There seems to be an attempt to distinguish between barrier-separated lanes and other types of facilities, but some of the *shall* conditions seem to contradict each other. The *shall* conditions in Section 2E.59 regarding ground and overhead mounting are as follows (numbers and list format by the authors):

1. Ground-mounted advance guide signs shall be provided at least 0.5 miles prior to the beginning or initial entry point to all types of preferential only lanes (including barrier-separated, buffer-separated, and concurrent flow) (p. 2E-64).

2. Ground-mounted guide signs shall be provided at the beginning or initial entry point and at intermediate access points to all types of preferential only lanes (p. 2E-64).
3. Overhead preferential only lane guide signs shall be used only as a supplement to ground-mounted preferential only lane guide signs unless an engineering study identifies that ground-mounted guide signs are not appropriate for a particular situation or location (p. 2E-64).
4. For barrier-separated preferential only lanes, overhead advance guide and overhead guide signs shall be provided in advance of and at the beginning or initial entry point to the preferential only lanes (p. 2E-65).

The requirements laid out in conditions 1-3 call for ground-mounted signs, while condition 4 mandates an overhead sign. These only reconcile if one assumes that the engineering study called for in condition 3 necessarily will result in the conclusion that a ground-mounted sign is never appropriate for barrier-separated facilities, thus producing condition 4. The rest of the guidance and options statements are similarly contradictory.

On some facilities, conflicting information regarding distances to exits may need to be displayed. For example, the distance to a particular cross street (e.g., Oak Street) may be one mile away for the general-purpose lanes, but the egress point from the managed lanes to the general-purpose lane to then access to that cross street may be much closer (e.g., ¼ miles). If the exit sign for the managed lanes stated “OAK ST ¼ MILE” and the advance guide sign for the general-purpose lane stated “OAK ST 1 MILE,” motorist confusion would likely arise.

Access Points

The federal *MUTCD* standards call for placing an “EXIT” sign at the gore to mark the movement from the general-purpose lane into a managed lane. TxDOT practices call for an “ENTRANCE” sign for the same movement. Focus group discussions on this topic favor the use of “ENTRANCE” rather than “EXIT.” Drivers perceive themselves to be *entering* the managed lanes facility rather than *exiting* the general-purpose lane.

The *MUTCD* further specifies that signs at exit and entry points shall have the HOV abbreviation or the diamond symbol somewhere in the legend. Meanwhile, lanes designated for bus or taxi traffic shall not use the diamond symbol on guide and exit signs. For barrier-separated facilities only, an exit direction sign is specified; the diagrams show the diamond symbol in the upper left corner of the “EXIT” direction sign (See *MUTCD* Figure 2E-47).

Signing at the transition from a managed lane back to the general-purpose lane also uses “EXIT” terminology. Advance exit and exit direction signs using the route shield and the word “EXIT” are called for to mark this transition for barrier-separated lanes (Figure 2E-47). While these signs alert drivers that a transition point is nearing that will require a merge maneuver, the use of the word “EXIT” and the use of the concurrent

route number is in opposition to the opinions expressed in the focus groups. For buffer-separated facilities that do not require a lane change at entrance and exit points, the “HOV LANE ENDS” (R3-15a) sign is specified (1).

Lane merging warning symbol signs (W4-2) are illustrated (Figure 2E-47) at merge points at the end of HOV lanes but are not referred to in the text of Section 2E.59. These signs are placed on the left median as a warning to drivers in the managed lanes that they must merge right. It is not clear in the *MUTCD* whether these merge signs should have the HOV plaque as recommended as an option in Section 2C.52. The TxDOT practice is to use warning text signs W9-1 (“LANE ENDS MERGE LEFT/RIGHT”) and W9-2 (“LEFT/RIGHT LANE ENDS”) for these applications.

Allowed Vehicles

Advance regulatory signing for preferential lanes calls for a particular format to be used for the signs, as stated in Section 2B.26. This section states that the HOV signs shall display the minimum allowable vehicle occupancy requirement established for each HOV lane. The vehicle occupancy requirement for an HOV lane shall be referenced immediately after the word message HOV of the diamond symbol. Figure 9-7 and Figure 9-8 illustrate these signs and requirements. Figure 9-9 illustrates a sign an agency uses to define the term HOV for unfamiliar drivers.

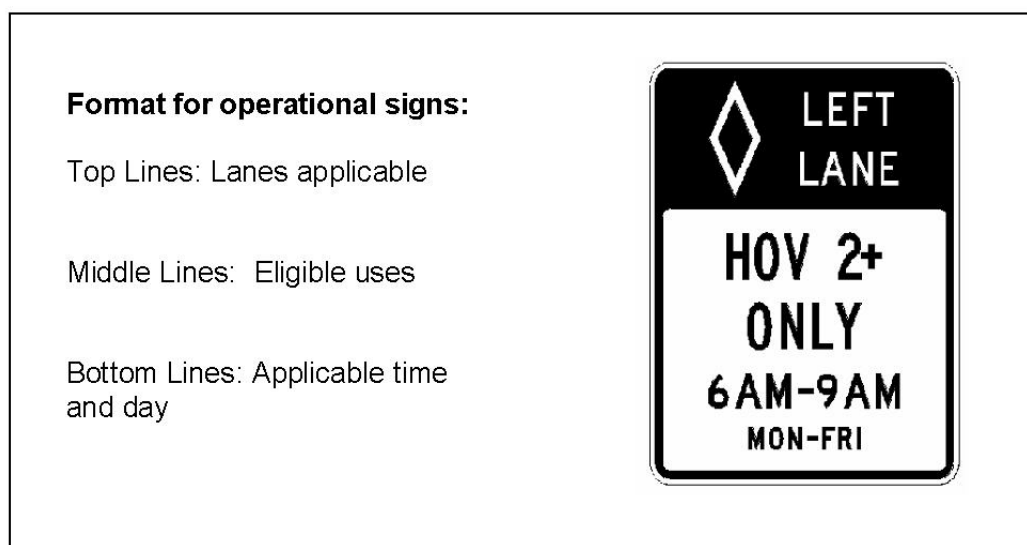


Figure 9-7. Ground-Mounted Occupancy Requirement Sign.

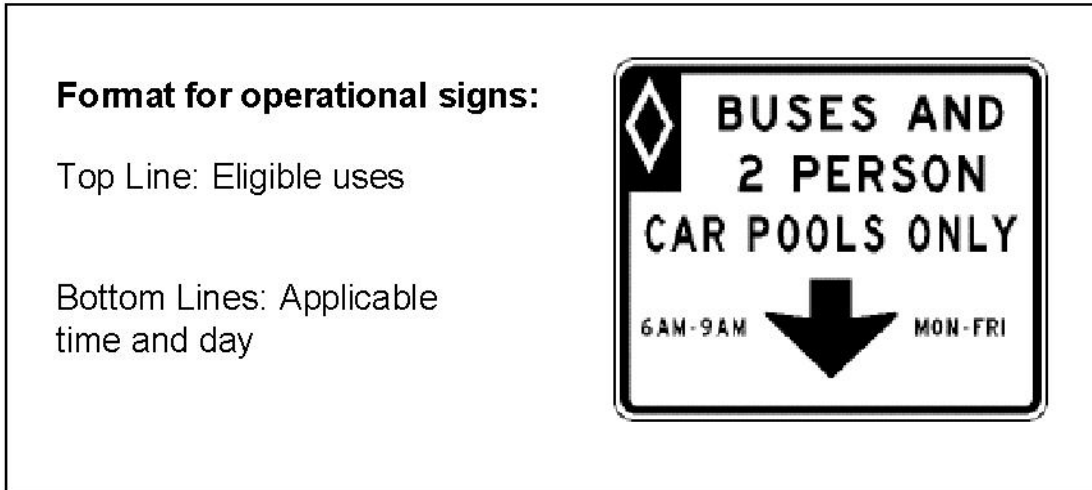


Figure 9-8. Overhead Occupancy Requirement Sign.

Agencies often wish to exclude certain vehicles from managed lanes based on weight or length. Regulatory signs stating these exclusions are used upon approach to the entrance to the managed lanes. Early research encourages the separation of these exclusions from signs containing allowed vehicles. [Figure 9-10](#) shows an example of a truck and trailer exclusion sign used in Houston. Meanwhile, an earlier TTI report recommended that the prohibited-vehicles sign be displayed in advance of the permitted-vehicles sign (11). This work also recommended that words only, not symbols, be used for prohibition with the word “NO” appearing before each vehicle class name. The researchers preparing that report also recommended no more than four lines of text on the prohibition signs.



Figure 9-9. Sign Used to Define HOV Term.



Figure 9-10. Vehicle Exclusion Sign in Houston.

In contrast to vehicle exclusion efforts, some managed lanes facilities have established separate carriageways based on vehicle type; signing is designed to guide motorists to the appropriate carriageway rather than restrict them from the lanes they are not intended for. The New Jersey Turnpike, for example, has an exclusive lane for passenger vehicles. They use green guide signs at the entry points to divert traffic to the proper lanes (see [Figure 9-11](#)).



Figure 9-11. Vehicle Segregation on the New Jersey Turnpike.

Coding of Traffic Control Devices to Facilitate Processing

The following sections describe ways in which coding of traffic control devices can facilitate drivers' processing of the information they provide.

Sign Color and Banners

The *MUTCD* utilizes a color code for signs to assist drivers in finding the type of information they seek (1). Section 1A.12 of the current *MUTCD* states:

The general meaning of the 13 colors (that have been identified as being appropriate for use in conveying traffic control information) shall be as follows:

- ◆ Black – regulation
- ◆ Blue – road user services guidance, tourist information, and evacuation route
- ◆ Brown – recreational and cultural interest area guidance
- ◆ Coral – unassigned
- ◆ Fluorescent Pink – incident management
- ◆ Fluorescent Yellow-Green – pedestrian warning, bicycle warning, playground warning, school bus and school warning
- ◆ Green – indicated movements permitted, direction guidance
- ◆ Light Blue – unassigned
- ◆ Orange – temporary traffic control
- ◆ Purple – unassigned
- ◆ Red – stop or prohibition
- ◆ White – regulation
- ◆ Yellow –warning

While the *MUTCD* contains no guidance particular to *managed* lanes, there are sections that pertain to preferential only or restricted lanes. These include bicycle, HOV, bus, light rail, or taxi lanes. Regulatory signs for preferential only lanes are described in Section 2B.26. These signs convey information on operating hours, occupancy requirements, and allowed vehicle types. They have black lettering on a white background. Other signs in this section include “HOV LANE AHEAD” and “HOV LANE ENDS” (R3-15 and R3-15a), which are also black on white regulatory signs. Some agencies have used distinctive logos or banners across the top of signs to identify

them as uniquely applying to managed lanes. Figure 9-12 shows a sign proposed for an HOV facility managed by Houston Metro Transit.

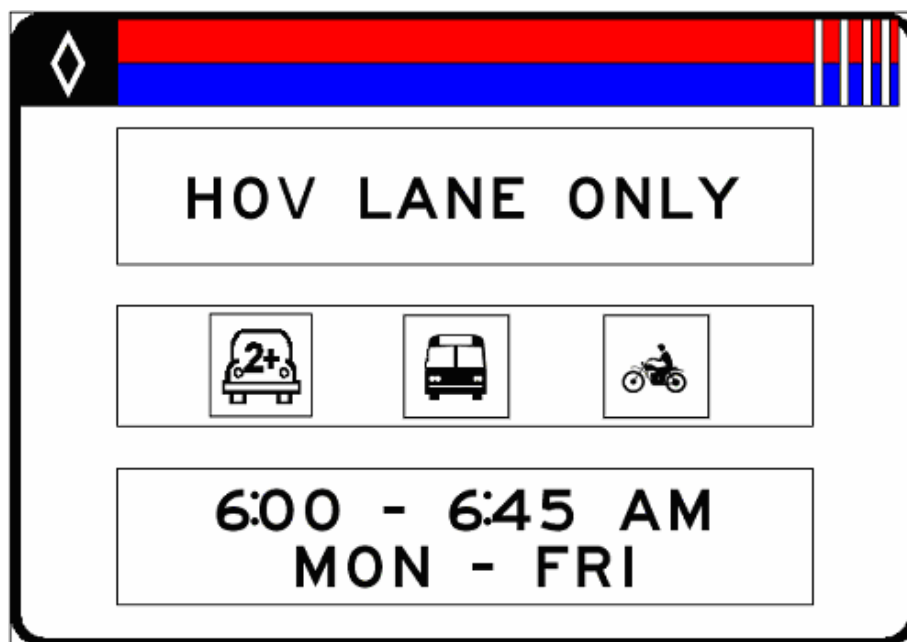


Figure 9-12. Guide Sign with Full-Span Banner across Top Proposed for Houston HOV Lanes.

Toll roads have been an area where agencies have been more willing to utilize banners, logos, and unique colors throughout their traffic control devices. Technically, toll roads are obligated to conform to the *MUTCD* since the document applies to all roads open to travel by the public. Toll road operators, however, have sought ways to “brand” their roads. While some in the transportation engineering community scoff at this branding as using traffic signs as advertisements, the use of a consistent and unique symbol or color may benefit travelers in navigating. This is an area where more research is needed.

For yellow-series signs, the new *MUTCD* contains an option to use a supplementary plaque, black letters on a yellow background with the letters “HOV” (W16-11). This option also allows for the use of the diamond symbol instead of the word message “HOV” on the supplementary plaque and for the addition of the words “ONLY” or “LANE” to the plaque.

For green-series signs, all of the illustrations in Section 2E.59 show guide signs with white letters on a green background. These guide signs also contain the diamond symbol in white outline on a black background, either in the upper left or across the top of all guide signs related to the HOV lane.

Symbols

The use of symbols to indicate which vehicles are allowed on a managed lanes facility has not yet been standardized in the *MUTCD*, but symbols are used frequently. A

consistent symbol set for buses, motorcycles, and ILEVs needs to be developed. In addition, occupancy symbols for carpools should be standardized. No visibility or comprehension research has been found on any of the symbols in use today. From a sign design perspective, symbols are preferred because they occupy less space and can be used in a modular fashion whereby the overall footprint of the symbol is a standard size. In addition, for areas with non-English-speaking drivers, symbols may be preferred as long as research supports their use. Research and design work are needed on these symbols to assure good legibility and comprehension. A symbol for ILEV could be particularly difficult to develop.

The use of symbols may also be extended into signs indicating excluded vehicles. The use of the red circle slash may need to be avoided on vehicle symbols because of the fine detail present in these icons, which could be obscured by the prohibition markings.

The *MUTCD* sets the standard that all HOV signs must use the diamond symbol. According to the manual, when the diamond symbol or HOV acronym is used on ground-mounted signs without corresponding text, the symbol should be centered on the top line of the sign. If the symbol or HOV acronym does have adjacent text, the symbol should appear to the left of the text. This standard applies to both the regulatory and guide signs. Concerning overhead signs, if used, the diamond symbol should appear in the top left quadrant, unless it is the “LANE ENDS” sign. For this sign, the diamond should appear on the entire left side of the sign. Again, this applies for regulatory and guide signs.

As this is new guidance in the *MUTCD*, the current practice, not surprisingly, varies considerably across jurisdictions.

The three photographs in [Figure 9-13](#) show three different locations for the diamond symbol on California facilities. All of these variants in position and size for the diamond symbol for regulatory signs are illustrated in the *MUTCD*, though the exact wording of these signs is not entirely consistent with the new manual.

The new *MUTCD* uses text to convey occupancy requirements (see Section 2B.26). Many existing facilities use variants of the “carpool” symbol, which shows the outline of a vehicle with a numeral inside the image indicating the required number of occupants. Other types of symbols that have been seen on managed lanes signs are outlines of taxis, motorcycles, or buses to indicate additional vehicle classes that are allowed in the lane.

[Figure 9-14](#) illustrates the occupancy requirements used on the Houston area HOV lanes. METRO staff report that these symbols were created in-house and were based on signs seen at other facilities ([13](#)).

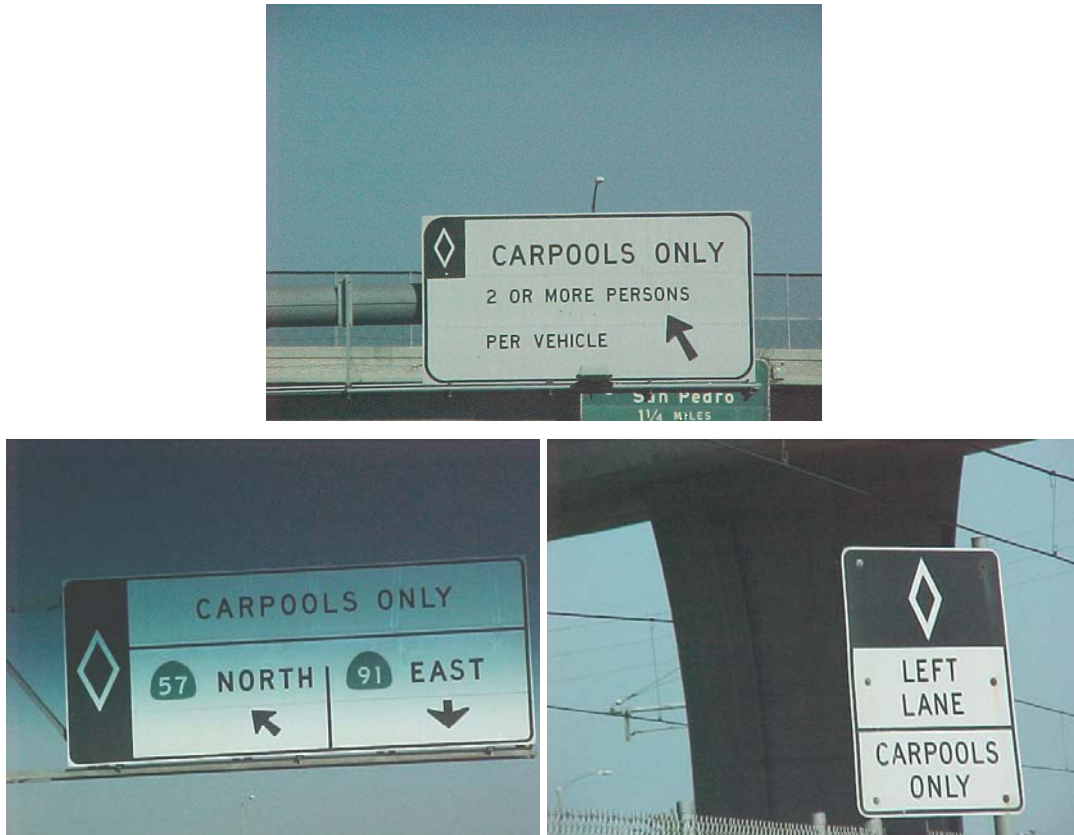


Figure 9-13. Diamond Symbol Used on California Facilities.



Figure 9-14. Occupancy Symbols Used in Houston.

Dynamic Message Signs

Dynamic message signs (DMSs) can be an important instrument to display traffic alerts, construction updates, and other real-time information. Existing guidelines concerning message construction and message phasing should be followed for managed lanes applications. Agencies may wish to consider placing a static plaque identifying the applicable lane above DMSs if the information in the sign applies only to the managed lanes.

Information overload may occur if complex operating schedules and variable pricing based on vehicle class and occupancy are conveyed through multiple-phase DMSs. Other communication means, such as highway advisory radio or mailings to subscribers, should be considered to convey this information.

Often DMSs are used in conjunction with fixed managed lanes signage. The only standards that the *MUTCD* provides concerning managed lanes are that when DMSs are used for preferential only lanes, they should have the appropriate sign size, letter height, and legend format for that type of roadway facility and speed. It allows agencies the option of using the diamond symbol or the HOV abbreviation on DMSs.

Large, overhead DMSs are commonly used along managed lanes. These signs allow for traffic conditions, incident notification, travel times, and tolls to be displayed dynamically. With newer electronic technology, the diamond symbol can be displayed full height on the sign to mimic the design of an overhead regulatory sign. [Figure 9-15](#) illustrates such a sign on SR 91 in California.



Figure 9-15. Overhead Dynamic Message Sign.

Lane Control Signals

The *MUTCD* allows the use of overhead lane control signals that permit or prohibit the use of specific lanes. They are often applied to reversible-flow lanes and at toll plazas to indicate payment lane status. Research has shown good driver comprehension of the red X and green arrow lane control signal symbols (14). An FHWA study in 1982 reports that lane control signals may be better understood if accompanied by an advance sign stating “LANE CONTROL SIGNALS AHEAD” (12).

Lane control signals can also be applied to shoulder lane operations to indicate allowable travel on the shoulder. The *MUTCD* contains guidance on placement and visibility of these signals.

Pavement Markings

The following sections discuss the use of pavement markings for managed lanes facilities.

Lane Line Markings

Longitudinal pavement markings can play a very important role in a driver’s understanding of allowable movements in managed lanes. The *MUTCD* distinguishes the appropriate markings for the different types of managed lanes based on whether lanes are reversible, physically separated, and on the right or left side of the general-purpose lanes. These requirements are summarized in the *MUTCD* in Section 3B.23. In all cases, whether physically separated or not, the right edge line should be white. The manual recommends “wide” white lines where crossing is prohibited but does not define the width. In industry terminology, standard edge lines are generally 4 inches in width, and wide lines are 8 inches. Carroll et al. report that some HOV projects are not meeting the minimum requirements set by the *MUTCD* regarding a “wider” stripe (15).

The *MUTCD* also discusses that all pavement markings associated with the preferential lane, including longitudinal pavement markings, word, and symbol, should end where the “LANE ENDS” sign is installed.

For concurrent-flow lanes, it is desirable to delineate areas where changing lanes in or out of the managed lanes is allowed. The *MUTCD* recommends using a single broken wide white line or single dotted normal-width white line in areas where crossing is permitted. In areas where crossing is prohibited, a double solid white line is specified. For those sections where crossing is discouraged but not prohibited, a single solid wide white line is the standard.

Horizontal Signing

Word and symbol pavement markings (also called horizontal signing) can also coincide with proper signage to convey the roles and rules of the managed lanes facility. The

MUTCD states that preferential markings should be used whether the lane is assigned full or part time a specific class or classes of vehicles. It recommends that the markings consist of white lines forming the standard diamond symbol or the word HOV. The manual also states that all of the preferential lane word and symbol markings shall be white and positioned laterally in the center of the lane. An example of the diamond symbol lane marking is shown in [Figure 9-16](#). The *MUTCD* recommends a longitudinal spacing of 984 ft (300 m), allowing for engineering judgment.



Figure 9-16. HOV Lane Pavement Marking Symbols in Houston.

Non-sign Methods of Information Dissemination

Information related to electronic toll tag subscriptions, transit information, carpool registries, and other programs is often presented along a roadway. This is even more important for managed lanes, due to their restrictive nature and the possible revenue enhancement from promoting these programs. The *MUTCD* currently prohibits the placement of Internet addresses on traffic control devices, yet examples of this have been found on the road. As Internet usage nears universality, the use of web addresses may be preferred to telephone numbers for these applications. Web addresses can be selected that are easier to remember than telephone numbers, thus lessening the information load on drivers.

Supplemental information should always come second to the necessary warning, guidance, and regulatory functions of traffic control devices. Care must be exercised in placing supplemental information to avoid installing signs near decision points or where they may direct attention away from necessary maneuvers.

Information about managed lanes operations may be provided to users by means of mailings, paid advertising, and public service announcements, which are often provided free of charge during traffic reports. For electronic transponder customers, home address information is typically required for billing purposes. Agencies may wish to use bill inserts to communicate complicated toll structures, intermediate exit information, and hours of service, particularly for facilities that are exclusively for use by subscription to a local transponder. As interoperability increases and transponders can be used throughout a state, region, or nation, it may become more difficult to use this method of information dissemination. Internet-based guides should be maintained for pre-trip planning purposes and billing questions.

Section 5 – References

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Section 1 – Overview

A managed lanes facility requires effective enforcement policies and programs to operate successfully. Enforcement of vehicle-occupancy requirements, use by authorized vehicles, or proper toll collection is critical to protecting eligible vehicles' travel-time savings and safety. Visible and effective enforcement promotes fairness and maintains the integrity of the managed lanes facility to help gain acceptance among users and non-users.

Successful enforcement of managed lanes requires appropriate application of available resources. This project identified the various enforcement strategies concerning the amount of enforcement required to ensure that the rules and regulations of managed lanes are maintained. This amount ranges from continuous enforcement to the simpler process of self-enforcement. A review of the various enforcement practices across the country indicates that there are multiple variations for the enforcement of managed lanes with varying levels of success.

Sections in this chapter cover:

- ◆ enforcement planning,
- ◆ enforcement considerations in design,
- ◆ automated enforcement technology, and
- ◆ enforcement considerations in operations.

Section 2 – Enforcement Planning

Development of enforcement policies and programs ensures that all appropriate agencies are involved in the process and have a common understanding of a project and the need for enforcement. Participation from enforcement agencies, tolling authorities, the courts and legal system, state departments of transportation, and transit agencies is critical for enforcement success.

Planning for enforcement of managed lanes is tied to the goals and objectives of the individual project, which determines the operating strategy and user groups. Once an operating strategy for the lanes is defined (i.e., type of managed lanes facility, allowable user groups, toll exemptions or discounts, designated access points by user group, etc.), the agencies involved in developing the project can determine what characteristics determine compliance.

For example, if the operating strategy for a facility is identified as a HOT lane with HOV 3+ free during peak periods, buses free, and SOVs and HOV 2s paying a variable toll, with no trucks allowed, the following items require enforcement:

- ◆ verification of HOV 3+ vehicles for toll exemption,
- ◆ payment of toll by all other vehicle groups, and
- ◆ use by allowable groups only.

All relevant agencies should be involved in the development of the operational plan for the managed lanes so that various perspectives can be taken into account.

Section 3 – Enforcement in Design

Traditional enforcement on managed lanes requires the specific design treatment known as dedicated enforcement areas. These areas are usually located immediately adjacent to the managed lanes facility and allow enforcement personnel to monitor the facility, pursue violators, and apprehend violators to issue appropriate citations. However, recent advances in automated enforcement technology may lower the number of dedicated enforcement areas needed in the future, thereby shifting the focus of design to proper placement of electronic equipment. Enforcement areas are discussed further here, with the topic of automated enforcement presented in [Section 4](#).

Classification identifies enforcement areas as either low-speed or high-speed and usually by type of separation from the general-purpose lanes. Low-speed enforcement areas are associated with facilities that offer some sort of barrier separation and are usually located near entrance or exit ramps. High-speed enforcement areas are associated with non-barrier separated or buffer-separated facilities, either concurrent flow or contraflow, and are located along the managed lanes mainline. The next sections discuss general characteristics for both types of enforcement areas, along with preferred design features for each.

Low-Speed Enforcement Areas

Busways, managed lanes on separate rights-of-way, and barrier-separated freeway projects usually locate low-speed enforcement areas at access points. Specific locations may include ramps, reversible-lane entrances, and queue bypasses where vehicle speeds are relatively slow, usually below 45 mph [75 kph]. In the case of reversible-exclusive managed lanes facilities, the geometric requirements for reversing a facility provide temporary enforcement areas within the ramp areas that serve the opposing peak-period direction.

Planners design areas to provide for monitoring, apprehension, and citing of violators and, where practicable, violator removal from the managed lanes facility. The design feature of barrier separation acts as a deterrent to potential misuse since violators are confined in the lanes once the decision is made to enter the facility. The following design features may be considered with low-speed enforcement areas:

- ◆ The enforcement area should be at least 100 feet [30 meters] in length and preferably up to 200 ft [60 m] on high-volume facilities, not including approach and departure tapers.
- ◆ The enforcement area should be at least a width of 14 to 15 ft [4.3 to 4.6 m].
- ◆ The enforcement area should have an approach taper of 2:1 or 30 ft [9.1 m].
- ◆ The enforcement area should have a departure taper of 10:1 or 150 ft [45.7 m] to allow for vehicle acceleration into the lane.

High-Speed Enforcement Areas

High-speed enforcement area design usually involves spacing multiple areas periodically along facilities that have multiple at-grade access locations or are lacking continuous shoulders wide enough for enforcement. These areas are usually designed for monitoring traffic and apprehending violators. Most apprehension activities occur at a downstream enforcement area or location with a wide left or right shoulder. The following design features may be considered with high-speed enforcement areas:

- ◆ The length of a high-speed monitoring area should be at least 100 ft [30 m], not including the approach and departure tapers. For monitoring and apprehension, the preferable length is 1300 ft [396 m].
- ◆ The enforcement area should be at least 14 to 15 ft [4.3 to 4.6 m] in width.
- ◆ The enforcement area should have an approach taper of 20:1 and a departure taper of 80:1 or higher, or it may be controlled by general freeway criteria as required to fit in the design for proper acceleration to the design speed.
- ◆ Enforcement areas should be provided a minimum interval of 2 to 3 miles [3.2 to 4.8 km] along the mainline managed lanes facility.

Enforcement of two-way and reversible barrier-separated managed lanes facilities is considered easier than with concurrent-flow lanes due to limited access points. Violators may be stopped at entry and exit points where travel speeds are usually lower. A reversible facility allows enforcement personnel to monitor the facility from ramps that are not in use due to managed lanes traffic moving in the opposing direction. [Figure 10-1](#) provides examples of cross sections using designated shoulders or other enforcement pockets located along the lane for facilitating enforcement activities.

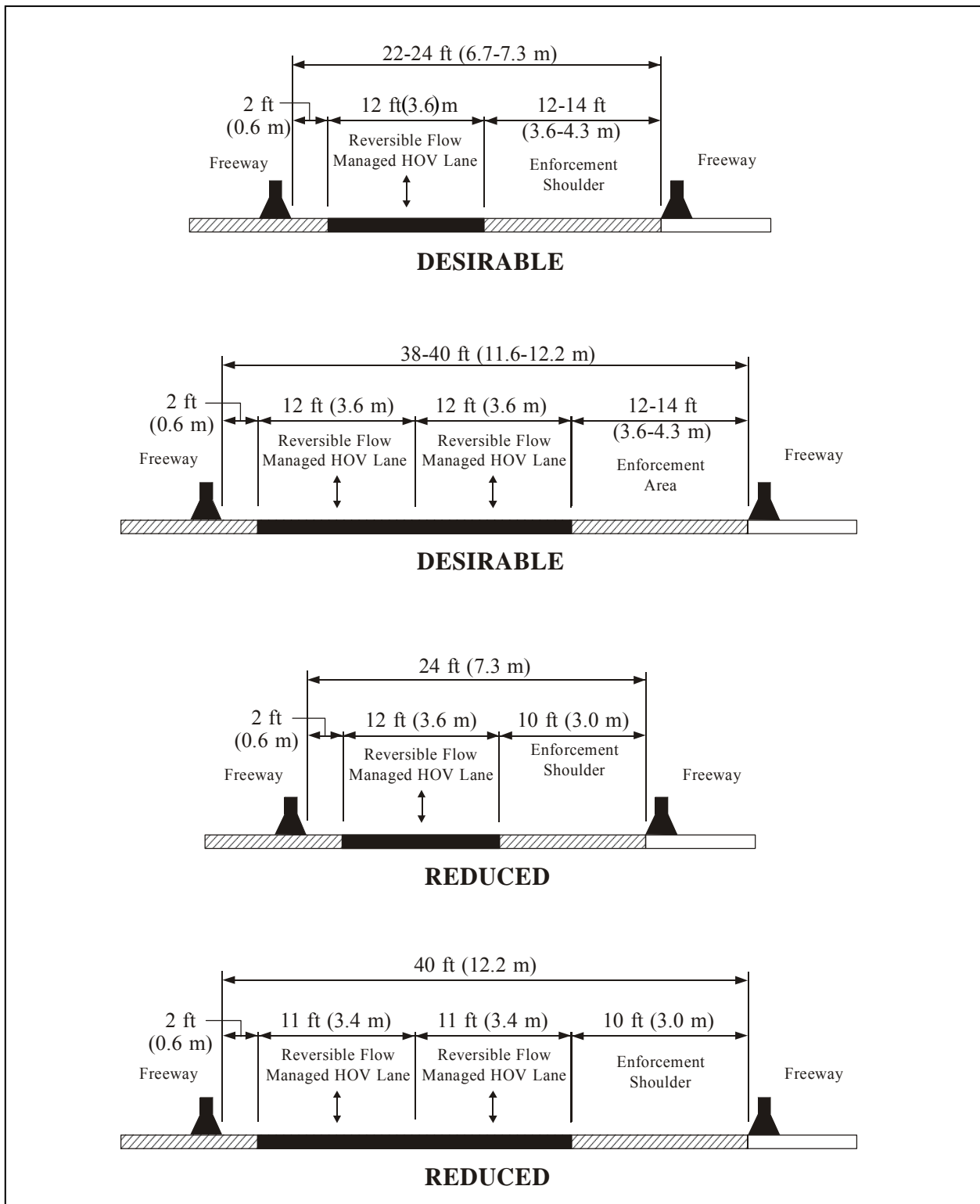


Figure 10-1. Examples of Cross Sections of Enforcement Areas along a Reversible Barrier-Separated Managed Lanes (Adapted from 1).

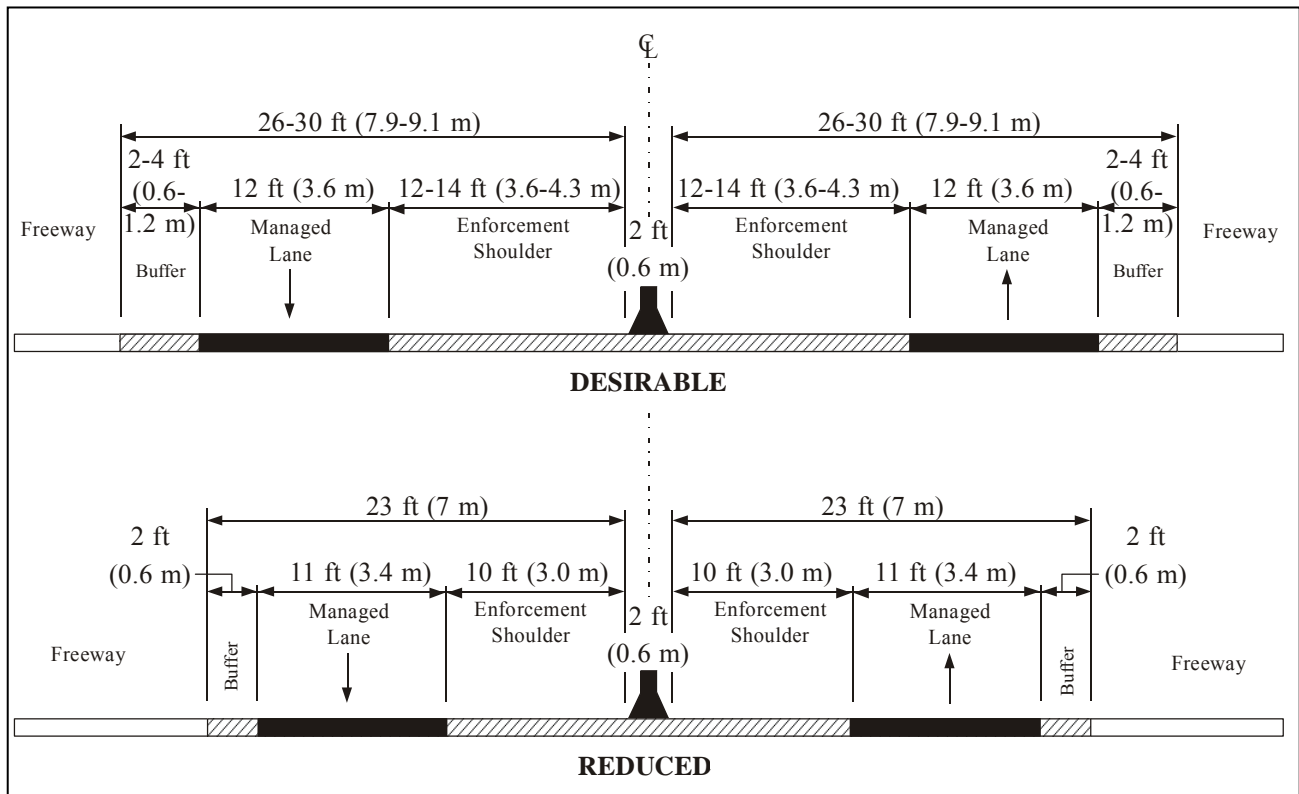


Figure 10-2. Examples of Cross Sections for Enforcement Areas along Concurrent-Flow and Exclusive Buffer-Separated Managed Lanes (Adapted from 1).

