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16. Abstract

Texas cities are currently considering the managed lane concept on major freeway projects. As a new concept of operating freeways in a flexible and possibly dynamic manner, it 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, 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 their jurisdiction. This document summarizes the activities of the first year of this multiyear project, including a comprehensive review of current practice and state-of-the-practice across the country and the hosting of a Managed Lanes Symposium. It 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 1 ANNUAL REPORT OF PROGRESS: OPERATING FREEWAYS WITH MANAGED LANES

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DISCLAIMER

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To more effectively conduct the research, task leaders established a task advisory committee made up of representatives from TTI, TxDOT, and other organizations that might have a stake in the task and will be implementing the results. These committees aid in directing the task and provide input as needed. The research team thanks the following individuals for their participation on these committees:

- Joseph Carrizales, P.E., Austin District, TxDOT
- Montrose Cunningham, Dallas District, TxDOT
- Jim Darden, P.E., Houston District, TxDOT
- Judy Freisenhahn, P.E., San Antonio District, TxDOT
- Janelle Gbur, Houston District, TxDOT
- Curtis Hanan, P.E., Ft. Worth District, TxDOT
- Jodi Hodges, Fort Worth District, TxDOT
- John Hurt, Austin District, TxDOT
- Matt MacGregor, P.E., Dallas District, TxDOT
- Lawrence Meshack, Community Relations, Dallas Area Rapid Transit (DART)
- Gilda Ramirez, Community Relations, Metropolitan Transit Authority of Harris County (METRO)
- Maggie Rios, San Antonio District, TxDOT

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Program Coordinator

- Gary Trietsch, P.E., Houston District, TxDOT

Project Director

- Carlos Lopez, P.E., Traffic Operations Division, TxDOT

Technical Panel

- Mike Behrens, P.E., Executive Director for Engineering Operations, TxDOT
- Bill Garbade, P.E., Austin District, TxDOT
- John Kelly, P.E., San Antonio District, TxDOT
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- Richard Skopik, P.E., Waco District, TxDOT
- Robert Wilson, P.E., Design Division, TxDOT

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1.0 INTRODUCTION

1.1 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 the 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 to 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 is looking to the managed lane operational approach to offer peak period free-flow travel to certain user groups. These user groups might be HOV, 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 are considering some form of managed lanes within upgraded urban freeway sections. These include the following:

- Katy Freeway (IH-10) in Houston,
- Northwest Freeway (US 290) in Houston,
- Lyndon B. Johnson (LBJ) Freeway (IH-635) in Dallas,
- 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.

1.2 PROJECT VISION AND OBJECTIVE

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

1.3 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. The research team is led by Beverly Kuhn, Head of the System Management Division at TTI, and Ginger Daniels, Head of the Austin Office of TTI. 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.

1.3.1. TxDOT Project Monitoring Committee

The project monitoring committee (PMC), composed of six district engineers and three 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 and provides input regarding the work plan and critical research needs, and ensures that the overall objectives of the project are met.

1.3.2. 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 their interests and concerns are considered throughout the project. The intent is to ensure their future buy-in to managed lane projects in the state.

1.3.3. 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. This team has an international reputation as a leader 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. Their involvement helps to ensure that no aspect of the operation of managed lanes is overlooked and the best possible results are reached.

1.3.4. 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.

