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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 objectives of this project are to investigate the complex and interrelated issues surrounding the safe and efficient operation of managed lanes using various operating strategies and to develop a managed lanes manual to help the Texas Department of Transportation (TxDOT) make informed planning, design, and operational decisions when considering these facilities for its jurisdiction. This document summarizes the activities of the first three years of this multiyear project, highlights the accomplishments to date, provides a status report of efforts underway, and outlines planned activities for the coming year.					
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**YEAR 3 ANNUAL REPORT OF PROGRESS:  
OPERATING FREEWAYS WITH MANAGED LANES**

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## **DISCLAIMER**

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. This project was conducted in cooperation with the Texas Department of Transportation (TxDOT) and the U.S. Department of Transportation, Federal Highway Administration (FHWA). The contents do not necessarily reflect the official view or policies of the Federal Highway Administration or the Texas Department of Transportation. The report does not constitute a standard, specification, or regulation. The engineers in charge of the overall project were Beverly T. Kuhn (Texas P.E. #80308) and Ginger Daniels Goodin (Texas P.E. #64560).

The United States government and the state of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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To gain insight into the interests and concerns of stakeholders in managed lane projects, the research team works with an external stakeholder committee, which has members from various key agencies and organizations in Texas, including cities, metropolitan planning organizations, transit and toll authorities, motor carriers, and others. The research team thanks the following individuals for their membership on this committee:

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- Robert Wilson, P.E., Design Division, TxDOT (Retired)

# TABLE OF CONTENTS

	Page
<b>List of Figures</b> .....	<b>xiii</b>
<b>List of Tables</b> .....	<b>xiv</b>
<b>Chapter 1: Introduction</b> .....	<b>1</b>
Background.....	1
Project Vision and Objective .....	3
Project Management Strategy .....	4
TxDOT Project Monitoring Committee .....	6
External Stakeholder Committee.....	6
Texas Transportation Institute Advisory Committee .....	6
Technical Advisory Committees .....	6
Research Plan and Timeline.....	7
<b>Chapter 2: Ongoing Activities</b> .....	<b>9</b>
Internet Site.....	9
Quarterly Newsletter.....	10
Contact with Project Representatives .....	11
Reports, Products, Presentations, Abstracts, Technical Papers, AND Other Efforts .....	11
<b>Chapter 3: Completed Work</b> .....	<b>17</b>
Definition of Managed Lanes .....	17
Review of Current Practice and State-of-the-Practice Literature .....	18
Glossary of Terms.....	18
Managed Lanes Symposium.....	19
Analysis of Operational Scenarios Based on User Group .....	19
Project Effort .....	20
Results .....	20
Conclusions and Recommendations.....	21
Concept Marketing Strategy .....	23
Geometric Design Recommendations.....	24
Identify State and Federal Legislative Changes or Requirements Needed.....	26
Funding and Financing of Managed Lanes.....	27
Enforcement Procedures and Design.....	28
Revisions and Additions to the Traffic Operations Manual .....	28
<b>Chapter 4: Work Underway</b> .....	<b>31</b>
Decision Matrix for Considering Design and Operational Options Based on a Particular User Group(s).....	31
Facilitating the Update of the AASHTO Guide for HOV Facilities and Guide for Park-and-Ride Facilities.....	33
Developing a Managed Lanes Manual .....	35

Identifying Traveler Information and Decision-Making Needs .....	37
Developing Recommendations for Traffic Control Devices for Managed Lanes .....	38
Developing a Framework for Optimum Incident Management.....	39
<b>Chapter 5: Year 4 Efforts.....</b>	<b>41</b>
Developing Recommendations for Interoperability with Existing and Future Technology.....	41
<b>Chapter 6: Final Remarks.....</b>	<b>43</b>
<b>References .....</b>	<b>45</b>

# LIST OF FIGURES

	<b>Page</b>
Figure 1-1. Project Management Organization.....	5
Figure 2-1. Managed Lanes Website.....	9
Figure 2-2. <i>FastLane</i> , Managed Lanes Quarterly Newsletter.....	10
Figure 4-1. Conceptual Design Framework.....	32

## LIST OF TABLES

	<b>Page</b>
Table 1-1. Questions To Be Answered by Project 0-4160 Research. ....	4
Table 1-2. Schedule of Project Tasks.....	7
Table 2-1. Published Project Deliverables and Products to Date.....	12
Table 3-1. Weaving Distances for Managed Lane Cross-Freeway Maneuvers.....	22

# CHAPTER 1: INTRODUCTION

## BACKGROUND

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, which is growing in popularity among users and agencies alike. Managed lanes maintain free-flow travel speeds on designated lanes or facilities by providing controlled service to eligible groups of vehicles. Moreover, the eligible user groups can vary by time of day or other factors depending on available capacity and the mobility needs of the community. Because true managed lanes are so new and the experience base is so small, numerous issues surrounding their design and operation deserve additional exploration as planning for them progresses.

Managed lanes are similar to special purpose lanes, which have been evolving for several decades. Initially, freeway lanes employed access restrictions to control the amount and entry location of traffic, thereby assuring smoother flow and maximum efficiency. Later, the development of high-occupancy vehicle (HOV) lanes increased total person-movement by providing a lane or lanes designated for buses, vanpools, and carpools only. In the last few years, several HOV lanes have begun using electronic tolling to expand the eligible groups of users, thereby further improving on operating efficiency; those facilities are generally referred to as “HOT lanes” (high-occupancy toll). Recently, transportation agencies are becoming more interested in not only controlling eligibility, but also in retaining real-time control over portions of a roadway via variable mechanisms, such as price.

With the exception of pure HOV lanes, the knowledge base for all forms of managed lane projects is very limited. In addition to the Katy (IH-10) and Northwest (US 290) QuickRide projects, two other similar projects are also in operation in the United States: the IH-15 FasTrak

project in San Diego and the SR 91 Express Lanes project in Orange County, California. Both projects have extensive evaluation programs that are examining effectiveness of the projects against established goals and objectives. Agencies and researchers can learn much from these experiences. However, all of these projects involve retrofitting existing freeway operations within fixed access, geometric, and operational configurations. Virtually no projects in operation offer researchers and transportation agency staff experiential data on the implementation of managed lane freeway sections with multiple operational strategies, including variations in eligible vehicle user groups by time of day.

TxDOT anticipates the managed lane operational approach will offer peak-period free-flow travel to certain user groups. These user groups might be HOVs, trucks, toll-paying vehicles, transit, low-emitting vehicles, or some combination of these and other groups. The current HOT lane pilot project on the Katy (IH-10) and Northwest (US 290) freeways in Houston are working examples of the potential application of allowing more than one vehicle user group into a lane designated exclusively for their use during peak travel times.

At present, several major investment studies (MIS) are underway or completed in Texas that consider some form of managed lanes within upgraded urban freeway sections. These studies include the following:

- Northwest Freeway (US 290) in Houston,
- Northeast Corridor (IH-35) in San Antonio,
- SH 121/114 in Fort Worth,
- Loop 1/US 183 in Austin, and
- IH-35 in Waco.

In at least four of these cases, regional transportation agencies have made a public policy decision to proceed with multiple managed lanes within a general-purpose-lane operating environment. Researchers must now address the traffic engineering issues of geometric design and functional operation to make these projects a reality. However, as stated previously, researchers know little about the complexities of designing a practical, flexible, safe, and efficient facility that may have multiple operating strategies throughout the course of a day, week, year, or beyond. Thus, TxDOT initiated this project to research these and other issues that need answering to help ensure the successful implementation of managed lanes.



## PROJECT VISION AND OBJECTIVE

TxDOT's needs associated with managed lanes research are broad and diverse. Answering any and every question associated with the planning, design, and operation of managed lanes in every conceivable scenario within the framework of one single project is difficult. Thus, in an attempt to clarify the overall direction of this project and to identify those issues the researchers plan to resolve, the project team drafted a vision and objective for the project. The idea was to ensure that all involved with the project are in agreement as to where the project is going and what the final product that will facilitate the implementation of research results will be.

The research supervisors, in collaboration with the Texas Transportation Institute (TTI) Advisory Council, identified the *vision* of managed lanes research as it relates to TxDOT. This vision is to develop a better understanding of how managed lanes can improve mobility for transportation system users. The *objective* of this managed lanes project is to investigate the complex and interrelated issues surrounding the safe and efficient operation of managed lanes and to develop a managed lanes manual to help TxDOT make informed planning, design, and operational decisions when considering these facilities for their jurisdiction.

Although the vision and objective of the project are conceptual, the research team realized that the key staff within TxDOT who will actually implement the research results need to understand what the project will provide to enable them to accomplish their jobs when involved in a managed lanes project. Thus, the research team identified typical questions that the project intends to answer. These questions, as provided in [Table 1-1](#), represent a comprehensive, though not exhaustive, look at the intended results of the project.