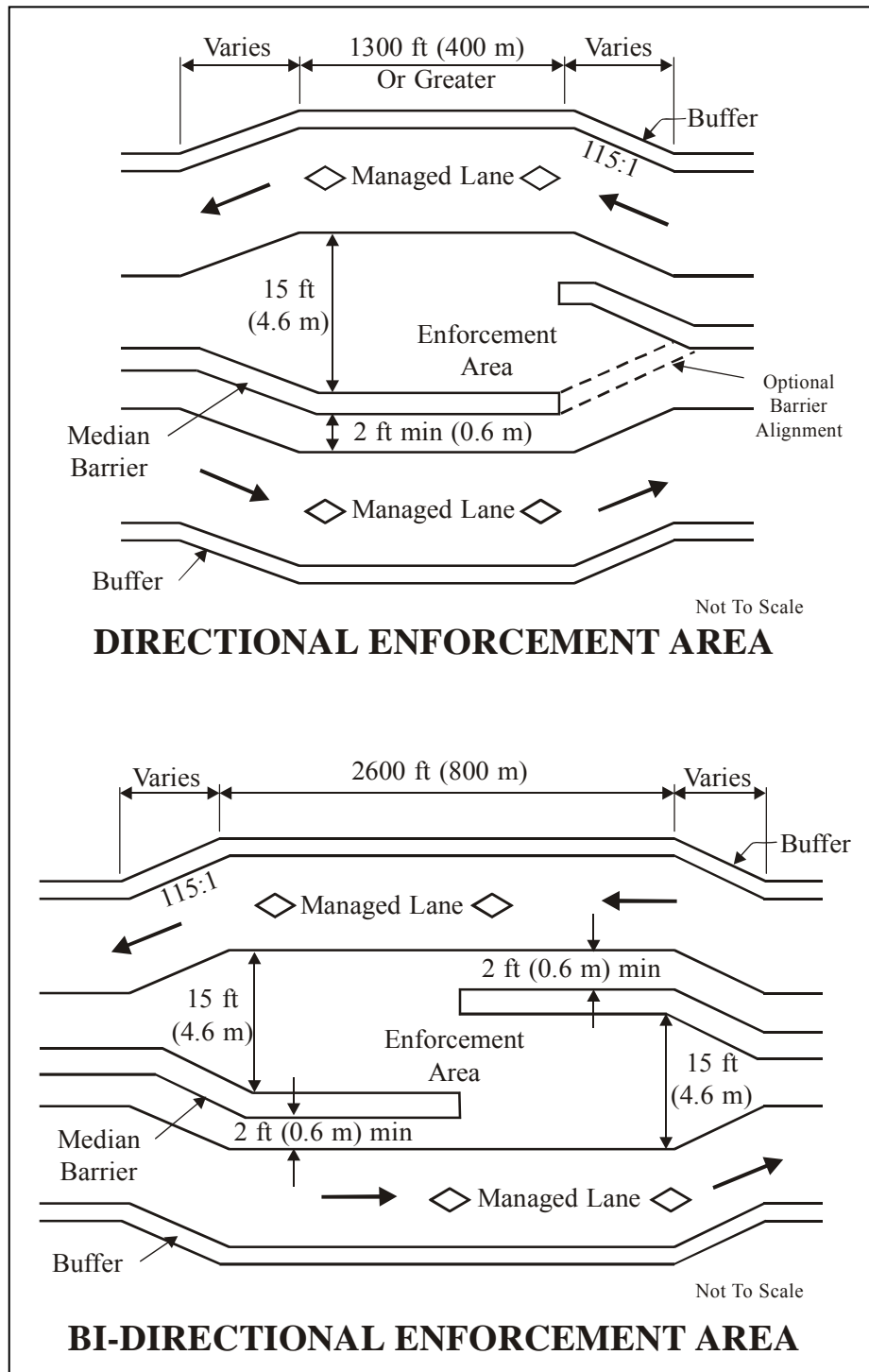


Figure 10-3. Examples of Directional and Bi-directional Enforcement Area Layouts (Adapted from *I*).

Three types of HOV lanes are commonly found on freeways and on a variety of different operations and approaches. These are exclusive HOV lanes, concurrent-flow HOV lanes, and contraflow HOV lanes. In addition, exclusive HOV lanes can be either bi-directional or reversible. The following subsections describe the characteristics of the various HOV treatments (1).

Exclusive HOV Facility

An exclusive HOV facility is a facility or lanes built within the freeway right-of-way that are physically separated from the general-purpose freeway lanes and are used exclusively by HOVs for all or a portion of the day. Most of these facilities are physically separated from the general-purpose lanes through the use of concrete barriers; a few facilities are separated by a wide painted buffer, with or without traffic channelizer separation. These may be bi-directional or reversible (Figure 10-1). The latter type usually operates inbound toward the central business district and other major activity centers in the morning and outbound (i.e., the reverse direction) in the afternoon. Some type of daily setup (for reversing directions) is required with reversible facilities.

Contraflow Lane

A contraflow lane is a freeway lane in the off-peak direction of flow (typically the innermost lane) that is designated for exclusive use by HOVs traveling in the peak direction. Normally, the contraflow lane is “separated” from the off-peak (or opposite) flow by insertable cones, pylons (Figure 10-2), or movable concrete barriers. Contraflow lanes are usually operated during the peak periods only.

Concurrent-Flow Lane

A concurrent-flow lane is a freeway lane in the same direction of travel (normally the inside lane or shoulder) that is not physically separated from the other freeway lanes but is designated for exclusive use by HOVs for all or a portion of the day. Paint striping is a common means used to delineate these lanes (Figure 10-3).

Ensuring that buses, vanpools, and carpools can easily and safely merge into and out of the HOV lane is critical to the success of the facility. A variety of treatments can be used as summarized below:

- ◆ **Direct merge.** Used on concurrent-flow HOV lanes, this approach allows HOVs to merge directly into HOV lanes from adjacent general-purpose lanes. Merging can be continuous along the entire length or at specific designated points. Where designated, the access openings are usually regulated with signs and pavement markings in accordance with guidelines in the *MUTCD*.
- ◆ **Slip ramps.** The at-grade slip ramps are easy and inexpensive to build. An opening large enough for normal merge/diverge maneuvers is placed in the barrier. This type of ramp is usually from a park-and-ride lot to the frontage road, the freeway, or the HOV lane.

- ◆ **Direct access ramps.** Grade-separated or direct access ramps provide exclusive ingress and egress for HOVs. Further, direct ramps may provide access from adjacent roadways, park-and-ride lots, and transit stations.
- ◆ **Direct freeway-HOV-to-freeway-HOV connection.** These facilities provide direct connections from an HOV on one freeway to an HOV lane on another freeway.

In addition to the physical alternatives for ingress, there are operational strategies, including:

- ◆ **HOV bypass lanes at ramp meters.** This operational strategy is used to provide priority treatment to HOVs at metered ramps. Typically, a separate lane is provided adjacent to the general-purpose lane(s) for HOVs so that they do not have to stop at the ramp meter signal, but rather move around the ramp queue and directly enter the freeway. In some systems, the HOV ramp lanes are also metered but at a relaxed rate relative to the general-purpose ramp lanes, still providing time savings.
- ◆ **Priority pricing.** Priority pricing is a variation of congestion pricing that allows non-HOVs to use HOT lanes for a charge. HOT lanes are discussed in [Section 2 of Chapter 9](#).

Barriers and Enforcement

Enforcement of two-way and reversible barrier-separated managed lanes facilities is considered easier than enforcement of buffer-separated lanes due to limited access points. Violators may be stopped at entry and exit points where travel speeds are usually lower. A reversible facility allows enforcement personnel to monitor the facility from ramps that are not in use due to managed lanes traffic moving in the opposing direction.

Non-barrier managed lanes are the most difficult to enforce due to motorists' ability to enter and exit the lane at any time with relative ease. The maneuver is as simple as moving from one lane to another. Therefore, routine and consistent enforcement, whether perceived or seen by the public, is critical to managing lane violations. [Figure 10-1](#) provides examples of cross sections for enforcement along reversible barrier-separated managed lanes.

Section 4 – Automated Enforcement Technology

The role of technology for managed lanes enforcement is growing at an ever-increasing rate. For many years, ITS technologies have been available for use in monitoring roadways as part of various TDM programs. Early detection and quick response times have been vital for incident management and effective use of emergency services. Such advances are the precursor for the use of technology in monitoring and enforcement of managed lanes facilities.

Automated enforcement of managed lanes may use many of the same technologies as ITS including speed sensors, road-imbedded vehicle detectors, surveillance cameras, and centralized traffic management centers. Successful enforcement of managed lanes facilities requires that enforcing agencies have the ability to identify specific vehicles and, when necessary, determine the number of vehicle occupants. This success is possible through innovations such as license plate recognition and video-imaging technologies. This technology is used widely for automated enforcement of managed lanes facilities that assess tolls. Toll collection is usually done with electronic transponders or manual toll payments. When a toll violation occurs, the low power radio (LPR) system is activated. A violator's license plate number may be stored locally, or it may be transmitted to a management center via standard dial-up telephone lines, cellular links, radio transmitters, and Ethernet networks.

Technology also exists for determining compliance with vehicle occupancy requirements on HOV/HOT lanes. HOT lane facilities allow vehicles not meeting the occupancy requirement to use the facility for a fee. Enforcement requires observation of the interior of vehicles for the appropriate number of occupants. A typical strategy for this includes installing three or more cameras with artificial lighting sources to capture the front windshield image, the side window image, and the rear license plate image. The semi-automatic review process notes when a violation has occurred and electronically saves the images of the vehicle's interior along with the license plate information for later use in violation processing. A semi-automated HOV enforcement and review system, known as HOVER, has been tested in Dallas, Texas, using the strategy discussed above.

The previous discussion provided a general overview of some uses of technology within a managed lanes environment for the purpose of enforcement. Actual application of enforcement products requires an understanding of the technology categories and the viability of particular product name brands, which are available from various vendors around the world. Managed lanes enforcement technology includes such categories as AVI systems, electronic toll collection systems (ETC), LPR systems, and video occupancy enforcement.

Section 5 – Enforcement Considerations in Operations

Enforcement is critical to the successful operation of an HOV facility. The role of an HOV lane enforcement program is to ensure that operating requirements, including vehicle occupancy levels, are maintained to protect eligible vehicles' travel time savings, to discourage unauthorized vehicles, and to maintain a safe operating environment. Visible and effective enforcement maintains the integrity of the HOV facility and can promote public acceptance.

Enforcement strategies for HOV facilities can generally be categorized into four basic approaches: routine enforcement, special enforcement, selective enforcement, and self-enforcement. All of these strategies may be appropriate for consideration with the various types of HOV projects, and the most effective approaches and techniques will vary somewhat for different types of facilities. To some extent, the level of relative priority assigned by the enforcement agency to the HOV enforcement program is usually indicated by the type of enforcement strategy selected.

Enforcement Approaches

The following sections discuss the four basic enforcement approaches agencies can consider using for a managed lanes facility.

Routine Enforcement

Routine enforcement represents the normal level of police patrols in an area, irrespective of the presence of an HOV facility. Under a routine enforcement approach, the existence of an HOV project does not significantly alter the enforcement agency's priorities, financing requirements, tactics, or objectives. Police officers assigned to patrol zones containing HOV facilities are typically permitted wide discretion in the degree to which they enforce HOV lane restrictions. The result is often an unequal or random distribution of enforcement effort. This inconsistency in enforcement can be reduced, provided that police management takes steps through policy pronouncements to inform its personnel of the importance of aggressive enforcement activity. Generally, routine enforcement may be an appropriate strategy if:

- ◆ an HOV facility has become well established and the violation rate is at a low or locally accepted level;
- ◆ the design or operation of an HOV facility makes it relatively easy to monitor; or
- ◆ resources are not available to fund other approaches, leaving routine enforcement as the only alternative available.

The initiative to provide an adequate level of enforcement to the HOV project may be absent within the structure of the enforcement agency due to concerns over unsafe vehicle movements associated with the HOV enforcement process (detection, apprehension, and issuance of the citation). A contributing factor to this tendency may

also be the relative exclusion of the enforcement agency from participation in the planning stages of the project, thereby removing a valuable source of information critical to the “enforceability” of the HOV project during its design phase.

Special Enforcement

Special enforcement is characterized by continuing, systematic manpower allocations and enforcement tactics specifically dedicated to enforce HOV violations. A special enforcement strategy is appropriately employed when the need for HOV enforcement is great. Approaches may include assigning a patrol car specifically to an HOV lane, adding extra patrols in a corridor with an HOV facility, or locating enforcement personnel along a facility during all operating hours. Special enforcement activities may be accomplished by reallocating existing personnel, hiring additional enforcement during key operating periods, or utilizing existing personnel on an overtime basis.

Selective Enforcement

The overall purpose of a selective enforcement strategy is to induce a high level of motorist compliance by applying routine and special enforcement strategies in an unscheduled manner, thereby not allowing motorists to predict when enforcement will occur. Selective enforcement is usually applied periodically to specific problem areas where violations of the HOV facility have been observed. Selective enforcement may also be undertaken in response to a number of different events, such as the opening of a new HOV facility, increasing facility vehicle-occupancy requirements, extending operating hours, or making other significant operating changes. Since the special enforcement activity in a selective enforcement program is of a temporary nature, the extra enforcement personnel is generally made available by a reassignment of manpower from other duties.

Self-Enforcement

This strategy involves self-regulation by HOV lane users and motorists in the general-purpose lanes. Self-enforcement is usually used with other approaches, rather than as the only enforcement strategy. The HERO program provides the best example of a self-policing HOV enforcement effort. This approach was first developed in Seattle and has subsequently been used in other areas including Houston and the northern Virginia/Washington, D.C., region. The tracking of repeat violators and the active participation by enforcement agencies in the notification process are some of the key features contributing to the success of the program. An example of the HERO program sign is shown in [Figure 10-4](#).



Figure 10-4. HERO Sign on HOV Facilities in Seattle, Washington.

Enforcement Techniques and Tactics

A variety of enforcement techniques can be used to monitor HOV facilities to enhance compliance. These techniques focus on providing surveillance of the lanes, detecting and apprehending violators, and issuing citations or warnings to violators. The following subsections describe each technique, and [Table 10-1](#) provides a comparison of their relative operational merits and drawbacks.

Stationary Enforcement Patrols

Stationary patrols involve the assignment of enforcement personnel at specific locations along an HOV facility. These locations may be dedicated enforcement areas or locations that provide the necessary vantage points and space for enforcement personnel. This technique is normally associated with either special or selective enforcement strategies and would be most appropriately located at entry/exit points to the HOV lane or locations experiencing a high number of HOV violations. Enforcement areas should provide adequate space and a safe environment for enforcement personnel to perform all necessary duties. These duties include monitoring the facility, pursuing a violator, and stopping the violator to issue a citation.

Roving Enforcement Patrols

This technique involves enforcement vehicles patrolling the length of the HOV facility. Marked or unmarked patrol cars or motorcycles may operate either on the HOV facility or on the adjacent freeway. Further, patrols may cover the total facility, or they may be assigned to specific segments or zones, provided that a safe area for apprehension and citation exists.

Team Patrols

This technique uses various combinations of stationary and roving patrols working in unison to monitor an HOV facility and to apprehend violators. Potential combinations may include multiple stationary patrols, multiple roving patrols, or a combination of

stationary and roving patrols. The team approach is generally utilized on HOV projects when it is impossible, or considered unsafe, for a single officer to detect and apprehend a violator. In this case, one officer detects the HOV violation and subsequently informs another officer stationed downstream for the purpose of apprehension.

Table 10-1. Comparison of Selected Enforcement Techniques.

Enforcement Technique	Advantages	Disadvantages
Stationary Enforcement Patrols	<ul style="list-style-type: none"> • Time efficient (no pursuit required) • High degree of safety with sufficient lane cross sections • Highly visible enforcement presence • Effective for monitoring and surveillance 	<ul style="list-style-type: none"> • Requires diversion of personnel or additional personnel • Limited locations • Enforcement locations may be circumvented by motorists on facilities with many access points
Roving Enforcement Patrols	<ul style="list-style-type: none"> • Operate anywhere on the HOV facility • Does not require reallocation of personnel 	<ul style="list-style-type: none"> • Greater apprehension times • Disruptive if shoulder/refuge areas not available • Less favorable vantage point for observation
Team Patrols	<ul style="list-style-type: none"> • Divides the detection and apprehension tasks • Offers greater flexibility for facilities with non-optimal design elements 	<ul style="list-style-type: none"> • Requires twice the personnel per apprehension • Not supported in jurisdictions where apprehending officer must also witness the violation
Electronic Monitoring	<ul style="list-style-type: none"> • Minimal or no enforcement presence • Unobtrusive 	<ul style="list-style-type: none"> • Current technology is less reliable than visual inspection
Citations or Warnings by Mail	<ul style="list-style-type: none"> • Greater safety since violators do not have to be apprehended • Requires a smaller refuge area • Highly time efficient 	<ul style="list-style-type: none"> • Currently not supported in law without apprehension of violator • Officer cannot conclusively verify occupancy – greater possibility of error

Electronic Monitoring

Electronic and other advanced technologies may be used to help monitor an HOV facility and to assist in detecting violators. Closed circuit television cameras (CCTV), infrared cameras, photographs of vehicles and license plates, and other technologies may help identify potential violators. Current technologies have yet to surmount the considerable

difficulties inherent to vehicle occupancy detection, and no HOV facilities in the United States employ this technique. Electronic monitoring is gaining increasingly widespread use for HOT operations.

Citations or Warnings by Mail

If the legal authority exists, enforcement personnel may be able to issue warnings or citations by mail, eliminating the necessity of stopping a vehicle violating the HOV requirement. The violators may be observed by police officers on the spot or with the aid of cameras and other advanced technologies. Another variant of this technique is the previously discussed HERO program, where warnings and/or program information is mailed to violators.

Multipurpose Patrols

Though not included in [Table 10-1](#), this technique utilizes patrols or personnel that are assigned multiple functions, including HOV lane enforcement. Responsibilities of these groups may include incident detection and response, operation of the HOV facility, general policing, and enforcement.

Enforcement and HOV Operations

An enforcement program can be considered successful if compliance rates on an HOV facility are within the established goals and if the enforcement function is accomplished in a safe and a cost-effective manner. To accomplish these objectives, the most appropriate enforcement techniques should be used with the various types of HOV facilities. Although no one enforcement technique equates specifically to one type of HOV facility, some approaches may be more appropriate for consideration with certain HOV projects. In addition, most areas use more than one technique.

Irrespective of the particular strategies or techniques employed, certain general practices have been shown to enhance the effectiveness and safety of enforcement activities.

Maintain a Visible Enforcement Presence

Enforcement efforts have a greater deterrent effect if they are visible to other motorists. Police personnel should conduct apprehensions and issue citations in designated enforcement areas adjacent to the HOV lane. HOV violators should not be removed to other areas of the freeway for ticketing unless there is no room along the facility for safe conduct of these activities.

Use Minimally Intrusive Enforcement Techniques

Although visible enforcement is desirable, heavy enforcement can be disruptive to traffic since it usually induces rubbernecking. The California Highway Patrol has been a leader in practicing non-intrusive enforcement techniques and recommends that officers:

- ◆ reduce the use of emergency lighting during traffic stops,
- ◆ avoid multiple patrol vehicles at one location,
- ◆ have no more than one car waiting to be ticketed at any time,
- ◆ do not stand outside the vehicle, and
- ◆ for concurrent-flow lanes, release violators cited in the median back into the HOV lane.

Tactics and Facility Types

The strategies and techniques currently in use with different types of HOV facilities are summarized in the following subsections, along with some of the issues that may need to be considered in developing enforcement programs for various types of HOV lanes.

Table 10-2 highlights the enforcement strategies and techniques commonly found with various types of HOV facilities.

Table 10-2. Examples of Enforcement Techniques Commonly Found with Various Types of HOV Facilities.

HOV Facility	Enforcement Strategies and Techniques
Barrier Separated	<ul style="list-style-type: none"> • Stationary patrol at beginning or end of lane • Team patrols • Multipurpose patrols • Self-enforcement
Concurrent Flow	<ul style="list-style-type: none"> • Stationary patrols at enforcement enclaves • Roving enforcement • Team patrols • Multipurpose patrols • Self-enforcement
Contraflow	<ul style="list-style-type: none"> • Stationary patrols at beginning or end of lane • Multipurpose patrols • Self-enforcement
Queue Bypass	<ul style="list-style-type: none"> • Stationary patrols at ramp entrance • Self-enforcement

Barrier-Separated HOV Facilities

Barrier-separated HOV facilities are easier to enforce due to limited ingress and egress and the physical separation from the general-purpose lanes. Stationary patrols, team

patrols, and multipurpose patrols may all be appropriate for consideration with exclusive HOV lanes. Enforcement areas can be provided at direct access ramps and at the beginning and end of a facility. The use of team enforcement, with one officer located at the beginning or mid-point of a facility radioing information on violators to an officer at the end of the facility where the apprehension takes place, can be an effective technique.

Concurrent-Flow HOV Facilities

These types of HOV lanes are the most difficult to enforce because violators are able to enter and exit at almost any time throughout the length of the facility. As a result, concurrent-flow HOV lanes require extra consideration and increased enforcement. Without an effective enforcement plan, buffer-separated facilities may be susceptible to high violation rates. Selective enforcement using roving and team patrols, in combination with standard apprehension and citation procedures, is used with many concurrent-flow facilities. Ensuring that safe and adequate enforcement areas are provided is also critical with this type of facility.

Contraflow HOV Facilities

Contraflow HOV lanes are often easier to enforce because of limited access – often just a single entrance and exit – and because of limited vehicle eligibility criteria. Enforcement personnel are usually stationed at the beginning and/or end of a lane, and violators can be stopped at these points. To maintain safety for this type of operation, it is very important to stop and remove any errant motorists who inadvertently enter the facility. This necessitates continuous monitoring at the entrance and some means of redirecting ineligible users back into the general-purpose traffic stream. Enforcement of contraflow facilities can be further enhanced with the incorporation of a rejection lane at the entrance to the facility. The rejection lane enables enforcement personnel to apply stationary strategies and procedures to maintain compliance.

Queue Bypasses

Techniques for enforcing queue bypasses are limited to a stationary enforcement area. Violations mainly occur where there is a clear view of the ramp, and therefore, violators are able to tell if enforcement activities are taking place. Enforcement may be made more unobtrusive and effective by screening enforcement vehicles from the view of oncoming motorists.

Section 6 – References

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Section 1 – Overview

Much has been documented regarding traffic incident management for general-purpose lanes on controlled-access highways. Incident management for general-purpose lanes and for managed lanes has many of the same goals; consequently, many of the techniques, policies, and procedures are the same for facilities of both categories.

Among the various principles for incident management for general-purpose facilities, perhaps the most important is the development, and maintenance, of relationships between key individuals from each of the involved agencies. While it may not be uncommon for the heads of agencies (e.g., local and state law enforcement, local and state transportation departments, transit agency, etc.) to meet periodically during the normal course of events, this type of interaction cannot take the place of familiarity and healthy working relationships among operations staff members from these and other critical agencies. In addition to working relationships, another characteristic of successful incident management programs is the use of various types of agreements, including mutual-aid agreements, hold-harmless agreements, wreckage clearance policies, etc.

These and various other elements of incident management programs are common to operations that successfully minimize non-recurring congestion due to freeway incidents in general-purpose lanes. These elements are also common to incident management programs for managed lanes facilities. However, the unique features of various types of managed lanes introduce additional aspects to incident management.

Many incident management tools for general-purpose lanes apply to incidents in managed lanes as well. Among these are the use of ITS incident detection and verification technologies; the use of dynamic message signs, highway advisory radio, and other means of motorist communication; team building and relationships among multiple agency personnel; etc.

However, a number of these tools have different impacts for facilities with managed lanes. They include:

- ◆ impact on managed lanes of public notification of incidents,
- ◆ incident responder access path to the incident scene,
- ◆ impact of adjacent roadway incidents to managed lanes operations,
- ◆ general-purpose traffic diversion into managed lanes,
- ◆ pre-positioned response crews,
- ◆ blocking a managed lane to create a safe work area, and
- ◆ mutual aid agreements between managed lane agencies and general-purpose lane agencies.

Sections in this chapter cover:

- ◆ incident management overview,
- ◆ multi-agency cooperation,
- ◆ public notification of an incident,
- ◆ pre-positioned response vehicles,
- ◆ creation of a safe work area,
- ◆ response vehicle access, and
- ◆ diversion into managed lanes.

Section 2 – Incident Management Overview

FHWA’s *Traffic Incident Management Handbook* (1) addresses the wide range of issues involved in incident management, including the steps of incident detection, verification, motorist communication, response, site management, traffic management, and clearance. In addition, the handbook identifies the steps in developing an incident management program, the characteristics of a successful program, and the benefits that accrue to the public. While the handbook thoroughly addresses incident management for general applications, it does not address the special incident management elements associated with managed lanes facilities.

A review of HOV lane and HOT lane facilities is included in a study for the Minnesota Department of Transportation (2). The study indicates that different managed lanes operators throughout the nation have incident management plans that allow for the diversion of general-purpose traffic into the managed lanes in response to an incident in the general-purpose lanes. However, there is variation in the incident duration that should serve as the trigger for the diversion plan. Virginia legislators had recommended a five-minute trigger for allowing diversion into the HOV lanes in Hampton Roads, Virginia; however, after the FHWA rejected the recommendation, Virginia later settled on a 10-minute trigger. The recommendation is that the incident duration trigger be established on a case-by-case basis.

The California Department of Transportation’s *High-Occupancy Vehicle Guidelines for Planning, Design and Operations* (3) acknowledges that when a managed lane is not barrier separated from the general-purpose lanes and an incident occurs in the managed lane, traffic frequently merges into the general-purpose lanes. In this situation, Caltrans recommends against designating one of the general-purpose lanes as a temporary HOV lane. When the incident is in the general-purpose lanes, Caltrans and the California Highway Patrol (CHP) jointly determine if the general-purpose traffic is allowed to divert into the HOV lanes.

On HOV lanes that are barrier separated from the general-purpose lanes, Caltrans recommends diverting managed lanes traffic into the general-purpose lanes when the incident blocks the managed lane. A major incident that blocks multiple general-purpose lanes may shift general-purpose traffic into the managed lane. Caltrans recommends caution in diverting traffic in this situation, especially if the HOV lane is reversible.

Washington State Department of Transportation (WSDOT) (4) reports in its review of HOV lane operating policies that the Virginia Department of Transportation estimated an average time saving of approximately four minutes per vehicle resulting from its policy of diverting general-purpose traffic into the HOV lane during incidents in the general-purpose lanes.

WSDOT also noted that most of the managed lanes facilities where diversion policies are in place “are barrier separated or reversible, in some cases both.”

Hoppers (5) reports on incident-induced diversion policies from six different regions of the nation and offers guidelines on the development of a diversion plan. The guidelines recognize the importance of multi-agency cooperation, coordination with the media, public acceptance of a diversion plan, and its impact on managed lanes motorists.

Incident diversion is thoroughly addressed in *NCHRP Synthesis 279: Roadway Incident Diversion Practices* (6). It presents the processes, hindrances, and technological tools that are associated with diversion plans. However, the context of the report is not specifically for facilities with managed lanes. The report does acknowledge that agencies with toll lanes and/or HOV lanes do lift user eligibility criteria when deploying the incident management program's diversion plan.

The FHWA's *A Guide for HOT Lane Development* (7) specifies two major reasons why incident management is critical for HOT lanes:

1. Because motorists pay a fee to use this type of managed lane, it is critical that incidents be cleared as soon as possible so that the duration of the incident is minimized and the fee-paying motorists/customers can more quickly return to receiving value for which they paid.
2. Since HOT lanes are typically barrier separated, an incident can often completely block traffic, thereby creating heightened anxieties among motorists who have come to a standstill.

For these reasons, the guide strongly recommends that HOT lanes be equipped with incident detection and surveillance equipment and that the facility be monitored at all times. Additionally, its recommendation explicitly calls for this equipment to be monitored by "observant staff."

Other recommendations include appropriate training for all staff involved in HOT lane incident response, including drills and training exercises. In addition, the guide reports that "tow trucks and other rescue vehicles are typically brought in from the opposite direction of traffic if the lanes are completely blocked."

The guide also adds recommendations for incident management in the HOT lane when there is construction at or near the incident scene:

- ◆ implement 24-hour service patrols in the construction zone;
- ◆ create temporary collision investigation/enforcement sites within the construction zone;
- ◆ establish the construction zone as an immediate tow area;
- ◆ develop agreements with construction companies to use their heavy equipment to assist in clearance of debris from truck accidents;

- ◆ identify landing locations for medical response helicopters near the construction zone;
- ◆ offer presentations to key stakeholders such as the trucking industry, major employers, and automobile clubs before construction starts; and
- ◆ install surveillance throughout the construction area to detect an incident and monitor traffic flows.

The San Diego Association of Governments (SANDAG) (8) reports, in its traffic operations plan for the Interstate 15 Managed Lanes Value Pricing Project, that the traffic detection, surveillance, and communications components that were originally intended for traffic management and toll collection can be integrated into the facility's incident management system. For example, the DMSs that were intended for communications regarding electronic tolls can also display incident-related messages to motorists. The SANDAG report also notes that the DMSs can be used in communicating messages regarding diversion of traffic between the HOT lanes and the general-purpose lanes.

Benefits of incident management–related design elements in the SANDAG report are as follows:

- ◆ Numerous ingress/egress points throughout the roadway will facilitate the diversion of traffic between the managed lanes and the general-purpose lanes.
- ◆ These access points will also enhance incident response vehicles' ability to quickly arrive and depart from an incident scene.
- ◆ The number of DMSs required for tolling would be increased to meet the needs of both the tolling and incident management goals.
- ◆ The CCTV cameras that are required for electronic tolling purposes are also useful for incident detection and verification.

Challenges of the incident management program for Interstate 15 in San Diego include the following:

- ◆ Where the HOT or toll lane is a single-lane configuration, an incident could completely block the lane and the shoulders, thereby creating a standstill in the managed lane. A blockage of this type may require pre-positioned service support vehicles to expedite the management of the incident and the clearance of the blockage.
- ◆ To facilitate mobility during an incident in a barrier-separated managed lane, additional width for shoulders is desirable; however, available right-of-way and cost can limit shoulder width.

Section 3 – Multi-agency Cooperation

As indicated previously, good incident management practices for non-managed lanes facilities include cooperation among the various agencies involved in all aspects of incident management. Among these participants are state departments of transportation, state and/or local law enforcement departments, local transportation departments, transit authority, fire departments, emergency medical services departments, medical examiner's office, towing contractors, etc. Incident management, as applied to managed lanes, requires as much or more cooperation as that for non-managed lanes facilities.

Where the makeup of the incident response team for the managed lanes is different from that of the nearby general-purpose lanes, the potential for poor incident management is heightened. For example, where an incident on, or immediately upstream of, the ramp to the managed lanes is within the purview of an incident response team that does not have jurisdiction over the managed lanes themselves, the operational efficiency of the managed lanes can suffer; yet the incident response team that is handling the incident may have no accountability to the agency operating the managed lanes. This scenario has financial implications for managed lanes where revenues are generated, e.g., HOT and toll lanes.

Conversely, where an incident in the managed lanes impedes access to the general-purpose lanes or frontage road, and the incident response teams differ for the two types of lanes, there is potential for the operations of the general-purpose lanes to suffer by the actions of a team that has no accountability for traffic operations in those lanes.

Where one law enforcement agency has responsibility for traffic laws and incident management, and yet another law enforcement agency has responsibility for managed lanes eligibility violations, there is potential for inefficiency and poor incident management when an incident occurs in the presence of the wrong law enforcement staff.

Ideally, the incident response team roles (e.g., police, fire, emergency medical services, traffic operations, etc.) for the managed lanes team are filled by the same agencies as those for the general-purpose lanes; however, because different agencies can have different goals, this is not always the case. In these circumstances, the negative potentials within these scenarios can be mitigated through multi-agency cooperation that includes mutual-aid agreements, hold-harmless agreements, quick clearance policies, abandoned vehicle policies, post-incident briefings, shared information, etc.

Section 4 – Public Notification of an Incident

Various traffic incident management programs use differing arrays of technologies to notify motorists of an incident. To communicate with motorists who are moments away from the incident, these technologies include fixed and portable dynamic message signing at upstream location(s) and on-site incident response personnel. In addition to these motorists, it is important to notify others who may be miles away, and perhaps not yet in a vehicle, of the presence of the incident so that they can plan alternate routes or even alternate departure times. For these motorists, additional notification technologies include AM/FM radio and television traffic reports as well as website reports.

Sometimes public notification of the clearance of the incident does not happen as rapidly as the notification of the onset of the incident. This delay or omission is likely due to a presumption that the clearance notification is less critical. However, the likelihood that a motorist will choose to use the managed lanes can be significantly reduced if the website and media report that the managed lanes are congested due to an incident in those lanes. Continued reporting of this message *after* the incident has been cleared reduces the usage of the managed lanes. In cases where the managed lanes are toll or HOT lanes, the erroneous continuation of an incident report, after it has cleared, can unnecessarily create adverse impacts on revenues. This result is in addition to the congestion implications of managed lanes—eligible motorists electing to forego the managed lanes option and choosing to join the congested general-purpose lanes.

Therefore, it is recommended that communications to the public regarding the clearance of an incident in the managed lanes be delivered quickly, just as with messages regarding the beginning of the incident. As with incident management for non-managed lanes, incident management for managed lanes should include coordinating statements to the media through a designated incident response team member, e.g., state department of transportation public information officer. In addition, this designated public information officer should provide regular briefings to other incident response team agencies.

Section 5 – Pre-positioned Response Vehicles

Many incident response teams on non-managed lanes facilities use contracted towing companies to clear wreckage from the scene where involved vehicles have become inoperable. The expense of pre-positioning tow trucks at strategically selected locations throughout the corridor is deemed prohibitive.

However, this expense may be worth considering for managed lanes facilities that generate revenue. Depending on the specific financial details of a managed lanes facility, it may be that the cost of pre-positioning tow trucks, or other response vehicles, is offset by the more rapid response to an incident. If the incident is cleared more quickly and the incident-induced congestion is thereby minimized, then potential toll-paying motorists may choose to use the HOT or toll lane more often. The consideration of deploying pre-positioned tow trucks is an issue of travel time reliability and the resultant beneficial impact on toll revenues.

Section 6 – Creating a Safe Work Area

When incident response teams arrive at a scene where a one-lane incident is sufficiently severe, it may require that a second lane be closed to create a safe work area in which the team can maneuver. Where this situation occurs on a facility that includes a non-barrier-separated managed lane, e.g., a concurrent-flow HOV lane, and the one-lane incident occurs in the general-purpose lane immediately adjacent to the managed lane, a question arises regarding which lane should serve as the second closed lane for the incident response team.