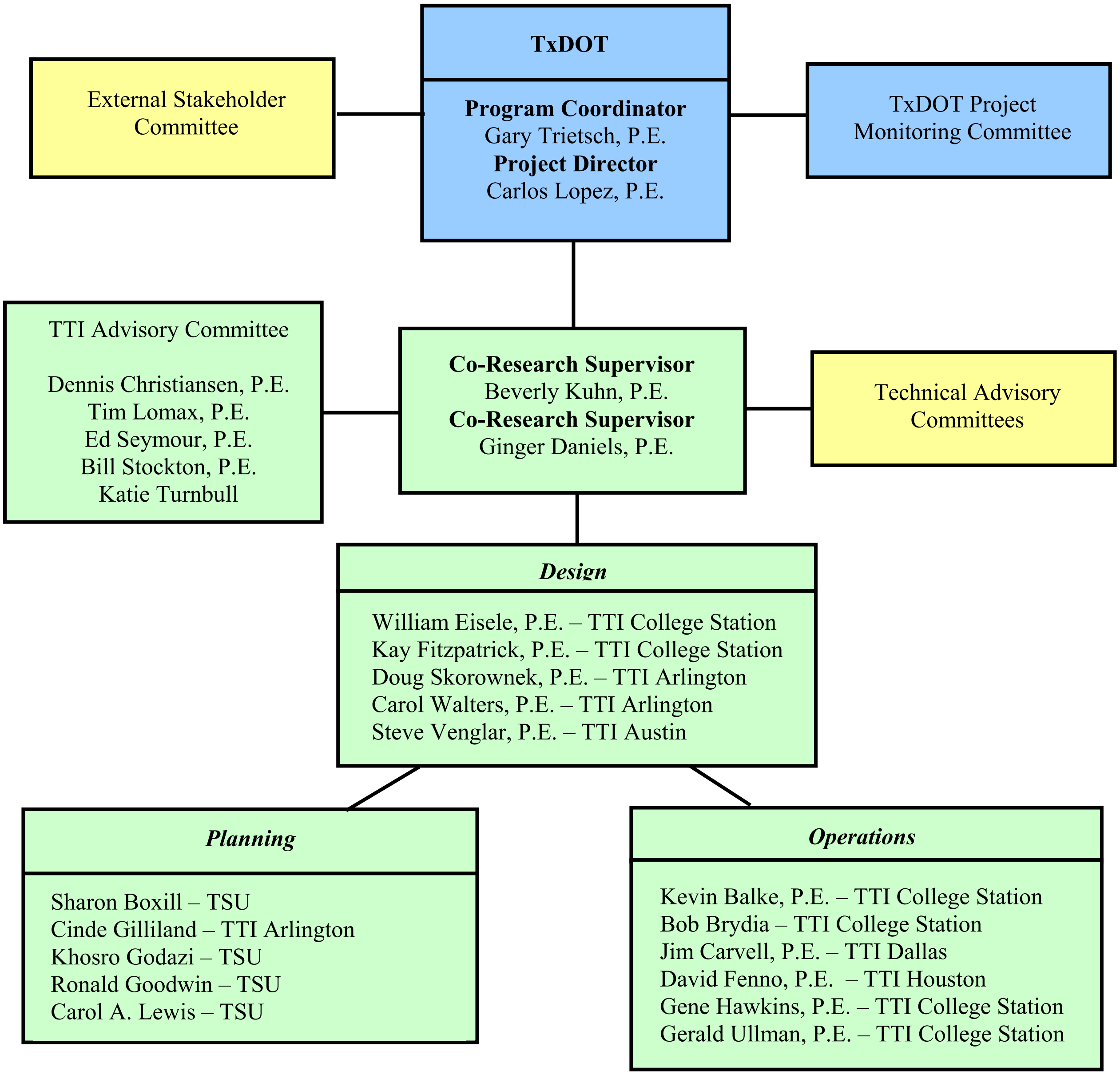

Figure 1-1. Project Management Organization.

1.4 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 allow the details to be refined and the road map to be updated 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.

Fiscal Year Start Date	Task
2000 – 2001	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 a Decision Matrix for Considering Design and Operational Options Based on Particular User Group(s)
	Develop Recommendations for Geometric Design of Managed Lanes
	Provide Recommendations for Changes to American Association of State Highway and Transportation Officials (AASHTO) Guides on HOV Design and Design of Park-and-Ride Facilities
	Provide Recommendations for Changes to AASHTO Guides on HOV Design and Design of Park-and-Ride Facilities
	Develop Managed Lanes Manual
	Develop a Concept Marketing Strategy
	Plan and Host Annual Workshop for TxDOT PMC
2001 – 2002	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
	Develop Recommendations for Revisions/Additions to the Traffic Operations Manual
	Plan and Host Annual Workshop for TxDOT PMC
2002 – 2003	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
2003 – Beyond	Develop Recommendations for Interoperability with Existing and Future Technology
	Develop a Project Marketing Strategy
	Provide Recommendations for Staffing and Training Needs
	Develop Strategies for Interim Managed Lane Use During Construction
	Develop Recommendations for Managed Lanes Evaluation and Monitoring

2.0 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, and hosting a managed lanes symposium for key stakeholders across Texas. The following sections provide a summary of the completed work and key findings for each task.

2.1 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. The intent of this exercise was to establish 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.

2.2 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. Appendix A includes the complete text of this literature review and its associated references.

2.3 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 is 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 contains the complete list of terms related to managed lanes.

2.4 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 and 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. The attendees gained insight from experts around the country, who provided current thinking about managed lane operations. The following sections provide a brief overview of the symposium and the key ideas and issues presented during the event. The complete proceedings of the symposium are contained in TxDOT Report number 4160-1: *Managed Lane Symposium Conference Proceedings (1).*

2.4.1 Introductory Remarks

Gary Trietsch, P.E., TxDOT district engineer for Houston and project coordinator for the managed lanes project, made opening remarks and emphasized the importance that managed lanes be built with flexibility to allow a wide variety of operating strategies. Without flexibility, accommodating and utilizing managed lanes in the long term will be difficult. Trietsch also recognized that managed lanes will be a considerable investment in any region and that decisions made today will set the tone for the next century.

Carlos Lopez, P.E., TxDOT director of the Traffic Operations Division and project director, provided attendees with the TxDOT definition of managed lanes as provided earlier in this report. He also noted that the key goal of a managed lane is to help relieve congestion and help meet the needs of users. He stressed the importance of incorporating regional goals in managed strategies and that planners and decision makers must identify their primary customers when considering which operational strategy to deploy. Furthermore, they must identify operational impacts and gather information to determine the success or failure of a facility. Finally, Lopez shared with the attendees that the purpose of the TxDOT managed lanes project is to help transportation agencies and other stakeholders make these and other critical decisions when considering managed lanes for their region.

2.4.2 Guest Speakers and Panelists

Several key panelists provided information relative to national perspective and local experiences. The intent was to provide a full perspective on the issue of managed lanes and to establish a basis of knowledge for generating discussion during the afternoon breakout sessions.

The first panelist, Dr. Kiran Bhatt with KT Analytic, Inc., provided an update on managed lanes projects across the country, focusing on four operational strategies: 1) HOV facilities, 2) HOT lanes, 3) variable-priced lanes, and 4) fast and intertwined regular (FAIR) lanes. After briefly discussing these four strategies, Bhatt noted that agencies considering managed lanes facilities should first consider several issues such as design constraints, enforcement, equity, and determining criteria for success. For instance, enforcement may require additional space and if conducted electronically will raise legal issues concerning privacy. The recipe for success is the demonstrated need for the project, forward-looking planners, careful design, responsiveness to user concern, and prospects for self-sufficiency. Bhatt noted that even if projects do not prove to be self sufficient, they might still be worthwhile given alternatives such as new construction.