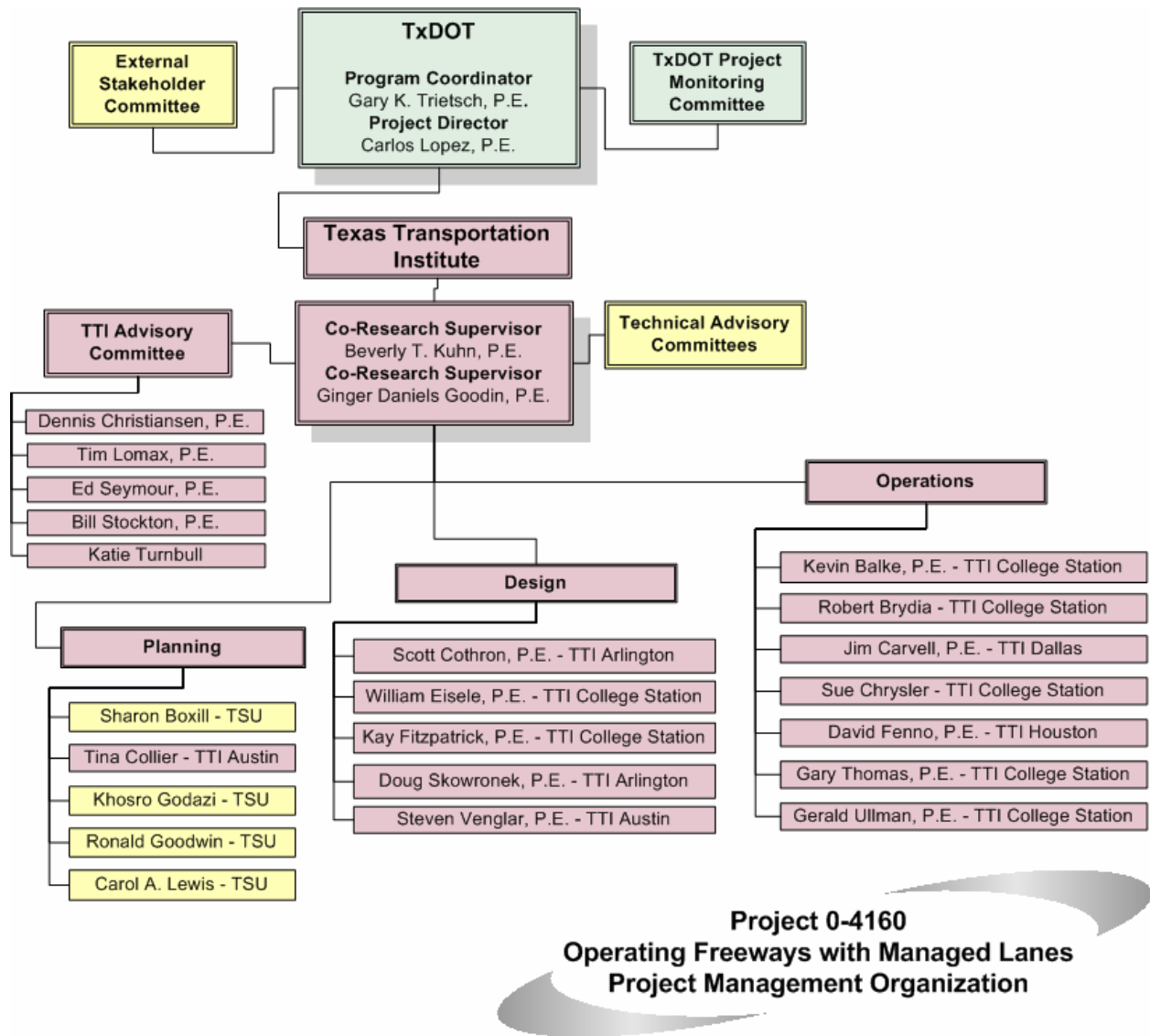
**Table 1-1. Questions To Be Answered by Project 0-4160 Research.**

Managed Lanes Project Phase	Critical Question To Be Answered
Planning Managed Lanes Facilities	<p>What are the operational options available for a managed lanes facility?</p> <p>How does an intended user group(s) affect a managed lanes facility’s design and operations?</p> <p>What defines a successful managed lanes project?</p> <p>How can I fund and finance a managed lanes project?</p> <p>How do I market a managed lanes project to help make it a success?</p> <p>How do I integrate other key agencies (transit, toll, law enforcement, etc.) into a managed lanes project to help overcome institutional issues and barriers?</p> <p>Are there any interim or temporary uses for a managed lanes facility?</p>
Designing Managed Lanes Facilities	<p>How do I design a managed lanes facility to handle a selected user group?</p> <p>How can I design a managed lanes facility to be flexible for future needs?</p> <p>What safety issues do I need to be aware of when designing a managed lanes facility?</p> <p>What interoperability issues do I need to be aware of when designing a managed lanes facility?</p> <p>What information do users need to make decisions about using a managed lanes facility?</p> <p>What approaches to delivering user information can be used to provide that information appropriately?</p>
Operating Managed Lanes Facilities	<p>What is the best way to enforce a managed lanes facility?</p> <p>How do I handle incidents on a managed lanes facility?</p> <p>What staff do I need to manage a managed lanes facility, and what training do they need?</p> <p>How do I evaluate and monitor a managed lanes facility to determine success?</p>

**PROJECT MANAGEMENT STRATEGY**

The complex nature of this project requires a well-defined and coordinated project management strategy. The project management team structure outlined in [Figure 1-1](#) provides for TxDOT oversight and guidance from the program coordinator, project director, and project monitoring committee. It also provides for input from key stakeholders to ensure their buy-in on managed lanes projects in their region via the external stakeholder committee. Beverly Kuhn,

head of the System Management Division at TTI, and Ginger Daniels, head of the Austin Office of TTI, lead the research team. Ad hoc technical advisory committees are formed to support specific tasks within the research effort and are composed of TxDOT staff and other stakeholders, as appropriate. Researchers from TTI and Texas Southern University (TSU) who possess expertise in specific areas of interest lead the various project tasks with guidance from the research supervisors and task-related technical advisory committees.



**Figure 1-1. Project Management Organization.**

### **TxDOT Project Monitoring Committee**

The project monitoring committee (PMC), composed of seven district engineers and seven engineers from various TxDOT divisions, assists the project director, the program coordinator, and the project team in directing the project to meet the needs of TxDOT. The PMC participates in the annual TxDOT workshop, provides input regarding the work plan and critical research needs, and ensures that the overall objectives of the project are met.

### **External Stakeholder Committee**

The external stakeholder committee has members from various key agencies and organizations in Texas, including cities, metropolitan planning organizations, transit and toll authorities, motor carriers, and others. Meeting once a year, this committee works with the project team to see that the stakeholder interests and concerns are considered throughout the project. The intent is to ensure the future buy-in of these stakeholders to managed lanes projects in the state.

### **Texas Transportation Institute Advisory Committee**

TTI provides the project team with an advisory committee composed of key leaders and TTI researchers at no cost to the project. These committee members have international reputations as leaders in the technical areas required for a successful research project. The project team meets with this committee periodically to discuss the direction of the project, specific tasks, problems encountered, results and findings, and other issues critical to the success of the project. This strategy allows the committee to be directly involved in the project in the most efficient and effective manner possible. The committee's involvement helps to ensure that no aspect of the operation of managed lanes is overlooked, and the best possible results are reached.

### **Technical Advisory Committees**

TxDOT staff from various districts and divisions as well as other related stakeholder organizations participate in ad-hoc technical advisory committees throughout the course of the project. Researchers assemble these committees on a task basis, and the task leaders charge the members with providing technical insight and guidance to the project team for that task. This

strategy ensures that the particular needs of the districts, divisions, and organizations are met in a manner that works with the TxDOT process while meeting the objectives of managed lanes.

## RESEARCH PLAN AND TIMELINE

The TTI work plan is a general road map to aid TxDOT and the research team in managing a successful project. The process established and the people involved enable refinement of the details updates to the road map to meet TxDOT’s needs as the project unfolds. Because of the newness of the concepts and the evolution of research principles, researchers will base work beyond the first three years on the results to date. Working closely with the TxDOT project monitoring committee and the TTI advisory committee during the annual modification process, the project team will develop detailed work plans for subsequent years one year prior to conducting the research so that the tasks and desired research can be refined to reflect the previous results and the needs of TxDOT. [Table 1-2](#) provides a summary of the project tasks and their anticipated start date by year.

**Table 1-2. Schedule of Project Tasks.**

Status	Task
Complete	Review of Current Practice and State-of-the-Practice Literature
	Plan and Host a Managed Lanes Symposium
	Analyze Operational Scenarios Based on User Group(s)
	Develop Recommendations for Geometric Design of Managed Lanes
	Develop a Concept Marketing Strategy
	Identify State and Federal Legislative Changes or Requirements Needed
	Develop Recommendations for Funding and Financing of Managed Lanes
	Develop Recommendations for Enforcement Procedures and Design
Underway	Develop a Decision Matrix for Consideration of Design and Operational Options
	Provide Recommendations for Changes to AASHTO HOV and Park-and-Ride Design Guides
	Develop Managed Lanes Manual
	Plan and Host Annual Workshops for TxDOT PMC
	Develop Recommendations for Revisions/Additions to the Traffic Operations Manual
	Identify Traveler Information and Decision-Making Needs
	Develop Recommendations for Traffic Control Devices for Managed Lanes
	Develop Recommendations/Additions to the Texas Manual on Uniform Traffic Control Devices
Develop a Framework for Optimum Incident Management	
Planned for 2004 and Beyond	Develop Recommendations for Interoperability with Existing and Future Technology
	Provide Recommendations for Staffing and Training Needs
	Develop Strategies for Interim Managed Lane Use during Construction and Other Situations
	Develop Recommendations for Evaluation and Monitoring of Managed Lanes

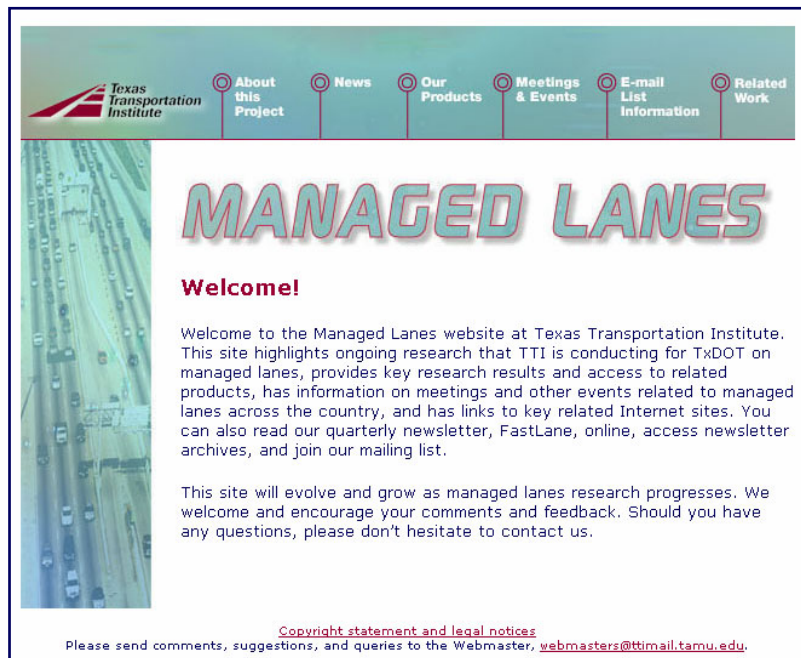


## CHAPTER 2: ONGOING ACTIVITIES

The research team works on a number of activities directly related to the overall success of the project and implementation of research results. The following sections highlight these activities and the specific accomplishments or developments in each to date.