If the managed lane is closed (see [Figure 11-1](#)) to create the safe work area, then the managed lanes traffic must merge to the right, into the general-purpose lanes. This channelization temporarily eliminates the benefits of the managed lane, and it may involve the merging of traffic from a lane operating at higher speeds into lanes operating at lower speeds. The result offers the possibility of secondary collisions.

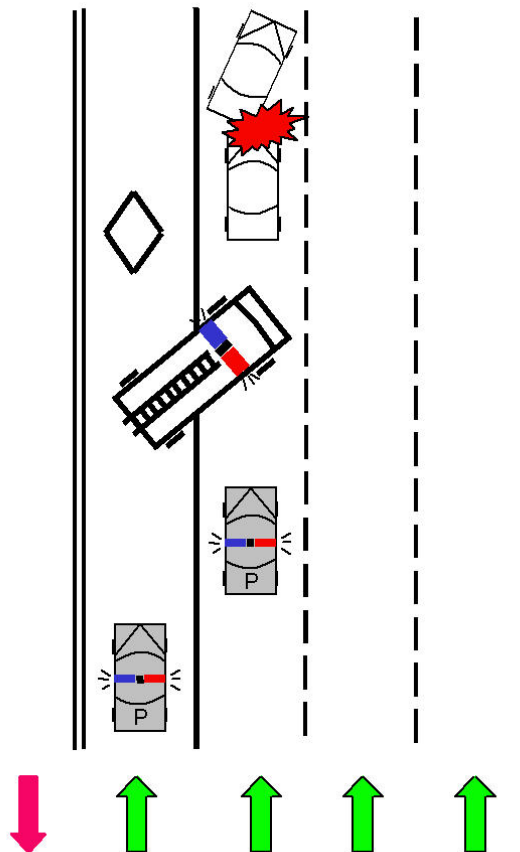


Figure 11-1. “Safe Work Area” Blocking Managed Lane (9).

The alternative is to keep the managed lane open and close the lane to the right of the incident lane, as illustrated in [Figure 11-2](#). This channelization results in the “safe work area” being a temporary island with moving traffic on both the right and left sides of the incident scene. Incident response teams report that the island concept should be avoided for the safety of everyone involved at the scene.

Both of these scenarios have shortcomings. This issue may be one for which additional research may be beneficial.

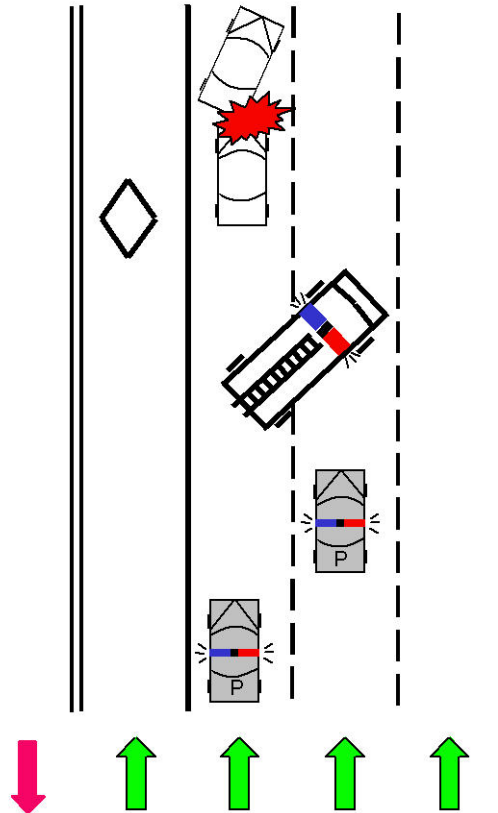


Figure 11-2. “Safe Work Area” as an Island (9).

Section 7 – Response Vehicle Access

Where managed lanes are separated from general-purpose lanes by a barrier, access to an incident, when congestion levels are high and speeds are slow, can be achieved via traveling on the shoulders. Where the best route to an incident scene is via the lanes on the opposite side of the barrier from the incident, emergency response vehicles can benefit by the use of emergency access points in the barrier.

Discussions with incident response team personnel argue against directing response vehicles to travel in a contraflow direction in a managed lane even when it is one lane, barrier separated, and completely blocked. Opposition to response vehicle contraflow is based on the high cost (head-on secondary collision) of making an error in reporting that the lane downstream of the incident is clear for a “wrong way” approach. The time required to achieve a sufficient level of certainty may be too great for the contraflow approach to be worthwhile as a time saver. Consequently, unless the managed lane downstream of the complete blockage is absolutely devoid of other moving vehicles, it is recommended that incident response vehicles access the incident scene without traveling in a contraflow direction. The exception to this recommendation is the completely blocked, one-lane, barrier-separated facility that has excellent coverage by CCTV cameras and is actively monitored by traffic management center personnel. In this case, emergency vehicle contraflow access to an incident scene may be accomplished with a sufficient level of safety for the responders.

Section 8 – Diversion into Managed Lanes

The first recommendation regarding the diversion plan is that it be developed by all the relevant parties, including all the agencies on the incident response team. Typically this team should include the state department of transportation, state law enforcement, transit authority, incident response team, fire department, hazardous materials team, freeway service patrols, emergency medical services, local government traffic engineering, towing companies, medical examiner, the designated agency’s public information office, etc.

The diversion plan should provide for the elimination, or curtailment, of the usual managed lanes user eligibility criteria during incidents in the general-purpose lanes. These eligibility criteria include vehicle type restrictions, occupancy restrictions, and toll payments.

It is recommended that the diversion plan be deployed if an incident has blocked, or will block, traffic for a specified duration (e.g., 10, 15, or 30 minutes). One managed lanes facility operator reported that since they introduced a 10-minute minimum threshold, the managed lanes users have issued fewer complaints regarding sharing the lane with general-purpose traffic. Agencies report that once the general-purpose traffic is allowed to divert into the managed lanes, it is very difficult to “turn it off.” Consequently, the specific threshold should be selected based on facility experience. It may be necessary to select the minimum duration such that the frequency of diversion plan deployment is not so often as to motivate managed lanes motorists away from regularly using it.

Where the managed lane’s physical features and communications infrastructure can support it, it is recommended that the diversion of general-purpose traffic into the managed lane cease prior to its reaching an unacceptable congestion level.

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Chapter 12 – Interim Use during Construction, Special Events, and Emergencies

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Section 1 – Overview

Managed lanes will largely function under their intended standard operating procedures, derived from goals and objectives set earlier in the planning process. However, certain conditions, such as construction or maintenance activities, special events, major incidents, or emergencies, may require interim use of the facilities.

Historically, a lack of guidance has resulted in highly variable interim use practices, dependent on the configuration of the managed lane, severity of the conditions, judgment of the on-scene field personnel, and agency policy (1). In addition, these practices have occurred with little knowledge of the potential impacts, positive or negative, surrounding interim managed lanes use.

Because interim use of managed lanes may detract from the facilities' intended use and performance related to mobility and congestion, reliability, accessibility, safety, environmental impact, system preservation, or organizational efficiency, carefully crafted interim use policies, developed in the planning stages, should guide decisions for the short-term use of managed lanes. This chapter supports the development of interim use policies by providing guidance related to:

- ◆ considerations for interim use,
- ◆ interim use criteria,
- ◆ implementation requirements for interim use, and
- ◆ planning for interim use.

This chapter also describes various operational strategies and potential motivating conditions for managed lanes interim use.

Sections in this chapter cover:

- ◆ operational strategies for interim use,
- ◆ motivating conditions for interim use,
- ◆ considerations for interim use,
- ◆ planning for interim use,
- ◆ interim use criteria, and
- ◆ implementation requirements.

Section 2 – Operational Strategies for Interim Use

Managed lanes facilities rely on different operational strategies to keep traffic flowing during standard operation. These strategies include:

- ◆ time of day restrictions – allowing access to managed lanes at certain times of the day (i.e., peak hours);
- ◆ vehicle occupancy restrictions – allowing access to managed lanes by vehicles having a minimum defined person-occupancy (i.e., 2+ carpool, 3+ carpool);
- ◆ vehicle type restrictions – allowing access to managed lanes by certain types of vehicles (i.e., buses, trucks); and
- ◆ value pricing – allowing access to managed lanes by travelers who are willing to pay a fixed or variable toll, irrespective of vehicle occupancy or type restrictions.

These same strategies used to “manage” lanes may be modified or eliminated to provide for interim use of the facility. Specifically, common strategies that may be employed during managed lanes interim use include:

- ◆ suspension of restrictions and/or
- ◆ suspension of tolls.

Suspension of Restrictions

During unusual conditions, managed lanes may be opened to all traffic regardless of time of day, vehicle occupancy, or vehicle type restrictions. Several issues need to be examined when considering this option. Bottlenecks may form at the terminus of the managed lane, which may reduce capacity and offset any potential benefits. Confusion may result because not all motorists may be familiar with managed lanes facilities; public awareness prior to interim use is needed to ease confusion. The beginning and end of the managed lanes interim use period must be clearly defined and relayed to the motoring public so that the managed lane can return to standard operating procedures. Furthermore, dropping time of day, vehicle occupancy, or vehicle type limitations sets a precedent for similar actions in the future, which may compromise managed lanes compliance during standard operation and increase the need for enforcement (2, 3).

Suspension of Tolls

Either singularly or in combination with the suspension of time of day, vehicle occupancy, or vehicle type restrictions, tolls can be temporarily suspended during periods of interim use. Historically, agencies have suspended toll collection during emergencies to increase capacity and reduce bottlenecks created by the toll collection process. Automated toll collection technologies have largely addressed the potential for

bottlenecks at toll plazas, but this strategy still provides an alternative when no suitable alternative routes exist and motorists would be forced to pay tolls (2, 3).

To invoke this practice, cooperative agreements should be established with the toll authority prior to implementation. As with other restriction suspensions, temporary toll suspension sets a precedent for similar actions in the future and may result in motorist pressure to suspend tolls when conditions do not warrant such action.

Section 3 – Motivating Conditions for Interim Use

Although managed lanes facilities will largely function under their intended standard operating procedures, certain conditions may require unusual interim use of the facilities. Such conditions may include:

- ◆ construction or maintenance activities that result in either a long-term reduction in capacity or a severe, short-term reduction in capacity;
- ◆ special events that result in a severe, short-term increase in traffic demand;
- ◆ major incidents that result in either a long-term reduction in capacity or a severe, short-term reduction in capacity; and
- ◆ large-scale emergencies and evacuation that results in either a long-term or severe, short-term increase in traffic demand.

Other conditions may warrant consideration of managed lanes interim use. Only these four categorical conditions are considered here.

Construction or Maintenance

Construction or maintenance activities can result in either a long-term reduction or a severe, short-term reduction in capacity, depending on the project characteristics and constraints. Variability in project scope and anticipated duration, general-purpose and managed lanes facility size and characteristics, site constraints, agency policies regarding contracting and construction (i.e., night paving), technological sophistication for monitoring traffic, etc. challenge the provision of guidance for managed lanes interim use during construction or maintenance. Most generally, managed lanes facilities can be opened to general-purpose traffic (i.e., no restrictions or tolls) to accommodate the existing traffic demand under capacity constraints, or can provide a staging and/or work area for construction equipment and resources that would otherwise occupy a general-purpose lane.

Special Events

The National Highway Institute (4) defines a special event as an occurrence that “abnormally increases traffic demand” (unlike construction or maintenance activities or incidents that typically restrict the roadway capacity). Under this definition, special events may include such things as sporting events, parades, fairs, and other planned events. This increase in traffic demand is usually short term, except for significant special events such as the international Olympic Games, but may be severe regardless of duration. To accommodate the increased traffic demand, managed lanes facilities can be opened to general-purpose traffic.

Major Incidents

An incident is traditionally defined as any non-recurrent event, such as a vehicle crash, vehicle breakdown, or special event, that causes a reduction of roadway capacity or an abnormal increase in traffic demand (4). Because special events are addressed as a separate motivating condition for managed lanes interim use, this section considers only incidents that result in a reduction of roadway capacity and only incidents considered to be “major.” An incident is typically categorized as “minor” or “major” on the basis of its expected duration, its location, the number of lanes blocked, and the length of blockage. However, the distinction between a “minor” incident and a “major” incident is not always clear. To illustrate, consider the following definitions for a “major” incident:

- ◆ any incident that occupies two or more lanes of traffic for two or more hours (Maryland State Highway Administration);
- ◆ an incident that typically involves heavy vehicles and/or a spill that requires specialized equipment and an extensive cleanup effort (Massachusetts Highway Department);
- ◆ a serious accident or incident that may cause a highway to be closed for six or more hours (Pennsylvania Department of Transportation);
- ◆ an incident that occurs on the Interstate Highway System that requires multiple agencies’ involvement to restore vehicular flow to normal volumes; an event that results in significant delay because of the removal of damaged property, roadway structure repair, or hazardous materials containment/cleanup; an event that involves closing a portion of the Interstate Highway System for a significant period of time and rerouting the interstate traffic onto primary or secondary roads (Northern Virginia District, Virginia Department of Transportation);
- ◆ an incident that requires variable message signing (VMS) and/or blocks travel lanes (New York Department of Transportation); and
- ◆ any incident that closes one or more lanes for one or more hours (Northwest Region, Washington State Department of Transportation) (4).

Note that the minimum duration and impact defining a major incident ranges from one to six hours and one lane to all facility lanes closed, respectively. This lack of clear definition for a “major” incident challenges the ability to define consistent managed lanes interim use criteria.

Most generally, major incidents typically affect one or more of the travel lanes, result in area-wide or corridor-wide traffic impacts, require response from multiple agencies or companies, require a more formal response plan, may involve fatalities or hazardous materials, and may require accident investigation. Major incidents occur less frequently but produce more severe impacts (4).

Major incidents can result in either a long-term reduction in capacity or a severe, short-term reduction in capacity. To accommodate the existing traffic demand under capacity constraints, managed lanes facilities can be opened to general-purpose traffic or can provide a staging and/or work area for incident management equipment and resources that would otherwise occupy a general-purpose lane. Managed lanes can also be used to provide access for emergency responders that is safe, secure, and free from traffic congestion.

Emergencies and Evacuation

Large-scale emergencies can require evacuation of an area, resulting in either a long-term or severe, short-term increase in traffic demand. Transportation-related emergencies can result from:

- ◆ natural or weather-related hazards such as hurricanes, flooding, tornadoes, volcanic eruptions, wildfires, fog, ice and snow storms, or earthquakes;
- ◆ technological hazards such as hazardous materials or radiological incidents, or nuclear power or chemical plant incidents; or
- ◆ civil/political hazards such as terrorism acts or civil disorder/riots (5).

To accommodate the increased traffic demand resulting from evacuation procedures, managed lanes facilities can be opened to general-purpose traffic. Managed lanes can also be used as staging areas for bus transportation to maximize person-movement and can be operated in reverse or contraflow operation to accommodate directional demand.

Similarities and Differences among Motivating Conditions

Similarities and differences with respect to the occurrence, impact, and interim use for each of these motivating conditions are summarized in [Table 12-1](#). Note that both construction and maintenance and special event activities can be anticipated (i.e., planned), while major incidents and emergencies are often unexpected (i.e., unplanned). Special events and emergencies result in either severe short-term or long-term increases in traffic demand, while construction or maintenance and major incidents result in long-term or severe, short-term reduction in capacity. In each instance, allowing general-purpose traffic to access and utilize the managed lanes facility is a strategy to address both the impacts from reduced capacity and increased traffic demand.

Table 12-1. Motivating Conditions for Managed Lanes Interim Use.

Condition	Occurrence	Impact	Interim Use
Construction or maintenance	Planned	Long-term or severe, short-term reduction in capacity	<ul style="list-style-type: none"> • Alleviate general-purpose demand • Use as a staging area
Special events	Planned	Severe, short-term increase in traffic demand	<ul style="list-style-type: none"> • Alleviate general-purpose demand
Major incidents	Unplanned	Long-term or severe, short-term reduction in capacity	<ul style="list-style-type: none"> • Alleviate general-purpose demand • Use as a staging area
Large-scale emergencies and evacuation	Unplanned	Long-term or severe, short-term increase in traffic demand	<ul style="list-style-type: none"> • Alleviate general-purpose demand • Use as a staging area

Section 4 – Considerations for Interim Use

The interim use of managed lanes facilities during construction or maintenance, special events, major incidents, or emergencies and evacuation has short-term advantages and disadvantages as well as long-term effects that need to be considered prior to any action. In the short term, managed lanes interim use may:

- ◆ reduce congestion and delay for general-purpose traffic during times of increased traffic demand or constrained capacity,
- ◆ improve access to a work zone or incident scene,
- ◆ provide a greater level of safety at a work zone or incident scene by reducing stop-and-go traffic, and
- ◆ speed evacuation clearance.

These benefits are tempered by:

- ◆ an increase in congestion and delay and a reduction in travel time reliability for managed lanes users;
- ◆ a potential decrease in safety for managed lanes users through increased exposure to conflict;
- ◆ a potential decrease in managed lanes compliance and consequent increase in required enforcement effort, following return to standard operations; and
- ◆ a reduction in revenue if existing tolls are temporarily suspended.

In the long term, frequent interim use of managed lanes outside of their intended purpose may:

- ◆ serve as a disincentive for transit use or carpooling,
- ◆ encourage negative public perceptions,
- ◆ compromise the regulatory conditions under which the lane was originally implemented, and
- ◆ ultimately lead to reversion of the managed lane to a general-purpose lane.

Understanding the short-term and long-term implications of interim managed lanes use will help to ensure sound decision making and action. This section describes these general considerations categorized as:

- ◆ operations, including enforcement;
- ◆ safety;
- ◆ public acceptance/perception;
- ◆ monetary impacts; and
- ◆ regulatory integrity.

Operations

The interim use of managed lanes facilities affects both the managed lanes and general-purpose facilities' level of congestion and enforcement efforts for managed lanes compliance following a return to standard operations. Secondary areas of impact may include facility access and egress points and adjacent road network performance.

Congestion

When managed lanes are opened to general-purpose traffic during interim periods of unusually high traffic demand or capacity constraints, the intended result is an improvement in congestion levels for general-purpose traffic with minimal impact on managed lanes congestion levels. The degree of improved congestion experienced by the general-purpose traffic depends upon:

- ◆ the nature of the motivating condition (i.e., duration, extent);
- ◆ the current congestion levels in the general-purpose lanes; and
- ◆ the current utilization of the managed lanes facility.

For congestion relief benefits to be realized through interim use of managed lanes facilities:

1. Excess capacity must be available on the managed lanes facility. Capacity expressed in terms of vehicle-movement rather than person-movement is more intuitive for determining available "space" in the lane for general-purpose traffic.
2. Some level of congestion must be present on the general-purpose lanes. Where no facility congestion exists, motorists are unmotivated to change their course.
3. If congestion is present on both the managed lanes facility and the general-purpose lanes, the level of congestion in the managed lanes should be less than the congestion in the general-purpose lanes. If higher, managed lanes-eligible vehicles will opt to use the general-purpose lanes because of a perceived greater time savings (see [Table 12-2](#)).

Table 12-2. Congestion Conditions Supporting Managed Lanes Interim Use.

Managed Lanes Facilities	General-Purpose Facilities	
	Uncongested	Congested
Uncongested	NO BENEFIT	BENEFIT
Congested	NO BENEFIT	NO BENEFIT / BENEFIT*

* Benefit only if: (1) the managed lanes facility has excess capacity and (2) the level of congestion on the managed lane is less than the level of congestion on the general-purpose facility.

These findings relating congestion and interim use of managed lanes have an empirical basis. In a study conducted by Hallenbeck et al. (6), researchers investigated the potential congestion effects of allowing general-purpose traffic into Seattle-area HOV lanes:

- ◆ During peak commute periods, high vehicle volumes in both the HOV and general-purpose lanes exist; researchers suggest that removal of HOV lane restrictions would generally result in an *increase* in congestion and delay, as well as a decrease in person throughput and the potential to cause a mode shift away from shared ride transportation.
- ◆ Late at night, both HOV and general-purpose lanes are free from congestion; researchers purport that a change in the current HOV regulatory practice to allow nighttime general-purpose use of HOV lanes would result in no practical change in freeway performance.
- ◆ During the weekends, the number of vehicles eligible to use HOV lanes generally varies from 30 to 60 percent, depending on the facility and time of day; HOV lane usage on weekends is basically a function of whether sufficient congestion exists in the general-purpose lanes to encourage eligible vehicles to use the HOV lanes.
- ◆ Showing the greatest potential for congestion relief, midday weekday periods experience the greatest difference between general-purpose and HOV lane congestion levels, with the HOV lane experiencing low levels of congestion and the general-purpose lanes experiencing higher levels of congestion.
- ◆ Under incident conditions, researchers note that congestion would still occur even if the HOV lanes were opened to general traffic; the congestion backup would be shorter (geographically), but HOV vehicles (often buses) would suffer a significant decrease in trip reliability.

Related to observed congestion levels, maximum lane carrying capacity should be considered. If three lanes of general-purpose traffic are blocked but only one managed lane of travel is available, congestion relief benefits will be limited by lane carrying capacity. The managed lanes facility will quickly become “overwhelmed” with general-purpose traffic. In instances where both the managed lanes facility and the general-purpose lanes may become congested, it is important that adequate shoulders provide responder access during emergencies. Where adequate shoulders do not exist, the importance of maintaining congestion-free travel in the managed lane is elevated.

Enforcement and Compliance Rates

In addition to operational considerations related to congestion, facility managers should consider the potential impacts on managed lanes compliance and enforcement. One concern with interim managed lanes use is that managed lanes violations will increase during subsequent standard lane operations (i.e., non-interim use periods). National experience with HOV lanes has indicated that violation rates increase near the beginning and end of the HOV-only time period and that violations tend to generate other violations (i.e., the more violations that motorists observe, the more likely they are to violate those restrictions themselves) (6).

Interim use of one managed lanes facility may adversely affect compliance of another managed lanes facility, depending on the circumstances of use (i.e., motorists may use the altered operation of some lanes as an excuse for using other managed lanes facilities in the same fashion, producing a significant increase in violations). Impacts may be less dramatic for weekend and off-peak interim use than for interim use during peak commute periods.

The degree of managed lanes violation following a return to standard operations is a function of how well the public is informed of the operational conditions and how heavily the operational conditions are enforced. The availability of additional public information and enforcement resources during post-interim use periods should be considered.

Safety

Safety-related benefits attributable to the interim use of managed lanes include:

- ◆ improved access to an incident scene by emergency responders;
- ◆ improved safety for emergency responders at the scene of an incident, construction personnel at a work zone and motorists approaching either an incident scene or a work zone; and
- ◆ quicker clearance during an evacuation. These safety benefits are realized either by moving fewer vehicles to or through the scene of an incident or a work zone (i.e., reduced backup and exposure) or by moving more vehicles away from the scene of a hazard.

The use of managed lanes facilities provides one option to accomplish this; use of alternate routes, including local street networks, should be considered in comparison or in conjunction with the interim use of managed lanes. Because these alternate facilities may not have been designed with this type or level of traffic in mind, facility managers should thoroughly assess the appropriateness of these alternate routes to avoid compromised safety levels.

Only managed lanes design and access considerations will be addressed here. For a full description of recommended design standards and access for managed lanes facilities, the reader is referred to [Chapter 8 – Managed Lanes Weaving, Ramp, and Design Issues](#).

Design Standards

Newly constructed managed lanes facilities may have been built to a lower design standard than general-purpose lanes. These “design deviations” were approved because of the relatively modest traffic volumes expected in the lanes and the familiarity of the drivers using the facility (i.e., during peak travel times, the majority of drivers are commuters familiar with the decision points and traffic conditions). Under these conditions, FHWA permits (on a case-by-case basis) modest relaxation of normal interstate design standards. If the managed lanes use is changed, the basic assumptions about their operating conditions are no longer valid; a complete review of design deviations is required before allowing the adoption of new operating rules.

When the new operating rules are of a temporary nature, and exercised only under unusual traffic demand or capacity constraint conditions, this review may not be as stringent. Interim use traffic will typically be traveling at low, congested speeds minimizing safety-related design concerns. Nonetheless, a cursory review of design deviations that may compromise traveler safety is warranted under these conditions.

Access

Direct access facilities serving managed lanes users may enter or exit the roadway on either the left- or right-hand side. Opening these interchanges to general-purpose traffic may result in hazardous merging conditions if volumes in the managed lanes are substantially higher than designed for (6). This may be particularly true with the high proportion of unfamiliar motorists using the facility.

Also related to the presence of unfamiliar motorists on a managed lanes facility is the adequacy of information at major decision points. At entrances to limited access lanes, motorists make a basic decision about what route provides them the best advantage. Some motorists make the choice early on, deliberately merging over to the lanes well before the decision point. However, experience has shown that other motorists make the choices at the last minute, merging over several lanes in just a few hundred feet. If general-purpose traffic were allowed in the managed lanes that have access points and termination points where the managed lane ends with a merge to the general-purpose lanes, a higher frequency of accidents may occur (6).

Public Acceptance/Perception

Users of managed lanes facilities are making some concession to do so – either riding with one or more other individuals, taking public transit, or paying a toll – for real or perceived personal benefits related to travel time savings, travel time reliability, or safety. As such, facility managers are tasked with providing an elevated level of service (e.g., keeping the average HOV lane speed above 45 mph) to managed lanes users to ensure facility credibility.

If the managed lanes restrictions are lifted too often for interim use, managed lanes users may question the value of the lane. This issue becomes particularly sensitive if motorists are paying a toll for managed lanes use. Also, general-purpose traffic may become accustomed to traveling in the managed lane, increasing violations, challenging enforcement, and decreasing incentive for high-occupancy travel.

While frequency of interim use plays an important role in determining public acceptance and perception, the *motivation* for interim use (i.e., construction or maintenance, special events, major incidents, and emergencies and evacuation) may also be significant in determining public response. Managed lanes users may be more accepting of interim use for unplanned major incidents, emergencies, and evacuations that pose significant safety hazards than construction, maintenance, and special event activities focused on congestion relief. The planned nature of these latter events also provides greater opportunities for traffic management strategies outside of managed lanes use (i.e., public information campaigns to encourage transit use, alternative route plans, etc.).

Construction or Maintenance

The primary intent of interim managed lanes use for construction or maintenance activities is to reduce congestion (general-purpose traffic would experience an improved level of service, while the level of service for managed lanes traffic may be compromised); secondary benefits relate to improved safety for on-site workers and improved access to the work zone.

Regardless of project duration, construction or maintenance of a particular roadway segment is a rare event. However, the motoring public may perceive a higher frequency of occurrence, encountering multiple construction or maintenance activities during their travels. Hence, the interim use of managed lanes facilities for construction or maintenance activities may encounter unusually high resistance from the motoring public based on a perceived rather than real frequency of occurrence.

Secondly, and perhaps more importantly, the planned nature of construction and maintenance activities provides greater opportunities for traffic management strategies outside of managed lanes use. These may include public information campaigns to encourage transit use, alternative route plans, or other means. By pursuing other traffic management alternatives and maintaining the integrity of the managed lanes facility, travelers have sufficient time to weigh the advantages and disadvantages of various travel

options. Those that choose to carpool, take transit, or pay a toll are rewarded with a higher level of transportation service.

Lastly, opening the managed lanes facility to general-purpose traffic during construction or maintenance activities sets precedents that may lead to “abuse” of the managed lanes facility. Comprehensive pre-planning that considers traffic management and public information as a priority should be encouraged; project managers and contractors should not rely on the use of managed lanes as an “easy” source for excess capacity.

Special Events

Special events vary in both magnitude and frequency. Large events may occur annually while smaller events, such as sporting events, may occur one or more times per week. Special events typically take place during non-peak commute hours. The primary intent of interim managed lanes use for special events is to reduce congestion (general-purpose traffic would experience an improved level of service, while the level of service for managed lanes traffic may be compromised).

As with construction and maintenance activities, the planned nature of special events provides greater opportunities for traffic management strategies outside of managed lanes use. These may include public information campaigns to encourage transit use, carpool or vanpool parking incentives at the special event venue, incentives to encourage staggered arrival times (i.e., local restaurant coupons for early arrival to the event), or other means. Again, by pursuing other traffic management alternatives and maintaining the integrity of the managed lanes facility, travelers have sufficient time to weigh the advantages and disadvantages of various travel options. Those that choose to carpool, take transit, or pay a toll are rewarded with a higher level of transportation service.

The potentially high frequency combined with the “entertainment” nature of special events may lead to strong public resistance for interim managed lanes use; however, the occurrence of these events outside of peak commute periods may temper this resistance.

Major Incidents

The primary intent of interim managed lanes use for major incidents is to reduce congestion (general-purpose traffic would experience an improved level of service, while the level of service for managed lanes traffic may be compromised); secondary benefits relate to improved safety for on-site responders and improved access to the incident scene.

While the motivation for interim managed lanes use is similar for major incidents and construction or maintenance – to reduce congestion for general-purpose traffic, to improve safety for on-site personnel, and to enhance access to the scene – fundamental differences may make managed lanes users more accepting of interim use for major incidents. First, the potential exposure hazard is greater for emergency responders during a major incident than for construction personnel; the planned nature of construction or maintenance activities allows for the setup of appropriate traffic control devices and

signing to protect the scene. Hence, diverting traffic away from the scene of an incident has a greater potential for improving personnel and motorist safety. Secondly, enhancing access to a construction site will speed the construction process, but enhancing access to the scene of an incident can directly affect the survivability of injured motorists.

The challenge is to define appropriate incident conditions under which interim managed lanes use is appropriate. If criteria are set too low (i.e., incidents lasting one or more hours), the frequency of interim use will detract from the managed lanes facility's intended use. If criteria are set too high (i.e., incidents lasting six or more hours), the infrequent occurrence of events would preclude benefits from interim use of managed lanes. These criteria may become dynamic, similar to occupancy criteria (i.e., 2+ versus 3+), with the incident conditions defining appropriate interim managed lanes use adjusting up or down depending upon the frequency of occurrence.

Emergencies and Evacuation

The intent of interim managed lanes use during major emergencies and evacuation is to minimize the clearance time away from the point of hazard. Emergencies and subsequent evacuation are infrequent and generally pose life-threatening conditions. Because of the significant safety hazards and life-threatening nature of emergencies and evacuation, little public resistance to interim use of managed lanes facilities under these conditions is anticipated.

Monetary Impacts

The most direct monetary impact resulting from interim use of managed lanes facilities relates to the temporary suspension of tolls on value-priced or HOT facilities. The amount of revenue loss depends upon the toll rates of the facility, the utilization of the managed lane, and the duration of interim use.

Additional costs associated with interim managed lanes use may also be significant. These associated costs may originate from a number of sources related to signing and public information, post-interim use enforcement, the need to “fix” any design deficiencies that are not acceptable for general traffic conditions (i.e., widening existing shoulders, removing or relocating signs and signal heads, and a variety of other geometric improvements) and potential environmental commitment violation penalties to the FHWA and EPA if managed lanes facility goals are focused on reducing environmental impact.

Regulatory Integrity

Changes in managed lanes operational strategies have the potential to violate environmental commitments made both to the federal government (FHWA and EPA) and various local communities. For example, according to Hallenbeck et al. (6), FHWA has stated that opening HOV lanes to general traffic on weekends or for midday operations is a significant action that would require WSDOT to complete project documentation

required by the National Environmental Policy Act (NEPA). Part of that process is documentation of previous environmental commitments.

As a second example, the IH-15 Congestion Pricing Project in San Diego, California, required enactment of state legislation to allow single-occupant vehicles to use the Express Lanes for a fee. Assembly Bill 713 (1994) contained two key restrictions:

- ◆ the level of service for the Express Lanes must remain at its original state, which was determined to be LOS C, and
- ◆ project revenue must be used for improving transit service and the HOV facility (7).

The first example, that considered recurring interim use of a managed lanes facility (i.e., during weekends or during midday weekdays), and the second example, that considered a permanent change to managed lanes operations, may distinguish themselves from the non-recurrent interim use of managed lanes considered here. Nonetheless, a careful review of governing legislation should be performed prior to any interim managed lanes use to ensure that operational strategies are appropriate.

Section 5 – Planning for Interim Use

Although interim use of managed lanes facilities is taking place currently, the consistency and success with which this strategy can be applied can be significantly improved with proper planning. In addition to developing specific interim use criteria for managed lanes (discussed in [Section 6](#)), facility managers should:

- ◆ assess the current transportation system, including: the managed lanes facility regarding its appropriateness for interim use, the general-purpose facility regarding its potential for alternative interim operational strategies (i.e., temporarily utilizing the shoulder as a travel lane), and other network facilities regarding their appropriateness as alternate routes;
- ◆ review and modify, as necessary, any internal agency policies or state or federal legislation that precludes the interim use of managed lanes facilities;
- ◆ develop inter-agency coordination agreements, which are particularly important between law enforcement (who are often first on the scene and making the decision to utilize the managed lanes facility) and the transportation agencies (who can support this decision-making process); and
- ◆ incorporate provisions for training in interim managed lanes use strategies into appropriate personnel training programs (i.e., transportation operations personnel, law enforcement academy cadets, etc.).

Transportation System Assessment

The most fundamental preparation measure a facility manager can take prior to implementing interim use strategies for managed lanes is to assess the existing transportation system and analyze its ability to function outside of standard operations. In particular, this assessment should include:

- ◆ the managed lanes facility and its appropriateness for interim use;
- ◆ the general-purpose facility and its potential for alternative interim operational strategies (i.e., temporarily utilizing the shoulder as a travel lane); and
- ◆ other network facilities and their appropriateness as alternate routes.

Specific considerations for each are listed in [Table 12-3](#).

Consideration of the general-purpose facility and its potential for alternative interim operational strategies (i.e., temporarily utilizing the shoulder as a travel lane) and other network facilities and their appropriateness as alternate routes is particularly important. A number of transportation agencies nationally have cited the importance of maintaining a higher level of service in the managed lanes facilities and a desire to exhaust alternative traffic management strategies prior to interim managed lanes use. In each case,

temporary conditions, such as construction or malfunctioning traffic control devices, should also be kept up to date and included in the assessment.

Table 12-3. Transportation System Assessment Considerations.

Managed Lanes Facility	<ul style="list-style-type: none"> ◆ capacity and geometric constraints, including accessibility ◆ general operating characteristics (i.e., hours of operation, occupancy requirements, tolling structure, etc.) ◆ availability of an operations center where information from the police and/or other highway operating personnel to the other agencies involved is relayed ◆ technologies available for monitoring traffic (i.e., loop detectors, radar, video, regular police patrol) ◆ technologies available for communicating with the motoring public ◆ manpower and traffic control device availability for real-time traffic management if needed
General-Purpose Facility	<ul style="list-style-type: none"> ◆ capacity and geometric constraints including bridges or overpasses that may preclude shoulder lane travel ◆ availability and condition (i.e., paved, reinforced, etc.) of suitable shoulder capacity ◆ manpower and traffic control device availability for “creating” an additional lane out of existing capacity (i.e., providing three narrow lanes instead of two 12-ft lanes and a shoulder) ◆ manpower and traffic control device availability for real-time traffic management if needed
Other Network Facilities	<ul style="list-style-type: none"> ◆ capacity and geometric constraints of likely alternative routes ◆ capacity of critical signalized and unsignalized intersections ◆ technologies available for monitoring traffic (i.e., loop detectors, radar, video, regular police patrol) ◆ technologies available for communicating with the motoring public ◆ “sensitive” locations within the system (i.e., schools, hospitals, etc.) ◆ manpower and traffic control device availability for real-time traffic management if needed

Policy and Legislation Review and Modification

When managed lanes facilities are implemented, many agencies simultaneously implement policies governing their use. In addition, the implementation of managed lanes may be tied to environmental commitments made both to the federal government (FHWA and EPA) and various local communities (6). Accompanying state legislation may also define managed lanes use requirements, a minimum level of service to be maintained, revenue use, and other items (7). Interim use of managed lanes has the potential to violate each of these governing conditions. The following question can support an internal review of such a policy or legislation (1):

- ◆ Does your agency currently allow the use of managed lanes facilities by general traffic for temporary durations?