Sally Wegmann, P.E., director of Transportation Operations for the TxDOT Houston District, gave a brief overview of the history of innovative mobility strategies in the Houston region. She reflected back to 1974 when HOVs were called transit ways and the lanes were intended to provide a free-flow lane for buses and car pools consisting of eight persons or more. Today, HOV lanes in Houston currently allow a minimum of two persons. The HOV lanes are highly successful at moving people from the suburbs to the central business district. However, as demand increases and the general lanes become more congested, the district must examine ways of responding. As a result, TxDOT is testing a HOT lane approach on the IH-10 corridor and on US 290 to assess feasibility. TxDOT must then examine ways to increase marketing and to identify other target groups and modes that need to be developed, including trucks, congestion pricing on general lanes, and express lanes that can be served as efficiently as the HOV lanes are being served.

George Beatty, Jr., division president of the Greater Houston Partnership, gave the perspective of managed lanes from the community at large. He expressed his belief that Houston is a transportation laboratory and that there are many scientists managing the project. He also stressed that transportation professionals must establish what the Houston transportation system is designed to accomplish. No longer can transportation professionals respond to congestion by building a road. Now, transportation professionals and community leaders need to consider other issues, including environmental concerns. Beatty suggested we think of HOT and HOV lanes not as individual units, but as a part that must fit into the whole. Transportation and system-wide benefits must be enumerated to both users and non users.

Matt MacGregor, P.E., LBJ project manager for the TxDOT Dallas District, spoke on managed lanes and the LBJ Freeway in Dallas, Texas. The project is 21 miles long and includes tunnels and multiple points of access. The challenge is to balance the trip patterns. LBJ has peak traffic hours for 12 hours a day, and traffic continued to grow during non peak hours. Traffic increases are experienced on arterial street systems, as well. Current options include main lanes with four HOV lanes, main lanes with four HOV lanes and express lanes, and main lanes with six HOV lanes. MacGregor cited numerous reasons for managed lanes, such as safety, predictability, air quality, and mobility. Other issues critical to the LBJ managed lane project include multiple access points, signing, tunnels, pricing, occupancy detection, electronic collection, and ticketing by mail. He also emphasized the importance of the regional plan and the inclusion of bus rapid transit as part of the managed lanes considerations.

Glenn McVey, P.E., congestion management engineer for the TxDOT Austin District, and Chuck Fuhs, AICP, deputy project manager with Parsons Brinckerhoff, Inc., gave the Austin perspective on managed lanes. McVey began by discussing the status of HOV studies in Austin, which include long-range and interim HOV operations for three roadway categories (Loop 1, IH-35, and arterials) and the possibility of HOT lanes. Several freeway sections currently under construction will be built with the ability to retrofit with HOV or managed lanes. A reversible HOV is planned for IH-35, which has a high directional distribution. Fuhs focused on the characteristics of Loop 1, which has high two-directional demand with high levels of congestion. Concepts screened for this facility include managed lanes at-grade, elevated, or in depressed sections and designed for limited access. A key area is the intersection of Loop 1 and US 183, a design that provides direct access into transit support systems, the downtown street system, and other key points. Thus, according to Fuhs, access management would be a key to regulate flow and balance demand, perhaps through tolling if necessary.

Dan Lamers, P.E., principal transportation engineer with the North Central Texas Council of Governments, discussed managed facilities in north central Texas. He highlighted the benefits of managed facilities, which are travel time savings, travel cost savings, generation of revenue, maximizing capacity and efficiency for the corridor and the facility, maintaining acceptable levels of service (again for the entire corridor), and maintaining operational flexibility. Key operational issues to consider include how an HOV can be adapted to a managed facility or how a toll road (already a managed concept) can be better managed. Lamers also stressed that it is important to recognize the viewpoints of other stakeholders and that managed facilities must provide additional modal options, particularly in light of environmental equity and other planning issues. He encouraged listeners to maintain sight of goals, stating that we are not just moving vehicles or people. We want to connect origins with what people want to do with their lives. He also encouraged the audience to focus on technology to ensure the technology is moving in a direction to support our long-term goals.

Peter Samuel, editor for *Toll Roads Newsletter,* spoke on demonstrating managed lanes' benefits to constituents. He stressed that community leaders and transportation professionals should not suppress the truth when discussing improvements or changes to the transportation system. Such thinking is critical for managed lanes. Samuel stressed that consummate leadership focuses on a single objective when eloquent, well-chosen words are used. Further, he posed a challenge about the term "managed lanes," as the term implies that other lanes are not managed.

2.4.3 Interactive Workshop Sessions

The second half of the symposium consisted of concurrent breakout sessions. During these interactive workshop sessions, attendees participated in one of three separate groups to discuss managed lanes issues and determine priorities. A facilitator and a scribe liaison coordinated each session and helped the flow of dialog to occur efficiently. In these sessions, the facilitator asked attendees to identify their most important issues associated with managed lanes. Each facilitator reviewed a potential list of issues as a starting point. Groups were asked to add, modify, and supply subcategories to the initial discussion list. The initial list included the following:

- design standards/access,
- eligible users/user groups,
- technology/interoperability,
- performance and evaluation,
- public awareness,
- equity,
- enforcement/operations,
- legislative requirements/regulatory, and
- funding/financing.