### INTERNET SITE

A key component of research success is implementation. However, ensuring that practicing transportation professionals have access to research results is challenging. Thus, to help facilitate implementation, the research team and TTI Advisory Committee developed a project website to provide an avenue for disseminating research results and exposure to the research surrounding managed lanes. The Managed Lanes site, which has an Internet address of <http://managed-lanes.tamu.edu>, highlights ongoing research that TTI is conducting for TxDOT on managed lanes, provides key research results and access to related products, has information on meetings and other events related to managed lanes across the country, and has links to key related Internet sites. Readers can also access the quarterly newsletter, *FastLane*, online and join the mailing list. [Figure 2-1](#) is a snapshot of the home page for the website.



**Figure 2-1. Managed Lanes Website.**

## QUARTERLY NEWSLETTER

To assist implementation, the project team publishes a quarterly newsletter to document lessons learned throughout the duration of the project. This newsletter, *FastLane*, allows department engineers and other key personnel quick access to implementable research findings without having to wait until completion of the project. The team publishes the newsletter electronically, with the approval of the project director (PD), and distributes it to the project mailing list of over 300 transportation professionals. The researchers reach an even broader audience by posting the newsletter on the project website. Figure 2-2 illustrates the format of the newsletter. To date, the research team has published eight newsletters with positive feedback from readers.

Managed Lanes- Increasing Highway Efficiency

# FAST LANE

Summer 2003

This Issue	Page
Welcome to FastLane	1
Research Team Out in Front	1
Houston QuickRide Program Enhancements	1
Managed Lanes on the Web	2
Upcoming Meetings of Note	2
Managed Lanes in the News	2
Update on Texas Legislation Regarding Managed Lanes	3
The Managed Lanes List	3
HOT Lane Project Handout	4

**Welcome to FastLane**

This is the eighth issue of *FastLane*: a quarterly newsletter that highlights ongoing activities and research in managed lanes in Texas. This issue features an update on Value Pricing Lanes in Houston and on recent Texas legislation regarding managed lanes. *FastLane* archives can be found on our web site, <http://managed-lanes.tamu.edu>. Please feel free to forward this newsletter to anyone who might be interested in its contents, and as always, we welcome your comments and suggestions.

**Research Team Out in Front**

In the last few months, two researchers from the managed lanes team have given presentations on the project to audiences of note. On May 20, 2003, Beverly Kuhn gave a presentation on *Freeway Operations and Managed Lanes* at the 13th Annual Meeting of the Intelligent Transportation Society of America in Minneapolis, MN. Also, Ginger Goodin gave a presentation on the project success and progress to the TxDOT Research Management Committee 2 at their meeting held on 9 June 2003 in San Antonio, Texas.

An article titled, "The Future of Freeways" in the *Texas Transportation Researcher*, focused on the managed lanes project and research team. The article highlighted using the concept of managed lanes to meet urban mobility needs in the face of rising construction costs, neighborhood impacts, and environmental concerns. The article also presented three areas key to laying groundwork for a successful managed lanes project: passing legislation to ensure legal authority to develop projects; educating to gain support from the public and policy makers; and funding and financing to overcome barriers. The entire article can be found at: [http://tti.tamu.edu/researcher/v39n2/39\\_2.pdf](http://tti.tamu.edu/researcher/v39n2/39_2.pdf)

**Houston QuickRide Program Enhancements in the Works**

Houston's present value pricing program, QuickRide, is now being studied and refined in an effort to increase usage, improve customer satisfaction, reduce net operating costs and smooth the traffic flow. Currently, QuickRide allows two-person carpools (HOV2) to use the HOV lane on the Katy and US 290 freeways for \$2 per trip during peak hours while larger carpools (HOV3) and buses use it for free. These High Occupancy Toll (HOT) lanes are the first in Texas and among the first in the United States. The Texas Transportation Institute (TTI) is developing recommendations for the current and future operation of these HOV lanes in the areas of enforcement, pricing, signing and marketing.

A project handout regarding HOT lanes is now available. The handout, found on page four of *FastLane* and at <http://managed-lanes.tamu.edu>, includes background information, project objectives and the current project status. The project findings and recommendations are being developed to help enhance HOT lanes now, as well as serve as a model for the expansion of the QuickRide program to other HOV lanes as congestion warrants.

**HOV Lanes Katy Freeway**

Figure 2-2. *FastLane*, Managed Lanes Quarterly Newsletter.



## **CONTACT WITH PROJECT REPRESENTATIVES**

The project team continues to periodically contact TxDOT staff who are instrumental in the various managed lanes projects across the state. Since the inception of this project, the research team has met with representatives from the Austin, Dallas, Fort Worth, Houston, San Antonio, and Waco TxDOT districts to discuss project progress and key findings relevant to their specific projects. The research team anticipates that they will have similar meetings in the future as research tasks are completed.

## **REPORTS, PRODUCTS, PRESENTATIONS, ABSTRACTS, TECHNICAL PAPERS, AND OTHER EFFORTS**

Researchers also help disseminate research results through presentations, abstracts, and technical papers. Whether at the local, state, national, or international level, these tools serve as powerful allies in giving practitioners access to the latest information to help them in their respective organizations. Since the beginning of this project, researchers have made presentations to and/or prepared technical papers for numerous conferences, meetings, and organizations, as highlighted in [Table 2-1](#). Additionally, the research team provides monthly status reports to the project director and program coordinator and prepares additional products and items that assist with the research effort and disseminate research results. [Table 2-1](#) summarizes all of these items as well as the project's official deliverables. The research team anticipates continuing this effort to help ensure that the research results reach the practitioner in a timely manner and to expedite implementation both in Texas and across the nation.

**Table 2-1. Published Project Deliverables and Products to Date.**

Type of Product	Description / Title / Event
<b>Fiscal Year 2003</b>	
Reports	Proceedings of Annual Workshops for TxDOT (FHWA/TX-03/4160-3) <i>Meeting Summary: 2002 Annual Project Monitoring Committee Workshop</i> Task 7 Report: Sample State and Federal Legislation (FHWA/TX-03/4160-8) <i>State and Federal Issues for Managed Lanes</i> Task 9 Report: Funding and Financing (FHWA/TX-03/4160-9) <i>The Funding and Financing of Managed Lanes Projects</i> Task 10 Report: Geometric Design (FHWA/TX-03/4160-10) <i>Managed Lane Ramp and Roadway Design Issues</i> Task 11 Report: Enforcement (FHWA/TX-03/4160-11) <i>Enforcement Issues on Managed Lanes</i> Annual Research Report: Year 2 (FHWA/TX-03/4160-12) <i>Year 2 Annual Report of Progress: Operating Freeways with Managed Lanes</i>
Products	Sample State and Federal Legislation (FHWA/TX-02/4160-P3) <i>Sample State and Federal Legislation</i>
Implementation	Policy Maker Brochure (4160-5-P1) <i>Managed Lanes: More Efficient Use of the Freeway System</i> Media Editorial Staff Brochure (4160-6-P2) <i>Managed Lanes: A New Concept for Freeway Travel</i>
Bulletins	<i>Managed Lanes Symposium (4160-1B)</i> <i>Managed Lanes – Traffic Modeling (4160-4B)</i> <i>Developing a Managed Lanes Position Paper for a Policy-Maker Audience (4160-5B)</i> <i>Developing a Managed Lanes Position Paper for a Media Audience (4160-6B)</i> <i>Marketing the Managed Lanes Concept (4160-7B)</i> <i>State and Federal Issues for Managed Lanes (4160-8B)</i> <i>The Funding and Financing of Managed Lanes Projects (4160-9B)</i> <i>Managed Lane Ramp and Roadway Design Issues (4160-10B)</i> <i>Enforcement Issues on Managed Lanes (4160-11B)</i> <i>Year 2 Annual Report: Operating Freeways with Managed Lanes (4160-12B)</i>
Newsletters	<i>FastLane – Fall 2002</i> <i>FastLane – Winter 2003</i> <i>FastLane – Spring 2003</i> <i>FastLane – Summer 2003</i>
Articles	The Future of Freeways: Research Identifies Strategies for Developing Managed Lanes, <i>Texas Transportation Researcher</i> , Vol. 39, No. 2 Managed Lanes: A New Concept for Freeway Travel, <i>The Dunn Deal</i> , Issue #9, May 2003
Published Papers	State Legislative Issues for Managed Lanes in Texas, 2003 TRB Annual Meeting Managed Lanes Research in Texas, 2003 ITE Annual Meeting
Unpublished Papers	A Legislative Framework for Operating Managed Lanes, 11 <sup>th</sup> International HOV Conference Managed Lane Ramp Design Issues, 2004 TRB Annual Meeting
Abstracts	Managed Lanes Research in Texas, 2003 ITE Annual Meeting
Presentations	Operating Freeways with Managed Lanes, 2002 PMC Workshop, September 2002 Operating Freeways with Managed Lanes, 2002 External Stakeholder Meeting, September 2002 Managed Lanes Facilities in Texas, 2002 TxDOT Short Course, October 2002 A Legislative Framework for Operating Managed Lanes, 11 <sup>th</sup> International HOV Conference, October 2002