If no, an agency must identify whether interim use prohibition is governed by agency policy, state or federal agreement, or state or federal legislation. In some instances, an agency may discover no formal means for prohibition; interim use has not been pursued out of “tradition” (i.e., the agency has never done that before). Depending on the level of governance affecting interim managed lanes use, different approaches will be required for change.

If yes, consider whether any aspects of the policy or procedures need to be changed or better defined:

- ◆ What conditions prompt this action (i.e., major incident, emergency, special event, holiday season, etc.)?
- ◆ What criteria are used to determine if and when interim use of managed lanes facilities should occur?
- ◆ How long is the general traffic allowed to travel on the managed lane after the motivating condition has ceased?
- ◆ Does your agency have a formal plan in place for the interim use of managed lanes facilities (i.e., how to direct motorists into and out of the lane, how to provide motorist information)?
- ◆ Is motorist diversion voluntary, mandatory, or variable depending on conditions?
- ◆ Does your agency actively measure the performance of managed lanes interim use strategies (i.e., motorist delay, queue length, estimated secondary accidents, or estimated flow rate before and during)?

Although the policies observed in practice are very general in nature with no specific criteria defined for supporting decisions related to interim use, a noted priority for preserving a higher level of service in the managed lanes facility is consistent.

Departments of transportation in Minnesota, Virginia, and Washington each indicated that agency policy supported standard operations for managed lanes facilities except when traffic congestion was severe and no other traffic management alternatives were available (1). Any policies, legislation, or other changes put into place need to be consistent with local priorities.

Inter-agency Coordination Agreements

When planning for and operating a managed lanes facility under standard conditions, the level of involvement is limited, comprising primarily transportation agencies, transit agencies, trucking companies, law enforcement agencies, and tolling authorities, depending on the nature of the managed lanes facility. Under usual, non-standard operating conditions such as construction or maintenance, special events, major incidents, or emergencies and evacuation, the scope of involvement becomes much larger. While it is important to appropriately involve all potential stakeholders in the planning process for managed lanes facilities, not all require formal coordination agreements for participation.

When determining which inter-agency relationships could most benefit from a formal coordination agreement to support interim managed lanes use, an agency first needs to identify (1):

- ◆ Which agencies are responsible for or most actively involved in construction and maintenance activities, special events, incident management, emergency management, and managed lanes operations in your area?
- ◆ Who has the authority to open the managed lane to general-purpose traffic under each of these conditions?
- ◆ How do these different agencies currently coordinate that action?

For construction and maintenance activities, the facility managers typically decide or approve recommendations to temporarily utilize the managed lanes facility. Similarly, though no examples of interim managed lanes use were found nationally, special event coordinators are required to submit requests to facility managers when modifications to the existing traffic flow are desired. Following submission, the facility manager approves or denies requests for interim use of managed lanes. In each of these planned cases, the facility manager is singularly responsible for authorizing interim managed lanes use; hence, no inter-agency agreements would be required.

For major incidents, emergencies, and evacuation, law enforcement agencies typically have the authority and make the decision to open managed lanes facilities to general-purpose traffic. Typically, the decision to open the managed lanes facility to general traffic is often made by a law enforcement officer on the scene without benefit of well-defined criteria for opening the lane, with little coordination or communication with the managing transportation agency and with little awareness of the long-term ramifications of such actions.

Inter-agency coordination agreements between law enforcement and managing transportation agencies could greatly enhance the existing decision-making process and ensure consistency with the managing transportation agency's policies and priorities for the managed lanes facility. In addition to providing interim managed lanes use guidance and support to law enforcement personnel during incidents or emergencies, an inter-agency coordination agreement could include:

- ◆ chain of command within an agency and among agencies,
- ◆ address and phone list of key personnel in each agency,
- ◆ agency lists of available manpower and equipment capabilities,
- ◆ method and sequence of alerting each agency during a major incident or emergency, and
- ◆ mutual-aid agreements to enable the sharing of resources and personnel and the crossing of jurisdictional boundaries (5).

Personnel Training

Personnel training helps to ensure that any change in policy, agreement, or legislation is successfully implemented. Common forms of training include workshops, short courses, conferences, video training tapes, informal staff meetings, and mock incident and emergency exercises. Inter-agency training is particularly beneficial to support newly developed or modified inter-agency coordination agreements. For managed lanes interim use, incorporating awareness training into law enforcement academy training may provide an efficient method for encouraging consistent decision making related to interim managed lanes use. Training also promotes safe practices and helps minimize liability.

Section 6 – Interim Use Criteria

A set of criteria that defines when a managed lanes facility should be open for interim use is imperative to provide consistency: in operation under non-standard conditions, and with the managing agency’s policies and priorities for the facility (i.e., to preserve a higher level of service for managed lanes users). These interim use criteria must be tailored to each facility but, in general, should consider the following:

- ◆ severity and nature of the conditions;
- ◆ time of day, anticipated duration, and anticipated traffic impacts; and
- ◆ availability of alternative facilities or strategies.

A summary of recommended interim use criteria related to each of these characteristics is provided in [Table 12-4](#) and detailed below.

Severity and Nature of Conditions

Considering the motivating factors for interim use of managed lanes facilities (i.e., construction or maintenance, special events, major incidents, and emergencies and evacuation), the severity and nature of conditions results in two primary effects: higher than normal congestion levels and/or compromised safety. Safety-related impacts are perceived to be more “severe” than congestion-related impacts, regardless of the degree of congestion. Further, unplanned events, such as major incidents or emergencies, are perceived to be more “severe” than planned events that include construction or maintenance activities or special events; planned events can utilize alternative traffic management strategies (i.e., HOV incentives, alternative routes, etc.).

Given these observations, the motivating conditions for interim managed lanes use can be prioritized as follows:

- ◆ Priority 1 – emergencies and evacuation,
- ◆ Priority 2 – major incidents,
- ◆ Priority 3 – construction or maintenance activities, and
- ◆ Priority 4 – special events.

Priority 1 – Emergencies and Evacuation

Emergencies and subsequent evacuation are infrequent and generally pose life-threatening conditions. Because of the significant safety hazards and life-threatening nature of emergencies and evacuation, interim use of managed lanes facilities under these conditions is recommended.

Table 12-4. Recommended Interim Use Criteria.

Criteria		Recommendation
Severity and Nature of Conditions	Emergencies and Evacuation	Recommended
	Major Incidents	Recommended with carefully defined criteria for interim use
	Construction or Maintenance	Not recommended; if necessary, schedule to minimize performance impacts (i.e., nighttime construction)
	Special Events	Not recommended
Time of Day	Morning Peak	Not recommended; both the managed lanes and general-purpose lanes are congested, and travel time reliability is key to managed lanes users
	Midday	Recommended if the level of congestion in the managed lane is less than the level of congestion in the general-purpose lanes
	Evening Peak	Not recommended; both the managed lanes and general-purpose lanes are congested, and travel time reliability is key to managed lane users
	Nighttime	Not recommended; both the managed lanes and general-purpose lanes are uncongested
Anticipated Duration and Traffic Impacts	Locally Defined	<p>Define in terms of event duration and lanes impacted; interim use strategy may vary by time of day</p> <p>Criteria may be dynamic to control frequency of interim use</p> <p>24-hour managed lanes facilities should resume normal operation as soon as possible following an event</p> <p>Peak period or extended operations should continue interim use through the remainder of the operational period to simplify enforcement</p>
Availability of Alternative Facilities or Strategies	Locally Defined	<p>Use of alternative facilities and of alternative operational strategies on the general-purpose facility (i.e., shoulder travel) should be considered prior to interim managed lanes use</p> <p>Use of alternative facilities is preferred; alternative operational strategies may compromise design or safety standards</p>

Under emergency or evacuation conditions, the decision to open the managed lanes for non-standard operations is largely driven by the decision to evacuate, eliminating indecision related to the time of day, duration of condition, level of impact, etc. Once evacuation procedures have been ordered, managing agencies should initiate steps to provide for interim use of the managed lanes facility as requested. These procedures should be well documented in area emergency response plans.

Priority 2 – Major Incidents

The motivation for interim managed lanes use is similar for major incidents and construction or maintenance activities (described below) – to reduce congestion for general-purpose traffic, to improve safety for on-site personnel, and to enhance access to the scene. Fundamental differences, however, make interim managed lanes use during major incidents a higher priority. First, the potential exposure hazard is greater for emergency responders during a major incident than construction personnel; the planned nature of construction or maintenance activities allows for the setup of appropriate traffic control devices and signing to protect the scene. Secondly, enhancing access to the scene of an incident can directly affect the survivability of injured motorists.

Given these fundamental differences, interim managed lanes use during major incidents is recommended, but agencies are strongly cautioned to define and follow carefully developed criteria for interim use under these conditions (i.e., incidents affecting three or more general-purpose lanes with an expected duration in excess of 4 hours). Further guidance for defining these criteria is provided below in “Time of Day, Anticipated Duration, and Anticipated Traffic Impacts.”

Priority 3 – Construction or Maintenance

The primary intent of interim managed lanes use for construction or maintenance activities is to reduce congestion; secondary benefits relate to improved safety for on-site workers and improved access to the work zone. Opening the managed lanes facility to general-purpose traffic during construction or maintenance activities sets precedents that may lead to “abuse” of the managed lanes facility. Further, the interim use of managed lanes facilities for construction or maintenance activities may encounter unusually high resistance from the motoring public based on a perceived rather than real frequency of occurrence because of multiple simultaneous construction projects in a region.

Observed as a more prevalent practice nationally, continued standard operation of a managed lanes facility is combined with alternative traffic management strategies (i.e., transit incentives, alternate route diversion, etc.) to ease congestion through the work zone.

Given the potential for public resistance, the availability of alternative traffic management strategies, and a noted national consensus in practice, interim use of managed lanes during construction or maintenance is not recommended. Instead, construction and maintenance activities should be used as opportunities to encourage use of the managed lanes under its intended operating structure.

In instances where no alternative exists to temporarily using a managed lanes facility in non-standard operation during construction or maintenance, every effort should be made to schedule activities such that no substantive change in facility performance will result (i.e., diverting general traffic to an HOV lane during nighttime construction activities when HOV lane and general-purpose traffic volumes are sufficiently low).

Priority 4 – Special Events

Given the singular focus on congestion relief for general-purpose traffic, combined with the potentially high frequency and the “entertainment” nature of special events, interim use of managed lanes during special events is not recommended. The occurrence of these events outside of peak commute periods is of benefit although insufficient to overcome the noted drawbacks. As with construction and maintenance activities, the planned nature of special events provides greater opportunities for traffic management strategies outside of managed lanes use. Special events should be used as opportunities to encourage use of the managed lane under its intended operating structure.

Time of Day, Anticipated Duration, and Traffic Impacts

In addition to the severity and nature of conditions, the time of day, anticipated duration of the condition, and the resulting traffic impacts – all interrelated – play an important role in determining the appropriateness of managed lanes interim use. Recall that the interim use of managed lanes is intended to result in an improvement in congestion levels for general-purpose traffic with only a slight detrimental effect on managed lanes performance. The degree of improved congestion experienced by the general-purpose traffic depends upon:

- ◆ the duration and extent of the motivating condition,
- ◆ the current congestion levels in the general-purpose lanes, and
- ◆ the current utilization of the managed lanes facility.

The congestion levels in the general-purpose lane and the utilization of the managed lanes facility are both dependent upon the time of day. In turn, high levels of congestion and utilization could affect the overall duration of conditions (i.e., extend the time required for an incident to clear).

Much of the following discussion relates to managed lanes interim use under major incident conditions because the interim use of managed lanes facilities is not recommended for construction or maintenance activities or special events, emergencies typically last 8 to 30+ hours, and the decision to evacuate during an emergency largely drives the decision to utilize the managed lanes facility for interim use (i.e., less indecision about when to use the lane).

Time of Day

Recall that for congestion relief benefits to be realized through interim use of managed lanes facilities:

- ◆ excess capacity must be available on the managed lanes facility (vehicle, not person-moving capacity);
- ◆ some level of congestion must be present on the general-purpose lanes; and
- ◆ if congestion is present on both the managed lanes facility and the general-purpose lanes, the level of congestion in the managed lanes should be less than the congestion in the general-purpose lanes.

Table 12-2, provided early in this chapter, summarized potential congestion conditions supporting managed lanes interim use. Building upon this approach, consider this same information segregated by general weekday time of day periods (see Table 12-5).

Table 12-5. Weekday Time of Day Supporting Managed Lanes Interim Use.

Weekday Time of Day	Managed Lanes Facilities	General-Purpose Facilities	Managed Lanes Interim Use
Morning Peak 6 A.M. – 9 A.M.	Congested	Congested	NO BENEFIT
Midday 9 A.M. – 3 P.M.	Uncongested	Congested/ Uncongested	BENEFIT*
Evening Peak 3 P.M. – 6 P.M.	Congested	Congested	NO BENEFIT
Nighttime 6 P.M. – 6 A.M.	Uncongested	Uncongested	NO BENEFIT

* Benefit only if: (1) the managed lanes facility has excess capacity and (2) the level of congestion on the managed lanes facility is less than the level of congestion on the general-purpose facility.

Hence, when considering time of day criteria for managed lanes interim use, midday time periods may present the only significant opportunity for benefit during weekdays. Managed lanes volumes may be high during peak commute periods. Adding general-purpose traffic to an already “at capacity” facility will not result in short-term benefits to traffic flow. Conversely, traffic late at night travels basically free from congestion. Therefore, removing the managed lanes restrictions late at night would have no impact on congestion.

During weekday midday periods, the general-purpose lanes and the managed lanes volumes likely experience the greatest difference in traffic volumes; general-purpose traffic may be relatively high compared to managed lanes traffic. While congestion

conditions appear suitable for interim use – excess capacity in the managed lanes with moderate to severe congestion levels in the general-purpose lanes – facility managers should be sensitive to the performance and reliability needs of managed lanes users during this time. In particular, transit operators may be dependent on quick and reliable travel during midday periods to adhere to certain trip and schedule requirements.

During weekends, variable traffic patterns by time of day, day of year, and locale challenge the development of more specific time of day criteria for interim managed lanes use. In general, if conditions suggest potential interim use of the managed lanes facilities, decision makers should confirm that:

- ◆ excess capacity is available on the managed lanes facility;
- ◆ some level of congestion exists on the general-purpose lanes; and
- ◆ if congestion is present on both facilities, congestion levels on the managed lanes facility are less than the congestion levels on the general-purpose facility.

In conjunction with other interim use criteria, such as the nature and severity of the motivating condition and the availability of alternative facilities or strategies, confirmation of these three criteria suggests appropriate use of a managed lanes facility.

These time of day recommendations for interim managed lanes use are supported by related findings in published literature (6, 8) and consistent with national practice. Departments of transportation in Minnesota, Washington, and Virginia expressed a reluctance to allow general-purpose traffic into managed lanes facilities during the peak commute periods, citing a loss of managed lanes credibility and integrity. Often, managed lanes use marketing touts the avoidance of recurrent or incident-induced congestion during peak commute periods as a reason for use.

Anticipated Duration and Traffic Impacts

The anticipated duration of the motivating condition for interim managed lanes use (i.e., major incident and emergency and evacuation) is difficult for managing personnel to accurately predict, may change as new conditions unfold, and may be extended as a result of attendant conditions (i.e., the amount of traffic backup resulting from an incident). The resulting traffic impact is also difficult to estimate and is highly dependent on the duration of the condition.

Again, because emergencies and evacuation are severe in scope and duration (typically lasting eight to 30+ hours) and because the decision to evacuate during an emergency may largely drive the decision to utilize the managed lanes facility for interim use (i.e., less indecision about when to use the lane), much of following discussion relates to managed lanes interim use under major incident conditions.

Interim use criteria on the basis of the anticipated duration of the condition and the resulting traffic impact must be sensitive to the practical decision-making process that

takes place. While it may be desirable to base the decision for interim managed lanes use on quantifiable metrics such as volume-capacity ratio thresholds in both the managed lanes facility and general-purpose facilities (the traffic management center could provide information on the volume-capacity ratio to field personnel from surveillance cameras and loop detectors), less quantifiable but more readily observable metrics from the field can speed the decision-making process and, hence, may be more beneficial. Under major incident conditions, law enforcement personnel on the scene have the authority and decision-making responsibility for managed lanes interim use. Appropriate criteria for managed lanes interim use under major incident conditions may include:

- ◆ the anticipated duration for clearing the incident based on the incident characteristics (i.e., fatality, multiple vehicle involvement, large truck involvement, etc.) and
- ◆ the number of general-purpose lanes impacted by observation.

The Virginia Department of Transportation opens its HOV lane facility to general-purpose traffic if an incident blocks 50 percent of the general-purpose lanes in the peak direction and is expected to take 2 hours or more to clear. While this was the only example uncovered that defined managed lanes interim use, a number of departments of transportation, in cooperation with law enforcement agencies, use similar criteria to define when road closures, and subsequent traffic diversions, are put into effect under major incident conditions. An example of such a policy is provided in *TRANSCOM's Incident Management Plan for I-287, New York State Thruway through Rockland County* (see [Table 12-6 \(9\)](#)). TRANSCOM has defined appropriate conditions by time of day, day of week, estimated incident duration and lanes blocked for roadway closures, and subsequent traffic diversion off the mainline.

These same guidelines can be used to direct decisions to open managed lanes facilities for interim use. In addition to congestion mitigation, diversion of traffic to the managed lanes facility may improve access to the incident scene by emergency responders and may lessen the likelihood of a secondary incident. In addition, there is some benefit to having consistent criteria for similar types of actions (i.e., diverting traffic to alternate routes versus utilizing excess capacity in managed lanes facilities).

The specific time of day, duration, and lane blockage thresholds are dependent upon local traffic and facility characteristics. Facility managers should define appropriate *local* incident, traffic, and facility conditions under which interim managed lanes use is appropriate. If criteria are set too low (i.e., incidents lasting one or more hours), the frequency of interim use will detract from the managed lanes facility's intended use. If criteria are set too high (i.e., incidents lasting six or more hours), the infrequent occurrence of events would preclude benefits from interim use of managed lanes. These criteria may be dynamic over time, similar to occupancy criteria (i.e., 2+ versus 3+), with the incident conditions defining appropriate interim managed lanes use adjusting up or down depending upon the frequency of occurrence.

Once interim use has been implemented, it is important to determine if the managed lanes will remain open for the duration of the operating period or if they will be available to all traffic only during the duration of the event (i.e., until the incident is cleared). For managed lanes facilities with 24-hour operating periods, standard operation should resume as soon as the motivating event has ended (i.e., the incident has been cleared or the emergency threat has passed). For managed lanes facilities with defined peak or extended hour operating periods, it may not be feasible to re-instate standard operating criteria immediately following an event. National practice suggests keeping the managed lanes facility open to general traffic throughout the remainder of the operating period, once interim use has been implemented (1).

Availability of Alternative Facilities or Strategies

When considering the availability of alternative facilities or strategies as criteria for allowing interim managed lanes use, the following discussion will again be limited to major incident conditions. Interim use of managed lanes facilities is not recommended for construction or maintenance activities or special events; the planned nature of these conditions allows for pursuit of public information and travel demand management strategies that enhance rather than compromise the standard operation of the managed lane. Emergencies and evacuation require high-speed, high-volume facilities, characteristics common to managed lanes facilities. Under emergency conditions, additional alternate route facilities may be used in conjunction with the primary alternative route, but use of the managed lane for evacuation should not be impeded.

Table 12-6. TRANSCOM’s Roadway Closure and Subsequent Traffic Diversion Criteria (9).

Time of Day	Estimated Duration	Lanes Blocked		
		1	2	3+
Weekday				
Midnight to 5:00 A.M.	1 hour			
	2 to 4 hours			
	More than 4 hours			Voluntary Diversion
5:01 A.M. to 11:00 A.M. and 2:01 P.M. to 8:00 P.M.	1 hour			Long-Term Diversion
	2 to 4 hours	Voluntary Diversion	Mandatory Diversion	Long-Term Diversion
	More than 4 hours	Voluntary Diversion	Mandatory Diversion	Long-Term Diversion
11:01 A.M. to 2:00 A.M. and 8:01 P.M. to Midnight	1 hour			Mandatory Diversion
	2 to 4 hours		Voluntary Diversion	Mandatory Diversion
	More than 4 hours	Voluntary Diversion	Mandatory Diversion	Mandatory Diversion
Weekend				
8:01 A.M. to 9:00 P.M.	1 hour			Mandatory Diversion
	2 to 4 hours		Voluntary Diversion	Mandatory Diversion
	More than 4 hours	Voluntary Diversion	Mandatory Diversion	Mandatory Diversion
9:01 P.M. to 8:00 A.M.	1 hour			
	2 to 4 hours			
	More than 4 hours			Voluntary Diversion

Considering major incident conditions, a number of state departments of transportation cited the importance of maintaining a higher level of service in the managed lanes facilities and a desire to exhaust alternative traffic management strategies prior to interim managed lanes use (1). As such, the availability of alternative routes for general-purpose traffic and alternative interim operational strategies (i.e., temporarily utilizing the shoulder as a travel lane) for the general-purpose facility should be fully considered prior to implementing interim use of the managed lanes. Alternate route use is typically preferred over alternative operational strategies; alternative operational strategies may expose motorists to substandard design conditions and may be confusing.

Alternative Facilities

The availability of alternative facilities or routes is location dependent and, hence, cannot be defined with specificity here. However, general recommendations for selecting and utilizing alternative routes are provided. Many areas already have an alternate route plan developed as part of incident management efforts or a larger emergency management plan. In general, before diverting traffic off the general-purpose facilities, the following considerations should be addressed:

- ◆ capacity and geometric constraints of likely alternative routes;
- ◆ capacity of critical signalized and unsignalized intersections;
- ◆ technologies available for monitoring traffic (i.e., loop detectors, radar, video, regular police patrol, etc.);
- ◆ technologies available for communicating with the motoring public;
- ◆ “sensitive” locations within the system (i.e., schools, hospitals, etc.);
- ◆ manpower and traffic control device availability for real-time traffic management if needed; and
- ◆ construction, maintenance, or other temporary activities that may affect the capacity of likely alternate routes.

Short-term traffic diversion poses less of a concern than long-term traffic diversion. Regular commuters will be more comfortable diverting than unfamiliar travelers. Also, cooperative agreements may be required between state and local jurisdictions to allow active direction to non-state alternate routes. If implemented effectively, use of alternate facilities provides a successful option outside of interim managed lanes use.

Alternative Strategies

In addition to the use of alternative facilities, alternative operational strategies may be employed during major incident conditions. Alternative interim use strategies include using shoulders as temporary travel lanes, implementing reversible flow on facilities, and implementing temporary vehicle restrictions.

Shoulder Travel. Along IH-66, through suburban Virginia and Washington, D.C., the right shoulders of IH-66 are used as an additional travel lane to accommodate traffic during peak-period travel times, providing three unrestricted travel lanes during the periods when the left (median) lane is converted for restricted HOV use. Empirical observation and experience have not shown any significant increases in accidents or driver confusion in this area. Anecdotal evidence also suggests that the driving public has been supportive of the lanes, and few complaints have been received. Interestingly, VDOT has received complaints when the shoulder lanes are not opened during off-peak

periods, when capacity-restricting incidents occur in the other lanes. For this reason, VDOT maintains a flexible operating policy that allows them to activate the shoulder lane as an incident management tool to increase the segment capacity when conditions warrant their use (10).

For this strategy to be effective, the shoulders need to be of sufficient width and structure to withstand repeated traffic loading and potential heavy vehicle traffic loading. Locations where the shoulder width is constrained (i.e., overpasses, bridges, etc.) will result in bottlenecks and limit the utility of this strategy. Shoulder travel may also impede access to or from an incident scene by emergency responders. Measures, such as temporary signing and law enforcement personnel on-site, may also be required to ease motorist confusion; driving on the shoulder violates driver expectancies (2).

Reversible Flow. Utilizing reversible flow strategies on existing facilities can be effective with certain limitations. Reverse-flow operations have been typically reserved for long-duration or recurrent activities such as alleviating capacity constraints during construction or accommodating directional flow during peak periods or during special events. In these instances, significant pre-planning has taken place, and sufficient permanent or temporary traffic control devices have been put into place. For unplanned, infrequent occurrence, implementation of reverse flow is more challenging and includes concerns with:

- ◆ violation of driver expectancy,
- ◆ safety issues,
- ◆ extensive manpower for implementation,
- ◆ problems in converting the roadway back to two-way flow without creating bottlenecks, and
- ◆ dangerous geometric implications (i.e., adverse superelevation, limited sight distance, etc.) (2, 3, 11).

Under major incident conditions, reverse flow may be appropriately limited to ramp facilities and for clearing traffic that reached the incident scene prior to implementation of an alternate route diversion. Qualified personnel on-site should actively direct this activity.

Vehicle Restrictions. To alleviate traffic demand at the scene of an incident, the movement of certain vehicles, such as oversize cargoes and mobile homes, can be restricted until standard operations can resume. These restrictions are only appropriate if the unusual conditions are anticipated to last for an extended duration (5).

Section 7 – Implementation Requirements

In addition to identifying *when* interim managed lanes use should occur, it is important to determine *how* interim managed lanes use should occur, including any accompanying actions that support implementation. Important considerations include:

- ◆ inter-agency communication and coordination,
- ◆ on-site signing and traffic control,
- ◆ network traffic management,
- ◆ public education, and
- ◆ monitoring and evaluation.

Inter-agency Communications and Coordination

When planning for and operating a managed lanes facility under standard conditions, the level of involvement is limited, comprising primarily transportation agencies, transit agencies, trucking companies, law enforcement agencies, and tolling authorities, depending on the nature of the managed lanes facility. Under usual, non-standard operating conditions such as construction or maintenance, special events, major incidents, or emergencies and evacuation, the scope of involvement becomes much larger.

For interim managed lanes use under major incident or emergency conditions, a communication and coordination linkage between law enforcement and transportation agencies is critical. Law enforcement personnel on-site typically prompt the implementation of interim use; transportation agencies have the traffic control (i.e., cones, barrels, signing, etc.) and technological resources to support this implementation, reducing traffic congestion and maintaining safety. Law enforcement should communicate both the start of interim use and the end of interim use following the event, allowing transportation agencies to ready appropriate resources and provide accurate and timely motorist information to reduce traffic demand through the affected site.

Communication and coordination between law enforcement and transportation agencies is challenged both by protocol and technological limitations (i.e., interoperable radio systems). Protocol-based challenges can be overcome through inter-agency training and inter-agency coordination agreements, but may require a change in agency policy. Technological challenges may be overcome by exchanging radio units, using cellular telephones, or communicating through a centrally accessible traffic or emergency operations center. In either case, pre-planning should occur to overcome these challenges prior to an event.

On-Site Signing and Traffic Control

During managed lanes interim use, traditional channelizing devices such as cones, tubes, barrels, and barricades can be used to:

- ◆ indicate a roadway or ramp closure;
- ◆ split a lane, shoulder, or ramp into two narrow lanes to increase capacity; or
- ◆ supplement other law enforcement directives (12).

Where available, lane control signals may also be used to control on-site traffic. Lane control signals display X's and arrows over individual travel lanes or alongside the roadway to show whether a lane is open or closed (8). Green arrows, yellow X's (or diagonal arrows), and red X's indicate if a lane is open, about to close, or closed, respectively.

Similarly, flashers can be used to signify lane use. Flashers that are blinking would signify that traffic in the managed lanes is restricted. If the flashers are turned off, general-purpose traffic is allowed to enter the managed lanes. Flashers are most effective if motorists are familiar with their use (i.e., if flashers are already used to indicate peak- or extended-hour managed lanes operations).

These traffic control devices must be accompanied by adequate signing, directing a motorist to the managed lanes and also directing the motorist out of the managed lanes, either downstream of the event or following its termination.

Clear and concise information must be presented to reduce any confusion for the motorist. A person who is accustomed to driving in the general-purpose lanes might not be familiar with the managed lanes facility. Key information to provide includes:

- ◆ reason for diversion to the managed lanes facility,
- ◆ whether the diversion is voluntary or mandatory,
- ◆ length of time or distance that the motorist is allowed/required to continue to drive on the managed lanes, and
- ◆ availability of entrance and exit points if the managed lanes facility is physically separated from the general-purpose facility.

Temporary static signs can be used to relay limited information to the motoring public. Flip-down signs can be permanently mounted along the managed lanes facility, or free-standing signs can be brought to the site and placed where needed. While these signs present only limited information, their availability and flexibility in placement provides significant benefit.

Portable or permanent changeable message signs (also called dynamic or variable message signs) can be used to provide additional information in real time. CMS messages are typically limited to three lines of brief text. Hoppers (1) suggests the following message for managed lanes interim use under major incident conditions:

MAJOR ACCIDENT
1 MILE AHEAD
USE HOV LANE

Changeable message signs can be permanently located along the managed lanes facility corridor (used for day-to-day traffic management) or available on mobile trailers. Transportation agencies may have unused portable CMSs at a storage facility for use or may opt to temporarily borrow portable CMSs from nearby construction projects.

CMS information can be supplemented with either portable or permanent Highway Advisory Radio (HAR). HAR requires a motorist to tune their radio to a specified AM frequency, where more detailed and potentially bilingual information is provided. Often, static signs and changeable message signs will direct motorists to tune to the HAR frequency for supplemental information.

The media (radio or television) is a very useful tool in providing the public with travel condition information. Radio-based media can reach motorists on-site, approaching the site, or not yet departed from work, home, or another location. Television-based media can reach motorists not yet departed from their home. The media can be used to inform the general public of:

- ◆ the level of congestion on the general-purpose and managed lanes facilities,
- ◆ available alternate routes,
- ◆ managed lanes diversion, and
- ◆ available exits if they choose to divert to the managed lanes (1).

A working relationship and possible cooperative agreements with the media should be in place prior to an event to establish a protocol for communications and to stress the importance of providing accurate real-time information.

Network Traffic Management

In addition to controlling traffic on-site, it is important to consider the larger traffic impacts. Traffic management or emergency operations centers, through the use of closed circuit television cameras or other surveillance technologies, can monitor traffic on the affected managed lanes and general-purpose facility, upstream and downstream of the affected facility and along alternative routes. Through careful and widespread surveillance, transportation agencies can better identify and remedy potential problems

and support decisions related to a return to standard operation for the managed lanes facility.

Network traffic management often requires cooperation between state and local jurisdictions to adequately accommodate diversion traffic. Even if the managed lanes facility is open for interim use by general-purpose traffic, many motorists will opt to take alternate local routes rather than the managed lanes facility. Local jurisdictions may need to modify traffic signal timings to provide additional green time or implement other traffic management strategies to accommodate this increase in demand. Hence, early and continuous communication with the local jurisdictions regarding the state of the general-purpose and managed lanes facility is important.

Public Education

Prior to a motivating event, public education efforts may be used to familiarize motorists with managed lanes interim use procedures. A number of state departments of transportation provide general information regarding their interim managed lanes use practices via the World Wide Web. Most often, this information is contained as a response to a “frequently asked question” on the agency’s website. This information should be carefully crafted to:

- ◆ communicate the potential for occasional use to general-purpose traffic and
- ◆ reassure managed lanes users of the infrequent nature of this use.

The Virginia Department of Transportation (VDOT) provides a good example of this balance:

Why are HOV lane restrictions lifted when there is an accident? Doesn’t VDOT want to reduce congestion and pollution by encouraging carpooling? VDOT does strive to encourage carpooling to reduce congestion and pollution on our highways, so we seldom lift HOV restrictions. Decisions to lift HOV restrictions are made in conjunction with, or at the request of, the Virginia State Police Department. The police only make such a request if an accident is deemed to be a major incident that will take an extended period of time to clear. I know it is frustrating to see solo motorists enjoying the HOV lanes when you are “playing by the rules,” but you will notice that even during snow conditions, HOV lane restrictions are not lifted unless the main lines are blocked (13).

Monitoring and Evaluation

If a facility manager opts to allow interim use of managed lanes facilities, an accompanying monitoring and evaluation plan should be developed. Monitoring and evaluation of interim use strategies will support decisions related to the conditions under which interim use is implemented (i.e., the duration and impact of an incident) and will provide the necessary information to justify these decisions. Performance metrics for

interim managed lanes use should relate to the intent of the motivating event and should include:

- ◆ congestion levels on both the managed lanes and general-purpose facility before and during interim use,
- ◆ safety of both motorists and responders, and
- ◆ public acceptance/perception.

Congestion levels, expressed in terms of vehicles per hour per lane, travel time, travel speed, etc. can be monitored by a traffic management center using surveillance technologies (i.e., electronic loop detectors, closed-circuit television cameras, etc.). A minor compromise in the managed lanes level of service and a corresponding improvement in the general-purpose facility level of service are desirable. A dramatic decrease in the managed lanes level of service may suggest a re-evaluation of interim managed lanes use criteria or discontinued interim use, especially if a negligible change is observed on the general-purpose facility.

Safety information can be obtained through accident records for the motoring public and through agency on-the-job injury reports for responders. A separate record of secondary incidents should be maintained; accident records don't distinguish secondary incidents. An improvement in responder safety suggests continuation of managed lanes interim use. These observations should be tempered with any observed increase in motorist-involved incidents at managed lanes ingress or egress points or elsewhere along the facility attributable to motorist unfamiliarity or confusion. An increase in motorist-involved incidents at these locations suggests a need for improved signing and traffic control at these locations, or it may prompt discontinued interim use of the managed lanes facility.

Lastly, a survey of users and non-users of the managed lanes facility should be performed to determine the public's opinion about whether the managed lanes should have been opened to general traffic. This survey can be conducted as an online survey or, depending on the nature of the managed lanes facility, can be distributed in hardcopy form to known managed lanes users (i.e., transit riders, motorists with toll tags, etc.). If the latter survey method is pursued, an effort should also be made to solicit opinions about non-managed lanes users who may or may not feel strongly about being able to utilize managed lanes during unusual conditions.

Performance metrics in each of these areas (i.e., congestion, safety, and public acceptance/perception) should be considered in combination to help shape and improve strategies for interim managed lanes use. These evaluation activities should be repeated periodically to capture changes in traffic volumes and travel patterns as well as changes in attitude towards the interim use of the managed lanes facility.

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Chapter 13 – Staffing and Training for Managed Lanes

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Section 1 – Overview

Managed lanes facilities present many new challenges to the agency or agencies responsible for their operation. The potential complexities associated with user groups and operational options will require agencies to have an appropriate number of qualified staff to ensure adequate oversight of operations and to ensure satisfactory customer service to the users. Thus, this chapter identifies those staffing needs related to operational options and specific training that might be required to ensure agency staff are fully prepared to perform their duties to the satisfaction of both the agency and the customer. Other issues addressed are the roles of job positions within the framework of managed lanes, the competencies required of those positions, and accessibility to appropriate training, education, and technical assistance to ensure these needs are met.

Sections in this chapter cover:

- ◆ staffing practices and training needs, and
- ◆ training opportunities.

Section 2 – Staffing Practices and Training Needs

Every agency has a slightly different approach toward delegating roles and responsibilities and training its staff, particularly with regard to managed lanes facilities. However, common themes and strategies exist that can help agencies ensure that their staff have the knowledge, skills, and abilities to perform their tasks associated with operating managed lanes efficiently. The following subsections highlight some of these strategies in more detail to gain insight into how agencies currently handle responsibilities and training for current managed lanes facilities.