Participants brainstormed the list of pertinent issues surrounding planning, constructing, implementing, and operating managed lanes. Thereafter, attendees identified their top five issues from among those on the list. Groups were structured to reflect the range of organizations and TxDOT divisions represented by attendees to foster discussion, exchange ideas, and appreciate different views on transportation concerns. The interesting result was that each group arrived at a similar list of critical managed lanes issues, as presented in Table 2-1. Other issues discussed, but not ranked, included equity, private institutional issues, private/public partnerships, and affordable transit access.

Table 2-1. Key Issues from Interactive Breakout Sessions.

Group 1	Group 2	Group 3
Eligibility and User Groups	Public Awareness	Enforcement/Operations
Design Standards/Access	Design Standards	Public Awareness
Public Awareness	Performance/Evaluation	Technology/Inoperability
Enforcement Operations	Eligibility/User Groups	Legislative Requirements/Regulatory
Legislative Requirements	Funding/Financing & Enforcement/Operations	Design Standards/Access
Funding/Financing		
Marketing		
Performance and Evaluation		

2.4.4 Next Steps

The research team was extremely pleased with the inaugural Managed Lanes Symposium. As evident by the large number of attendees, managed lanes is a major issue that urban areas across Texas and the country are considering for help in maintaining mobility. The results from the symposium, particularly from the breakout sessions, have helped the research team direct the project so that they address the major issues and concerns of stakeholders over the course of the project. It is anticipated that future symposia will be held to continue the dialogue between stakeholders and to present key research findings that can aid them in planning, designing, and operating managed lanes facilities in their region.

3.0 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.

3.1 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 task leader and task team used the proposed Katy Freeway corridor as a case study under the direction of the program coordinator and project director. The lengthy (13 miles) and complex project – which includes frontage roads, interchanges, ramps, mainlanes, and two variations of managed lanes – provides the researchers with an excellent test case for this task. Using traffic volumes provided by TxDOT and frontage signal timing computed using PASSER III-98, the task team are using the VISSIM traffic simulation model to model the corridor.

To date, the task has concentrated on deficiencies in the tools and procedures currently available in design development and analysis/evaluation of managed lanes. These issues, as noted in Table 3-1, are ranked by how well they are covered by current practice and procedures; critical items are not adequately covered, and noncritical items are covered sufficiently by existing methods.

Table 3-1. Ranking of Scenarios for Investigation.

Element	Location	Ranking
Freeway weaving	Freeway entrance to managed lane entrance	Critical
	Managed lane exit to freeway exit	Critical
Weaving within managed lanes	Entrance/exit auxiliary lane	Noncritical
Entrance merge	From park-and-ride lot	Noncritical
Exit diverge	To park-and-ride lot	Noncritical

The modeling and analysis under this task will focus on freeway weaving in small, 1-2 mile sections, rather than all 13 miles of the project. If the cross-freeway weaving analysis is completed quickly, the noncritical issues will also be examined. In performing the cross-freeway weaving analysis, researchers will use both VISSIM and the Highway Capacity

Software (HCS) to examine multiple cases, each involving various volume levels, weaving distances, and weaving volumes. The cases that will be under investigation are the following:

- freeway entrance to managed lanes entrance,
- freeway entrance to managed lanes entrance with intermediate exit ramp,
- managed lane exit to freeway exit, and
- managed lane exit to freeway exit with intermediate entrance ramp.

Each case will be analyzed using medium traffic volumes (v/c ratio between 0.5 and 0.6) and high traffic volumes (v/c ratio between 0.85 and 0.95) as well as with weaving distances varying from 1500 ft to 5000 ft, in 500 ft increments. The percent ramp volumes that will be performing the cross-freeway weaving maneuver will be at 10, 30, 50, and 70 percent. During the task, comparisons between output from the HCS and VISSIM will be used to verify the HCS and establish ranges of applicability for this tool. Where results from the HCS and VISSIM depart, recommendations and guidelines will be provided based on results from VISSIM. General rules of thumb gleaned from the literature will be examined. These design guidelines include: a weaving distance minimum of 500 ft per freeway lane *(2)*; weaving distance per lane 500 ft minimum, 1000 ft desired *(3)*; and a distance of 2500 ft or more is suggested between an entrance or exit ramp and slip ramp *(4)*.

To date, the modeling work is about 75 percent complete. The task team has completed the medium- and high-volume cases in HCS and has done the medium volume cases in VISSIM. They also need to include the results of the modeling work and their ramifications. The team will also be doing some modeling work to find out how much distance is required to "sort" vehicles into the correct lane for eventual access to a managed facility access point. The cases have been laid out for that, but the modeling has not yet begun.

3.2 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 the realistic considerations for planning, designing, and operating a managed lane facility. Researchers will explore factors related to operational flexibility and time-of-day variations. The matrix will be updated continually as each task of the project is completed. Each task will provide 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 will form 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.

Early efforts have focused on exploring tools and techniques for capturing the complex interrelated decision points and presenting the supporting information in a useful format for the end users. “End users” needs to be more clearly defined before detailed work begins. The research team has taken initial steps to build a model of the decision process using cognitive mapping techniques, utilizing hypothetical project objectives, or success criteria as the starting point to identify applicable user groups. They will then convert the model 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.