**Table 2-1. Published Project Deliverables and Products to Date (continued).**

Type of Product	Description / Title / Event
<b>Fiscal Year 2003 (continued)</b>	
Presentations (continued)	Concept Marketing of Managed Lanes, 11 <sup>th</sup> International HOV Conference, October 2002
	Managed Lanes Design Issues, 11 <sup>th</sup> International HOV Conference, October 2002
	Managed Lanes – Operational Issues and Design Treatments, 11 <sup>th</sup> International HOV Conference, October 2002
	Operating Freeways with Managed Lanes, RMC 4 Meeting, November 2002*
	Managed Lanes in Texas: What Are the Challenges and Opportunities, 2003 TRB Annual Meeting*, January 2003
	Managed Lanes in Freeway Operations, 2003 TRB Annual Meeting*, January 2003
	Weaving Recommendations for Managed Lanes, 2003 TRB Annual Meeting*, January 2003
	State Legislative Issues for Managed Lanes in Texas, 2003 TRB Annual Meeting*, January 2003
	Involving the Public in a New Concept: Managed Lanes, 2003 TRB Annual Meeting*, January 2003
	Managed Lanes in Freeways Operations, 2003 ITSA Annual Meeting*, May 2003
	Operating Freeways with Managed Lanes, RMC 2 Meeting, June 2003
	Managed Lanes in Texas, UDOT Managed Lanes Video Conference, July 2003
	Managed Lanes Research in Texas, 2003 ITE Annual Meeting*, August 2003
Semiannual Reports	Research Supervisor Semiannual Progress Report – February 2003
	Research Supervisor Semiannual Progress Report – August 2003
Status Reports	Monthly Status Report – September 2002
	Monthly Status Report – October 2002
	Monthly Status Report – November 2002
	Monthly Status Report – December 2002
	Monthly Status Report – January 2003
	Monthly Status Report – February 2003
	Monthly Status Report – March 2003
	Monthly Status Report – April 2003
	Monthly Status Report – May 2003
	Monthly Status Report – June 2003
	Monthly Status Report – July 2003
	Monthly Status Report – August 2003
Tech Memos	2002 External Stakeholder Committee Meeting Summary (TTI TM 4160-6)
<b>Fiscal Year 2002</b>	
Reports	Annual Research Report: Year 1 (FHWA/TX-02/4160-2)
	<i>Year 1 Annual Report of Progress: Operating Freeways with Managed Lanes</i>
	Proceedings of Annual Workshops for TxDOT (FHWA/TX-02/4160-3)
	<i>Meeting Summary: 2001 Annual Project Monitoring Committee Workshop</i>
	Task 5 Report: Analysis of Operational Scenarios (FHWA/TX-02/4160-4)
<i>Managed Lanes – Traffic Modeling</i>	
Task 8 Product: Developing a Managed Lanes Position Paper for a Policy-Maker Audience (FHWA/TX-02/4160-5)	
<i>Developing a Managed Lanes Position Paper for a Policy-Maker Audience</i>	

**Table 2-1. Published Project Deliverables and Products to Date (continued).**

Type of Product	Description / Title / Event
<b>Fiscal Year 2002 (continued)</b>	
Reports (continued)	Task 8 Product: Developing a Managed Lanes Position Paper for a Media Audience (FHWA/TX-02/4160-6) <i>Developing a Managed Lanes Position Paper for a Media Audience</i>
	Task 8 Report: Concept Marketing Strategy (FHWA/TX-02/4160-7) <i>Marketing the Managed Lanes Concept</i>
Products	Position Paper for Key Policy Makers (FHWA/TX-02/4160-P1) <i>Managed Lanes: More Efficient Use of the Freeway System: A Position Paper for Policy Makers</i>
	Position Paper for Media Editorial Staff (FHWA/TX-02/4160-P2) <i>Managed Lanes: A New Concept for Freeway Travel: A Position Paper for the Media</i>
Newsletters	FastLane – August 2001
	FastLane – December 2001
	FastLane – March 2002
	FastLane – June 2002
Articles	Managed Lanes, <i>Transportation Management + Engineering</i> , December 2001/January 2002
	Managed Lanes Offer Choices, Flexibility, <i>Texas Transportation Researcher</i> , Vol. 38, No. 2
Unpublished Papers	State Legislative Issues for Managed Lanes in Texas, 2003 TRB Annual Meeting
	Weaving Recommendations for Managed Lanes, 2003 TRB Annual Meeting
Abstracts	Concept Marketing of Managed Lanes, 11 <sup>th</sup> International HOV Conference
	A Legislative Framework for Operating Managed Lanes, 11 <sup>th</sup> International HOV Conference
	Life-Cycle Graphical Representation of Managed HOV Lane Evolution, 11 <sup>th</sup> International HOV Conference
	Weaving Lengths for Managed Lanes Access and Egress, 11 <sup>th</sup> International HOV Conference
	Managed Lanes in Texas: A New Strategy, 11 <sup>th</sup> International HOV Conference
Presentations	Operating Freeways with Managed Lanes, RMC 2 Meeting, November 2001
	Marketing Managed Lanes in Texas, 2002 TRB Annual Meeting*, January 2002
	Managed Lanes Research, 2002 TRB Annual Meeting*, January 2002
	Operating Freeways with Managed Lanes, TxDOT Managed Lanes Project Managers, March 2002
	Managed Lanes Concept, TxDOT Design Conference, April 2002
	Managed Lanes Concept, Florida Statewide HOV Workshop*, April 2002
	Operating Freeways with Managed Lanes, RMC 4 Meeting, June 2002
	Design Issues Regarding Managed HOV Lanes, AASHTO 2002 Annual Meeting – Subcommittee on Design*, June 2002
	Managed Lane Concept, 2002 Texas Transportation Summit, August 2002
Semiannual Reports	Research Supervisor Semiannual Progress Report – February 2002
	Research Supervisor Semiannual Progress Report – August 2002
Status Reports	Monthly Status Report – September 2001
	Monthly Status Report – October 2001
	Monthly Status Report – November 2001
	Monthly Status Report – December 2001
	Monthly Status Report – January 2002
	Monthly Status Report – February 2002
	Monthly Status Report – March 2002
	Monthly Status Report – April 2002
	Monthly Status Report – May 2002

**Table 2-1. Published Project Deliverables and Products to Date (continued).**

Type of Product	Description / Title / Event
<b>Fiscal Year 2002 (continued)</b>	
Status Reports (continued)	Monthly Status Report – June 2002
	Monthly Status Report – July 2002
	Monthly Status Report – August 2002
Tech Memos	Current State of the Practice (TTI TM 4160-4)
	Glossary of Terms for Managed Lanes (TTI TM 4160-5)
	Current State of the Practice (TTI TM 4160-4F)
	Glossary of Terms for Managed Lanes (TTI TM 4160-5F)
<b>Fiscal Year 2001</b>	
Reports	Proceedings of Managed Lanes Symposium (FHWA/TX-02/4160-1) <i>Managed Lanes Symposium - Conference Proceedings</i>
Articles	Managed Lanes – The Future of Freeway Travel, <i>Texas Transportation Researcher</i> , Vol. 37, No. 2
Unpublished Papers	Summary of Updates to the HOV and Park-and-Ride Facilities Design Guides by the AASHTO Subcommittee on Design, 2002 TRB Annual Meeting
Presentations	Developing Managed Lanes, 2000 TxDOT Short Course
	Operating Freeways with Managed Lanes, RMC 4 Meeting, June 2001
	Operating Freeways with Managed Lanes, 2001 PMC Meeting, August 2001
Semiannual Reports	Research Supervisor Semiannual Progress Report – February 2001
	Research Supervisor Semiannual Progress Report – August 2001
Status Reports	Monthly Status Report - May 2001
	Monthly Status Report - July 2001
	Monthly Status Report - August 2001
Tech Memos	Definition of Managed Lanes – Draft (TTI TM 4160-1)
	Definition of Managed Lanes – Final (TTI TM 4160-2)
	Project Vision and Objective (TTI TM 4160-3)

\* Travel for presentation NOT paid for by project 0-4160.



## **CHAPTER 3: COMPLETED WORK**

As a concise review of the status of the project, the following sections provide a summary of completed work to date. They are organized by task and related activities critical to the successful completion of the project.

During the first year of work, the project team undertook several tasks that set the tone for the entire effort. These tasks included establishing a definition of managed lanes, reviewing current literature in the area of managed lanes, establishing a glossary of terms, and hosting a managed lanes symposium for key stakeholders across Texas. During the second year of work, researchers completed work on the analysis of operations, concept marketing, geometric design, legislation, funding and financing, enforcement, and potential revisions to the TxDOT Traffic Operations Manual. The following sections provide a summary of the completed work and key findings for each task.

### **DEFINITION OF MANAGED LANES**

At the onset of the project, the project director and the program coordinator wanted to agree upon a definition for managed lanes. This agreement established a definition that would serve as the official definition of managed lanes for the entire TxDOT organization. Thus, with the guidance and consensus of the TxDOT Project Monitoring Committee, the project team established the following as a definition for managed lanes:

“A managed lane facility is 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.”

The definition is very general, and yet it reflects the complexity and flexibility of the managed lanes concept. The definition allows each district across the state to determine what “managed lanes” means for their jurisdiction. Thus, it respects the needs of the community without requiring the application of a specific strategy that does not meet those needs. Moreover, it encourages flexibility, realizing that the needs of a region may change over time, thereby requiring a different managed lane operational strategy.

## **REVIEW OF CURRENT PRACTICE AND STATE-OF-THE-PRACTICE LITERATURE**

The research team conducted an extensive and exhaustive review of current practice and related research on the operation of managed lanes in areas throughout the country and around the world. Based on over 100 documents published over the past 20 years, the review highlights key managed lane operational strategies currently in use. These strategies include HOV lanes, HOT lanes, value-priced facilities, exclusive lanes (e.g., busways and truck lanes), separation and by-pass lanes, dual facilities, and lane restrictions. Furthermore, the review brings to light key issues regarding the implementation of managed lanes, such as operational issues, safety, economics, legal and policy issues, environmental concerns, social and public opinion issues, and enforcement.

The results of this task create an overall framework for the research planned for the project. They identify the operational strategies available to agencies and draw attention to the various issues that agencies need to address when considering a managed lane facility. The complete text of this literature review and its associated references are published as Appendix A in Report 4160-2: *Year 1 Annual Report of Progress: Operating Freeways with Managed Lanes (1)*.