Primary Responsibilities

The primary responsibility of a managing agency is normally to oversee contract management for the managed lanes facility. Outsourcing is a common practice since operation-related funds are limited and staff resources are stretched to the limit. Additionally, the tolling component of some managed lanes facilities adds operational complexities that are not the specialty of DOTs. In such cases, the DOT often contracts with a tolling agency to handle the financial daily operations of the managed lanes facility.

Managed lanes operational agencies also often utilize existing public relations and marketing personnel to assist with the public outreach aspect of the managed lanes. With regard to the customer service aspect of managed lanes operations where HOT lanes are involved, agencies typically outsource this work and do not have a direct hand in the day-to-day customer service for the facility. For example, one operating agency has an outsource contractor that has five employees who exclusively handle the operations of managed lanes customer service. Two of these staff have management roles, and the other three are customer service representatives handling direct relations with customers.

Customer Service

Training for customer service staff of managed lanes facilities is typically not a primary responsibility of the managing agencies. Since such responsibilities are normally outsourced to different contractors, agencies leave that responsibility to the individual contractor. However, some agencies cite that an operations plan was developed by an initial contract operator. The plan outlines policy considerations and their outcomes and customer service staff guidance for handling a variety of transactional and service-related questions for the future responsible personnel. This plan also provides guidance on the use of a proprietary software application that was developed to host the account and transactional data.

Operations

Different practices exist with regard to the handling of traffic operations and incident management for the managed lanes facilities. Some agencies undertake this responsibility within their organization and conduct internal training to ensure that the

personnel working in the local transportation management center (TMC) are familiar with the managed lanes operation and their role in that operation. This training may consist of a group seminar to review procedures. This information may also be incorporated into training of new TMC personnel. However, some agencies operating a managed lanes facility may not have responsibility for local traffic operations and incident management. In such cases, the operation of the area TMC is not within their jurisdiction. Thus, these agencies may rely on the TMC personnel to have adequate training. Also, any change in this arrangement such that the operating agency would assume these responsibilities would require that they conduct extensive training to ensure that their personnel charged with these new duties gain the knowledge and expertise required to perform their new roles efficiently.

Required Knowledge, Skills, and Abilities

To date, training practices are currently limited with regard to managed lanes facilities. However, a number of skill sets or knowledge bases exist that should be met to ensure smooth operations of a managed lanes facility. These skill sets include:

- ◆ contract management and supervision,
- ◆ customer service relations,
- ◆ accounts handling,
- ◆ traffic operations management,
- ◆ incident management, and
- ◆ public relations and marketing.

For agencies operating managed lanes facilities, skilled personnel should be identified within the agencies. Otherwise, appropriate personnel should receive training during the startup of operations, or appropriate personnel should be secured through outsourcing.

Other Issues

As discussed previously in this handbook, public opinion of a managed lanes facility can have a significant influence on either the success or failure of the project. Training and staffing can have a great impact on how this aspect of the project is undertaken. By raising the knowledge level of this type of staff, either through training or hiring of appropriately knowledgeable personnel, it will increase the effectiveness of communications with the general public about the value of a managed lanes project.

Also, studies have indicated that enforcement is as important to the proper function of an HOV facility as other operational considerations. The importance of enforcement cannot be overemphasized, as noted in *Chapter 10 – Enforcement Issues for Managed Lanes*. Note specifically:

- ◆ The level of enforcement is dependent upon the type of facility, and concurrent-flow facilities require more enforcement.
- ◆ An officer must have a safe and convenient place to issue citations that is within view of the facility.
- ◆ A visible enforcement presence must be maintained.
- ◆ On limited access facilities, diversion of potential violators prior to traversing some part of the facility may be safer and more efficient than after the fact.
- ◆ Enforcement personnel should be located at terminal points.

The inclusion of law enforcement personnel in training activities related to the anticipated operational strategies for a new managed lanes facility benefit both the function of the system and the officers' ability to enforce the planned managed lanes approach.

Section 3 – Training Opportunities

When considering managed lanes facilities, agencies should ensure that staff have the opportunities to gain training on relevant topics that can enhance their job performance. Typical methods of obtaining this training include workshops, seminars, conferences, and technical meetings. The following subsections highlight current courses available that fit some of the typical knowledge and skill needs of personnel.

Courses

Several courses and workshops are currently available that provide background knowledge for staff who may be involved with managed lanes facilities. While not all of them are specifically for managed lanes strategies, some provide information on various elements of managed lanes that have been discussed throughout this handbook. Also, while their availability may vary over time, they represent possible opportunities for personnel to gain the knowledge, skills, and abilities necessary to perform a role within the operating agency. They do not represent an exhaustive list. Rather, they serve as examples of the topics available that may serve the needs of managed lanes facility personnel. Courses that are similar in nature can suffice if available.

The first of two these courses are related to HOV lanes and corridor management, speaking directly to HOV lane topics. The third and fourth do not specifically state that they are related to either managed lanes or HOV facilities; however, the topics, strategies for urban traffic congestion and context sensitive solutions, both lend themselves to looking for new or alternative solutions to be used in the management of traffic flow in urban areas. These ideas could be directly related to the use of managed lanes strategies to meet the objectives for mobility and safety. Finally, the last course is related to tolling technologies, which has direct relevance for an agency looking to begin a HOT lane operational strategy for its managed lanes. Through this type of training, agencies can gain knowledge of the new challenges created through the implementation of a toll system.

High Occupancy Vehicle (HOV Facilities)

Length: 3 days

Description: This training course will provide participants with a general appreciation and understanding of the key policies, technical issues, and other issues to consider in the planning, design, implementation, management, operation, and marketing of HOV facilities. HOV facilities are a strategy to assist public agencies and transportation services providers to address the identified mobility, safety, productivity, environmental, and quality of life needs in metropolitan areas.

Audience: Traffic engineers, transportation planners, roadway design engineers, transportation managers/supervisors, transit planners, transit

managers/supervisors, and public information specialists who are involved in the planning, design, management, operations, and marketing of an HOV system

Offered by: National Highway Institute

Website: <http://www.nhi.fhwa.dot.gov/coursedesc.asp?coursenum=91>, Accessed August 2005

Corridor Management

Length: 1.5 days

Description: The widespread, widely embraced ITS movement has emphasized the benefits of integrated systems elements. This course focuses on ramp control, HOV treatments, and control centers as a way to manage corridors using integrated systems elements.

Audience: Public-sector transportation professionals including USDOT engineers, planners, project managers, and field staff; FTA regional staff; ITS specialists; and others as appropriate. Transportation professionals from state, regional, and local agencies would also benefit from participation in the course.

Offered by: Consortium for ITS Training and Education (CITE)

Website: <http://www.citeconsortium.org/courses/1mod9.html>, Accessed August 2005

Strategies for Urban Traffic Congestion Workshop

Length: 5 days

Description: Traffic congestion has traditionally been associated with the “central city” part of an urban area. In recent years, the entire metropolitan region has experienced changes in development patterns and growth. Office development in the suburbs, for example, has been increasing in size and density. With these changes come shifts in travel patterns and, in turn, traffic congestion. In fact, public opinion polls rate traffic problems very high on the list of “city” concerns, in some cases higher than crime, housing issues, and pollution. As a result, there is mounting pressure to mitigate the negative effects of traffic congestion on air quality, fuel consumption, economic vitality, and the quality of life in our metropolitan and developing areas.

Transportation analysts need to be aware of techniques and programs that are designed to address the growing problem of traffic congestion. This workshop is designed to meet the needs of the transportation analyst. The objective of the workshop is to enable participants to gain an understanding of the methods and tools available to assist in evaluating traffic conditions and in testing alternative

strategies to better manage congestion. Strategies to alleviate congestion-related problems on the freeway, arterial, and residential street systems, as well as throughout the transportation network, are identified. Attention is also given to organizational programs as another tool for congestion management.

Audience: Traffic engineers and planners from government agencies, planning organizations, and private firms, and those with responsibilities for congestion reduction measures

Offered by: Northwestern University Center for Public Safety

Website: http://server.traffic.northwestern.edu/course/course_more.asp?id=683, Accessed August 2005

Context Sensitive Solutions

Length: 2 days

Description: Context sensitive solutions (CSS) is an emerging approach to project development and management that asks more from transportation professionals than ever before. CSS methods use more inclusive processes to find elegant solutions for highly complex problems and achieve more than the usual “safe and efficient movement of people, goods, and services.” Recent federal legislation places greater emphasis on applying CSS principles to transportation projects.

This two-day workshop will help you become an effective participant in the art of context sensitive solutions. Through lecture and class discussions, you will learn essential CSS methods for rural, suburban, and urban settings. Individual and small group exercises allow you to practice the tools and techniques. Illustrative case studies and hypothetical scenarios make the material interesting, relevant, and lively.

The course will also increase your understanding of public involvement processes, collaborative problem solving, and decision-making systems.

Audience: Planners, engineers, designers, project managers, and administrators from government agencies and private firms

Offered by: Institute of Transportation Engineers

Website: <http://www.ite.org/education/clearinghouse/>, Accessed August 2005

Electronic Payment Systems (EPS)

Length: 4 hours

Description: This overview of electronic payment systems is focused on the areas of applications, EPS architecture and components, and electronic media characteristics. Public transit, road tolling, parking, and multipurpose applications are discussed in the first section and followed by a brief review of the most important security criteria relevant to EPS. The next segment, on EPS architecture and components, addresses the topics of cards and their characteristics, reader types and functions, open and closed networks, and the major functions of the host system, and it introduces the concept of the clearinghouse. The major types of electronic media are described in detail in the following segment. Finally, two examples of EPS deployments are discussed with emphasis on the technologies used and effectiveness in reaching their respective objectives.

Audience: Public-sector transportation professionals including USDOT engineers, planners, project managers, and field staff; FTA regional staff; ITS specialists; and others as appropriate. Transportation professionals from state, regional, and local agencies would also benefit from participation in the course.

Offered by: Consortium for ITS Training and Education

Website: <http://www.citeconsortium.org/courses/2mod2.html>, Accessed August 2005

Conferences and Seminars

Specialty conferences and seminars are offered throughout the year that provide relevant information on managed lanes operational strategies. They provide excellent learning opportunities for personnel since they are topic specific and allow attendees to have closer interaction with practitioners and experts in the field of managed lanes. The list of those events that either have a direct or indirect applicability to managed lanes is too lengthy to include here. However, two recent conferences of note that are specific to managed lanes issues are listed below.

12th International HOV Systems Conference: Improving Mobility and Accessibility with Managed Lanes, Pricing, and Bus Rapid Transit

Date: April 18-20, 2005

Description: The conference theme focused on HOV systems, managed lanes, and pricing: strategies for improving metropolitan mobility and accessibility.

Sponsor: Transportation Research Board Committee on High Occupancy Vehicle Systems

Website: <http://www.trb.org/Conferences/HOV/#conference>, Accessed August 2005

USDOT Road Pricing Seminar

Date: January 13, 2005

Description: The purpose of the seminar was to provide a briefing on innovative road pricing projects in the United States and internationally.

Sponsor: Road Pricing Team, FHWA

Website: <http://knowledge.fhwa.dot.gov/cops/hcx.nsf/aa5aec9f63be385c852568cc0055ea16/08bd19aa1c6a68f785256fb80052305b?OpenDocument>, Accessed August 2005

Audiences

Overall, the audiences identified for the training courses, as listed with the course descriptions above, are composed of decision makers. Primarily, it is specified that transportation professionals in the positions of engineers, planners, or other management or supervisory roles would benefit from the courses. This consistency emphasizes the idea that the topics covered are not necessarily related to day-to-day operations of the facilities, but they will be associated with decision making regarding how, when, or where to implement different strategies and how to identify the appropriate conditions for those strategies. One exception to this is the course on electronic payment systems where field staff is specifically identified as a possible audience for the topic. This course is based to a greater extent upon the understanding of applications and technologies related to this topic.

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Section 1 – Overview

A successful performance monitoring and evaluation program generally comprises six indistinct and overlapping steps:

1. setting goals and objectives that reflect the program or system’s desired performance and are consistent with agency or regional priorities;
2. identifying appropriate performance measures to accurately evaluate attainment of the goals and objectives;
3. identifying required data and sources to support calculation of the performance measures;
4. defining appropriate evaluation methods within the constraints of data availability and staff training;
5. defining an appropriate schedule for ongoing, periodic monitoring of the system; and
6. reporting the results in a usable and easily understood format (1).

Successful performance monitoring and evaluation activities support an agency’s provision of day-to-day services, direct facility and administrative management decisions, and guide short- and long-range planning efforts.

Despite not so recent legislative or regulatory mandates (i.e., the Transportation Equity Act for the 21st Century’s requires performance monitoring as an eligibility criteria for federal funding of transportation projects), transportation agencies have been challenged to adequately monitor and evaluate transportation facility performance. Neudorff et al. (1) characterized several of these challenges as follows:

- ◆ current *Highway Capacity Manual (HCM 2000)*–based levels of service measures do not adequately capture the effects of operational strategies, which are often more subtle than capacity expansion projects;
- ◆ the concept of a “peak hour” has been rendered irrelevant by travel patterns that have led to “peak periods”;
- ◆ the proper perspective for measuring performance – the view of the user (traveler) versus the view from the facility – is under debate;
- ◆ the concept of “reliability” is growing in importance, and the variability that occurs day to day is important; and
- ◆ traditional monitoring data, which are scattered and sampled, lack the resolution to capture the effects of more modest operational improvements.

Much of the progress made in addressing these challenges, developing performance measures, and refining evaluation methods has considered general freeway facilities, as documented in the *Freeway Management and Operations Handbook (1)*, the *Performance Measurement Initiative (2)*, and most recently the *Guide to Effective Freeway Performance Measurement, Version 1.0 (3)*. These reference guides address site-specific to corridor-level operations analysis, alternative investments analysis, area-wide planning, and public information studies for a variety of strategies used for freeway management and operations.

While these guides are comprehensive in topic, they lack specificity for managed lanes facilities. Managed lanes facilities are unique, typically requiring a higher degree of active (sometimes real-time) management, addressing goals and objectives that are inconsistent with the general freeway facility (i.e., revenue generation, person rather than vehicle throughput, etc.), and accessing an exclusive set of management tools (i.e., gate closures, etc.). These differences may affect how managed lanes facility performance is successfully monitored and evaluated.

To address the potential differences between managed lanes facilities and general freeway facilities, this investigation was conducted to isolate and document the best performance monitoring and evaluation practices and principles explicitly for managed lanes facilities. More specifically, this chapter summarizes:

- ◆ positive performance monitoring and evaluation practices for managed lanes (i.e., in published literature or observed practice) that could be recommended for widespread implementation;
- ◆ reportable managed lanes benefits that may guide the development of performance “benchmarks” for monitoring and evaluation; and
- ◆ any issues for consideration surrounding performance monitoring and evaluation practices for managed lanes.

Supporting Information

The novelty of managed lanes as a traffic management strategy, the diversity of managed lanes facility types (i.e., high-occupancy vehicle lanes, exclusive truck lanes, etc.), and the breadth of motivating factors for managed lanes implementation (i.e., to improve mobility and congestion, reliability, accessibility, safety, environmental impact, system preservation, organizational efficiency, etc.) challenged the identification and selection/reduction of pertinent literature. Nonetheless, three general types of information emerged:

- ◆ collective guidelines related to overall freeway performance monitoring and evaluation;
- ◆ collective guidelines related to singular managed lanes facility (i.e., high-occupancy vehicle lane facilities) performance monitoring and evaluation; and

- ◆ site-specific findings (i.e., national practice) related to managed lanes facility performance monitoring and evaluation.

Collective Guidelines for Overall Freeway Performance Monitoring and Evaluation

In response largely to TEA-21's requirements for performance monitoring as an eligibility criterion for receipt of federal funding, a number of studies were conducted in the 1990s that focused on guiding or enhancing these activities. These efforts focused almost exclusively on:

- ◆ defining appropriate performance measures,
- ◆ improving data quality and the efficiency with which it is captured, and
- ◆ integrating this performance data into the decision-making process to support facility operations and management or planning.

These seminal studies culminated in the development of national guidelines for general freeway performance monitoring and evaluation. The *Freeway Management and Operations Handbook (1)* considers a broader spectrum of topics but devotes one chapter to describing best practices for freeway performance monitoring and evaluation. In addition, the NTOC (2) recently published results from its *Performance Measurement Initiative* that detail a short list of recommended performance measures that can be used for internal agency management, external communications and comparative measurement. Most recently and currently under development, the *Guide to Effective Freeway Performance Measurement (3)* provides comprehensive direction for defining and utilizing freeway performance measures and developing a comprehensive freeway performance management program. This investigation relied heavily upon the guidance provided in these recent documents to ensure consistency with national performance monitoring and evaluation guidelines and to reflect prior lessons learned for these activities.

Concurrently with the development of collective guidelines for overall freeway performance monitoring and evaluation, a number of state departments of transportation were undertaking their own efforts to develop performance monitoring guidelines tailored to their specific needs. Shaw (4) comprehensively documented state-level performance monitoring and evaluation practices in *Performance Measures of Operational Effectiveness for Highway Segments and Systems*. State-level programs described in this synthesis review included Arizona, California, Delaware, Florida, Maryland, Minnesota, New York, Texas, Virginia, and Washington. These state-level observations helped to temper the collective recommendations for performance monitoring and evaluation by demonstrating activities feasible for implementation.

Additional guidance, focused on some aspect of facility performance, is also available. For example, FHWA publishes the *TEA-21 Evaluation Guidelines (5)* and the *ITS Evaluation Resource Guide (6)* to support the evaluation of technology-related facility

improvements. More focused documents, such as these, were not extensively considered as part of this investigation.

Collective Guidelines for Managed Lanes Facility Performance Monitoring and Evaluation

Only two documents were uncovered that provided collective guidelines for managed lanes facility performance and monitoring:

- ◆ *Suggested Procedures for Evaluating the Effectiveness of Freeway HOV Facilities (7)* and
- ◆ *High Occupancy Vehicle Monitoring and Evaluation Framework (8)*.

Not surprisingly, both documents are focused on HOV lane facilities; HOV lane facilities, more than other types of managed lanes facilities, experienced early and widespread implementation and hence have been the subject of significant study.

National Practices for Managed Lanes Facility Performance Monitoring and Evaluation

With the exception of the two HOV-related documents referenced above, information specific to managed lanes facilities was largely limited to site-specific evaluation studies. Much of the information considered managed lanes facilities currently in operation (i.e., HOV lanes, truck lane restrictions, etc.) or in operation as a demonstration project; however, a number of studies were uncovered that considered the feasibility of various managed lanes facilities prior to implementation (i.e., valued-priced and HOT lanes, exclusive bus and truck lanes, etc.). The results of these evaluation studies were used primarily to establish a range of performance targets by facility type but also to identify and confirm the appropriateness of various performance monitoring and evaluation activities as specifically applied to managed lanes facilities.

Chapter Organization

Following this introductory information, the remainder of this chapter contains the following information:

- ◆ [Section 2](#) highlights key findings and recommendations from national guidance documents for each step in the six-step performance monitoring and evaluation process;
- ◆ [Section 3](#) summarizes, in textual and tabular form, pertinent guidelines and observed national practice related specifically to the monitoring and evaluation of managed lanes performance, including any reportable benefits; and
- ◆ [Section 4](#) concludes with a discussion of chapter limitations.

Section 2 – General Guidelines for Performance Monitoring and Evaluation

To ensure consistency with national performance monitoring and evaluation guidelines and to reflect prior lessons learned for these activities, notable findings and recommendations related to each step of the step-by-step performance monitoring and evaluation process are provided below.

Goals and Objectives

For transportation facilities, including managed lanes, goals and objectives typically focus on mobility and congestion, reliability, accessibility, safety, environmental impacts, system preservation, and/or organizational efficiency. With these various focus areas in mind, successful goals and objectives should:

- ◆ be measurable and quantifiable, adequately describing changes in operation;
- ◆ consider performance at the system, project, agency, regional, or statewide level and involve the public, local business interests, elected officials, and agency personnel;
- ◆ drive the data to be collected, not be driven by data availability;
- ◆ consider qualitative (i.e., related to customer satisfaction) goals; and
- ◆ prioritize conflicting goals (i.e., system preservation goals may require an increase in maintenance expenditures, while agency efficiency goals seek to minimize maintenance costs).

Performance Measures

Similar principles for success exist when defining related performance measures. To be successful, performance measures should be:

- ◆ limited in number to prevent data collection and analytical requirements from overwhelming an agency's resources or decision makers;
- ◆ simple and understandable with consistent definitions and interpretations to address the needs of a wide-ranging audience, while still achieving the required precision, accuracy, and detail to facilitate system or program improvement;
- ◆ easily captured either automatically using various technologies or manually with minimal manual data entry and processing to produce usable results;
- ◆ sensitive to change and able to adequately capture observed changes in system or program performance;

- ◆ consistent with staff skills (simplistic evaluation methods with accurate results are preferred over advanced methods that may be erroneous if staff are not adequately trained);
- ◆ consistent in timeframe with decision-making needs, ranging from real-time to long-term; and
- ◆ geographically appropriate with decision-making needs, ranging from corridor specific to region-wide, statewide, or even nationwide.

Emerging trends or “principles” in the selection of performance measures for transportation facilities are as follows:

- ◆ mobility measures should be based on travel time (travel time, or other similar derivatives of speed and delay, is easily understood by practitioners and the public and is applicable to both the user and facility perspectives of performance);
- ◆ multiple metrics should be used to report performance;
- ◆ traditional *HCM*-based performance measures (*V/C* ratio and level of service) should not be ignored but should serve as supplementary, not primary, measures of performance in most cases;
- ◆ both vehicle-based and person-based performance measures should be developed (person-based measures provide a “mode-neutral” way of comparing alternatives);
- ◆ both mobility and efficiency performance measures should be developed, and improvements in efficiency should be linked to positive changes in mobility;
- ◆ customer satisfaction measures should be included;
- ◆ three dimensions of freeway congestion should be tracked with mobility measures: source of congestion, temporal aspects, and spatial detail; and
- ◆ the buffer index – the amount of extra time needed to be “on time” 95 percent of the time – is emerging as the preferred reliability measure.

Data Collection

Three general categories of data are generally collected to support transportation facility performance monitoring and evaluation: facility use and performance data (i.e., traffic volumes, travel times, and delay); staffing and resource allocation and use data; and event and incident data, including location, duration, and nature. Data can be collected through a variety of means including automatic or manual techniques. Further, data can be collected continuously across a facility or sampled through special studies. Notable lessons learned with respect to data collection are as follows:

- ◆ Automatic techniques may suffer from reliability problems and questionable accuracy. It is essential to confirm the accuracy of automatically collected data by periodic use of manual devices.
- ◆ Special studies are typically short in duration and generally focused on collecting data (i.e., vehicle occupancy and transit ridership information) not available through existing sources. Care must be taken to avoid bias when utilizing special studies sampled data.
- ◆ To capture motorist perception data, focus groups, stated preference surveys, or revealed preference surveys can be used. Each has advantages and disadvantages that should be considered related to the level of information provided and the potential for extrapolation to a larger population.
- ◆ When selecting data collection methods, the cost and accuracy of each method, the availability of local resources to implement each method, the ease of implementation, and the ultimate data analysis requirements should be considered.

Monitoring and Evaluation

Evaluation activities may range from a simplistic analysis of quantitative measures to produce descriptive or inferential statistics to any number of more comprehensive, robust analyses related to capacity and level of service, simulation, before-after effects or alternatives selection. Capacity analysis and simulation are appropriate for ongoing system monitoring, while before-after and alternatives analyses are more appropriate for evaluation prior to or following implementation.

The required frequency of evaluation (i.e., monitoring) is variable and highly dependent upon the amount of variation observed for a particular facility and constraints upon agency resources. In general:

- ◆ continuously collected data (i.e., traffic volumes, travel times, etc.) should be analyzed monthly, quarterly, and/or annually;
- ◆ continuously collected data should be compared with supplemental manually collected data (i.e., from travel time studies) at a monthly or quarterly frequency to ensure adequate data quality (higher frequencies of comparisons are required if significant inconsistencies are observed);
- ◆ data that have infrequent occurrences (i.e., accidents) should be analyzed annually or every two to three years; and
- ◆ similarly, data that require considerable data collection resources (i.e., customer satisfaction surveys) should be analyzed annually or every two to three years.

In each case, the frequency of evaluation (i.e., monitoring) can decline over time as the facility performance stabilizes.

Reporting

The audience for performance monitoring and evaluation information is broad but can be effectively categorized by jurisdictional levels:

- ◆ local, requiring real-time information to select and implement operational plans, provide traveler information, and plan future improvements;
- ◆ regional, requiring aggregated real-time information to address the performance of the system and implement and monitor regional response plans;
- ◆ state, requiring information specific enough to distinguish modal performance for resource allocation and programming and long-range planning; and
- ◆ national, requiring long-term, aggregate information to determine net effect of strategies, support policy making and goal setting, develop/justify legislation, etc.

Common media and formats for relaying performance monitoring and evaluation information include:

- ◆ real-time websites providing specific traveler information (i.e., incidents, etc.);
- ◆ operations planning reports supporting daily road or transit operations;
- ◆ annual, monthly, and quarterly reports summarizing regional or statewide conditions, recent performance, and trends;
- ◆ before-after and issue studies focusing on corridors, times of day, or specific problems (i.e., travel time variations and freight movement);
- ◆ project analysis reports, used to support public transportation, operational, or demand management programs, describing total system effects; and
- ◆ long-range planning reports providing trend information and travel forecasts, along with more typical planning measures.

Section 3 – Guidelines and Practices for Managed Lanes Performance Monitoring and Evaluation

Despite the novelty of managed lanes as a traffic management strategy, the diversity of managed lanes facility types, and the breadth of motivating factors for managed lanes implementation, some general consistency in practice was observed with respect to performance monitoring and evaluation. Common goals, objectives, and performance measures were observed across similar facility types. Significant differences were also observed across similar facility types with respect to observed performance outcomes and evaluation methodologies. Differences in observed performance outcomes are likely explained by the variety in facility design (i.e., length of facility, accessibility, etc.) and operation (i.e., eligibility requirements, toll rates, etc.), even within a similar facility type. Differences in the evaluation methodologies used to arrive at these observed performance outcomes are likely reflective of the available resources for analysis at the time of evaluation and the evolving state of analysis methodologies.

With a focus on the commonalities across similar facility types, [Table 14-1](#) depicts typical goals, objectives, and performance measures for the various managed lanes facilities considered as part of this investigation.

Note that in general, passenger-focused managed lanes facilities have a primary interest in increasing person throughput, reflected as a function of increased average vehicle occupancies and increased travel speeds. Encouraging the mode shift to higher occupancy vehicles is the potential for travel time savings and travel time reliability. Value-priced and HOT lanes present unique opportunities for toll revenue, capitalizing on the time savings benefit with less emphasis on encouraging mode shift. Safety and environmental effects are of secondary interest and are primarily reported to confirm no adverse impacts from implementation of a managed lanes facility. Accidents generally occur infrequently and hence require a lengthy evaluation period. Environmental effects are loosely estimated as a function of travel speeds.

Freight-focused managed lanes facilities, on the other hand, often have a primary interest in safety and a unique interest in preserving the pavement infrastructure. Resulting benefits attributable to time savings are secondary in nature. Hence, freight-focused opportunities for toll revenue (i.e., exclusive lanes and mixed-flow separation/bypass lanes) report limited likely success. Additional observations on a facility-by-facility basis are described below.

High-Occupancy Vehicle Lane Performance Monitoring and Evaluation

High-occupancy vehicle lane facilities have the most extensive history of performance monitoring and evaluation; HOV lanes facilities experienced early and widespread implementation and hence have been the subject of significant study. Early site-specific evaluation studies conducted in northern Virginia, California, Texas, Washington, Minnesota, and New Jersey were considered by Turnbull et al. (7), culminating in the *Suggested Procedures for Evaluating the Effectiveness of Freeway HOV Facilities*.

Table 14-1. Common Goals, Objectives, and Performance Measures for Managed Lanes Facilities.

GOALS/OBJECTIVES	PERFORMANCE MEASURES	MANAGED LANES FACILITIES								
		HOV Lanes	Value-Priced and HOT Lanes	Exclusive Lanes		Mixed-Flow Separation/Bypass Lanes		Lane Restrictions	Dual Facilities	
		Passenger	Passenger	Passenger	Freight	Passenger	Freight	Freight	Passenger and Freight	
MOBILITY/CONGESTION	Increase overall mobility during recurring and nonrecurring congestion while maintaining accessibility									
	Increase throughput	<ul style="list-style-type: none"> Daily and hourly volume on managed lane (ML) facilities (vehicle, person volumes) Total, daily and hourly facility volume (general purpose[GP], ML, other) Total, daily and hourly facility volume (vehicle, person, truck volumes) Vehicle-, person-, or truck-hours of travel Vehicle-, person-, or truck-miles of travel 	P	P	P	P	P	S	S	P
		<ul style="list-style-type: none"> Percent peak-period volume (vehicle, person, truck volumes) 	S		S		S			S
		<ul style="list-style-type: none"> Per lane efficiency (speed x pphpl) 	S		S					S
		<ul style="list-style-type: none"> Vehicle occupancy (per/veh) 	P	S	S		P			S
		<ul style="list-style-type: none"> Temporal shift 		P						
		<ul style="list-style-type: none"> Transit ridership Carpool use Transit market share 	P		P		P			P
		<ul style="list-style-type: none"> Mode shift 	S	P	S		S			S
	Increase average travel speeds	<ul style="list-style-type: none"> Average lane (ML and GP) and facility speed 	P	S	P	P	S	S	S	P
	Decrease average travel times	<ul style="list-style-type: none"> Travel time rate (minutes per mile) 	S		S					S
		<ul style="list-style-type: none"> Travel time savings per mile Annual travel time savings (\$) 	P	S	P	P	P	S	S	P
		<ul style="list-style-type: none"> Customer perceptions on travel time 	S	S	S	S	S	S	S	S
Decrease delay	<ul style="list-style-type: none"> Average delay (day and annually) Average delay (vehicle, person, and ton-mile) 		S			P	S	S		
Decrease violators	<ul style="list-style-type: none"> ML compliance 	P	S	S	S	P	S	S	S	
RELIABILITY	Increase reliability during recurring and nonrecurring congestion									
	Decrease travel time variation	<ul style="list-style-type: none"> Std. deviation (travel time, speed) Variance (coefficient of variation, travel time, speed) 	P	S	P	P	P	S	S	P
		<ul style="list-style-type: none"> Customer perceptions on reliability 	S	S	S	S	S	S	S	S

P = primary, S = secondary

Table 14-1. Common Goals, Objectives, and Performance Measures for Managed Lanes Facilities (Cont.).

GOALS/OBJECTIVES	PERFORMANCE MEASURES	MANAGED LANES FACILITIES								
		HOV Lanes	Value-Priced and HOT Lanes	Exclusive Lanes		Mixed-Flow Separation/Bypass Lanes		Lane Restrictions	Dual Facilities	
		Passenger	Passenger	Passenger	Freight	Passenger	Freight	Freight	Passenger and Freight	
REL.	Increase “on-time” performance	<ul style="list-style-type: none"> • Buffer index (95th percentile travel time by corridor and major trip) • Percent of trips that arrive in acceptable time window 	P	S	P	P	P	S	S	P
SAFETY	Increase overall safety levels									
	Decrease the frequency and severity of incidents	<ul style="list-style-type: none"> • Number of incidents (by type and location) • Incident severity • Incident reduction savings (\$) 	S	S	S	P	S	P	P	P
ENVIRON.	Decrease overall impacts to the environment and resources									
	Decrease fuel consumption	<ul style="list-style-type: none"> • Fuel consumption (per PMT, VMT, or TMT) 	S	S	S	S	S	S	S	S
	Increase air quality/decrease pollutants	<ul style="list-style-type: none"> • Tons of pollutants • Number of days in air quality non-compliance 	S	S	S	S	S	S	S	S
SYSTEM PRESERV.	Maintain or increase overall system service life									
	Decrease deficient facilities	<ul style="list-style-type: none"> • Pavement deterioration rate change • Remaining service life 				P		S	P	P
		<ul style="list-style-type: none"> • Roughness index for pavements • Percent of roads with deficient ride quality (VMT, TMT) • Percent of roadway pavement rated good or better 				S		S	S	S
		<ul style="list-style-type: none"> • Maintenance costs per year 				P		S	P	P
ORGANIZ. EFFICIENCY	Increase productivity without compromising public’s expectations for efficient and effective travel									
	Increase customer satisfaction ratings	<ul style="list-style-type: none"> • Percentage of projects rated good to excellent • Qualitative customer comments 	S	S	S	S	S	S	S	S
	Minimize costs	<ul style="list-style-type: none"> • Cost for construction (per lane-mile, VMT, PMT, or TMT) 	P	S	P	P	P	P	S	P
		<ul style="list-style-type: none"> • Vehicle operating costs (per lane-mile, VMT, PMT, or TMT) • Cost-benefit measures 	P	S	P	P	P	P	P	P
Maximize revenue	<ul style="list-style-type: none"> • Toll revenue 		P		P		P			

P = primary, S = secondary

Building upon this earlier work, Bracewell et al. (8) supplemented these suggested procedures with more recent site-specific evaluations conducted in Washington and Minnesota to develop a *High Occupancy Vehicle Monitoring and Evaluation Framework*. This investigation supplemented these guidance documents with additional site-specific evaluations from Massachusetts, New York, Texas, Utah, Georgia, and others. Common observations are described below.

With a primary interest in increasing person throughput, HOV lane performance monitoring and evaluation activities commonly consider lane volumes and classifications, vehicle occupancies, carpool use and transit ridership, and increased travel speeds to demonstrate a higher performance than general-purpose lane facilities. HOV lane users are attracted by the potential for travel time savings and travel time reliability and often perceive their travel time savings to be higher than it actually is. HOV lane compliance is of primary concern since illegal use of the lane can discourage its use (and the corresponding shift to higher occupancy vehicles).

Safety and environmental effects are typically of secondary interest, unless the HOV lane was implemented to remedy a particular problem with safety or air quality compliance, as was the case in Massachusetts.

To best compete with more traditional facility expansion projects, HOV lanes typically compare benefits attributable to travel time savings against the cost of building, operating, and maintaining the facility. In some instances, an observed improvement in safety is also quantified as a primary benefit although the infrequent nature of accident occurrence and the consequent lengthy required evaluation time often preclude quantification of safety-related benefits.

Table 14-2 provides additional details regarding observed performance, data collection, and evaluation and monitoring methods for HOV lane facilities.

Value-Priced and HOT Lane Performance Monitoring and Evaluation

A number of value-priced and HOT lane projects at various sites around the country were initiated through the Congestion Pricing Pilot Program (funded through ISTEA) and more recently the Value Pricing Pilot Program (VPPP) (funded through TEA-21). Of most interest to this investigation were projects that are in the operational or demonstration phase, including sites in California, Texas, and Florida. Also considered as part of this investigation, however, were the results of various feasibility studies that considered the potential impacts of value-priced and HOT lanes in California, Minnesota, and Georgia. These efforts, in combination, formed the basis for the following observations.

Value-priced and HOT lane facilities have both similar and distinct motivations from HOV lane facilities. Value-priced and HOT lanes rely on a dynamic (i.e., reflecting real-time traffic conditions) or fixed but varying (i.e., higher flat rate during most congested peak hour) toll rate schedule to encourage changes in travel behavior.

Table 14-2. HOV Lane Performance Monitoring and Evaluation Summary (Cont.).