3.3 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. Under this task, the task team will formulate a broad concept marketing strategy that will define the most effective approaches for communicating and building consensus for managed lanes based on corridor and community goals. Issues that will be addressed include:

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

To accomplish this task, the task team has formed a technical advisory committee to advise and offer feedback as the task progresses. This committee consists of public information officers from key TxDOT districts with managed lanes projects under development and directors of community relations from DART and METRO. The team will also conduct a literature review, targeting agencies around the country to document approaches, success factors, lessons learned, and key messages used to communicate the concept of managed lanes to the general public. They will then develop a report of findings and two position papers: one for policy-makers (audience: elected officials, boards and commission members, executives of public agencies, TxDOT, cities, counties, transit authorities, and metropolitan planning organizations [MPOs]) and one for media editorial boards (newspaper editorial boards, TV and radio news directors, and magazine editors).

3.4 GEOMETRIC DESIGN RECOMMENDATIONS

The task leader, in conjunction with the research supervisors, has changed the name of this task to Operational Effects of Geometric Design. The new name reflects the need to have a better understanding of the relationship between the design of a facility and its effect on operations.

Based on current geometric design policies and practices for managed lanes identified in the literature review and the results of the complex operational analyses, the research team will develop recommendations for the geometric design of managed lanes based on user groups and operational options. This task is being coordinated with that of current TxDOT Project 0-4161, *Entry-Exit and Intersection Design Criteria for Barrier Separated HOV Facilities* to ensure compatibility and to eliminate the likelihood of duplication of effort. Key issues researchers are addressing in this task include:

- location decisions,
- in-lane design concepts,
- interchange design concepts,
- basic design criteria,
- design decisions, and
- standards issues.

The proposed efforts will begin with identifying existing guidelines for managed lanes facilities such as HOV lanes, express lanes, truck facilities, toll roads, and other relevant facilities, including the research findings from TxDOT Project 0-4161. The task team will define problems and issues associated with these facilities through site visits, literature, telephone calls to key agency personnel, and, potentially, an electronic or paper survey. The team will identify gaps in the knowledge, identify tools available to evaluate operations and different designs, and document findings.

3.5 ASSIST WITH FACILITATING AASHTO CONSIDERATION OF THE NCHRP *HOV SYSTEMS MANUAL* AS AN UPDATE TO THE *AASHTO GUIDE ON HOV DESIGN AND DESIGN OF PARK-AND-RIDE FACILITIES*

The most recent and comprehensive source of information on planning, designing, operating, enforcing, and marketing HOV lanes and park-and-ride facilities is the National Cooperative Highway Research Program (NCHRP) *HOV Systems Manual.* This document provides much more extensive and current information than the AASHTO Guide on HOV Design and Design of Park-and-Ride Facilities. The NCHRP *HOV Systems Manual* has not been formally reviewed by the AASHTO Subcommittee on Design and its Task Force on Public Transportation Facilities. This review process is needed to incorporate the NCHRP *HOV Systems Manual* into AASHTO accepted practices and guidelines. TxDOT is a leader in the appropriate AASHTO subcommittee and task force responsible for reviewing the NCHRP *HOV Systems Manual* and incorporating it into accepted AASHTO practice. TTI is assisting the Traffic Operations Division in facilitating the task force and subcommittee review of the *HOV Systems Manual* and in updating the appropriate AASHTO guides.

The task force held their first meeting at the end of May 2001 to discuss the revision activities. Task leaders have been assigned to each section, and each group is identifying potential synthesis needs in the knowledge base. The goal is to submit the synthesis areas to AASHTO this fall. Each group is beginning work on their updated draft chapters as well. It is anticipated that AASHTO will fund this work.

4.0 YEAR TWO EFFORTS

The following sections outline those tasks that will begin during year two of the project. Key results that researchers expect from these tasks are highlighted.

4.1 IDENTIFY STATE AND FEDERAL LEGISLATIVE CHANGES OR REQUIREMENTS NEEDED

The operation of managed lanes may be sufficiently different from typical freeway operation that it will require changes in legislation and/or regulation. The existing HOT lane in Houston is operated under a special provision of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 and the 1998 sustaining legislation of the Transportation Equity Act for the 21st Century (TEA-21) with authorization from the Texas Transportation Commission. It is enforced under City of Houston ordinances. If additional and more complex facilities are to be pursued, then appropriate legislation should be in place to enable, support, and enforce the operation.

The issues to be explored in this task include:

- local, state, and federal legislative or policy changes required to design, operate, and enforce managed lanes under a variety of control scenarios;
- regulatory authority needed to collect, retain, and distribute tolls; and
- legal/regulatory flexibility needed to make appropriate operational and eligibility changes over time as conditions change.

Results from the task will include sample legislation, policy changes, or other legal guidelines, as appropriate.

4.2 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. The research team will document available financing options, the realistic expectations of using toll revenues to finance capital and/or operating costs, distinctions in project funding issues related to retrofit versus new projects, financial considerations regarding private versus public construction and operation, and issues involving trucking use and financing. A set of alternative funding strategies for managed lanes will be formulated.

As a part of this task, the research team will monitor and report on the financial experiences of the current HOT lane projects in California and Texas as the projects mature. In addition, there are several studies conducted in other states that have focused on revenue generation, the results of which the research team document and incorporate into the development of alternative funding strategies for managed lanes in Texas.

4.3 ENFORCEMENT PROCEDURES AND DESIGN

Enforcement of managed lanes is a direct function of the intended use of those lanes and their geometric design. This task will outline recommended enforcement procedures and design for enforcement areas in managed lanes based on the user groups, operational options, and technologies used for those options. Included in these recommendations will be sample interagency agreements to handle enforcement in the event that such facilities have shared uses or cross-jurisdictional boundaries.

The proposed METRO value-pricing implementation project in Houston includes significant experimentation with enforcement technology and techniques. The experience gained in that project, as well as ongoing work in San Diego, will be incorporated into the recommended enforcement procedures and designs.