## **GLOSSARY OF TERMS**

During the course of the review of current practice, it became evident to the researchers that managed lanes are a complex concept with an equally complex lexicon of terms. The research reports and documents indicated that the consistent use and meanings of terms, phrases, and concepts are lacking. This inconsistency has the propensity to confuse the reader and generate questions when discussing specific issues or operational strategies for managed lanes.

To eliminate potential confusion and to clarify the intended course of the research project, the research team compiled a glossary of terms related to managed lanes that emerged from other TTI work. The terms included came from a glossary developed for the Austin TxDOT district as part of its HOV planning work and from a pricing glossary under development by the Transportation Research Board (TRB) pricing subcommittee. This glossary serves as a framework upon which researchers will base future efforts. Appendix B of Report



4160-2: *Year 1 Annual Report of Progress: Operating Freeways with Managed Lanes* contains the complete list of terms related to managed lanes (1).

## **MANAGED LANES SYMPOSIUM**

As part of this project, the research team organized a managed lanes symposium to begin generating a dialogue between all potential partners and to provide insight into the concerns of those partners regarding operation of managed lanes. The research team hoped that a symposium would serve as a starting point for continued movement toward using managed lanes to maximize capacity on congested roadways and enhancing the mobility of the transportation user.

The TxDOT-sponsored symposium assembled over 90 key staff, decision makers, and other related stakeholders from transportation agencies across Texas to discuss issues pertinent to the planning, design, and operation of managed lane facilities. Attendees gained insight from experts around the country, who provided current thinking about managed lane operations. The complete proceedings of the symposium are contained in Report 4160-1: *Managed Lanes Symposium: Conference Proceedings* (2).

## **ANALYSIS OF OPERATIONAL SCENARIOS BASED ON USER GROUP**

As discussed previously, managed lanes are a complex issue. They incorporate several operational strategies that have unique characteristics. Thus, one of the research team's initial tasks was to analyze the various operational strategies available for managed lanes based on the user group to demonstrate the impacts of those strategies on design and traffic operations. The charge was to evaluate factors such as access design, access spacing, and geometric design to provide insight into such key factors as signing, delineation, and traveler information needs. The exercise of testing "what-if" scenarios can identify key features that agencies must consider with such facilities.

The purpose of this task was to demonstrate the impacts of alternative operating strategies on design and traffic operations considerations for managed lanes. Using planning-level vehicle demands and trip characteristics available to TTI staff, the corridor study team developed a simulation model to evaluate factors such as access design, access spacing, and geometric design to provide insight into signing, delineation, and traveler information needs.

## **Project Effort**

Researchers selected the VISSIM model from among several traffic models capable of performing detailed modeling of managed lanes within freeway corridors. They then created a VISSIM model of the Katy Freeway corridor in Houston, Texas, as a platform for an analysis of the frequency and location of at-grade (i.e., from within the freeway) access points for managed lanes. Researchers identified several key issues (not fully documented in current analytical practices and guidelines) that have a bearing on managed lanes operation. These issues are:

- freeway weaving from a freeway entrance to a managed lane entrance,
- freeway weaving from a managed lane exit to a freeway exit, and
- intra-freeway vehicle stream separation of vehicles destined for managed lane access.

For each of these key issues, VISSIM models were constructed to examine different combinations of freeway volume level, percentage of weaving vehicles, weaving distance, and weaving complexity. In total, the research team designed more than 650 combinations of weaving distance, weaving complexity, and traffic volume conditions into modeling experiments and performed over 2000 simulations.

## **Results**

For freeway weaving across five lanes between a standard, right-side freeway entrance ramp and a left-side managed lane entrance ramp, modeling indicates that the impacts of heavy vehicles in the vehicle stream are more pronounced at shorter weaving distances. Freeway operation tended to stabilize at weaving distances greater than 3000 ft for medium volume levels and 3500 to 4000 ft for high freeway volume levels. When an intermediate ramp was located between the freeway and managed lane entrances, operation stabilized at weaving distances greater than 3500 ft for moderate volumes and 4000 ft for high volumes.

For freeway weaving across three lanes between a left-side managed lane exit and a right-side freeway exit ramp, modeling indicates that weaving and non-weaving freeway operations tend to stabilize at weaving distances greater than 3000 ft for medium volumes and 3500 ft for high volumes. In more complex exit ramp simulations, where an intermediate entrance ramp was located between the managed lane exit and the freeway exit ramp, weaving and non-weaving flow stabilized for a four-lane weaving section at distances greater than 3000 ft.

Intra-freeway weaving for accessing managed lanes is the “sorting” of vehicles destined for the managed lanes into the leftmost freeway lane. This maneuver can be viewed as the weaving distance required for a driver who has decided he/she is a candidate for using the managed lanes to reach the correct lane for a transition into the managed portion of the freeway facility. Consistent with expectations, greater selective separation weaving distance exhibits improved performance. Also as expected, non-weaving speeds are consistently higher than weaving speeds, as the non-weaving – or through – vehicle population was not required to discover and maneuver into gaps in adjacent lanes in order to reach the leftmost, managed facility access lane. For medium volume levels, selective separation results stabilize at distances greater than and equal to 1 mile. For high volume levels, selective separation results stabilize at distances between 1.5 and 2 miles and greater. Impacts of truck percentage on performance were determined to be more substantial than the impact of bus percentage. Again, such results were expected, as the truck vehicle class is both larger and slower to accelerate/decelerate than buses.

## **Conclusions and Recommendations**

The recommendations of the managed lanes modeling effort are summarized in list format:

1. Standard analysis techniques, especially the Highway Capacity Manual (HCM) and Highway Capacity Software (HCS), are appropriate for isolated entrance, exit ramp, and one-sided weaving section analysis where these features must be studied within corridors with managed lanes applications. More complex issues, such as cross-freeway weaving and intra-freeway weaving, are most appropriately and practically studied using simulation.
2. The simulation tools CORSIM and Integration offer sufficient data input flexibility to accommodate a variety of managed lane simulation modeling issues, including complex geometrics, signalization/control, and some routing capabilities. However, where multiple vehicle classes and selective real-time control and routing must be modeled, the simulation tools Paramics and VISSIM are most applicable.
3. Typical managed lane design guidelines specify either minimum (500 ft) and desirable (1000 ft) weaving distances per lane, or a preferred minimum distance (2500 ft) between a freeway entrance or exit and a managed lanes facility entrance or

exit. The current research updates and places conditionality on these generic guidelines. A recommended weaving distance application table has been developed for anticipated conditions in the design year (see [Table 3-1](#)). The managed facility designer has the option of:

- a. specifying medium or high volume in the design year (based on HCM level of service [LOS]),
- b. allowing for or not allowing for up to a 10 mph reduction in operating speed due to managed lane related weaving, and
- c. having or not having intermediate ramp(s) between the freeway entrance/exit and the managed lanes entrance/exit.

**Table 3-1. Weaving Distances for Managed Lane Cross-Freeway Maneuvers.**

Design Year Volume Level	Allow up to 10 mph Mainlane Speed Reduction for Managed Lane Weaving?	Intermediate Ramp (between Freeway Entrance/Exit and Managed Lanes Entrance/Exit)?	Recommended Minimum Weaving Distance per Lane (feet)
Medium (LOS C or D)	Yes	No	500
		Yes	600
	No	No	700
		Yes	750
High (LOS E or F)	Yes	No	600
		Yes	650
	No	No	900
		Yes	950

Note: The provided weaving distances are appropriate for freeway vehicle mixes with up to 10% 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 per lane is suggested.

4. For general managed lane planning purposes, the recommended minimum and desirable distances between a freeway entrance/exit ramp and a managed lanes entrance/exit are 2500 ft and 4000 ft, respectively. The minimum distance applies in cases where a speed reduction of up to 10 mph is acceptable and freeway volumes are moderate. For high freeway volumes, especially in cases where an intermediate ramp is present between the freeway entrance/exit and the managed lanes entrance/exit, 4000 ft of cross-freeway weaving distance is appropriate.
5. Under moderate volume freeway conditions (i.e., LOS C or D), a maximum weaving volume of 450 vehicles per hour is recommended between any given freeway

entrance and the next downstream managed lanes entrance (and conversely, for any given managed lanes exit and the next downstream freeway exit). Under high volume freeway conditions, a maximum weaving volume of 350 vehicles per hour is recommended for the same conditions. In corridors where freeway ramp location, spacing, and origin-destination patterns cause managed lane-related weaving volumes that exceed these values, it is recommended that direct access from park-and-ride/transit facilities to the managed lanes be provided.

To preserve freeway quality of service in the vicinity of managed lanes entrance and exit ramps, it is recommended that for moderate freeway volumes in the design year, a transition distance of 1 mile be allowed for vehicles to selectively maneuver from their initial position in any freeway lane to the leftmost (or rightmost) freeway lane so that they can access a managed lane facility. Under high volume freeway conditions in the design year, a transition distance of 1.5 to 2 miles is appropriate. For both moderate and high volume freeway conditions, the presence of ramps within the transition distance requires that the given value be increased. Note that these distances are the required transition distances once drivers have already determined whether or not they are candidates for the managed facility. Driver perception and decision distances added to the values given here should determine sign location. Also note that the transition distance values given here provide sufficient upstream warning so that mainlane speeds are not significantly impacted by the selective separation of weaving vehicles; if lesser transition distances are used, mainlane and weaving vehicle speed will be reduced. The complete results of this research task are contained in Report 4160-4: *Managed Lanes – Traffic Modeling (3)*.

## **CONCEPT MARKETING STRATEGY**

The success of a managed lanes facility relies in part on successful marketing on the part of the operating agencies. The goal of this marketing effort is to build understanding, relationships, and constituencies for managed lanes. To facilitate this task, the task team formed a technical advisory committee, which provided useful feedback. The committee consisted of public information officers from key TxDOT districts with managed lanes projects under development and directors of community relations from Dallas Area Rapid Transit (DART) and Metropolitan Transit Authority of Harris County, Texas (METRO). Under this task, researchers

identified broad concept marketing strategies that defined the most effective approaches for communicating and building consensus for managed lanes based on corridor and community goals. The team addressed several issues, including:

- determining public perception,
- identifying and communicating with stakeholder and special interest groups,
- communication techniques, and
- media relations.