GOALS/ OBJECTIVES	PERFORMANCE MEASURES		DATA COLLECTION														EVALUATION/ MONITORING									
	MEASURES	OBSERVED PERFORMANCE/ TARGETS	Continuous, Automated			Sampled, Manual			Customer Surveys				Agency Surveys				descriptive statistics	inferential statistics	capacity analysis	simulation	before-after analysis	alternatives analysis				
			volumes/classifications	speeds/travel times	density/lane occupancy	travel times	vehicle occupancy	violation rates	origin-destination	perceived time savings	ridership/mode use	satisfaction	vehicle productivity	on-time performance	operating costs	capital costs							accidents	enforcement levels	toll revenue	
Increase overall mobility during recurring and nonrecurring congestion while maintaining accessibility (Cont.)																										
MOBILITY/CONGESTION (Cont.)	Increase average travel speeds	<ul style="list-style-type: none"> Average lane (HOV, GP) and facility speed 	+3.72 to 6.84 mph increase, GP (8) 12 to 40 mph, GP, 46 to 50 mph, HOV (14)	P		S														M Q A	M Q A	Q A	A	O	O	
	Decrease average travel times	<ul style="list-style-type: none"> Travel time rate (minute/mile) 	1 minute/HOV mile (7) 0.1 to 2.9 minutes/HOV mile (9) 0.33 to 3.55 minutes/HOV mile (14)	P		S															M Q A	M Q A	Q A	A	O	O
		<ul style="list-style-type: none"> Travel time savings (minute) Travel time savings (\$/mile) Annual travel time savings (\$) 	>5 to 7 minutes, peak hour (7) 3 to 41 minutes (9) 2.8 to 8.1 minutes (8) 13 to 30% improvement (13)	P		S															M Q A	M Q A	Q A	A	O	O
		<ul style="list-style-type: none"> Customer perceptions on travel time 	15 minutes avg. reported savings (10)								P											A	A			
	Decrease violators	<ul style="list-style-type: none"> Managed lane compliance 	80 to 85% compliance (8) 80 to 95% compliance (12) 80 to 95% compliance (13)				S	P											S		M Q A	M Q A	Q A	A	O	O
Increase reliability during recurring and nonrecurring congestion																										
RELIABILITY	Decrease travel time variation	<ul style="list-style-type: none"> Std. deviation (travel time, speed) Variance (coefficient of variation) (travel time, speed) 	SD 3.0 to 3.9, HOV (8) SD 5.1 to 5.2, GP (8)	P		S														M Q A	M Q A	Q A	A	O	O	
		<ul style="list-style-type: none"> Customer perceptions on reliability 								P											A	A				
	Increase "on-time" performance	<ul style="list-style-type: none"> Buffer index (95th percentile travel time by corridor and trip) Percent of trips that arrive in acceptable time window 	>95% on time (7)	P		S								S							M Q A	M Q A	Q A	A	O	O

P = primary, S = secondary, M = monthly, Q = quarterly, A = annually



Table 14-2. HOV Lane Performance Monitoring and Evaluation Summary (Cont.).

GOALS/ OBJECTIVES	PERFORMANCE MEASURES		DATA COLLECTION																EVALUATION/ MONITORING													
	MEASURES	OBSERVED PERFORMANCE/ TARGETS	Continuous, Automated			Sampled, Manual			Customer Surveys				Agency Surveys						descriptive statistics	inferential statistics	capacity analysis	simulation	before-after analysis	alternatives analysis								
			volumes/classifications	speeds/travel times	density/lane occupancy	travel times	vehicle occupancy	violation rates	origin-destination	perceived time savings	ridership/mode use	satisfaction	vehicle productivity	on-time performance	operating costs	capital costs	accidents	enforcement levels							toll revenue							
SAFETY	Increase overall safety levels																															
	Decrease incident frequency and severity	<ul style="list-style-type: none"> Number of incidents (type, location) Incident severity 																			P	S		Q	Q		A	O	O			
ENVIRONMENT	Decrease overall impacts to the environment and resources																															
	Decrease fuel consumption	<ul style="list-style-type: none"> Fuel consumption (per VMT, PMT) 		P	P	S	S	S																	Q	Q		A	O	O		
ENVIRONMENT	Increase air quality/decrease pollutants	<ul style="list-style-type: none"> Tons of pollutants Days in air quality non-compliance 	+9 to -28% VOC (14) +20 to -16% NOx (14) +12 to -30% CO (14)	P	P	S	S	S																Q	Q		A	O	O			
	Increase productivity without compromising public's expectations for efficient and effective travel																															
ORGAN. EFFICIENCY	Increase customer satisfaction	<ul style="list-style-type: none"> Percentage rated good to excellent Qualitative customer comments 	65 to 94% rate HOVs "good" (9)																							A	A					
	Minimize costs	<ul style="list-style-type: none"> Cost for construction (per lane-mile, VMT, PMT) 		P				P	S																		A	O		O	O	
		<ul style="list-style-type: none"> Vehicle operating costs (per lane-mile, VMT, PMT) 	5% to 20% improvement (7)	P				P	S																		Q				O	O
ORGAN. EFFICIENCY			6 to 48 B/C (15)	P	P			S																			A				O	O

P = primary, S = secondary, M = monthly, Q = quarterly, A = annually

These behavior changes include:

- ◆ mode shift to higher occupancy vehicles (i.e., higher occupancy vehicles travel free or pay a reduced toll rate);
- ◆ temporal shift from the most congested peak hour to the shoulders of the peak hour (i.e., when additional excess capacity is available at a reduced toll rate); or
- ◆ combined mode and temporal shift (i.e., travelers shift to higher occupancy vehicles to move from the shoulders of the peak hour to the peak hour).

Similar to HOV lanes, value-priced and HOT lanes seek to encourage mode shift to higher occupancy vehicles and promote travel time savings as a primary facility benefit. Unlike HOV lanes, value-priced and HOT lanes do not exclusively restrict facility use and subsequent travel time savings on the basis of vehicle occupancy; SOVs or HOVs not meeting standard eligibility requirements can pay a high-rate toll to take advantage of the potential travel time savings during peak periods, and/or alter trip times to take advantage of lesser tolls during the shoulders of the peak periods when additional excess capacity is available (i.e., peak spreading). A significant challenge is separating the performance of the value-priced and HOT lane from standard HOV lane performance. [Table 14-3](#) provides additional details regarding observed performance, data collection, and evaluation and monitoring methods for value-priced and HOT lane facilities.

Exclusive Lane Performance Monitoring and Evaluation

Exclusive lane facilities can be passenger focused (i.e., exclusive busways and dedicated bus lanes) or freight focused (i.e., exclusive truckways and dedicated truck lanes).

Passenger-Focused Exclusive Lanes

Many of the early passenger-focused exclusive lane facilities were converted to HOV lanes, with carpools being the predominant users. Recently, the implementation of exclusive busways has seen resurgence under the FTA's Bus Rapid Transit Demonstration Program. Summarizing the observed performance of a number of BRT systems currently in the demonstration phase, the *Characteristics of Bus Rapid Transit for Decision-Making (16)* largely formed the basis of passenger-focused exclusive lane facility performance monitoring and evaluation observations.

Performance monitoring and evaluation activities for exclusive lanes with a passenger focus very closely resemble those activities for HOV lanes, with a focus on increasing person throughput supported by reduced travel times and increased travel time reliability. Transit ridership and transit market share are generally better descriptors of passenger-focused exclusive lane performance than vehicle occupancy or carpool use since exclusive lanes are often limited to only buses. With such limited vehicle use (i.e., buses only), compliance is of secondary concern; violators would be easily recognized and cited.

Table 14-3. Value-Priced and High Occupancy Toll Lane Performance Monitoring and Evaluation Summary.

GOALS/ OBJECTIVES	PERFORMANCE MEASURES		DATA COLLECTION														EVALUATION/ MONITORING										
	MEASURES	OBSERVED PERFORMANCE/ TARGETS	Continuous, Automated		Sampled, Manual		Customer Surveys				Agency Surveys						descriptive statistics	inferential statistics	capacity analysis	simulation	before-after analysis	alternatives analysis					
			volumes/classifications	speeds/travel times	density/lane occupancy	travel times	vehicle occupancy	violation rates	origin-destination	perceived time savings	ridership/mode use	satisfaction	vehicle productivity	on-time performance	operating costs	capital costs							accidents	enforcement levels	toll revenue		
MOBILITY/CONGESTION	Increase overall mobility during recurring and nonrecurring congestion while maintaining accessibility																										
	Increase throughput	<ul style="list-style-type: none"> Daily, hourly volume on HOV facilities (vehicle, person) Total, daily and hourly facility volume (HOV, GP) Total, daily and hourly facility volume (vehicle, person) 	7 (off peak) to 35% (P.M. peak) use lane (range 24,000 to 33,000 vpd) (17) 50 to 90 vpd, A.M. peak (18) 40 to 50 vpd, P.M. peak (18) 0.89 avg. uses per week (18) 2.5 to 17.2% increase in PPUF (range 45.1 to 65.7%) (19)	P																	M Q A	M Q A	Q A	A	O	O	
		<ul style="list-style-type: none"> Vehicle occupancy (per/veh) 																				M Q A	M Q A	Q A	A	O	O
		<ul style="list-style-type: none"> Temporal shift 	-7.6 to 12.0% increase in PPDF (range 60.9 to 80.3%) (19) 10% (A.M.) and 3.6% (P.M.) are HOV 2 paying toll to move to peak out of shoulders (18) 70 to 101% (A.M.) and 20 to 67% (P.M.) decrease in ADT (20) 89 to 94% (A.M.) and 50 to 70% (P.M.) increase in ADT during discounted periods (20) 71% changed time of travel 1+ times/week (21)	P																		M Q A	M Q A	Q A	A	O	O
<ul style="list-style-type: none"> Mode shift 		HOV 3+ increased 4 to 40% (17) 51 (A.M.) and 58% (P.M.) drove alone (18) 11 (A.M.) and 5% (P.M.) changed from bus to carpool (18)																				M Q A	M Q A	Q A	A	O	O

P = primary, S = secondary, M = monthly, Q = quarterly, A = annually

Table 14-3. Value-Priced and High Occupancy Toll Lane Performance Monitoring and Evaluation Summary (Cont.).

GOALS/ OBJECTIVES	PERFORMANCE MEASURES		DATA COLLECTION														EVALUATION/ MONITORING														
	MEASURES	OBSERVED PERFORMANCE/ TARGETS	Continuous, Automated			Sampled, Manual			Customer Surveys				Agency Surveys				descriptive statistics	inferential statistics	capacity analysis	simulation	before-after analysis	alternatives analysis									
			volumes/classifications	speeds/travel times	density/lane occupancy	travel times	vehicle occupancy	violation rates	origin-destination	perceived time savings	ridership/mode use	satisfaction	vehicle productivity	on-time performance	operating costs	capital costs							accidents	enforcement levels	toll revenue						
MOBILITY/CONGESTION (Cont.)	Increase overall mobility during recurring and nonrecurring congestion while maintaining accessibility (Cont.)																														
	Increase average travel speeds	<ul style="list-style-type: none"> Average lane (HOV, GP) and facility speed 	40 to 63 mph HOV, 12 to 45 mph GP, A.M. peak (not exclusive of HOV lane effects) (18) 54 to 75 mph HOV, 15 to 34 mph GP, A.M. peak (not exclusive of HOV lane effects) (18)																		M	M	Q	A	O	O					
	Decrease average travel times	<ul style="list-style-type: none"> Travel time savings (minute) Travel time savings (\$/mile) Annual travel time savings (\$) 	12 to 13 minutes/trip (22) 20 minutes/trip (23) 19.3 minutes/trip, A.M. peak (range 5 to 51 minutes) (18) 21.4 minutes/trip, P.M. peak (range 9 to 39 minutes) (18) 7 to 29 minutes/trip, P.M. peak, simulated 2030 (24)																		M	M	Q	A	O	O					
		<ul style="list-style-type: none"> Customer perceptions on travel time 									P										A	A									
	Decrease delay	<ul style="list-style-type: none"> Average delay (per day, annually) Average delay (vehicle, person) 	360.42 hours/day, P.M. peak (25)	P	P		S	S	S												M	M	Q	A	O	O					
Decrease violators	<ul style="list-style-type: none"> Managed lane compliance 						S	P										S		M	M	Q	A	O	O						
RELIABILITY	Increase reliability during recurring and nonrecurring congestion																														
	Decrease travel time variation	<ul style="list-style-type: none"> Std. deviation (travel time, speed) Variance (coefficient of variation) (travel time, speed) 																			M	M	Q	A	O	O					
		<ul style="list-style-type: none"> Customer perceptions on reliability 																		P	A	A									
Increase "on-time" performance	<ul style="list-style-type: none"> Buffer index (95th percentile travel time by corridor and trip) Percent of trips that arrive in acceptable time window 																			P	S					M	M	Q	A	O	O

P = primary, S = secondary, M = monthly, Q = quarterly, A = annually

Table 14-4 provides additional details regarding observed performance, data collection and evaluation and monitoring methods for passenger-focused exclusive lane facilities.

Freight-Focused Exclusive Lanes

Supporting information for freight-focused exclusive lane facilities was limited by a lack of facilities either planned or in operation (planned facilities were reported in New York and Massachusetts, but no additional substantive information was uncovered). Hence, observations related to the performance monitoring and evaluation of freight-exclusive lane facilities is largely based on feasibility and simulated impact studies conducted in Washington, California, Florida, Georgia, and along the IH-35 multi-state corridor. In addition, feasibility studies are currently underway in Virginia along IH-81 and the IH-69 multi-state corridor.

Similar to passenger-focused exclusive lane facilities, freight-focused exclusive lanes offer benefits related to reduced travel times and increased travel time reliability, with a focus on cargo throughput rather than person throughput. Because the efficiency of freight movement relates to tangible associated costs, performance outcomes are commonly reported in terms of dollars rather than minutes saved, etc.

Despite the potential for travel time and reliability benefits, freight-focused exclusive lanes are more commonly motivated by potential gains in safety and pavement preservation. Public agency benefits related to the rate of change of pavement deterioration on facilities without any truck traffic and the ability to adequately construct heavy-volume truck facilities are often reported. The potential for truck toll revenue has been considered to support development of new construction facilities; however, the lack of importance placed on travel time reduction or reliability by trucks (likely affected by external factors such as delivery windows, geographic distances, etc.) suggest limited potential. Table 14-5 provides additional details regarding observed performance, data collection, and evaluation and monitoring methods for freight-focused exclusive lane facilities.

Mixed-Flow Separation/Bypass Lane Performance Monitoring and Evaluation

Similar to exclusive lane facilities, mixed-flow separation/bypass lane facilities can be either passenger focused or freight focused.

Passenger-Focused Mixed-Flow Separation/Bypass Lanes

Similar to the facility benefits of HOV lanes and passenger-focused exclusive lanes, passenger-focused mixed-flow separation/bypass lanes seek to increase person throughput, reflected as a function of increased average vehicle occupancies and increased travel speeds. Encouraging the mode shift to higher occupancy vehicles is the potential for travel time savings and travel time reliability. Distinguishing passenger-focused mixed-flow separation bypass lanes from HOV lanes and passenger-focused

Table 14-4. Exclusive Lane Performance Monitoring and Evaluation Summary – Passenger Focus.

GOALS/ OBJECTIVES	PERFORMANCE MEASURES		DATA COLLECTION														EVALUATION/ MONITORING										
	MEASURES	OBSERVED PERFORMANCE/ TARGETS	Continuous, Automated		Sampled, Manual		Customer Surveys				Agency Surveys						descriptive statistics	inferential statistics	capacity analysis	simulation	before-after analysis	alternatives analysis					
			volumes/classifications	speeds/travel times	density/lane occupancy	travel times	vehicle occupancy	violation rates	origin-destination	perceived time savings	ridership/mode use	satisfaction	bus service levels	vehicle productivity	on-time performance	operating costs							capital costs	accidents	enforcement levels		
Increase overall mobility during recurring and nonrecurring congestion while maintaining accessibility																											
MOBILITY/CONGESTION	Increase throughput	<ul style="list-style-type: none"> Daily, hourly volume on exclusive facilities (vehicle, person) Total, daily and hourly facility volume (exclusive, GP) Total, daily and hourly facility volume (vehicle, person) 		P																M Q A	M Q A	Q A	A	O	O		
		<ul style="list-style-type: none"> Percent peak-period volume (vehicle, person) 		P				P	S												M Q A	M Q A	Q A	A	O	O	
		<ul style="list-style-type: none"> Per-lane efficiency (speed x pphpl) 		P	P		S	P	S													M Q A	M Q A	Q A	A	O	O
		<ul style="list-style-type: none"> Vehicle occupancy (per/veh) 						P														M Q A	M Q A	Q A	A	O	O
		<ul style="list-style-type: none"> Transit ridership Transit market share 	135 to 186% increase (range 5,000 to 30,000 ppd), at-grade/grade-separated lanes (16) 185% increase (range 435 to 14,105 ppd), mixed-flow/dedicated lanes (16)	P				P	S			P										M Q A	M Q A	Q A	A	O	O
	<ul style="list-style-type: none"> Mode shift 	11 to 34% drove car, at-grade/grade-separated lanes (16) 25.1% drove car, mixed-flow/dedicated lanes (16)									P											M Q A	M Q A	Q A	A	O	O
Increase average travel speeds	<ul style="list-style-type: none"> Average lane (exclusive, GP) and facility speed 	17 to 30 mph, at-grade/grade-separated lanes (16)																			M Q A	M Q A	Q A	A	O	O	
		12 to 17 mph, mixed-flow/dedicated lanes (16)		P		S																M Q A	M Q A	Q A	A	O	O

P = primary, S = secondary, M = monthly, Q = quarterly, A = annually

Table 14-4. Exclusive Lane Performance Monitoring and Evaluation Summary – Passenger Focus (Cont.).

GOALS/OBJECTIVES	PERFORMANCE MEASURES		DATA COLLECTION														EVALUATION/MONITORING									
	MEASURES	OBSERVED PERFORMANCE/TARGETS	Continuous, Automated			Sampled, Manual		Customer Surveys				Agency Surveys					descriptive statistics	inferential statistics	capacity analysis	simulation	before-after analysis	alternatives analysis				
			volumes/classifications	speeds/travel times	density/lane occupancy	travel times	vehicle occupancy	violation rates	origin-destination	perceived time savings	ridership/mode use	satisfaction	bus service levels	vehicle productivity	on-time performance	operating costs							capital costs	accidents	enforcement levels	
MOBILITY/CONGESTION (Cont.)	Increase overall mobility during recurring and nonrecurring congestion while maintaining accessibility (Cont.)																									
	Decrease average travel times	<ul style="list-style-type: none"> Travel time rate (minute/mile) 			P	S														M	M	Q	A	O	O	
		<ul style="list-style-type: none"> Travel time savings (minute) Travel time savings rate (minute/mile) Annual travel time savings (\$) 	26 to 55% reduction compared systemwide, at-grade/grade-separated lanes (16) 26 to 35% reduction compared with local, mixed-flow/dedicated lanes (16)			P	S														M	M	Q	A	O	O
		<ul style="list-style-type: none"> Customer perceptions on travel time 	85% report 14-minute reduction (average), at-grade/grade-separated lanes (16) 73.2% rate above average or excellent, mixed-flow/dedicated lanes (16)								P										A	A				
Decrease violators	<ul style="list-style-type: none"> Managed lane compliance 					S	P												S	M	M	Q	A	O	O	
RELIABILITY	Increase reliability during recurring and nonrecurring congestion																									
	Decrease travel time variation	<ul style="list-style-type: none"> Std. deviation (travel time, speed) Variance (coefficient of variation) (travel time, speed) 	CV reduced from 18.8 to 10.2%, at-grade/grade-separated lanes (16) CV range 0 to 10%, mixed-flow/dedicated lanes (16)			P	S													M	M	Q	A	O	O	
		<ul style="list-style-type: none"> Customer perceptions on reliability 	68% perceive improvement, at-grade/grade-separated lanes (16) 65% rate above average or excellent, mixed-flow/dedicated lanes (16)								P										A	A				
Increase "on-time" performance	<ul style="list-style-type: none"> Buffer index (95th percentile travel time by corridor and trip) Percent of trips that arrive in acceptable time window 				P	S														M	M	Q	A	O	O	

P = primary, S = secondary, M = monthly, Q = quarterly, A = annually

Table 14-4. Exclusive Lane Performance Monitoring and Evaluation Summary – Passenger Focus (Cont.).

GOALS/ OBJECTIVES	PERFORMANCE MEASURES		DATA COLLECTION														EVALUATION/ MONITORING																			
	MEASURES	OBSERVED PERFORMANCE/ TARGETS	Continuous, Automated			Sampled, Manual			Customer Surveys				Agency Surveys				descriptive statistics	inferential statistics	capacity analysis	simulation	before-after analysis	alternatives analysis														
			volumes/classifications	speeds/travel times	density/lane occupancy	travel times	vehicle occupancy	violation rates	origin-destination	perceived time savings	ridership/mode use	satisfaction	bus service levels	vehicle productivity	on-time performance	operating costs							capital costs	accidents	enforcement levels											
SAFETY	Increase overall safety levels																																			
	Decrease incident frequency and severity	<ul style="list-style-type: none"> Number of incidents (type, location) Incident severity 																			P	S	Q	Q	A	O	O									
ENVIRONMENT	Decrease overall impacts to the environment and resources																																			
	Decrease fuel consumption	<ul style="list-style-type: none"> Fuel consumption (per VMT, PMT) 		P	P	S	S	S																	Q	Q	A	O	O							
	Increase air quality/decrease pollutants	<ul style="list-style-type: none"> Tons of pollutants Days in air quality non-compliance 		P	P	S	S	S																	Q	Q	A	O	O							
ORGAN. EFFICIENCY	Increase productivity without compromising public's expectations for efficient and effective travel																																			
	Increase customer satisfaction	<ul style="list-style-type: none"> Percentage rated good to excellent Qualitative customer comments 																									A	A								
	Minimize costs	<ul style="list-style-type: none"> Cost for construction (per lane-mile, VMT, PMT) 	\$5 to \$7 million/mile, at-grade/grade-separated lanes (16)		P					P	S																	A	O			O	O			
		<ul style="list-style-type: none"> Vehicle operating costs (per lane-mile, VMT, PMT) 	\$1 million/year, at-grade/grade-separated lanes (16)		P						P	S																P	S	Q	A			O	O	
	<ul style="list-style-type: none"> Cost-benefit measures 			P	P		S																				P	P	S	S	A				O	O

P = primary, S = secondary, M = monthly, Q = quarterly, A = annually

Table 14-5. Exclusive Lane Performance Monitoring and Evaluation Summary – Freight Focus.

GOALS/ OBJECTIVES	PERFORMANCE MEASURES		DATA COLLECTION															EVALUATION/ MONITORING							
	MEASURES	OBSERVED PERFORMANCE/ TARGETS	Continuous, Automated			Sampled, Manual			Customer Surveys			Agency Surveys						descriptive statistics	inferential statistics	capacity analysis simulation	before-after analysis	alternatives analysis			
			volumes/classifications	speeds/travel times	density/lane occupancy	travel times	cargo tonnage	violation rates	origin-destination	perceived time savings	ridership/mode use	satisfaction	vehicle productivity	infrastructure condition	operating costs	capital costs	accidents						enforcement levels	toll revenue	
MOBILITY/CONGESTION	Increase overall mobility during recurring and nonrecurring congestion while maintaining accessibility																								
	Increase throughput	<ul style="list-style-type: none"> Daily, hourly volume on exclusive lanes (vehicle, tons) Total, daily and hourly facility volume (exclusive, GP) Total, daily and hourly facility volume (vehicle, tons) Miles of travel (VMT, TMT) Hours of travel (VMT, TMT) 	-0.001 to 0.2% change in VMT, range 159,695,000 to 160,138,000 (24) -4.8 to -6.5 change in VHT, range 5,742,000 to 5,843,000, simulated 2030 (24)	P	P		S	P		S										M Q A	M Q A	Q A	A	O	O
	Increase average travel speeds	<ul style="list-style-type: none"> Average lane (exclusive, GP) and facility speed Percent of time at capacity/congested (exclusive, GP) 	29% (base) to 22 to 24% decrease at capacity/congested, GP, P.M. peak, simulated 2030 (24)		P		S													M Q A	M Q A	Q A	A	O	O
	Decrease average travel times	<ul style="list-style-type: none"> Travel time savings (minute) Travel time savings rate (\$/mile) Annual travel time savings (\$) 	2.5 minutes/trip (8%), trucks (27) \$10 million annually, trucks (27) \$30 million annually, GP (27) 6 to 68 minutes/trip, major truck corridors (24) 14 to 80 minutes/trip, regional TOT network, simulated 2030 (24) \$1.08 billion, annually (28)		P		S													M Q A	M Q A	Q A	A	O	O
		Customer perceptions on travel time																			A	A			
Decrease violators	<ul style="list-style-type: none"> Managed lane compliance 							P											S	M Q A	M Q A	Q A	A	O	O

P = primary, S = secondary, M = monthly, Q = quarterly, A = annually

Table 14-5. Exclusive Lane Performance Monitoring and Evaluation Summary – Freight Focus (Cont.).

GOALS/ OBJECTIVES	PERFORMANCE MEASURES		DATA COLLECTION														EVALUATION/ MONITORING																										
	MEASURES	OBSERVED PERFORMANCE/ TARGETS	Continuous, Automated			Sampled, Manual			Customer Surveys				Agency Surveys				descriptive statistics	inferential statistics	capacity analysis	simulation	before-after analysis	alternatives analysis																					
			volumes/classifications	speeds/travel times	density/lane occupancy	travel times	cargo tonnage	violation rates	origin-destination	perceived time savings	ridership/mode use	satisfaction	vehicle productivity	infrastructure condition	operating costs	capital costs							accidents	enforcement levels	toll revenue																		
Increase reliability during recurring and nonrecurring congestion																																											
RELIABILITY	Decrease travel time variation	<ul style="list-style-type: none"> Std. deviation (travel time, speed) Variance (coefficient of variation) (travel time, speed) 																				M	M	Q	A	O	O																
		<ul style="list-style-type: none"> Customer perceptions on reliability 																					A	A																			
	Increase “on-time” performance	<ul style="list-style-type: none"> Buffer index (95th percentile travel time by corridor and trip) Percent of trips that arrive in acceptable time window 																					M	M	Q	A	O	O															
Increase overall safety levels																																											
SAFETY	Decrease incident frequency and severity	<ul style="list-style-type: none"> Number of incidents (type, location) Incident severity Incident reduction savings (\$) 																											P	S	Q	Q	A	A		A	O	O					
Decrease overall impacts to the environment and resources																																											
ENVIRONMENT	Decrease fuel consumption	<ul style="list-style-type: none"> Fuel consumption (per VMT, TMT) 																																		Q	Q	A	A		A	O	O
	Increase air quality/ decrease pollutants	<ul style="list-style-type: none"> Tons of pollutants Days in air quality non-compliance 																																			Q	Q	A	A		A	O

P = primary, S = secondary, M = monthly, Q = quarterly, A = annually

exclusive lanes is their length. Mixed-flow separation/bypass lanes are typically short in length and are intended to alleviate only site-specific or spot congestion for eligible users (i.e., ramp metering bypass). Given this distinction, travel time-related performance of these facilities is more appropriately reported in terms of delay (for interrupted flow) rather than a travel time savings or travel speed. In addition, compliance is an important factor to consider; the mixed vehicle use (i.e., buses and carpools) and the short duration may tempt violators to use the bypass lane.

Despite common implementation and study of ramp metering performance, ramp metering bypass performance (by transit and HOVs) has not been widely studied. Recent focus (through the BRT Program in California and North Carolina) has been directed towards mixed-flow separation/bypass lanes on arterial streets, combined with traffic signal priority.

Table 14-6 provides additional details regarding observed performance, data collection, and evaluation and monitoring methods for passenger-focused mixed-flow separation/bypass lane facilities.

Freight-Focused Mixed-Flow Separation/Bypass Lanes

Unlike passenger-focused mixed-flow separation/bypass lanes, freight-focused mixed-flow separation/bypass lanes facilities are more commonly motivated by a desire to improve operations and safety, with less attention to travel time savings. Representative facilities exist in California and Oregon, but limited examples were uncovered nationally that evaluated the performance of these facilities.

Table 14-7 provides additional details regarding observed performance, data collection, and evaluation and monitoring methods for freight-focused mixed-flow separation/bypass lane facilities.

Lane Restriction Performance Monitoring and Evaluation

More than half of the states in the United States currently employ some type of truck lane restrictions; only Nevada, Florida, Illinois/Wisconsin, Washington, Virginia, and Texas have formally studied their effects. Several other states have reported qualitative findings. Challenging the comparison of findings over related studies is the variety in motivating factors for the lane restriction, as well as the variety in restriction characteristics (i.e., statewide versus site specific, number of facility lanes, number of restricted lanes, left or right restricted lanes, peak period versus continuous, etc.).

Similar to the performance monitoring and evaluation activities for freight-focused exclusive or mixed-flow separation/bypass lane facilities, lane restriction performance monitoring and evaluation activities are focused on enhancing safety, preserving pavement infrastructure, and improving traffic operations (i.e., reduced travel times and increased reliability). These enhancements, however, are typically not realized by truck traffic. For example, restricting trucks from the right lane of a facility may extend

Table 14-6. Mixed-Flow Separation/Bypass Lane Performance Monitoring and Evaluation Summary – Passenger Focus.

GOALS/ OBJECTIVES	PERFORMANCE MEASURES		DATA COLLECTION														EVALUATION/ MONITORING											
	MEASURES	OBSERVED PERFORMANCE/ TARGETS	Continuous, Automated			Sampled, Manual			Customer Surveys				Agency Surveys				descriptive statistics	inferential statistics	capacity analysis simulation	before-after analysis	alternatives analysis							
			volumes/classifications	speeds/travel times	density/lane occupancy	travel times	vehicle occupancy	violation rates	origin-destination	perceived time savings	ridership/mode use	satisfaction	vehicle productivity	on-time performance	operating costs	capital costs						accidents	enforcement levels	toll revenue				
MOBILITY/CONGESTION	Increase overall mobility during recurring and nonrecurring congestion while maintaining accessibility																											
	Increase throughput	<ul style="list-style-type: none"> Daily, hourly volume on HOV facilities (vehicle, person) Total, daily and hourly facility volume (HOV, GP) Total, daily and hourly facility volume (vehicle, person) 		P																	M Q A	M Q A	Q A	A	O	O		
		<ul style="list-style-type: none"> Percent peak-period volume (vehicle, person) 		P																		M Q A	M Q A	Q A	A	O	O	
		<ul style="list-style-type: none"> Vehicle occupancy (per/veh) 																				M Q A	M Q A	Q A	A	O	O	
		<ul style="list-style-type: none"> Transit ridership Carpool use Transit market share 		P																			A	A				
		<ul style="list-style-type: none"> Mode shift 	23% formed carpools (30)																				M Q A	M Q A	Q A	A	O	O
	Increase average travel speeds	<ul style="list-style-type: none"> Average lane (HOV, GP) and facility speed 																				M Q A	M Q A	Q A	A	O	O	
	Decrease average travel times	<ul style="list-style-type: none"> Travel time savings (minute) Travel time savings (\$/mile) Annual travel time savings (\$) 	10 to 20 minutes/trip, A.M. peak (31) 1.7 to 3.8 minutes/trip, peak period (30)																				M Q A	M Q A	Q A	A	O	O
		<ul style="list-style-type: none"> Customer perceptions on travel time 	5 to 10 minutes/trip (30)																				A	A				
	Decrease delay	<ul style="list-style-type: none"> Average delay (day and annually) Average delay (vehicle, person, ton-mile) 																					M Q A	M Q A	Q A	A	O	O
Decrease violators	<ul style="list-style-type: none"> Managed lane compliance 	55 to 64% compliance (30)																				M Q A	M Q A	Q A	A	O	O	

P = primary, S = secondary, M = monthly, Q = quarterly, A = annually

Table 14-7. Mixed-Flow Separation/Bypass Lane Performance Monitoring and Evaluation Summary – Freight Focus.

GOALS/ OBJECTIVES	PERFORMANCE MEASURES		DATA COLLECTION															EVALUATION/ MONITORING											
	MEASURES	OBSERVED PERFORMANCE/ TARGETS	Continuous, Automated			Sampled, Manual			Customer Surveys			Agency Surveys						descriptive statistics	inferential statistics	capacity analysis	simulation	before-after analysis	alternatives analysis						
			volumes/classifications	speeds/travel times	density/lane occupancy	travel times	cargo tonnage	violation rates	origin-destination	perceived time savings	riderhip/mode use	satisfaction	vehicle productivity	infrastructure condition	operating costs	capital costs	accidents							enforcement levels	toll revenue				
Increase overall mobility during recurring and nonrecurring congestion while maintaining accessibility																													
MOBILITY/CONGESTION	Increase throughput	<ul style="list-style-type: none"> Daily, hourly volume on exclusive lanes (vehicle, tons) Total, daily and hourly facility volume (exclusive, GP) Total, daily and hourly facility volume (vehicle, tons) Miles of travel (VMT, TMT) Hours of travel (VMT, TMT) 		P	P		S	P				S												M	M	Q	A	O	O
	Increase average travel speeds	<ul style="list-style-type: none"> Average lane (exclusive, GP) and facility speed Percent of time at capacity/ congested (exclusive, GP) 	20 to 25 mph increased to 50 mph, trucks, merge area (32)			P	S	S																M	M	Q	A	O	O
	Decrease average travel times	<ul style="list-style-type: none"> Travel time savings (minute) Travel time savings (\$/mile) Annual travel time savings (\$) 				P		S																M	M	Q	A	O	O
		Customer perceptions on travel time											P												A	A			
	Decrease delay	<ul style="list-style-type: none"> Average delay (day and annually) Average delay (veh, per, ton-mile) 				P		S																M	M	Q	A	O	O
Decrease violators	<ul style="list-style-type: none"> Managed lane compliance 								P														S	M	M	Q	A	O	O
Increase reliability during recurring and nonrecurring congestion																													
RELIABILITY	Decrease travel time variation	<ul style="list-style-type: none"> Std. deviation (travel time, speed) Variance (coefficient of variation) (travel time, speed) 			P		S																	M	M	Q	A	O	O
		Customer perceptions on reliability											P												A	A			
	Increase "on-time" performance	<ul style="list-style-type: none"> Buffer index (95th percentile travel time by corridor and trip) Percent of trips that arrive in acceptable time window 			P		S																	M	M	Q	A	O	O

P = primary, S = secondary, M = monthly, Q = quarterly, A = annually

Table 14-7. Mixed-Flow Separation/Bypass Lane Performance Monitoring and Evaluation Summary – Freight Focus (Cont.).