4.4 REVISIONS AND ADDITIONS TO THE TRAFFIC OPERATIONS MANUAL

The Highway Operations Volume of the *Traffic Operations Manual* is a key document that TxDOT engineers and personnel use to plan, design, operate, and enforce highways within their jurisdiction. As the document currently stands, little is included regarding such aspects and issues associated with managed lanes. Thus, this task will yield recommendations for revisions and/or additions to this document to enhance its applicability and use by TxDOT personnel. These recommendations will be in the form of sample text and/or graphics as appropriate. Changes will most likely be recommended for, but not limited to, the following chapters in the *Traffic Operations Manual*:

Chapter 2. Operational Considerations in Project Development,
Chapter 3. Operational Considerations in Design,
Chapter 4. Design Considerations to Improve Operations,
Chapter 5. Operational Considerations for Scheduled Activities,
Chapter 7. Data Collection,
Chapter 8. Traffic Operations Analysis,
Chapter 9. Incident Management,
Chapter 10. Control Strategies, and
Chapter 11. Information Systems.

The results from each of the previous tasks in the project that address these specific issues will be used to produce the material for the appropriate chapter(s).

4.5 DEVELOPMENT OF 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 will develop a *Managed Lanes Manual*, which will be in interim form at the end of the third year of the project. This document will include 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. The outline for this document will include, but not be limited to, the following:

A. Guide to the *Managed Lanes Manual*
B. Introduction to Managed Lanes
C. Planning Managed Lanes
   a) Community/Corridor Policy Determination
   b) User Group Determination
   c) Funding and Finance
   d) Marketing
D. Design of Managed Lanes
   a) Geometric Design
   b) Traveler Information
   c) Public Awareness
   d) Signing, Striping, and Delineation
E. Operations and Enforcement
   a) Incident Management
   b) Staffing
   c) Evaluation and Monitoring
F. Appendices

5.0 CLOSING 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.

This year, researchers initiated work on several fronts, including the analysis of operational scenarios based on user groups, the development of a decision matrix for considering design and operational options, concept marketing, geometric design, and the assistance of AASHTO in manual revisions. 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 coming year, researchers will complete the work analyzing operational scenarios and the related task of looking at the operational effects of the geometric design. They anticipate that these tasks will provide guidance on specific design considerations and tradeoffs associated with those features. Concept marketing will deliver material useful in successfully marketing a managed lane project to critical stakeholders and other constituents. New tasks to begin in the coming year include legislative issues, funding and financing, and enforcement. As with previous tasks, researchers will take a team approach to completing their work, ensuring the 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.

6.0 REFERENCES

1. *Managed Lanes Symposium: Conference Proceedings,* Report 4160-1, Texas Southern University, Houston, TX, 2001.

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3. C.A. Fuhs, *High Occupancy Vehicle Facilities: A Planning, Design, and Operation Manual,* Parsons Brinckerhoff Quade and Douglas, Inc., New York, NY, 1990.

4. Texas Transportation Institute; Parsons Brinckerhoff Quade and Douglas, Inc.; and Pacific Rim Resources, Inc., *HOV Systems Manual,* NCHRP Report 414, Transportation Research Board, National Research Council, Washington, D.C., 1998.

7.0 APPENDIX A

CURRENT STATE-OF-THE-PRACTICE FOR MANAGED LANES

CURRENT STATE-OF-THE-PRACTICE FOR MANAGED LANES

1.0 INTRODUCTION

Increasing population 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 corridors due to cost, land consumption, neighborhood impacts, environmental concerns, and other factors. To meet this growing demand, the Texas Department of Transportation (TxDOT) has begun looking at operational strategies offered by managed lane facilities.

A managed lane facility is one that increases freeway efficiency by packaging various operational and design actions. Operating agencies may adjust lane management operations at any time to better match regional goals. Managed lanes are intended to provide peak period free-flow travel to certain user groups.

A review of literature concerning the various operational strategies for managed lanes revealed that numerous studies are being conducted and numerous strategies are being tested in an attempt to improve freeway efficiency. Strategies, terms, and acronyms are often used interchangeably to describe a particular action or variation of a design without strict adherence to definitions. For example, what may be described by one jurisdiction or study as a high-occupancy toll (HOT) lane is described by another jurisdiction as a value express lane. Meanwhile, a third entity uses the term value express lane for a totally different strategy. An effort has been made to distinguish the various strategies. However, in some instances definitions by authors of reports reviewed may seem to conflict traditional definitions of a particular strategy.

Managed lane operational strategies include high occupancy vehicle (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. HOV lanes are by far the best documented of the managed lane strategies. 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 (1)*, which were originally developed for HOV lanes:

- improve operating level of service for high-occupancy vehicles, both public and private, thereby maximizing 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 *(1)*.

2.0 MANAGED LANE OPERATIONAL STRATEGIES

2.1 High Occupancy Vehicle (HOV) Lanes

HOV lanes, first implemented in the Washington, D.C., and northern Virginia area in 1969, are designed to increase the person-moving capacity of the existing infrastructure *(2)*. HOV lanes, simply put, are separate lanes that are restricted to vehicles with a specified occupancy and may include carpools, vanpools, and buses *(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, the following three types of facilities are used—separated roadway, concurrent flow lanes, and contraflow lanes *(1)*. Additionally, the separated roadway facility may be either a two-way facility or a reversible-flow facility.