The team then conducted a literature review that targeted various agencies around the country and their efforts to communicate the concept of managed lanes to the general public. The research documented different approaches, key messages, success factors, and lessons learned.

The research resulted in the publication of two reports that documented the findings of the research that was used in the development of two position papers. These reports are TxDOT Report 4160-5 (4) and 4160-6 (5). The team also published a position paper for a media audience (6) and a position paper for a policy-maker audience (7) as a result of this research. The media audience position paper is incorporated into the website as an aid in defining managed lanes (<http://managed-lanes.tamu.edu/about/definition.stm>).

Both papers were also implemented by developing them into user-friendly formats and distributing them to the respective audiences. The products (8, 9) were distributed to elected officials, boards and commission members, executives of public agencies, TxDOT personnel, cities, counties, transit authorities, and metropolitan planning organizations (MPOs), as well as to newspaper editorial boards, television and radio news directors, and magazine editors.

## **GEOMETRIC DESIGN RECOMMENDATIONS**

Information on geometric design features for ramps is available in a number of sources including the American Association of State Highway and Transportation Officials (AASHTO) *A Policy on the Geometric Design of Highways and Streets* (10) and the *Texas Roadway Design Manual* (11). A review of state design manuals demonstrated that the Texas manual includes more discussion and examples on ramp design than most other state manuals. An issue not well discussed in any document is where to place the ramp with respect to other entrance and exit ramps. General guidelines are provided (900 to 1000 ft or 300 m); however, these guidelines are

not sensitive to the expected ramp volume, the anticipated destination of the ramp vehicles (e.g., the next exit ramp or a downstream entrance to a managed lane facility), or the number of lanes on the freeway. Work completed as part of TxDOT project 0-4160, specifically the task on the analysis of operational scenarios based on user group – provided recommendations for spacing needs for cross-freeway weaving (e.g., between a right-side entrance ramp and a downstream left-side exit ramp to a managed lane facility) (3).

Research conducted under the geometric design task found that a direct connect ramp between a generator and the managed lane facility should be considered when 400 veh/hr is anticipated to access the managed lanes. If a more conservative approach to preserving freeway performance is desired, then a direct connect ramp should be considered at 275 veh/hr (which reflects the value when the lowest speeds on the simulated corridor for the scenarios examined were at 45 mph or less).

The New Jersey Turnpike has two separate roadways in each direction of travel with each roadway having its own exit and entrance ramps. The “dual-dual” roadway improves operations and safety by separating heavy vehicles from light vehicles and increases capacity (heavy vehicles are only permitted on the outer roadway). It also increases flexibility for managing incidents as drivers can be directed to the roadway without the incident through the use of changeable message signs. Available crash information showed lower crash rates for the dual-dual portion as compared to segments of the Turnpike without separate roadways (between 26 and 61 percent for 1994 to 1998). The dual-dual design used on a portion of the New Jersey Turnpike has significant operational and safety benefits. These benefits need to be quantified and a benefit-cost evaluation needs to be performed to determine if this approach is feasible within Texas. If the approach is feasible, research should determine the conditions when the design should be considered.

Recent literature on ramp design has focused on ramp design speed and truck performance. The current process allows for as much as a 50 percent reduction in design speed from a freeway to a ramp. Research has shown that the use of these minimum values of design speed provides little to no margin for error for large and/or heavily loaded trucks. The use of such large reduction can also impact operating speeds as a vehicle moves from one facility to another. To maintain high performance for the managed lanes facilities, the design speed selected for the ramps must consider the anticipated speeds of the vehicles entering the ramp, the

desired speed of the vehicles on the ramp, and the speeds of the vehicles the ramp vehicles will encounter when they are attempting to merge. A design speed less than the anticipated or desired operating speed will affect the performance of the managed lanes. If trucks are a primary vehicle type for the facility, they need to be explicitly considered during the selection of the design features for both the ramp and the managed lanes as well as the signing to be used. The complete results of this research task are contained in Report 4160-10: *Managed Lane Ramp and Roadway Design Issues* (12).

## **IDENTIFY STATE AND FEDERAL LEGISLATIVE CHANGES OR REQUIREMENTS NEEDED**

Transportation professionals are currently considering the managed lane concept on major freeway projects in Texas cities. The term “managed lanes” encompasses a variety of facility types, including HOV lanes, HOT lanes, single occupancy vehicle (SOV) express lanes, special-use lanes, and truck lanes. The premise of the managed lanes concept is to increase freeway efficiency and provide free-flow operations for certain freeway users by packaging various operational and design strategies. The strategies deployed offer the flexibility to be adjusted to match changing corridor and regional goals. The objective of this task was to assess the federal and state legislative needs necessary for Texas to successfully implement the various types of managed lane facilities across the state. Numerous federal and state laws govern the operations of these facilities in Texas. However, some gaps exist that prevent TxDOT and other operational agencies from having the complete arsenal of options available to design, operate, and enforce managed lanes under a variety of control scenarios and to make operational and eligibility changes over time as conditions change. At the federal level, FHWA fails to provide permanence to HOT lanes. At the state level, several gaps exist. The researchers recommend the following changes to remedy these gaps:

- define managed lanes as an operational concept in Texas and authorize entities to develop these facilities for congestion mitigation purposes,
- allow entities operational flexibility with managed lane facilities,
- authorize entities to develop exclusive lane facilities for congestion mitigation purposes,



- authorize TxDOT to establish lane restrictions for congestion mitigation purposes and remove the time-of-day limitation on the current municipal authorization for this strategy, and
- make unlawful violations in any managed lane facility in Texas punishable by fine.

Incorporating these recommended changes into the Texas statutes broadens the powers of TxDOT and other transportation organizations and provides them with the tools they need to successfully implement managed lane facilities in their jurisdictions in the most effective manner, thereby working to reduce congestion and enhance the mobility of Texans. Several of the recommendations were incorporated into Texas HB 1208, which Governor Perry signed into law on June 20, 2003. The complete results of this research task are contained in Report 4160-8: *State and Federal Legislative Issues for Managed Lanes (13)*.

## **FUNDING AND FINANCING OF MANAGED LANES**

Numerous innovative financing approaches may be applicable to managed lanes, each with a unique set of considerations related to capital costs and operating expenses. As part of this task, the research team explored available financing options and the applicability of each as they relate to financing managed lanes projects. The research identified several alternative-financing methods from the traditional pay-as-you-go method that may be utilized for a managed lanes project. The research also identified gaps in current state and federal legislation where changes could result in more financially feasible projects.

The task team assembled an advisory committee of personnel from TxDOT, Harris County Toll Road Authority (HCTRA), North Texas Tollway Authority (NTTA), Texas Turnpike Authority (TTA), FHWA, and the private sector as well as project managers involved in developing managed lanes projects. The committee provided input on the scope of the task and valuable review comments during the research.

The complete research report (14) includes an appendix that highlights operating managed lanes projects around the country. The case studies presented in the appendix document the financial plans of several projects that are in operation or are being developed.

## **ENFORCEMENT PROCEDURES AND DESIGN**

The purpose of the enforcement task was to outline enforcement procedures and design elements of managed lanes. These vary depending on user groups, operational parameters and application of available technologies. The research report for this task (15) highlights several corridors operating with managed lanes that incorporate multiple combinations of enforcement procedures and designs. The intent of information provided is to give a comprehensive overview for the state-of-practice concerning managed lane enforcement while acknowledging the migration to increased automated enforcement. Key information provided in the task report includes the following:

- the role of enforcement on managed lanes,
- various strategies for enforcement,
- general enforcement information and procedures from various managed lane locations,
- incorporating enforcement in design,
- discussion of agencies and their responsibility of enforcing managed lanes at various locations around the country, and
- managed lane enforcement technology.

## **REVISIONS AND ADDITIONS TO THE TRAFFIC OPERATIONS MANUAL**

The *Highway Operations* volume (16) of TxDOT's *Traffic Operations Manual* (17) is a document that TxDOT engineers and personnel can use to plan, design, operate, and enforce highways within their jurisdiction. As the document currently stands, little is included regarding the issues associated with managed lanes. Researchers began assessing this document to identify recommendations for revisions and/or additions to this document to enhance its applicability and use by TxDOT personnel. However, upon greater inspection of the document, the research team determined that the entire document was in need of updating and revision.

The Traffic Operations Division of TxDOT canvassed the districts to determine to what extent staff use this document in their daily work, the result being that few staff members regularly use this document. The Traffic Operations Division decided that a complete revision of the document would not be cost-effective given its limited use. Thus, the project director agreed to terminate this task. Researchers have ceased work on this task, and the research team

will request a modification eliminating this task and the related deliverable during the next fiscal year.



## CHAPTER 4: WORK UNDERWAY

The following sections provide a brief overview of tasks that are underway but will be completed in subsequent years. They outline milestones and progress throughout the course of the year and highlight key issues or interim findings that were of critical importance.

### **DECISION MATRIX FOR CONSIDERING DESIGN AND OPERATIONAL OPTIONS BASED ON A PARTICULAR USER GROUP(S)**

The type of users authorized to use a managed lane facility will play a critical role in the feasibility, design, and operation of a managed facility. A matrix of possible operating strategies for various eligible user groups will correlate eligibility decisions with realistic considerations for planning, designing, and operating a managed lane facility. Researchers are exploring factors related to operational flexibility and time-of-day variations. The matrix is updated as each task of the project is completed. Each task provides critical information in creating a comprehensive matrix containing all of the information necessary to make informed decisions regarding the design and operation of managed lane facilities. The matrix forms the backbone of the final project product: the *Managed Lanes Manual*.

This task is an ongoing process throughout the research effort to develop a framework for supporting decisions related to the development of managed lane projects. It is envisioned that research results will be incorporated into the framework over time. Furthermore, the process of developing the framework itself will lead to identification of gaps in the knowledge base that the research project can address.