GOALS/ OBJECTIVES	PERFORMANCE MEASURES		DATA COLLECTION														EVALUATION/ MONITORING																	
	MEASURES	OBSERVED PERFORMANCE/ TARGETS	Continuous, Automated			Sampled, Manual			Customer Surveys				Agency Surveys				descriptive statistics	inferential statistics	capacity analysis	simulation	before-after analysis	alternatives analysis												
			volumes/classifications	speeds/travel times	density/lane occupancy	travel times	cargo tonnage	Violation rates	origin-destination	perceived time savings	ridership/mode use	satisfaction	vehicle productivity	infrastructure condition	operating costs	capital costs							accidents	enforcement levels	toll revenue									
SAFETY	Increase overall safety levels																																	
	Decrease incident frequency and severity	<ul style="list-style-type: none"> Number of incidents (type, location) Incident severity Incident reduction savings (\$) 																	P	S			Q	Q			A	O	O					
ENVIRONMENT	Decrease overall impacts to the environment and resources																																	
	Decrease fuel consumption	<ul style="list-style-type: none"> Fuel consumption (per VMT, TMT) 		P	P	S	S	S																					Q	Q		A	O	O
	Increase air quality/ decrease pollutants	<ul style="list-style-type: none"> Tons of pollutants Days in air quality non-compliance 		P	P	S	S																					Q	Q		A	O	O	
SYSTEM PRES.	Maintain or increase overall system service life																																	
	Decrease deficient facilities	<ul style="list-style-type: none"> Pavement deterioration rate change Remaining service life 		P				P								P												A	A			O	O	
		<ul style="list-style-type: none"> Roughness index for pavements Percent of roads with deficient ride quality (VMT, TMT) Percent of roadway pavement rated good or better 		S				S								P													A	A			O	O
		<ul style="list-style-type: none"> Maintenance costs per year 														P													A	A			O	O
ORGAN. EFFICIENCY	Increase productivity without compromising public's expectations for efficient and effective travel																																	
	Increase customer satisfaction	<ul style="list-style-type: none"> Percentage rated good to excellent Qualitative customer comments 													P													A	A					
	Minimize costs	<ul style="list-style-type: none"> Cost for construction (per lane-mile, VMT, TMT) 		S				S											P									A	O			O	O	
		<ul style="list-style-type: none"> Vehicle operating costs (annually, per lane-mile, VMT, TMT) Cost-benefit measures 		S				S								P			P	P	S	S						Q	A			O	O	
	Maximize revenue	<ul style="list-style-type: none"> Toll revenue 		P	P		S	P								P												P	Q			A	O	O

P = primary, S = secondary, M = monthly, Q = quarterly, A = annually

the remaining life of the pavement structure but may extend truck travel times or decrease safety levels. Similarly, restricting trucks from the left lane improves travel times for faster moving general-purpose traffic but may again extend truck travel times or decrease safety levels.

More so than other managed lanes facilities, when monitoring and evaluating freight-focused lane restrictions, it is important to consider impacts to all users of the facility and to consider the variety of potential impacts to accurately assess performance. It is also important to assess where and when potential increases or decreases in performance are anticipated and acceptable.

Table 14-8 provides additional details regarding observed performance, data collection, and evaluation and monitoring methods for freight-focused restricted lane facilities.

Dual Facilities Performance Monitoring and Evaluation

The New Jersey Turnpike – with a 35-mile segment that consists of interior (passenger car) lanes and exterior (truck, bus, and car) lanes within the same right of way – is the only example uncovered of a dual facility in operation. No formal studies were uncovered that reported the performance of this facility. Hence, with no collective guidance and no site-specific evaluation efforts, recommendations for performance monitoring and evaluation are based solely on comparative facility characteristics of other managed lanes strategies that have been more extensively studied.

The potential performance monitoring and evaluation activities for dual facilities most closely resemble those of exclusive lane facilities, with a combined passenger and freight focus, since dual facilities are intended to enhance both passenger and freight movement. Hence, a wider array of measures may be required to adequately describe the performance of dual facilities. Public agencies should prioritize these measures to better manage data collection and analysis resources and avoid conflicting performance goals and objectives.

[Table 14-9](#) summarizes potential performance measures, data collection, and evaluation and monitoring methods for dual facilities.



Table 14-8. Lane Restriction Performance Monitoring and Evaluation Summary – Freight Focus.

GOALS/ OBJECTIVES	PERFORMANCE MEASURES		DATA COLLECTION																EVALUATION/ MONITORING								
	MEASURES	OBSERVED PERFORMANCE/ TARGETS	Continuous, Automated			Sampled, Manual			Customer Surveys				Agency Surveys						descriptive statistics	inferential statistics	capacity analysis	simulation	before-after analysis	alternatives analysis			
			volumes/classifications	speeds/travel times	density/lane occupancy	travel times	cargo tonnage	violation rates	origin-destination	perceived time savings	ridership/mode use	satisfaction	vehicle productivity	infrastructure condition	operating costs	capital costs	accidents	enforcement levels							toll revenue		
Increase overall mobility during recurring and nonrecurring congestion while maintaining accessibility																											
MOBILITY/CONGESTION	Increase throughput	<ul style="list-style-type: none"> Daily, hourly volume on exclusive lanes (vehicle, tons) Total, daily, hourly facility volume (restricted, non, vehicle, tons) Miles of travel (VMT, TMT) Hours of travel (VMT, TMT) 		P	P		S	P		S												M Q A	M Q A	Q A	A	O	O
	Increase average travel speeds	<ul style="list-style-type: none"> Average lane (restricted, non-restricted) and facility speed Percent of time at capacity/congested (restricted, non-restricted) Speed differential (restricted, non) 	2.9 mph before, 2.2 mph after (33) no change in speed, trucks or other (34) no change in speed, trucks or other (35, 36)			P		S														M Q A	M Q A	Q A	A	O	O
	Decrease average travel times	<ul style="list-style-type: none"> Travel time savings rate (minute/mile) Travel time savings (minute) Annual travel time savings (\$) 	19.52 minutes/year/truck increase (37) \$4.84/year/truck cost (37) 82.2 hours/year increase for industry (37) \$1,155/year cost for industry (37)			P		S														M Q A	M Q A	Q A	A	O	O
			<ul style="list-style-type: none"> Customer perceptions on travel time 									P											A	A			
	Decrease delay	<ul style="list-style-type: none"> Average delay (day and annually) Average delay (veh, per, ton-mile) 				P		S															M Q A	M Q A	Q A	A	O
Decrease violators	<ul style="list-style-type: none"> Change in lane redistribution (trucks, other) Managed lane compliance 	60% of trucks voluntarily traveled in non-restricted lane (no change in other traffic) (38) 94.3 to 99.1% compliance, 3-lane facilities (33) 89.8% compliance, 2-lane facilities (33) 97.9% compliance, truck distribution unchanged (37) 62% compliance, no change in other traffic (35, 36) 70 to 90% compliance (39)			P					P										S		M Q A	M Q A	Q A	A	O	O
Increase reliability during recurring and nonrecurring congestion																											
REL.	Decrease travel time variation	<ul style="list-style-type: none"> Std. deviation (travel time, speed) Variance (coefficient of variation) (travel time, speed) 				P		S														M Q A	M Q A	Q A	A	O	O
		<ul style="list-style-type: none"> Customer perceptions on reliability 										P											A	A			

P = primary, S = secondary, M = monthly, Q = quarterly, A = annually

Table 14-8. Lane Restriction Performance Monitoring and Evaluation Summary – Freight Focus (Cont.).

GOALS/ OBJECTIVES	PERFORMANCE MEASURES		DATA COLLECTION													EVALUATION/ MONITORING																				
	MEASURES	OBSERVED PERFORMANCE/ TARGETS	Continuous, Automated			Sampled, Manual			Customer Surveys			Agency Surveys				descriptive statistics	inferential statistics	capacity analysis	simulation	before-after analysis	alternatives analysis															
			volumes/classifications	speeds/travel times	density/lane occupancy	travel times	cargo tonnage	violation rates	origin-destination	perceived time savings	ridership/mode use	satisfaction	vehicle productivity	infrastructure condition	operating costs							capital costs	accidents	enforcement levels	toll revenue											
REL.	Increase "on-time" performance	<ul style="list-style-type: none"> • Buffer index (95th percentile travel time by corridor and trip) • Percent of trips that arrive in acceptable time window 		P		S													M	Q	A															
	Increase overall safety levels																																			
SAFETY	Decrease incident frequency and severity	<ul style="list-style-type: none"> • Number of incidents (type, location) • Incident severity • Incident reduction savings (\$) 	34.43% (truck), 56.81% (truck injury) accident decrease (40) 13.8% rate inc., 20% injury acc. decrease (34) 68% rate decrease (w/ increased enforcement) (39)															P	S							Q	A	Q	A		A	O	O			
	Decrease overall impacts to the environment and resources																																			
ENVIRONMENT	Decrease fuel consumption	<ul style="list-style-type: none"> • Fuel consumption (per VMT, TMT) 		P	P	S	S	S																				Q	A	Q	A		A	O	O	
	Increase air quality/ decrease pollutants	<ul style="list-style-type: none"> • Tons of pollutants • Days in air quality non-compliance 		P	P	S	S	S																					Q	A	Q	A		A	O	O
	Maintain or increase overall system service life																																			
SYSTEM PRES.	Decrease deficient facilities	<ul style="list-style-type: none"> • Pavement deterioration rate change • Remaining service life • Maintenance costs per year • Construction cost savings 	5- to 10-year increase (38) \$1.1 million, annually (38) 10 to 20% reduction in future work (38)	P				P																					A	A			O	O		
																		P											A	A			O	O		
																		P											A	A			O	O		
	Increase productivity without compromising public's expectations for efficient and effective travel																																			
ORGAN. EFFICIENCY	Increase customer satisfaction	<ul style="list-style-type: none"> • Percentage rated good to excellent • Qualitative customer comments 	90.85% (motorists), 31.96% (trucks) favor (37) 60% (motorists), 28% (trucks) favor before (35, 36) 48% (motorists), 20% (trucks) favor after (35, 36) 90% (motorists) favor (39)																											A	A					
	Minimize costs	<ul style="list-style-type: none"> • Cost for construction (per lane-mile, VMT, TMT) • Vehicle operating costs (annually, per lane-mile, VMT, TMT) • Cost-benefit measures 		S				S																					A	O			O	O		
				S				S																					Q	A			O	O		
				P	P			S	P																				A				O	O		

P = primary, S = secondary, M = monthly, Q = quarterly, A = annually

Table 14-9. Dual Facilities Performance Monitoring and Evaluation Summary – Combined Passenger and Freight Focus.

GOALS/ OBJECTIVES	PERFORMANCE MEASURES		DATA COLLECTION																	EVALUATION/ MONITORING																			
	MEASURES	OBSERVED PERFORMANCE/ TARGETS	Continuous, Automated			Sampled, Manual			Customer Surveys				Agency Surveys							descriptive statistics	inferential statistics	capacity analysis	simulation	before-after analysis	alternatives analysis														
			volumes/classifications	speeds/travel times	density/lane occupancy	travel times	vehicle occupancy	cargo tonnage	violation rates	origin-destination	perceived time savings	ridership/mode use	satisfaction	vehicle productivity	on-time performance	infrastructure cond.	operating costs	capital costs	accidents							enforcement levels	toll revenue												
Increase overall mobility during recurring and nonrecurring congestion while maintaining accessibility																																							
MOBILITY/CONGESTION	Increase throughput	<ul style="list-style-type: none"> Daily, hourly volume on exclusive facilities (vehicle, person, tons) Total, daily, hourly facility volume Total, daily and hourly facility volume (vehicle, person, tons) Miles of travel (VMT, PMT, TMT) Hours of travel (VMT, PMT, TMT) 	P	P		S	P	P	S													M	Q	A	M	Q	A	Q	A	A	O	O							
		<ul style="list-style-type: none"> Percent peak-period volume (vehicle, person, tons) 	P				P	P	S														M	Q	A	M	Q	A	Q	A	A	O	O						
		<ul style="list-style-type: none"> Per-lane efficiency (speed x pphpl) 	P	P		S	P		S														M	Q	A	M	Q	A	Q	A	A	O	O						
		<ul style="list-style-type: none"> Vehicle occupancy (per/veh) 					P																M	Q	A	M	Q	A	Q	A	A	O	O						
		<ul style="list-style-type: none"> Transit ridership Carpool use Transit market share 	P				P		S			P											M	Q	A	M	Q	A	Q	A	A	O	O						
		<ul style="list-style-type: none"> Mode shift 										P											M	Q	A	M	Q	A	Q	A	A	O	O						
	Increase average travel speeds	<ul style="list-style-type: none"> Average lane and facility speed Percent of time at capacity/ congested 		P		S																M	Q	A	M	Q	A	Q	A	A	O	O							
	Decrease average travel times	<ul style="list-style-type: none"> Travel time rate (minute/mile) 																				M	Q	A	M	Q	A	Q	A	A	O	O							
		<ul style="list-style-type: none"> Travel time savings (minute) Travel time savings (minute/mile) Annual travel time savings (\$) Customer perceptions on travel time 		P		S																	M	Q	A	M	Q	A	Q	A	A	O	O						
	Decrease violators	<ul style="list-style-type: none"> Managed lane compliance 								S		P																P	M	Q	A	M	Q	A	Q	A	A	O	O

P = primary, S = secondary, M = monthly, Q = quarterly, A = annually

Section 4 – Chapter Limitations

The information summarized in this chapter represents an assimilation of information contained in published literature and observed through national practice regarding the monitoring and evaluation of managed lanes facility performance. This information represents a significant step in:

- ◆ understanding the differences between general freeway facilities and managed lanes facilities,
- ◆ supporting local development of a comprehensive managed lanes facility performance monitoring and evaluation program, and
- ◆ setting potential performance targets.

While this report represents advancement in each of these areas, information related to ongoing facility monitoring and potential performance targets is still lacking. With respect to managed lanes facility performance monitoring, little information is available to support recommendations pertaining to the frequency of monitoring required. In nearly every observed instance, the reported findings resulted from a one-time before-after or feasibility evaluation; few examples were provided regarding changes in these initial observations over time.

With respect to potential performance targets, variation in managed lanes facility design and operation and in the measures and methods selected for performance monitoring and evaluation challenged development of a comprehensive list of performance targets for the various facility types. More common performance measures, such as travel time savings, were well covered, but many others were not. As such, agencies are cautioned when considering the observed performance/targets presented here; the reader should carefully consider the facility characteristics before transferring the observed performance results/targets to a comparable local facility. Nonetheless, it was thought useful to include these reported observations to provide a magnitude of scale and direction to the original source for additional information.

As agencies utilize these findings and begin a comprehensive program of performance monitoring and evaluation for managed lanes facilities, the level of consistency in performance measures and evaluation methods will improve. In addition, the bank of knowledge related to the required frequency of monitoring and reasonable performance targets for similar facility types will continue to expand.

Section 5 – References

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Section 1 – Overview

Bringing a managed lanes facility to completion is a complex process of planning, design, and daily operation. Once complete, these ongoing operations may include management, enforcement, incident detection, revenue collection, maintenance, and more. Often, a managed lanes facility is crosscutting, not only in the use of multiple operating concepts to achieve goals, but also in the involvement of multiple agencies and vehicle user groups.

These types of relationships all point to a level of interaction heretofore unseen for most roadways. In essence and indeed in practice, while it may serve special user groups, a managed lanes facility becomes an integral part of the transportation system. A typical statement is that the facility must be interoperable with other facilities in the transportation system.

Interoperability is the ability of a system to use the parts, information, or equipment of another system. In the case of a managed lane, the facility must act in concert with the adjacent infrastructure to accomplish mobility goals. This chapter discusses the critical interoperability concerns for a managed lanes facility so that planners, designers, and operators can focus on these interactions and create a successful facility.

Sections in this chapter cover:

- ◆ [interoperability overview and](#)
- ◆ [interoperability considerations.](#)

Section 2 – Interoperability Overview

What is interoperability? At the lowest level, the term basically means that certain things should work together. As an example, a videotape recorded in one brand of machine should play in a machine of another brand, as long as the format is the same. The machines would then be interoperable. As another example, the electronic version of this handbook can be read on any computer that uses the same software that was used to create it. In fact, this level of interoperability goes beyond the use of the same software. Because multiple programs understand the underlying format of the electronic file, this report can actually be read and edited in any number of software applications. The data format is the same, which allows the applications to work together.

Managed Lanes and Interoperability

In the dictionary, interoperability is defined as “the ability of a system to use the parts or equipment of another system” (1). Within the application of managed lanes, it is entirely possible that interoperability could also refer to the exchange of information to other systems. Therefore, the definition that governs managed lanes can best be expressed as “the ability of a system to use the parts, information, or equipment of another system.”

Armed with a basic understanding of interoperability, the next important concept to examine is why interoperability is important. Recall that a major goal of the transportation system is to be seamless. We would likely agree that having various aspects of the system working together is critical to that goal. Ramps and access points must connect a mainline facility with the managed lanes. Motorists must be able to get information about how to get on the managed lanes, where they are allowed, when they are allowed, and how much it will cost. Police and emergency services must plan for enforcement and emergency operations that may utilize both the mainline and managed lanes. The concept of all of the roadway and operational elements working together, across all aspects of the transportation system, is interoperability.

Because both interoperability and managed lanes are relatively new concepts in transportation, literature pertaining to these specific subjects is not extensive within the field of transportation. While the specific focus of existing interoperability literature is not within the managed lanes framework, it is obvious that interoperability is a key concept that must be addressed in managed lanes. In many cases, the concepts of interoperability from other fields are directly applicable to the managed lanes environment. In fact, a key concept pervasive throughout the literature is that interoperability exists at multiple levels. For the purposes of a managed lanes environment, these levels were identified as agency, facility, and equipment.

Interoperability Levels

In general, interoperability within the context of managed lanes can exist at three levels: at the agency level, at the facility level, and/or at the equipment level. These three levels, expressed in [Figure 15-1](#), can essentially be used to provide more structure and definition to the identified interactions. By defining the levels of interoperability, the focus of each interaction also becomes clearer. For example, agency-level interactions typically consist of long-term planning or design coordination, as well as broad-scale agreements for creating similar policies and procedures for operating managed lanes facilities. In sharp contrast to that high-level planning and interaction, coordination at the equipment level is meant to ensure that data elements from one system can be transmitted, received, and understood by another system, regardless of their eventual use in both systems. In the middle of the two endpoints are the facility-level interactions, which typically would occur in areas such as geometric design, traffic control devices, enforcement, etc.

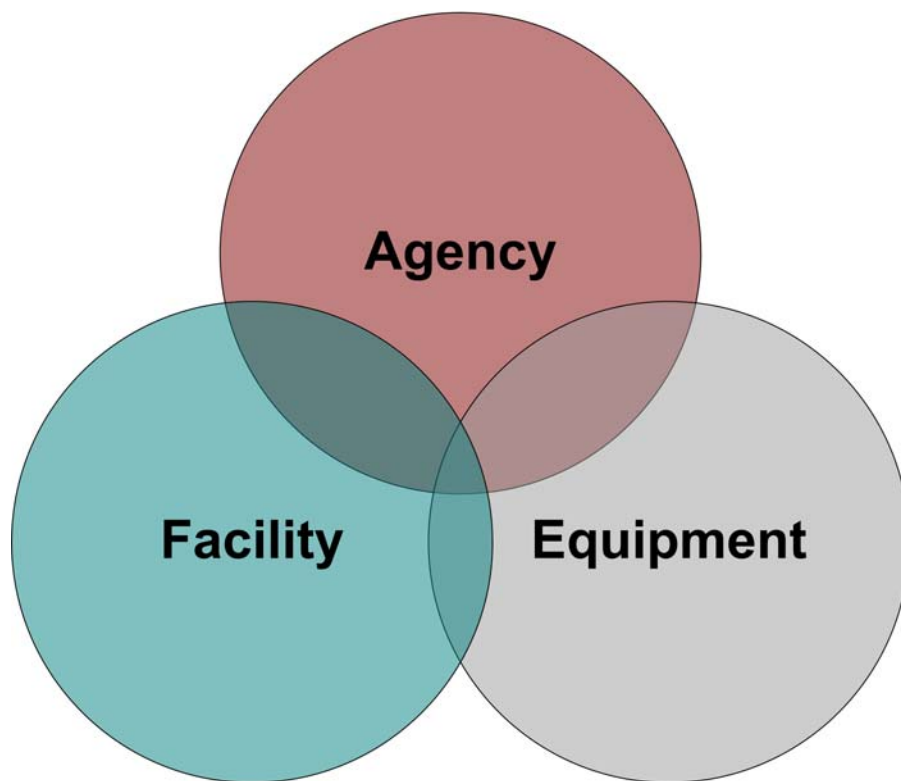


Figure 15-1. Levels of Interoperability.

Other critical interoperability issues for consideration in the managed lanes environment include:

- ◆ There are differences between incident management in a managed lanes facility and a non-managed lanes facility (2).
- ◆ In some regions, the public does not seem to perceive tolling to be inequitable as long as there are other options (3).
- ◆ Various agencies should be able to communicate despite having different kinds of equipment (4).
- ◆ The existence of formal agreements among agencies is important (5).
- ◆ Managed lanes should not be developed separately from each other or from other infrastructure (6).
- ◆ The decisions of one agency (or facility) will impact other agencies (or facilities) (5).
- ◆ Evaluations are necessary to properly identify benefits and rewards (7).
- ◆ Seasonal effects should be considered since large volumes of traffic may require a different operational plan (8).
- ◆ Tolls collected on managed lanes may be used to manage demand and/or generate revenue, depending on the jurisdiction and the goals and objectives of the project (3).
- ◆ Plans should be scalable to accommodate agencies and facilities of different sizes (6).
- ◆ Due to privacy concerns, there is reluctance among government agencies to share certain information with the public (9).
- ◆ Interoperability requires both institutional agreements and adherence to common technological formats and standards. This allows for flexibility and advancements, while preserving the base investment used to develop systems and solutions (10).

Section 3 – Interoperability Considerations

The successful completion of a managed lanes facility involves a multitude of steps across the planning, design, and operations environments. As a result of the complex interactions that can occur across many aspects of the managed lanes facility, other facilities, and the agencies responsible for their design and operation, interoperability is a key concept to address in the managed lanes concept. Simply put, interoperability is the ability of a system to use the parts, information, or equipment of another system. In this case, the managed lanes facility is one system, and it interacts with other systems or roadways.

Interoperability Needs

Table 15-1 identifies a list of areas where interoperability should be considered when developing managed lanes projects. The table identifies two areas as *very important*. This categorization comes from the recognition of these areas as the single most important concept to consider at each level of interoperability, namely the agency, facility, or equipment level. It recognizes that the development of any crosscutting facility, like a managed lanes facility, must be supported by all of the involved agencies and must support the broad-based transportation goals of the region. By comparison, the identification of traffic control devices as the critical area to consider for facility interoperability may be surprising at a first glance. However, when the driver information needs (to assess route alternatives, provide driver guidance, and achieve traffic separation) are considered, along with the fact that these needs are typically accomplished with traffic control devices, the criticality of this area should be evident.

Table 15-1. Matrix of Interoperability Needs.

Interoperability Need	Agency	Facility	Equipment
Very Important	<ul style="list-style-type: none"> • Planning 	<ul style="list-style-type: none"> • Traffic Control Devices 	
Important	<ul style="list-style-type: none"> • Incident Management 	<ul style="list-style-type: none"> • Geometric Design • Operations • Evaluation and Monitoring • Incident Management 	<ul style="list-style-type: none"> • Evaluation and Monitoring • Traffic Control Devices

Table 15-1 also identifies a number of areas as *important* to consider in managed lanes project development. Some, like incident management, are listed at both the agency and facility level. The dual listing simply highlights the importance of the item at multiple levels. For incident management, agency-level interoperability might address the need to

share resources and the operation facilities with common goals and policies for incident management. Agency-level interoperability also addresses the myriad of agencies that can be involved in incident response across a region, depending on the level of the incident and the particular location. At the facility level, incident management might address a standard concept of operations for the adjoining non-designated lanes, including diversions of traffic, use of shared lanes, ingress and egress paths to an incident on the managed lanes, and even the use of the managed lanes to support traffic during an incident on the non-designated lanes.

The following sections provide more detail on the various types of interoperability needs included in the table. It should be noted that communications is not included in the above listing as an important issue. However, communications is a critical component of both surveillance and monitoring and traffic control devices at the equipment level. Any discussion of interoperability in the handbook would be remiss in neglecting this important facet.

Planning

Long-term planning is typically the start of any process for building roadway infrastructure. In a managed lanes facility, while planning may be initiated by a particular agency, it is critical that the process reach out to additional agencies who may ultimately be involved in the overall design and daily operations of the facility. However, it is recognized that regional coordination can be a difficult task. In many cases, the definition of what constitutes the region and what agencies should participate in regional discussions are not questions with clear-cut answers. At a minimum, all parties involved in the shared infrastructure should be involved in discussions pertaining to the planning aspects. After all, a managed lanes facility is not a stand-alone portion of the roadway infrastructure; it is merely a component of the overall system. In most cases, managed lanes rely on the traditional infrastructure to deliver traffic both to and from the facility.

By addressing system integration or interoperability needs at the onset, agency partners can work together to ensure that a managed lanes facility satisfies regional mobility goals. In particular, working together, agencies should consider the following minimum aspects of managed lanes planning:

- ◆ establish a regional perspective for transportation and the role of the managed lanes facility;
- ◆ establish a shared customer vision for the managed lanes facility;
- ◆ embrace non-traditional partners at the planning stage, such as emergency service providers;
- ◆ create inter-agency agreements for funding partnerships;
- ◆ create policies for operations and incident management;

- ◆ support the use of geometric guidelines to create safe transitions to and from the facility;
- ◆ establish regional or facility coordination of traffic control devices (signs, signals, and markings) to promote uniformity and to help provide for consistent driver expectations;
- ◆ determine how and by whom the managed lanes facility will be managed;
- ◆ determine what information the managed lanes facility can provide to traveler information systems (at the planning level, this task should focus on the process of what the information needs are, to whom the information should be given, and how often it should be provided, and not on the specific means of accomplishing information transfers);
- ◆ determine what communications systems are necessary for shared operations; and
- ◆ determine what needs exist for effective information exchange with agency partners, third-party information providers, and the traveling public.

Geometric Design

Managed lanes are often considered to be a freeway within a freeway and are generally designed to appropriate state or national standards for the class of roadway. However, several aspects of having adjacent freeways are not addressed in those standards. In order to provide the best level of interoperability, adjacent facilities should utilize similar geometric guidelines in order to accommodate the same traffic and not violate any driver expectancy established by the presence of particular geometric standards on the adjacent freeway.

Research has identified ramps as one of the most critical geometric aspects to consider in making a managed lanes facility interoperable with other facilities. In particular, the important aspects to consider in the geometric design of the ramps are ramp type as well as ramp spacing. These guidelines typically vary by traffic level, so understanding both the current and future traffic impact of the facility is important to ensure geometric adequacy both at the time of construction and in future years of operation. This handbook provides significant guidance on these issues.

Other important aspects of geometric interoperability include establishing consistent techniques for lane separation as well as considering the design of specialized areas for enforcement activities.

Traffic Control Devices

Traffic control devices are a primary method of sending information to users of any facility. However, due to a lack of established guidelines, managed lanes facilities currently in design or operation have largely had to interpret and improvise to develop

traffic control plans. Prior research has noted that these efforts have led to some good practices, but that managed lanes use may be hampered by inconsistencies in use. In addition, motorists may also perceive managed lanes facilities as confusing, limiting their desire to utilize the facility.

To help address these shortcomings, traffic control device interoperability should be considered at two levels. At the facility level, interoperability should focus on the consistency of the information being sent to the motorist. This information includes all types of communication, both verbal and visual, from the use of standard markings, colors, shapes, and terminology, to the specific text utilized to convey payment and enforcement messages. Consistency is achieved by:

- ◆ coordinating the above aspects with adjacent infrastructure,
- ◆ providing needed information in advance of decision points, and
- ◆ in the absence of national or state guidelines, establishing and following regional plans for clear dissemination of information to motorists.

At the equipment level, it should be recognized that many traffic control devices can be utilized to change information, according to the time of day, type of operation in effect, etc. If the facilities are to be used in a shared control capability, this requires, at a minimum, communications and software interfaces that work across multiple types of equipment and that can be accessed and utilized by more than one agency. Additionally, placement and use of traffic control devices should be such that it is clear who the intended recipient is, e.g., that the messages directed to users of the managed lanes are not interpreted as applying to the adjacent infrastructure and vice versa. All of these interoperability issues require foresight and careful planning to accomplish.

Operations

The operation of a managed lanes facility is not a simple concept, nor is it a phrase relating to a single concept. Indeed, “operations” is a complex and multi-faceted plan to achieve safe and efficient movement of goods and people on a facility. A critical component of achieving that goal is considering interoperability, especially at the facility level.

Research identified a number of aspects of operations that were critical to coordinate. Coordination with adjacent or nearby facilities has a number of benefits. First, the agencies involved in the day-to-day operations benefit from having a consistent management plan, especially for items such as incident management and toll collection. Second, the motorists benefit from having consistency between not only a managed lanes facility and the adjacent infrastructure, but also across all facilities within the region or area. Finally, utilizing shared operations and equipment affords a far quicker mobilization to an area-wide emergency, such as a natural disaster or a homeland security event.

Toll collection is certainly one aspect of operations that could provide enormous interoperability benefits if all facilities utilized a standard method, location, and equipment for paying fares. In particular, research identified the following aspects of operations as gaining benefit from being interoperable across facilities and, potentially, agencies:

- ◆ traveler information systems,
- ◆ incident management,
- ◆ toll collection,
- ◆ congestion management,
- ◆ special event coordination,
- ◆ emergency services,
- ◆ enforcement operations, and
- ◆ roadway monitoring.

These and other aspects of operations can be coordinated through the creation of shared policies and procedures, pre-established action plans with priority of implementation, and the use of shared management and, potentially, control of equipment, especially in response-type activities.

Incident Management

Incident management is an activity typically associated with the operations of a managed lanes facility. While incident management is a critical component in which to ensure interoperability, the reader is referred to the section on operations for discussions of this activity.

Evaluation and Monitoring

One of the most basic activities used to help achieve smooth flowing operations on any facility is to monitor the roadway for any changes or conditions that may indicate the presence of congestion or incidents. Early detection of these conditions combined with a prompt response can decrease the timeframe of disruption and restore the facility to smooth operations.

This evaluation can be done through the use of sensors, which relay data about the roadway characteristics, such as speed and occupancy. Monitoring can also be performed through the use of video, which operators or automated readers examine for any changes that would indicate the presence of breakdown conditions.

At the facility level, one aspect of achieving interoperability might focus on the use of shared management centers although this not a requirement for successful operations. Today, the concept of multiple agencies sharing a traffic management center is commonplace and helps to increase the coordination of the agencies and the efficiency of the facilities.

Another aspect of achieving facility-level interoperability in evaluation and monitoring capabilities is participation in traveler information systems to help ensure a comprehensive view of transportation mobility.

At the equipment level, achieving interoperability with evaluation and monitoring has a myriad of aspects, including:

- ◆ the support for multiple communications systems to exchange data,
- ◆ the use of common communications protocols to support data exchange,
- ◆ the use of common message sets and data elements to construct information, and
- ◆ particular to video surveillance, the support for multicast communications to enable video reception at multiple agencies or endpoints.

Note that the above is not a recommendation for establishing a single vendor solution for surveillance and monitoring equipment. While uniformity has many appealing aspects, such as cost reductions and decreased support problems, uniformity is not a prerequisite to successful interoperability.

Communications

Interoperability with respect to communications can be achieved in multiple ways. Communications is one area where the expression “one size fits all” most certainly does *not* apply. Even if different equipment and vendors are used, the use and support of common protocols, message sets, and data elements can enable the smooth transfer of data between multiple agencies. Agencies should be careful of systems requiring proprietary protocols since they are not the wave of the future.

If there are multiple agencies involved, the key concepts to understand are the design of the overall communications network in which the managed lane will participate. Some of the critical items to be aware of:

- ◆ What communications systems will be used to exchange data?
- ◆ What protocols will be used for data exchange?
- ◆ What message sets and data elements will be used to send and receive information?

- ◆ What data formats will be supported?
- ◆ What video formats will be supported?
- ◆ What video distribution mechanisms will be supported?

It should be noted that understanding the above requirements allows for the use of multiple vendors within the communications systems. While uniformity has many appealing aspects, it is not a prerequisite to successful interoperability.

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Overview

The Strategy Selection Screening Tool was developed in Visual Basic.NET® and can be run on a computer with Microsoft Windows® versions 9X/ME/NT/2000/XP with a 486 processor or greater and 40 MB available hard disk space. The compact disk (CD) included with this handbook contains the program, which should be downloaded to the computer’s hard drive before beginning. [Figure A-1](#) shows the introduction screen of the Strategy Selection Screening Tool. The “Weighting” tab allows the user to easily turn the weighting feature on or off depending on his or her needs.

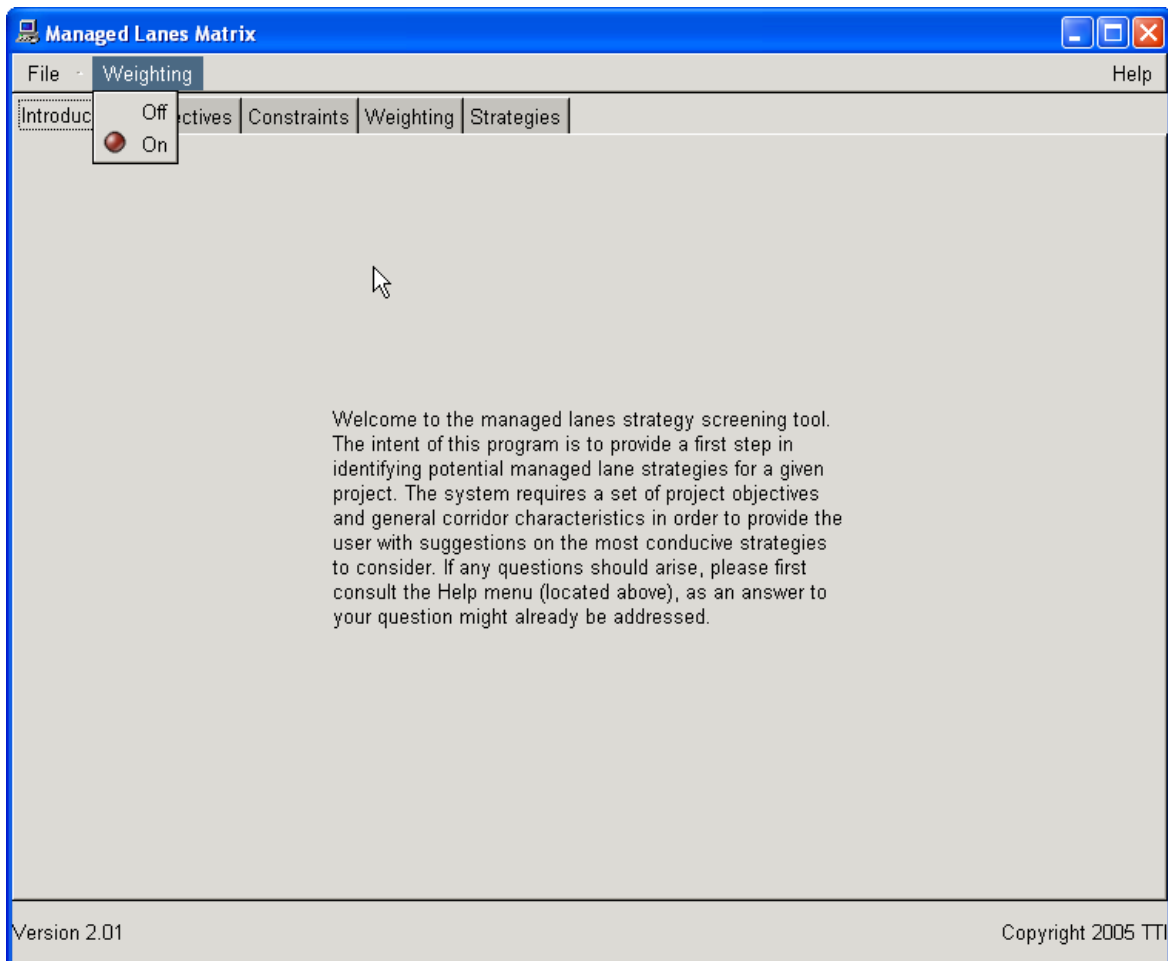


Figure A-1. Strategy Selection Screening Tool Introduction Screen.