2.1.1 Separated Two-Way HOV Lanes

The separated HOV facility is physically separated from main lanes or general-purpose lanes of the freeway. Although concrete barriers separate many HOV lanes, a wide painted buffer isolates some separate HOV lanes. As previously noted, 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 *(2)*. Examples of separate two-way HOV facilities are found in Los Angeles; Orange County, California; Seattle; and a small section in Houston *(4)*.

The reversible lane is the most common type of separated lane HOV facility. 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 allows maximum use of the lane during peak hours. Examples of barrier-separated reversible HOV lanes are found in Denver, Northern Virginia, Dallas, Houston, San Diego, Minneapolis, Pittsburgh, Norfolk, and Seattle *(4)*.

2.1.2 Concurrent-Flow HOV Lanes

A concurrent-flow HOV lane is a freeway lane that flows in the same direction 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. Examples of concurrent-flow HOV lanes can be found in Phoenix; Vancouver, British Columbia; Sacramento; Denver; Hartford; Fort Lauderdale; Miami; Orlando; Atlanta; Honolulu; Montgomery County, Maryland; Boston; Minneapolis; New Jersey Turnpike; New York City; Portland; Ottawa, Ontario; Memphis; Nashville; Dallas; Northern Virginia; Norfolk/Virginia Beach; Seattle; Houston; and numerous California counties *(4)*.

2.1.3 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 this type of HOV lane is used primarily by buses, some contraflow lanes allow use by all multiple occupant vehicles. Examples of contraflow HOV lanes can be found in Honolulu, New Jersey, New York City, Dallas, Boston, and Montreal *(4)*.

2.1.4 HOV Lane Expectations and Constraints

The number of operating HOV lanes being proposed and implemented throughout North America is steadily increasing. This 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 *(5)*. 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 *(3)*.

2.2 Value-Priced Lanes and High Occupancy Toll (HOT) 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-price, 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 DOT, are similar to HOT lanes *(6)*. 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.

The idea behind HOT lanes is to improve the HOV lane utilization and sell unused lane capacity *(3)*. In a study for the Colorado DOT, Urban & Transportation Consulting, et al. found that 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 to be constructed.
- 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 *(6)*.

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 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)*. Concerns regarding HOT lanes include legality, equity, societal issues, and public acceptance *(8, 9)*. HOT lane programs are in operation in Houston; Orange County, California; and San Diego. Feasibility studies and proposal studies for implementing HOT lanes are being conducted in Colorado, Maine, Minnesota, Maryland, Oregon, California, Washington, New York, Texas, and Arizona. Numerous countries have implemented value pricing, including France (Paris), Norway, Singapore, Canada (Toronto), Germany (Stuttgart), South Korea (Seoul), and Hong Kong *(9)*.

2.3 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 *(10)*. In recent years, a number of truly exclusive busways have been implemented in various metropolitan areas.

2.3.1 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 *(11)*. 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 *(12)*. Busways have been implemented in Ottawa, Canada; Pittsburgh, Pennsylvania; Runcorn, United Kingdom; Brisbane City, Australia; Abidjan, Cote D'Ivoire; Ankara, Turkey; Istanbul, Turkey; Porto, Alegre, Brazil; Sao Paulo, Brazil; Curitiba and Belo Horizonte, Brazil; and South Miami-Dade, Florida *(12, 13)*.

2.3.2 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. 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 *(14)*.

In 1986, a research study *(15, 16)* by TTI examined the feasibility of an exclusive truck facility for a 75-mile segment of IH-10 between Houston and Beaumont. The options considered in the study included the construction of an exclusive truck facility within the existing IH-10 right-of-way, construction of an exclusive truck facility immediately adjacent to IH-10 outside of the existing right-of-way, or construction of an exclusive facility on, or immediately adjacent to, an existing roadway that parallels IH-10 (US 90). The studies concluded that existing and future trends in traffic volumes did not warrant an exclusive facility along the IH-10 corridor.

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. Feasibility studies for exclusive truck lanes have also been conducted in Virginia, California, the United Kingdom, and the Netherlands. However, to date, none of the proposed exclusive facilities have been implemented *(11)*.

2.4 Separation and 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 the following characteristics: weaving area, a significant grade, high percentage of truck traffic, and/or congestion. Weaving areas are segments of freeway formed when a diverge area closely follows a merge area. Operationally, weaving areas are of 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 *(17, 18)*.

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 reenter traffic downstream of the interchange. Passenger cars are also allowed to use the bypass facilities. One reason this facility is needed is a significant grade 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 is entering 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 *(19)*.

Interstate 5 north of Los Angeles is a corridor with a very heavy volume of truck traffic. In the 1970s, 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 *(19)*.

2.5 Dual Facilities

Dual facilities are managed lane 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. 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 *(19)*.

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 *(17)*.

2.6 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 or have designated exclusive truck lane facilities. In 1986, the Federal Highway Administration (FHWA) 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:

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

It should be noted that some states provided more than one reason for the restriction *(20)*.

3.0 ISSUES REGARDING THE IMPLEMENTATION OF MANAGED LANES

3.1 Operational Issues

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. The major goal of transportation systems management and lane management is to improve vehicular flow and increase the efficiency of the roadway system. Successful implementation of an operational strategy should result in decreased congestion, increased average travel speeds, increased safety, and reduced travel time *(11, 21)*.