Years 2 and 3 have focused on the development and refinement of a conceptual decision-making framework (Figure 4-1) that depicts the sequential elements considered in implementing a managed lanes project. Features of the diagram 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;

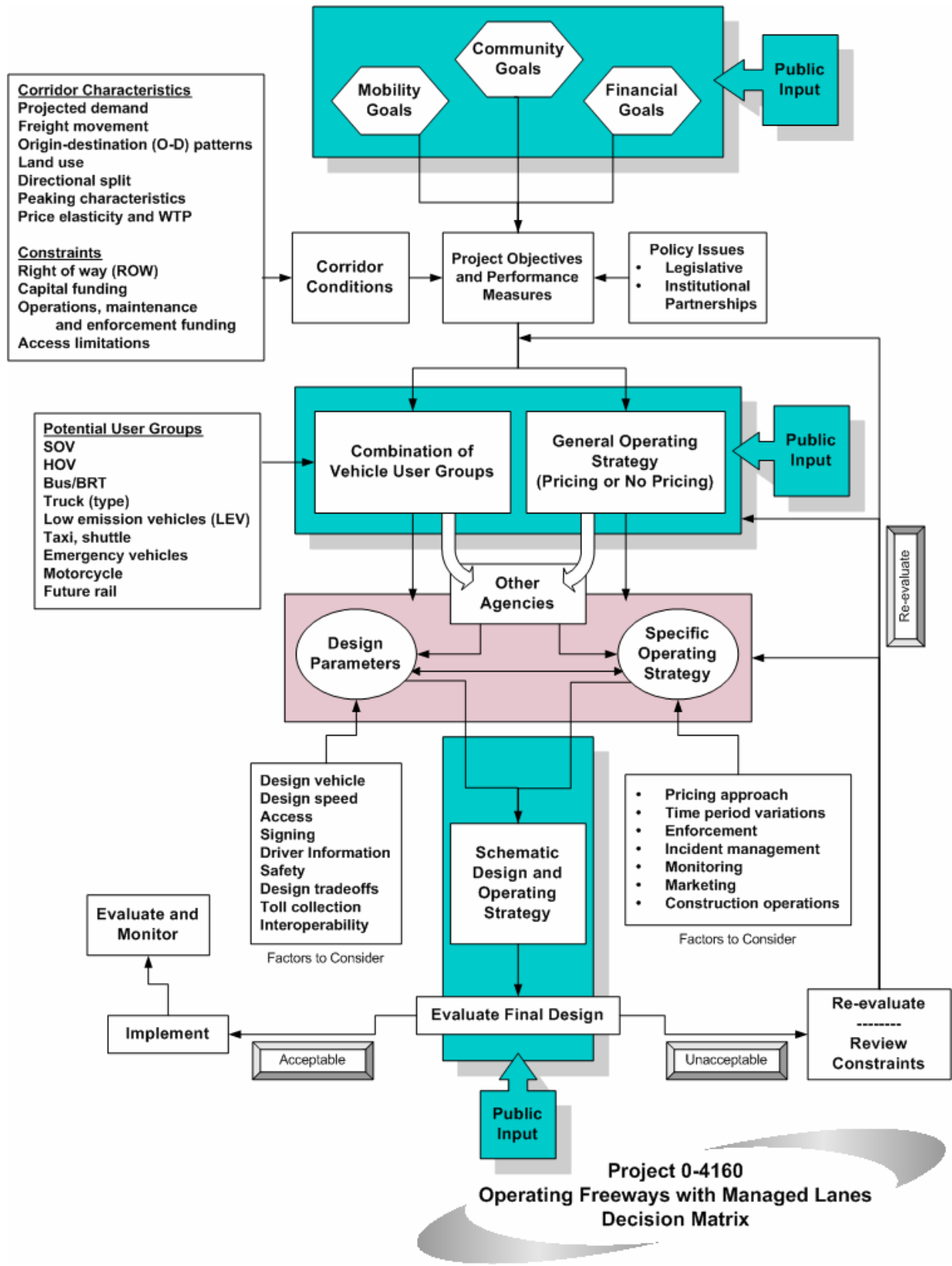


Figure 4-1. Conceptual Design Framework.

- 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 outcome.

A national peer group reviewed the framework in January 2002 and provided feedback.

In March 2002, a group of district-level project managers reviewed the framework for applicability at the local project development level and offered comments. As the backbone of the *Managed Lanes Manual*, this framework will ultimately be converted to a user-friendly computer-based decision support system (DSS) or expert system that provides links to supporting resources and information within a constructed database and/or on the Internet. Initial work has begun in developing a menu of project objectives and performance measures. As other research tasks are completed they will be incorporated into the framework.

The research team has been exploring ways to convert the conceptual decision framework flowchart into a web-based decision support system using dynamic HTML. The upper end of the flowchart would lead the user through a series of steps, guiding the input of various project objectives and attributes. The system produces guidance on optimal operating strategy and eligible vehicle groups for the proposed managed lane facility. The bottom portion of the flowchart would include guidance and/or links to resources for design and operations based on the specific operating strategy selected. The information contained in the *Managed Lanes Manual* would be an integral component of the decision support system, as would research results from other projects such as the FHWA Houston Value Pricing Project on I-10. Work has involved conceptual planning for the web-based system, including an exploration of advantages/disadvantages of using dynamic HTML, and development of a relational diagram of the flowchart elements to more readily identify interrelationships between the different decision elements.

## **FACILITATING THE UPDATE OF THE AASHTO GUIDE FOR HOV FACILITIES AND GUIDE FOR PARK-AND-RIDE FACILITIES**

The objective of this task is to assist AASHTO in updating the *Guide for the Design of High-Occupancy Vehicle Facilities* (18) and the *Guide for the Design of Park-and-Ride*

*Facilities (19)*. There are significant additional experiences and research in these areas that need to be incorporated into the guides since they were last published in 1992. National Cooperative Highway Research Program (NCHRP) 20-7 funding also supports work conducted under this task.

The Task Force for Public Transportation Facilities Design of the AASHTO Subcommittee on Design is responsible for updating the guides. The Task Force held their first meeting at the end of May 2001 to discuss the revision activities with TTI facilitating. Task Force members were assigned as leaders to sections of the HOV guide to update them as needed. In the fall of 2001, the Task Force section leaders identified areas within their sections that required the most extensive changes. Subsequently, the Task Force leaders updated their sections of the HOV guide and submitted their initial drafts of the updated sections to TTI in early 2002.

After receiving the updated changes from the Task Force, the TTI research team then began editing and organizing the sections of the HOV guide. The research team also developed some sections that were not assigned to Task Force members and provided additional text to enhance the flow of the document. The primary references used for the update to the new HOV guide were the NCHRP *HOV Systems Manual (20)*, the TxDOT-sponsored *Guidance for Planning, Operating, and Designing Managed Lane Facilities in Texas (21)*, the previous AASHTO HOV and park-and-ride guides (*18, 19*), and the AASHTO *Green Book (10)*. The *Park-and-Ride Planning and Design Guidelines (22)* published by Parsons Brinckerhoff was used to assist in the update of the park-and-ride guide. Finally, TTI updated all figures and photographs throughout both guides.

The research team completed a first draft of both guides by the end of August 2002. The research team then distributed copies of the drafts to the Task Force by September 1, 2002. At a meeting with the Task Force in October 2002, the research team obtained comments on both guides. Based upon the comments, the second draft of each guide was distributed to the Task Force and to a peer review team in March 2003.

The research team received comments on the second draft of each guide by May 2003. The research team has been critically reviewing the comments, questions, and suggestions received. The third draft will be released in early August 2003 to the Task Force for any final



comments over a two-week period. It is anticipated that the guides will be completed by the end of the fiscal year and submitted to AASHTO for approval at that time (or shortly thereafter).

## **DEVELOPING A MANAGED LANES MANUAL**

To assist in implementation of the managed lanes research results of this project, particularly in areas that are in the beginning phase of planning such a project, the team has developed the initial four chapters of a *Managed Lanes Manual*. These chapters, which include a guide to the manual, an introduction to managed lanes, planning, and design, are in draft form. This document includes all of the research 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. Detailed outlines for the initial four chapters and the titles of the remaining chapters follow.

### **1. Guide to the Managed Lanes Manual**

1. Overview
2. Overall Conceptual Framework
3. Chapters at a Glance
4. Chapter Format

### **2. Introduction to Managed Lanes**

1. Overview
2. Definition of Managed Lanes
  - TxDOT Definition
  - Focus on Flexibility
3. Managed Lanes Operational Strategies
  - Variety of Terms
  - Managed Lane Operational Strategies
4. High-Occupancy Vehicle Lanes
  - Separated Two-Way HOV Lanes
  - Concurrent-Flow HOV Lanes
  - Contraflow HOV Lanes
  - Expectations and Constraints
5. Value-Price Lanes and High-Occupancy Toll Lanes
6. Exclusive Lanes
  - Exclusive Busways
  - Exclusive Truck Lanes
7. Separation/Bypass Lanes
8. Lane Restrictions

9. Dual Facilities
10. References

### **3. Managed Lanes Facility Planning**

1. Overview
2. Goals and Objectives
  - Mobility Goals
  - Community Goals
  - Financial Goals
3. Data Collection
  - Corridor Conditions
  - Policy Issues
  - Project Objectives and Performance Measures
4. Selection of Operating Strategy and User Groups
5. Institutional Partnerships and Agency Roles
6. Public Input and Outreach
  - Public Input
  - Public Outreach

### **4. Managed Lanes Facility Design**

1. Overview
2. Geometric Considerations for Managed Lanes Facilities
  - Overview
  - Design Vehicle
  - Design Speed
  - Horizontal Clearance
  - Vertical Clearance
  - Stopping Sight Distance
  - Superelevation
  - Cross Slope
  - Minimum Turning Radius
  - Horizontal Curvature
  - Vertical Curvature
  - Gradients
  - Summary of Managed Lane Mainland Design Guidelines
3. Cross-Sections for Managed Lanes Facilities
  - Design Considerations for Exclusive Freeway Managed Lanes
  - Design Considerations for Concurrent Flow Managed Lane Facilities
  - Design Considerations for Freeway Contraflow Managed Lanes
4. Design Considerations for Terminal and Access Treatments
  - Overview
  - Selecting Ramp Type
  - Design Speed
  - Direct Access Ramps
  - Managed-Lane-to-Managed-Lane Connection

- At-Grade Access
- Slip Ramps
- Design Considerations for Bypass Lanes at Ramp Meters

## **5. Enforcement**

## **6. Incident Management**

## **7. Construction, Interim, and Special Operations**

## **8. Monitoring and Evaluation**

## **9. Administration and Staffing**

### **IDENTIFYING TRAVELER INFORMATION AND DECISION-MAKING NEEDS**

One of the more critical aspects of managed lanes is the need for information of the traveler using the managed lanes. Depending on the intended user groups and the operational options of the lanes, the information needed to make critical travel decisions varies. For instance, if HOV lanes are provided, the traveler needs to know the restrictions of lane use and entrance and exit location information. If HOT lanes are provided, the traveler needs to know restriction information as well as toll schedules. Specific travelers might have similar needs if they travel in truck lanes or other special-use lanes. All of this information is necessary in order for the intended user group to make informed decisions and perform required maneuvers in a safe and efficient manner so as to maximize the performance of the lanes.