Entries in the Array

The following sections highlight the various entry screens for the preliminary screening tool. For more information on the use of the screening tool and logic behind its structure, see [Chapter 4 – Planning Managed Lanes Facilities](#).

Objectives

Figure A-2 illustrates the screen where the user selects one or more managed lanes objectives he or she would like to address with a particular project.

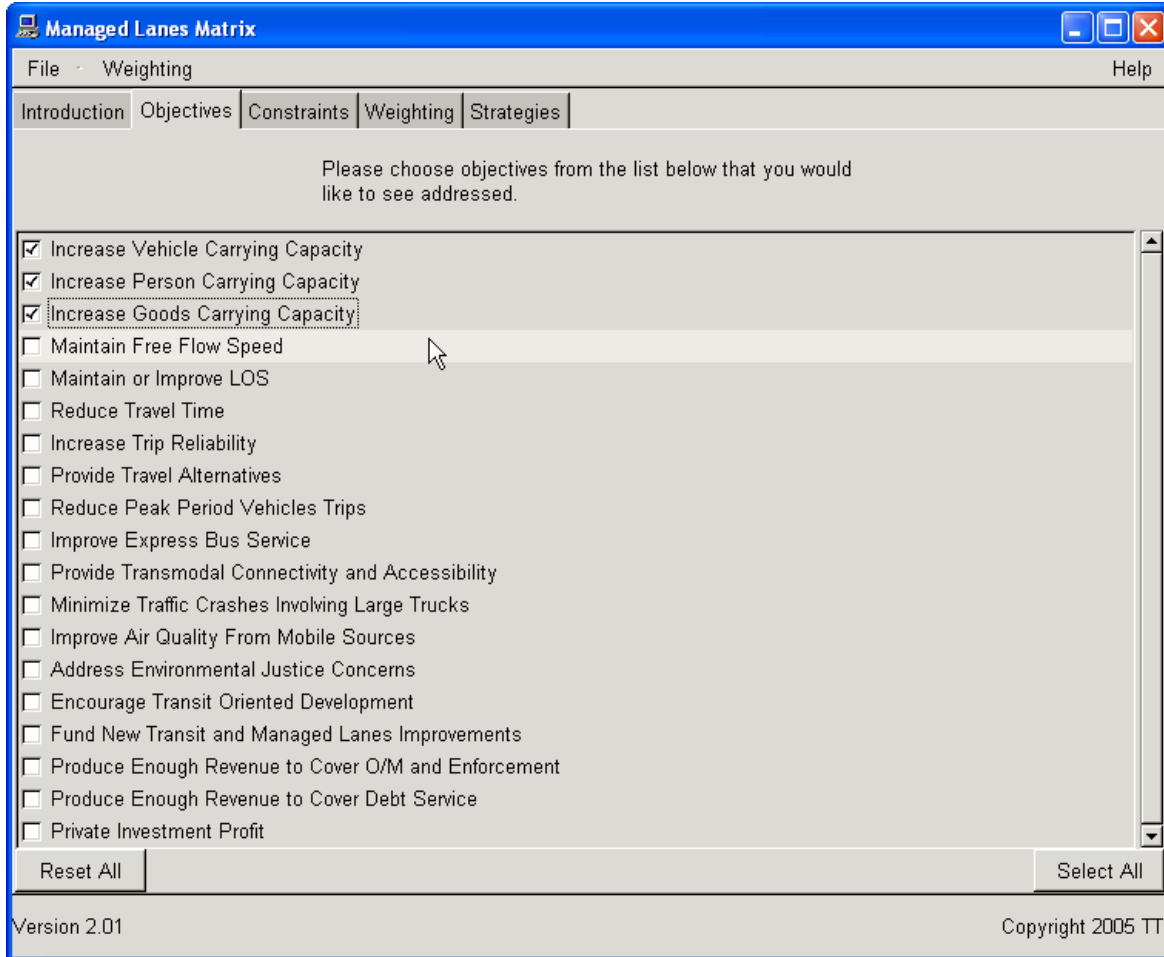


Figure A-2. Strategy Selection Screening Tool Objective Selection Screen.

The complete list of objectives is below:

1. Increase Vehicle-Carrying Capacity
2. Increase Person-Carrying Capacity
3. Increase Goods-Carrying Capacity
4. Maintain Free-Flow Speeds
5. Maintain or Improve the LOS
6. Reduce Travel Time
7. Increase Trip Reliability
8. Provide Travel Alternatives
9. Reduce Peak-Period Vehicle Trips
10. Improve Express Bus Service

11. Provide Transmodal Connectivity and Accessibility
12. Minimize Traffic Crashes Involving Large Trucks
13. Improve Air Quality From Mobile Sources
14. Address Environmental Justice Concerns
15. Encourage Transit-Oriented Development
16. Fund New Transit and Managed Lanes Improvements
17. Produce Enough Revenue to Cover O/M and Enforcement
18. Produce Enough Revenue to Cover Debt Services
19. Private Investment Return on Investment

Table A-1 highlights the correlation of the objectives to different managed lanes strategies. The values shown are those associated with giving each objective a default weight of “Important.”

Table A-1. Strategy Selection Screening Tool Entry Array*.

Objective	HOV	HOT	TE	NTE	Transit.	Dedicated	Restricted
1	9	21	20	24	6	9	12
2	24	22	10	10	25	4	2
3	2	4	14	9	4	25	10
4	18	23	23	9	13	11	13
5	16	20	21	15	15	14	15
6	25	25	25	17	18	15	14
7	19	20	24	11	22	15	11
8	22	22	20	9	20	9	4
9	21	11	12	4	17	0	3
10	23	17	12	5	24	0	0
11	15	8	5	4	19	14	4
12	3	4	5	1	3	22	19
13	21	14	15	8	22	10	3
14	16	9	4	8	15	3	1
15	13	6	5	0	24	0	0
16	0	16	20	0	0	0	0
17	0	16	21	0	0	0	0
18	0	12	20	0	0	0	0
19	0	9	19	2	1	5	0

*Strategy Abbreviations: TE (Tolled Express), NTE (Non-tolled Express), Transit (Transitways), Dedicated (Dedicated Truck Lanes), Restricted (Truck-Restricted Lanes)

Weighting Example

Figure A-3 illustrates the weighting screen where the user weights the objectives as “Important,” “Higher Importance,” or “Less Important.”

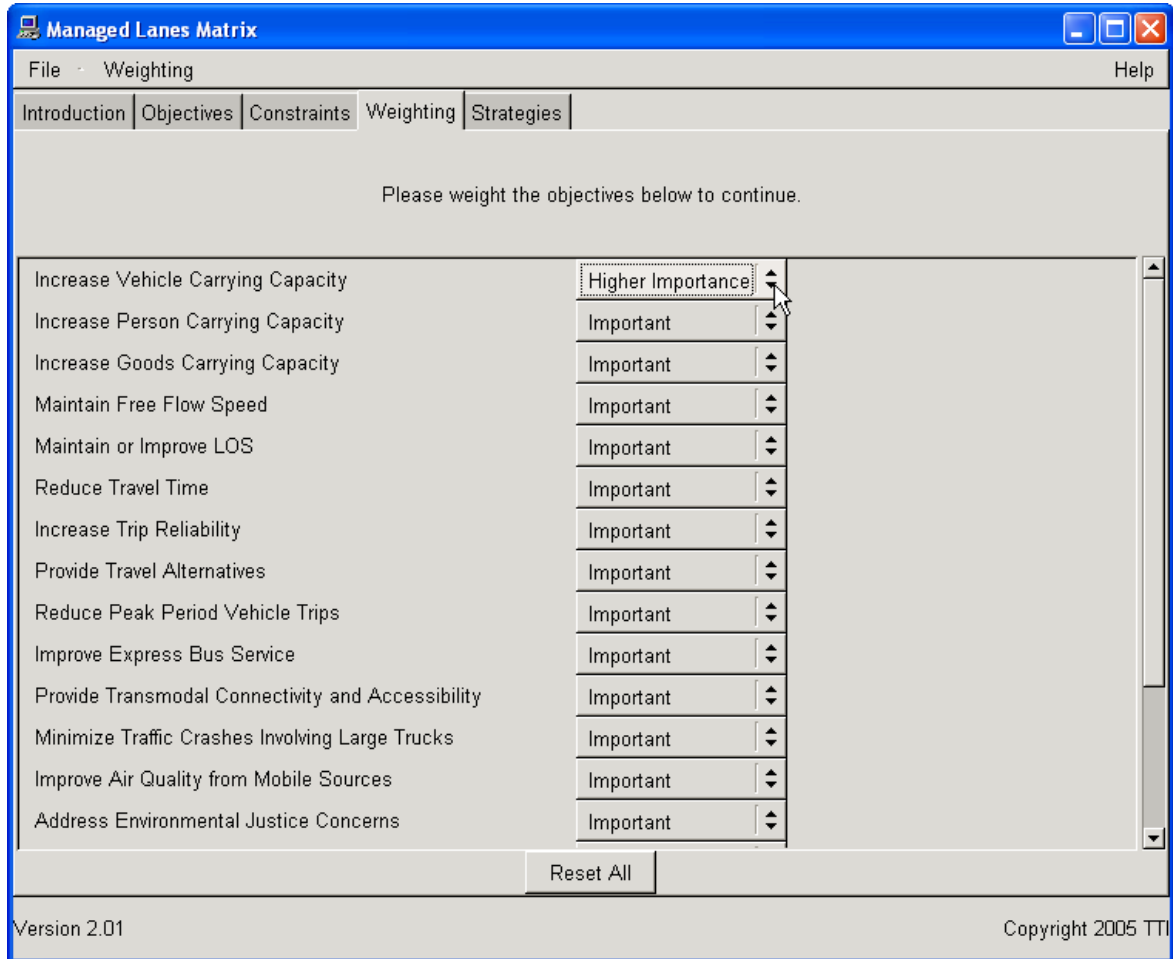


Figure A-3. Strategy Selection Screening Tool Weighting Screen.

The process of modifying the objective values is done by taking the objective in question and either doubling or halving the values in the given row. For example, if the user were to label “Increase Vehicle-Carrying Capacity” as Higher Importance, Table A-1 would be modified to this end result in [Table A-2](#).

Table A-2. Strategy Selection Screening Tool Weighting Example.

Obj	HOV	HOT	TE	NTE	Transit.	Dedicated	Restricted
1	18	42	40	48	12	18	24
2	24	22	10	10	25	4	2
3	2	4	14	9	4	25	10

Rating System for Exclusionary Tests

Figure A-4 shows the screen where the user sets the constraints for a particular project.

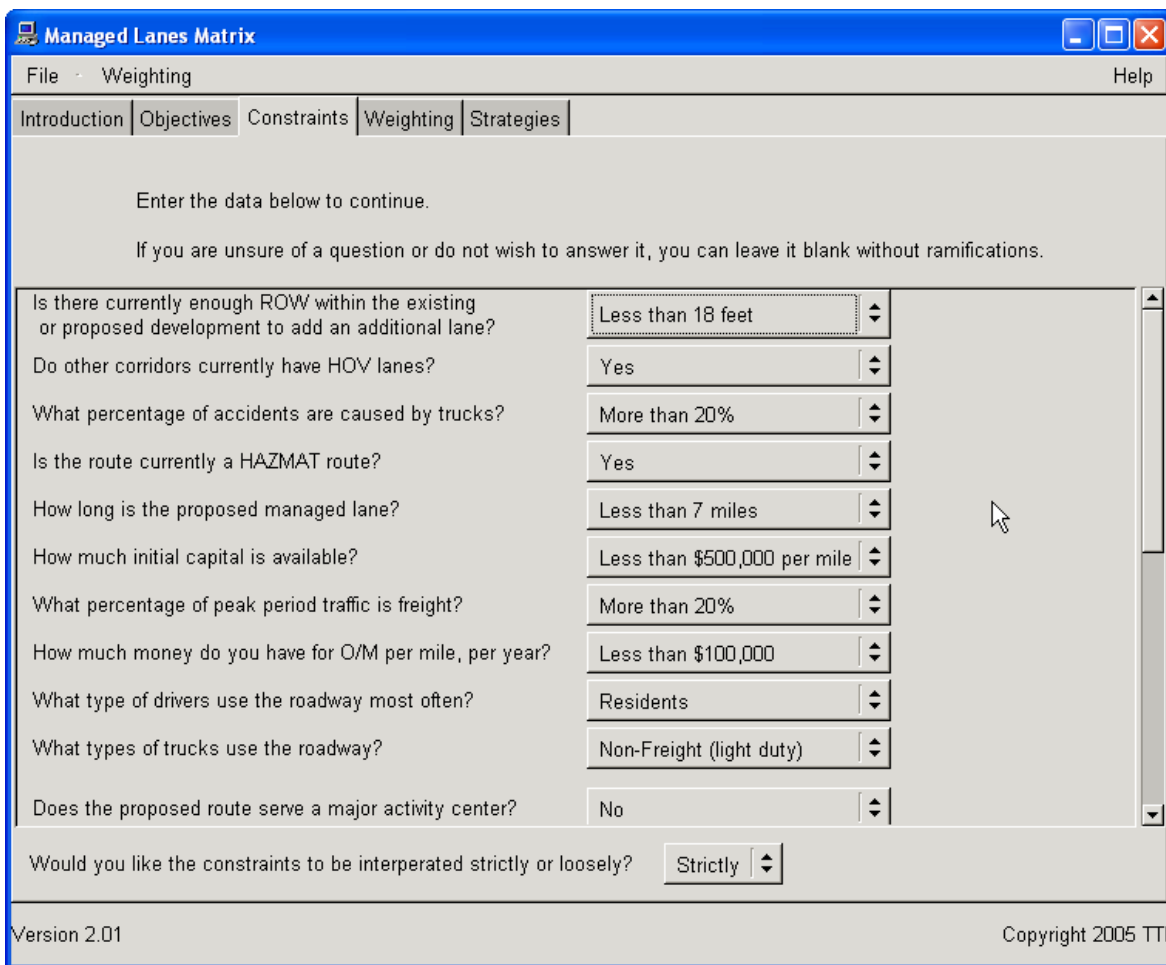


Figure A-4. Strategy Selection Screening Tool Constraints Screen.

The following illustrates the rating system for the various exclusionary tests incorporated into the strategy selection screening tool.

1. Is there currently enough ROW within the existing or proposed development to add an additional lane?

If ROW less than 18 ft:

HOV: +100
HOT: +100
TE: +100
NTE: +100
Transitways: +100
Truck Dedicated: +100

2. Do other corridors currently have HOV lanes?

If Yes

HOV: -5
HOT: -5

3. What percentage of accidents are caused by trucks?

If more than 20%

HOV: +10
HOT: +10
Tolled Express: +10
Non-tolled Express: +10
Transitways: +10

If less than 20%

Truck Dedicated: +10
Truck Restricted: +10

4. Is the route currently a HAZMAT route?

If Yes

Truck Dedicated: -5

5. How long is the proposed managed lane?

If Less Than 7 Miles

HOV: +10
HOT: +10
Transitways: +10

6. How much initial capital is available?

If Less Than \$500,000 per Mile

HOV: +10
HOT: -5
Tolled Express: -10
Non-tolled Express: +10
Transitways: +10
Truck Dedicated: -5

7. What percentage of peak-period traffic is freight?
If More Than 20%
HOV: +10
HOT: +10
Tolled Express: +10
Non-tolled Express: +10
Transitways: +10
Truck Dedicated: -10
Truck Restricted: -10
8. How much money do you have for O/M per mile, per year?
If Less Than \$100,000
Non-tolled Express: +10
Transitways: +10
Truck Dedicated: +10
9. What type of drivers use the roadway most often?
If Residents
Truck Dedicated: +3
Truck Restricted: +3
10. What types of trucks use the roadway?
If Non-freight
Truck Dedicated: +10
Truck Restricted: +10
11. Does the proposed route serve a major activity center?
If No
HOV: +2
HOT: +2
Tolled Express: +2
Non-tolled Express: +2
Transitways: +2
12. What is the congestion index for the roadway in question?
If Less Than 1
HOV: +5
HOT: +5
Tolled Express: +5
Non-tolled Express: +5
Transitways: +5
13. What is the median family income in the corridor?
If Less Than \$30,000
HOV: -5
HOT: -5
Tolled Express: +5
Transitways: -10
14. How many vehicles per household are in the corridor?
If Less Than 1
Transitways: -10

15. Do you have another form of mass transit in your city?
If Yes
Transitways: +10
16. How many buses will use this managed lane per day?
If Less Than 100
Transitways: +15
17. Are there currently truck-restricted lanes in your city?
If Yes
Truck Dedicated: -10
18. Is the corridor a trucking route?
If Yes
HOV: +5
HOT: +5
Tolled Express: +5
Non-tolled Express: +5
Transitways: +5
Truck Dedicated: -20
Truck Restricted: -20
19. Is there political opposition to toll roads in your city?
If Yes
HOT: +10
Tolled Express: +10
20. Are there alternative truck routes nearby?
If Yes
Truck Dedicated: -10

Strategy Considerations

Figure A-5 shows the resulting strategy consideration screen which provides three managed lanes operational strategies in order of overall score.

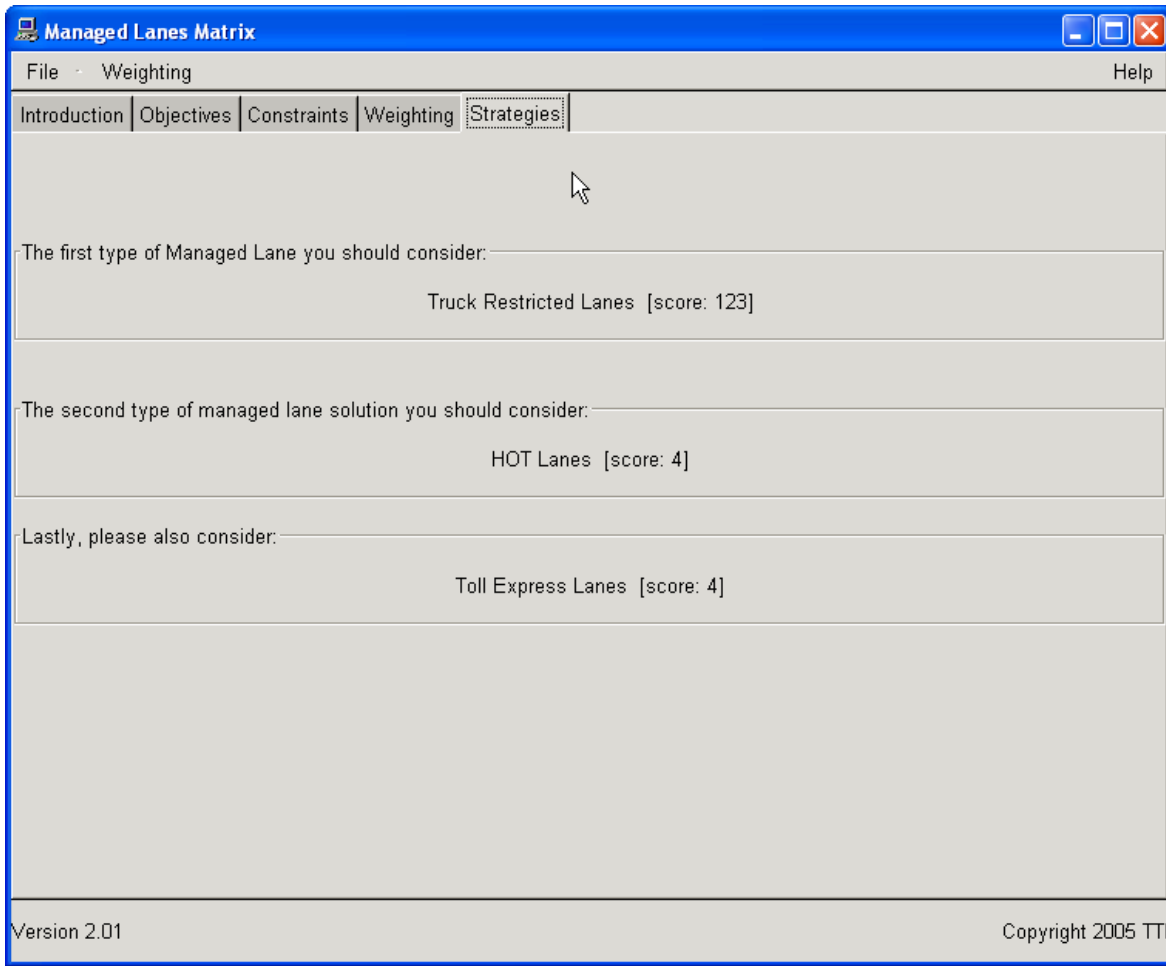


Figure A-5. Strategy Selection Screening Tool Strategy Screen.

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Managed Lanes: More Efficient Use of the Freeway System

The mission of the Texas Department of Transportation (TxDOT) is “to provide the safe, effective, and efficient movement of people and goods.” Through the department’s mission and vision, TxDOT strives to be a progressive transportation agency by providing transportation systems and alternatives that are comfortable, safe, durable, cost-effective, accessible, environmentally sensitive, and aesthetically appealing. TxDOT continually refines its policies and strategies to achieve these goals and objectives.

Today’s levels of congestion in the urban centers throughout the state are affecting the safety, economic viability, and quality of life for everyone in those areas. Peak periods of congestion in these areas may stretch to 6 hours. Even with this increased congestion, the daily vehicle miles traveled continue to increase. Texans drove more than 2.1 billion miles in 2000. The time spent in traffic congestion results in wasted fuel, increased air pollution, and lack of productivity.

The simple answer to these problems may appear to be more roads; however, many factors make this option impractical, if not impossible. Construction costs, right-of-way limitations, environmental concerns, and neighborhood impacts make adding capacity or building new capacity on the transportation network very challenging. TxDOT is exploring a number of alternative concepts for maximizing the existing capacity while maintaining the safety of the system for users.

Managed Lanes

One concept TxDOT is considering is *managed lanes*. TxDOT defines managed lanes as follows:

A facility that increases freeway efficiency by packaging various operational and design actions. Lane management operations can be adjusted at any time to match regional goals (1).

The theory behind managed lanes is to set aside certain freeway lanes and to use a variety of operating strategies to move traffic more efficiently, providing travelers with more choices than driving alone on a congested freeway. Strategies that could be used include:

- ◆ allowing use by certain vehicle groups by time of day,
- ◆ charging a toll for access to the lanes to manage demand, or
- ◆ controlling access points.

Whatever strategies are used, the idea is to modify the strategies as needed over time to meet regional goals. This concept provides flexibility that results in optimal use of the system.

Benefits of Managed Lanes

Managed lanes seek to:

- ◆ improve freeway efficiency,
- ◆ manage demand in the corridor,
- ◆ offer choices that provide travel time savings and trip reliability, and
- ◆ improve safety.

Revenue Generation

In addition to providing flexibility and maximizing efficiency, a managed lanes project may generate revenue by charging a toll. TxDOT estimates that it currently has only 35 percent of the funds needed to complete projects necessary to maintain mobility throughout the state. Therefore, utilizing tolling may provide the only opportunity to get the project built.

Time Savings

Additionally, a tolling project that is funded by bond proceeds may be completed in less time than one funded by traditional state financing methods. By implementing a tolling project financed through bond money, the money that was allocated for this project may be reallocated to other local non-tolling projects in the funding pipeline, allowing those projects to advance more quickly.

Safety

Managed lanes may improve the safety of a roadway. By maintaining free-flow, uncongested travel conditions within the managed lanes, the chances for conflict are minimized. This situation is especially true in the case of large trucks. Large trucks do not have the maneuverability of passenger autos and thus are at increased risk. A lane or lanes restricted to trucks take the trucks out of the regular mix of traffic, resulting in a decreased risk for both motorists and truckers.

Environmental Benefits

Other potentially positive benefits of managed lanes are environmental impacts. As congestion in large urban areas increases, air quality decreases. Emissions from motor vehicles stuck in traffic contribute to the decline in air quality. Emissions, combined with other pollutants, may lead to a non-attainment designation by the U.S. Environmental Protection Agency. This designation has many ramifications, one of which is the loss of millions of dollars in federal highway funding. This loss could seriously limit roadway construction and the ability to make improvements that reduce traffic congestion.

Community Acceptance

Even though the population in these urban areas is increasing and congestion is becoming worse, new roadway construction is limited by a number of factors, such as right-of-way acquisition, construction limitations, and neighborhood and community impacts, creating a cycle of problems. By more effectively managing existing capacity, the need to add more capacity is lessened. This results in fewer negative community impacts. For instance, by installing managed lanes in the median of an existing roadway, TxDOT may not need to acquire additional right-of-way where neighborhoods may be affected. At the same time, the managed lanes may move more people in high-occupancy vehicles (HOVs) than simply adding general-purpose lanes.

Examples of Successful Managed Lanes Facilities

A variety of managed lanes concepts have been implemented successfully in several areas of the United States. One such project is the *FasTrak* program on IH-15 in San Diego, as shown in [Figure B-1](#). Faced with increasing congestion and limited funding, the San Diego Association of Governments (SANDAG) implemented managed lanes, or Express Lanes, in the median of IH-15. The reversible, barrier-separated lanes were previously operated as HOV lanes for buses and carpools of two or more people. However, this operating scenario resulted in excess capacity on the HOV lanes while the mainlanes of I-15 remained heavily congested. SANDAG, working with the California Department of Transportation and the Federal Highway Administration, implemented a demonstration managed lanes program in 1996. The FasTrak program allows single-occupant vehicles (SOV) to “purchase” excess capacity on the Express Lanes by paying a toll for access to the lanes. The program continues to operate successfully today by providing options for motorists.



Figure B-1. IH-15 in San Diego, California.

The Express Lanes allow access only at the beginning and the end of the roadway. There are no intermediate access points along the 8-mile section of roadway. This limited access improves traffic flow on the Express Lanes as well as the adjacent mainlanes since there are no conflicts with traffic entering and exiting either facility. This operating strategy allows the entire corridor to operate more efficiently.

HOVs and transit ridership are encouraged by not charging a toll to these user groups. SOVs that choose to use the Express Lanes are issued an electronic transponder after an account is established. An electronic device reads the transponder when the vehicle enters the Express Lanes, and the toll is debited from the driver's account. The toll varies according to the level of congestion in the Express Lanes. Variable message signs, located before the entrance to the Express Lanes, indicate the amount of the toll; drivers can then decide whether or not to use the lanes.

Bus ridership in the corridor has increased by 25 percent, and the number of daily carpools increased 57 percent since project inception. It has provided options for commuters in the corridor, resulting in the better overall operating efficiency of the entire facility. In addition to providing choices for the commuter, the project has generated revenue that has been used to fund transportation improvements in the corridor.

Recent public opinion research in the IH-15 corridor indicates broad support for the project. Eighty-eight percent of the FasTrak users and 66 percent of the non-users approve of the program, and a majority of both groups agree that the FasTrak program reduces congestion on IH-15. A vast majority of the motorists agree that it is a good idea

to have a time-savings option on IH-15. These high levels of approval are represented across all income levels and ethnic groups.

QuickRide is a project similar to FasTrak that operates on IH-10 in Houston during the morning and afternoon peak periods and on US 290 in the morning peak period. Shown in [Figure B-2](#), this program allows two-person HOVs (HOV 2s) access to the HOV lane during the three-or-more-person restriction by paying a flat toll of \$2.00 per trip. For this fee, HOV 2s travel at free-flow conditions in the barrier-separated HOV lane. Like in the *FasTrak* program, participants in the program must register and be issued an electronic transponder, and the tolls are debited from the driver's account. Motorists who take advantage of *QuickRide* cite flexibility as an incentive for using the program.



Figure B-2. IH-10 Katy Freeway in Houston, Texas.

These projects offer examples of how altering operating scenarios can maximize the efficiency of the transportation system. Agencies operating the programs are able to move more people and goods in a more efficient manner utilizing the available capacity of the transportation network. Agencies also have the flexibility to adjust operations quickly to respond to incidents or, over a longer time period, to meet regional goals. By matching the operating expectations of transportation systems to the regional goals of the community, TxDOT can produce results that will provide commuters with choices, enable goods to be transported expeditiously, and minimize community and environmental impacts.

The Future of Managed Lanes in Texas

TxDOT is considering managed lanes facilities as part of a number of freeway reconstruction projects around the state. Each project has unique characteristics, and TxDOT is approaching each in a way that meets the travel needs in the corridor and is consistent with community objectives. It is part of TxDOT's ongoing effort to explore

alternatives that will maximize the efficiency of the system and balance demands with the desires of the communities that the roadways are to serve. Managed lanes projects provide options in meeting these challenges.

References

1. B. Kuhn, G. Daniels, and D. Jasek. *Year 1 Annual Report of Progress: Operating Freeways with Managed Lanes*. Report 4160-2, Texas Transportation Institute, The Texas A&M University System, College Station, TX, 2002.

Appendix C – Position Paper for Media and General Public

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Managed Lanes: A New Concept for Freeway Travel

What was once known as rush hour may now last up to 6 hours each day in Texas' most congested cities. But the idea of “managed lanes” is giving transportation planners another way to address the growing problem of traffic congestion.

Limited land availability, scarce funds, and social and environmental concerns may prevent adding new freeway lanes. The combination of these factors is forcing transportation planners and engineers to explore new ways to more effectively operate the existing transportation network.

“Managed lanes” is one such concept that is being used successfully across the country.

What Are Managed Lanes?

The theory behind managed lanes is to set aside certain freeway lanes and to use a variety of operating strategies to move traffic more efficiently in those lanes. As a result, travelers have an option not to travel on a congested freeway. High-occupancy vehicle (HOV) lanes, operating successfully in Houston and Dallas for the last two decades, are examples of managed lanes. The concept of HOV-only lanes is evolving into a new type of facility that offers more choices and more flexibility for a wider range of freeway motorists.

The Texas Department of Transportation (TxDOT) believes that using managed lanes will allow it to leverage existing capacity and move both people and goods in the most efficient manner possible. The managed lanes concept is a tool that is available to the transportation community. This tool may be used as part of a comprehensive plan to achieve regional goals.

Managed lanes strategies can:

- ◆ maximize existing capacity,
- ◆ manage demand,
- ◆ offer choices,
- ◆ improve safety, and
- ◆ generate revenue.

How Do Managed Lanes Work?

There are different strategies that can be employed to keep traffic flowing on a managed lanes facility. Demand management techniques include:

- ◆ Time of day restrictions – allowing access to certain lanes at certain times of the day;
- ◆ Vehicle type restrictions – allowing access to managed lanes only to certain types of vehicles, such as carpools, buses, trucks, or vehicles paying a fee; and
- ◆ Value pricing – charging motorists for access to managed lanes and/or charging at varying rates for specific time periods (all fees would be collected electronically without the need for toll booths).

Techniques that can be used to operate managed lanes offer incentives to rideshare through improved access for buses and HOVs, which is an important component of regional goals to reduce vehicle travel. Additionally, value pricing is a mechanism that may be used to offer free or reduced-fee travel at certain times as an incentive to shift motorists out of the peak hours.

The key to successfully operating managed lanes is the ability to alter the operations of the lanes in ways that keep traffic flowing. This strategy provides flexibility, not only in the day-to-day operations of the lanes, but in situations where isolated incidents such as a major accident call for the lanes to be open to more or different user groups.

What Are the Benefits?

In addition to maximizing *capacity*, managed lanes may generate *revenue*. TxDOT estimates that it currently has only 35 percent of the funds needed to complete projects necessary to maintain mobility throughout the state. Therefore, utilizing tolling mechanisms may provide the only opportunity to get a project built. Additionally, a managed lanes project with pricing may be completed in less time than traditional state financing by using bond proceeds to finance the project. By implementing a project financed through bond money, other local non-tolling projects in the funding pipeline may be advanced more quickly.

Managed lanes may improve the *safety* of a roadway. By reducing congestion, the chances for conflict are also minimized. This is especially true in the case of large trucks. Large trucks do not have the maneuverability of passenger autos and thus are at increased risk. Lanes restricted to trucks take the trucks out of the regular mix of traffic, resulting in a decreased risk for both motorists and truckers.

Other potentially positive benefits of managed lanes are *environmental impacts*. As congestion in large urban areas increases, air quality decreases. Emissions from motor vehicles stuck in traffic contribute to the decline in air quality. Emissions, combined with other pollutants, may lead to a non-attainment designation by the U.S. Environmental Protection Agency. This designation has many ramifications, one of which is the loss of millions of dollars in federal highway funding. This funding loss could seriously limit roadway construction.

Even though the population in these urban areas is increasing and congestion is becoming worse, new roadway construction is limited by a number of factors, creating a cycle of problems. By more effectively managing existing capacity, the need to add more capacity is lessened, resulting in fewer negative community impacts. For instance, by installing managed lanes in the median of an existing roadway, TxDOT may not need to acquire additional right-of-way where neighborhoods may be affected. At the same time, the managed lanes may move more people in HOVs than simply adding general-purpose lanes.

Where Is It Working?

One of the most successful examples of a managed lanes facility is the IH-15 project, known as *FasTrak*, in San Diego, California. IH-15 is a very heavily congested corridor where motorists typically experienced more than 30 minutes of delay daily. The corridor includes two reversible express lanes in the median of IH-15. These lanes are separated from the other lanes with concrete barriers.

This two-lane, 8-mile stretch of separated lanes was restricted to high-occupancy vehicles with two or more people. With this restriction the Express Lanes were underutilized while the adjacent mainlanes of IH-15 were heavily congested. The San Diego Association of Governments, the metropolitan planning organization for the area, acting with the California Department of Transportation and the Federal Highway Administration, implemented a demonstration program whereby single-occupant vehicles could use the excess capacity by paying a toll to travel in the Express Lanes. The toll varies from \$0.50 to \$4.00 depending on the level of congestion in the Express Lanes.

The IH-15 project has been operating successfully since 1996. Drivers now have an option for their daily commute. HOVs continue to use the lanes free of charge, and solo drivers can decide whether or not to pay the toll for a faster commute. The operating agencies are now using the roadway capacity more effectively. The program also generates revenue that funds transit improvements in the corridor.

Bus ridership in the corridor has increased by 25 percent, and the number of daily carpools increased 57 percent since project inception. In fact, an entirely new bus service, *Inland Breeze*, is funded solely from revenue generated by the FasTrak program. A 20-mile extension of the project is planned.

Recent public opinion research in the IH-15 corridor indicates broad support for the project. Eighty-eight percent of the FasTrak users and 66 percent of the non-users approve of the program, and a majority of both groups agree that the FasTrak program reduces congestion on IH-15. A vast majority of the motorists agree that it is a good idea to have a time-savings option on IH-15. These high levels of approval are represented across all income levels and ethnic groups.

What's Ahead for Texas?

In Houston, the managed lanes concept is currently being used on the IH-10 and US 290 HOV lanes. HOVs with two people (HOV 2s) are allowed to use the lanes during the HOV three-person (HOV 3+) time period by paying a flat-fee toll of \$2.00 per trip. For this fee, HOV 2s travel at free-flow conditions in the barrier-separated HOV lane. Similar to the FasTrak program, participants in QuickRide must register and be issued an electronic transponder, and the tolls are debited from the driver's account. Motorists who take advantage of the program cite its flexibility as an incentive for using the program.

Throughout the state there are a number of major freeway reconstruction projects where managed lanes are either planned or being considered. Each project has unique characteristics, and TxDOT is approaching each in a way that meets the travel needs in the corridor and is consistent with community objectives.

The managed lanes concept is but one tool available to transportation planners. When used in conjunction with a comprehensive, long-range transportation plan, the concept has the ability to achieve the intended goals of the entire community.