During this year, the emphasis of this task has been to fully identify the interrelationships that exist between various managed lane design options, operational strategy combinations, and information needs for travelers wishing to enter or exit a managed lane facility. Initially, researchers worked on developing a managed lane design/operational strategy matrix to help define and prioritize at a conceptual level the information needs of managed lane travelers. Researchers have utilized the draft signing and marking plans of the Houston Katy Managed Lanes Project as a case study to more fully understand, characterize, and prioritize the difficulties that arise in meeting traveler information needs within the context of a particular managed lane configuration. The results of this effort helped to focus the research activities being undertaken on the task addressing traffic control devices to develop better traffic control device guidance for managed lane facilities.

Researchers are also extracting key positive guidance principles and other human factors considerations from the literature as they pertain to roadway signing and marking concepts. These principles and considerations are being consolidated as guidance fundamentals to assist practitioners in addressing conflicts that arise when developing signing and marking plans for future managed lane facilities. These fundamentals will serve as a key component of the chapter on traveler information needs being prepared for the *Managed Lanes Manual*.

## **DEVELOPING RECOMMENDATIONS FOR TRAFFIC CONTROL DEVICES FOR MANAGED LANES**

Perhaps the most critical design element of managed lanes outside of the physical facility is the user information system. This system, consisting of traffic control devices, is the manner in which key operational information about the facility is provided to travelers. Delivered in the form of traffic signs, pavement markings, and general delineation, this system provides appropriate information to travelers at the correct time and in a format easily understood. If the user information system does its job correctly, travelers can make informed decisions regarding their use of the managed lane facility and can navigate into, through, and out of the facility in a safe and efficient manner. Obviously, the challenges associated with providing this information are complex given the varied information and decision-making needs that will be identified in the user information task.

During this fiscal year, researchers identified the user information needs for the various facility types and user groups served by managed lanes. In the related task on traffic control devices, researchers are currently developing recommendations for traffic control devices (TCDs) to convey this information. Candidate signs, dynamic messages, and pavement marking treatments are being identified through contact with other agencies and literature review. One challenge to effective conventional signing on a managed lane facility is the limited area on the center median for sign supports. Ground-mounted signs must be kept small so they do not impinge on travel lanes. Overhead-mounted signs are a clear alternative, but when placed on the same structure as main lane signing, they may add to driver information overload. The use of horizontal signing, in the form of words and symbols on the road surface, is another way to provide lane-specific information that is under consideration. Another planning issue under

review is trailblazing signs placed on the feeder/collector network surrounding access points to the managed lanes.

In August of 2003, focus groups will be conducted in Houston, Dallas, and Bryan/College Station. These focus groups of typical drivers will address drivers' general conception of the managed lanes as they relate to the main lanes. Do they think of it as a totally separate system, or do they think of it as just additional lanes? This general conceptual understanding has implications for how ingress/egress points are signed. Should they be "exits" from the mainlanes or "entrances" to the managed lanes? Another signing issue that results from this is how to segregate information intended exclusively for one portion of the facility. For instance, the access point from the managed lane to the mainlane for a particular exit may be 2 miles prior to the actual exit ramp from the mainlane. Signs indicating the exit intended only for the managed lane may be seen and misunderstood by mainlane traffic. The use of color-coding, logos, or banners on managed lane signs will be explored in the focus groups.

Based on the feedback received at these sessions, a sign comprehension study is planned which will utilize a computer-based presentation of candidate signs. This method has been developed and tested by TTI in the past year. Complex sign arrays can be displayed for a brief period of time, and comprehension questions can be asked in terms of route selection to a particular destination. This testing can be completed on a laptop computer, so testing can be done in urban areas to include drivers familiar with existing freeways. Analyses of candidate sign arrays will also be conducted. NCHRP Report 470 (23), released in May 2003, provides a method and tool to analyze the information content of sign arrays along a corridor. This analytic tool will allow comparisons of alternative sign content and sign spreading strategies.

## **DEVELOPING A FRAMEWORK FOR OPTIMUM INCIDENT MANAGEMENT**

A key strategy to successfully operating a facility with managed lanes is to have an organized and planned procedure for handling incidents within the facility. This procedure needs to consider the various agencies that might be involved in handling an incident, their specific needs related to their role in incident management, the institutional and technical challenges for interagency cooperation, and the variety of strategies available to handle a wide range of incidents with respect to type and severity.

A survey will be administered to agencies operating managed lane facilities across the United States to assess the state-of-practice of incident management programs for managed lane facilities. Developing an efficient incident management program for a managed lane facility is a function of a host of factors, including whether the facility is buffer or barrier separated, the number of lanes in the facility, the types of vehicles authorized to use the lane, access spacing, etc. Strategies to detect, verify, respond, and clear incidents, and provide motorist notification will be presented. Opportunities may exist through interagency cooperation to leverage off of existing mainlane infrastructure for detecting and verifying incidents, and providing motorist information. Managed lane facilities may also be used to increase corridor throughput during major mainlane incidents by reducing or eliminating tolls or eliminating occupancy/vehicle type restrictions. The tradeoffs associated with this type of operation will be examined.

This section will offer a framework for managing incidents within a managed lane facility such that the incident is cleared in a safe, effective, and efficient manner so as to minimize its impact on the managed lanes and the entire facility. This framework might include a matrix for use in identifying the appropriate strategy or strategies for handling specific incidents and the decisions and procedures for incident management based on the agencies involved and the needs of the travelers.

## CHAPTER 5: YEAR 4 EFFORTS

The following [section](#) outlines the tasks that will begin during year four of the project. Key results that researchers expect from these tasks are highlighted.

### **DEVELOPING RECOMMENDATIONS FOR INTEROPERABILITY WITH EXISTING AND FUTURE TECHNOLOGY**

With the rapid innovation and adoption of technologies in the transportation arena, the need to examine solutions for interoperability and flexibility is paramount. For any implementation, potential solutions must first be examined with respect to:

- the operational concepts of the facility,
- the associated needs of the technology in use,
- the needs of the agencies involved,
- the data requirements, and
- future growth needs.

Additionally, each solution may also need to be evaluated for compliance with TxDOT standard practices, the intelligent transportation systems (ITS) architecture, national standards such as the National Transportation Communications for ITS Protocol (NTCIP) and other applicable agency considerations.

Finally, engineers must also evaluate potential solutions for items such as:

- monitoring,
- management,
- enforcement,
- communications,
- multimodal operations,
- security,
- revenue/costs/benefits,
- public private operations, and
- legislative constraints.

All of these factors combine to form a multidimensional decision matrix. When incorporated into the *Managed Lanes Manual*, this interoperability information will identify the

critical elements of the decision matrix, assist the engineer in using the matrix to evaluate technologies, and guide the engineer towards a solution that meets the overall needs for interoperability and flexibility, within the realm of a managed lanes operation.



## CHAPTER 6: FINAL REMARKS

The first year of the managed lanes project was critical to the future success of the project and provided a strong foundation for effective and comprehensive work researchers will undertake in subsequent years. Initially, the research team formalized the various oversight committees necessary for the complex management of the project. These committees help build support and garner input and priority needs from TxDOT project managers, staff, and other stakeholders in the managed lane arena. The research team also worked with TxDOT to define managed lanes for the purpose of the project. This definition serves as the official definition for the entire TxDOT organization, reflecting the flexibility and complexity of the managed lanes concept. Using this definition as a foundation, the research team then identified a vision for managed lanes research and specific objectives for this particular project, both of which help guide the project and ensure that TxDOT's needs are met along the way.

The literature review, which reviews operational strategies and highlights key issues regarding the implementation of managed lanes, created an overall framework for the research planned in the project. Researchers will rely on this document and the companion glossary of terms to provide insight into specific areas of concern for various operational issues they investigate. The results from the managed lanes symposium also aided the researchers in directing the project so that they address the major issues and concerns of stakeholders over the course of the project.

During the second year, researchers completed numerous tasks, including the analysis of operational scenarios based on user groups, concept marketing, legislative needs, funding and financing, geometric design, and enforcement. The team also continued to work on the development of a decision matrix for considering design and operational options, and assisting with the revision of the AASHTO manuals. The team approach to managing the project, which includes bi-monthly task leader meetings, helps researchers identify gaps in the knowledge, coordinate their tasks with those of others, and ensure that they are effective in their research.

During the third year, researchers began assessing the subjects of traveler information, traffic control devices, and incident management. Because of the depth of research required for these tasks, researchers will continue their efforts into the next fiscal year and report their findings upon completion.

During the coming year, researchers will continue to work on the decision matrix, continue development of the managed lanes manual, and undertake the assessment of interoperability needs pertaining to infrastructure and technology. As with previous tasks, researchers will take a team approach to completing their work, ensuring efforts are not duplicated and the results are comprehensive and cohesive.

The research team looks forward to another productive project year and the success of finding more pieces of the complex puzzle of managed lanes.

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