3.1.1 HOV Lanes and HOT Lanes

Operational issues regarding HOV lanes should be included in an HOV operation and enforcement plan designed for the facility. Issues to be considered include the type of vehicles allowed to use the facility, the vehicle-occupancy requirement, transit services provided, hours of operation, enforcement techniques, incident management, and ingress and egress points. Operational management strategies should also consider the operational impact of converting a main lane to an HOV lane as well as consider the possibility of using priority-pricing strategies, truck use, intelligent transportation systems (ITS), conversion to a fixed-guideway transit system, and slow vehicles *(2, 5)*. HOV lane operational strategies are commonly associated with the following general objectives:

- improve the capability of a congested freeway corridor to move more people by increasing the number of persons per vehicle,
- increase the operating efficiency of the bus service,
- improve travel time and provide a more reliable trip time,
- favorably impact air quality and energy consumption,
- not unduly impact mainlane operations,
- increase per lane efficiency of the total freeway facility,
- be safe and not unduly impact safety of the freeway mainlanes,
- have public support, and
- be a cost effective transportation improvement *(5)*.

Since the reduction of travel time is a commonly used measure for assessing the efficiency of an HOV facility, any type of incident including vehicle breakdowns on the HOV facility can cause major delays. Incident detection and response are key to minimizing delays. In the *Guide for the Design of High Occupancy Vehicle Facilities,* AASHTO cites operational planning, coordination, and cooperation among agencies as an important part of the operations management for HOV lanes *(1)*.

Another important operational consideration for HOV lanes is the occupancy requirement for vehicles to utilize the lane. HOV facilities should select an initial occupancy requirement that will optimize the number of vehicles utilizing the lane. Peak hour traffic volumes need to be high enough to mitigate public concerns about under-utilization of the HOV facility *(1)*.

Equally important to the proper function of an HOV facility is enforcement. The importance of enforcement cannot be overemphasized *(1)*. A TTI study regarding enforcement found the following:

- 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 HOV lane.
- 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 *(22, 1)*.

The concept of the use of priority pricing was first suggested in 1959 as an operational strategy to solve urban congestion problems *(23)*. As previously noted, the idea behind HOT lanes is to improve the HOV lane utilization by selling unused lane capacity. Operational issues agencies must consider for HOT lanes include pricing strategies, toll collection, enforcement, and the type of access provided *(24)*.

Pricing strategy is one of the keys to the operational success of HOT lanes. There are basically two types of pricing, fixed and variable or dynamic pricing. Fixed pricing is a set price for all users and does not change in response to traffic conditions. Although this is the simplest operational pricing strategy, it does not discourage peak period travel and is not always an adequate mechanism for congestion relief. Variable or dynamic pricing, on the other hand, is adjusted to overall demand and traffic conditions, with the price increasing in direct proportion to the traffic congestion *(25)*. The core principle that must be recognized is that the facility is a limited-use HOV lane. If, in the future, the facility reaches capacity from multi-occupant or transit vehicles, then permitted single occupancy vehicle (SOV) or lower occupant vehicle access may be restricted or prohibited *(24)*.

In 1996, Trowbridge et al. *(26)* considered the impacts that would occur from providing trucks reserved capacity lanes that are in some cases separate from general traffic or allowing trucks access to HOV lanes. The authors reference a study by BST Associates *(27)* in 1991 that found that trucks generally make up less than 5 percent of average daily traffic in urban areas and note that an undue amount of effort is used devising strategies to restrict and manage this small portion of total traffic. In lieu of strategies restricting truck traffic, the authors propose providing trucks access to reserve capacity lanes— i.e., high occupancy vehicles lanes— to relieve congestion.

The reserve capacity lanes investigated consisted of two options for roadways in the Seattle area. The first option permitted heavy trucks to use existing HOV lanes, while the second option added a lane for the exclusive use of trucks on all facilities that had an existing or planned HOV lane. The authors attempted to determine the impacts of these options on vehicle travel time and vehicle miles traveled for SOVs, HOVs, and trucks. The authors collected traffic data and performed a traffic simulation and an estimate of the economic impacts of this type of strategy *(26)*.

3.1.2 Busways

Busway transit is a true mass rapid transit operation that offers both flexibility and self-enforcement. Operational issues and considerations for the successful implementation of a busway include:

- the need to integrate the system into existing transit plans in such a way that the busway provides a level of service comparable to private vehicles;
- provide passengers improvements in comfort, economy, travel time, and quality of service;
- provide express service for transit riders;
- busway design should define and control conflicts between the busway and adjacent road traffic; and
- provide riders with busway facilities that are comfortable, convenient, and safe *(12)*.

3.1.3 Exclusive Lanes and Lane Restrictions

As previously stated, exclusive lane facilities and lane restrictions are most often designated for buses and trucks. Agencies must consider a number of operational considerations when implementing this type of managed lane strategy. Highways are designed for a mix of vehicle types; however, an increased presence of large trucks on a roadway may result in serious degradation of flow quality for the following reasons: trucks are significantly heavier than passenger cars, trucks are considerably longer than other vehicles, and trucks have lower rates of deceleration and acceleration *(28)*. In urban areas, the demand on the highway system has grown much more rapidly than the corresponding increases in available capacity. This increase in demand has led to high levels of congestion and an increased awareness for traffic operations. Correspondingly, studies concerning the effect of trucks on highway operations have also increased *(29)*.

In 1990, Zavoina, Urbanik, and Hinshaw examined the effects of truck restrictions on rural interstates in Texas *(30)*. This study analyzed the operational effects of restricting trucks from the left lane in Texas. Study sites were six-lane rural interstate highway sections with speed limits of 65 mph for automobiles and 60 mph for trucks. Vehicle distributions according to classification, vehicle speeds, and time gaps between vehicles were examined. The study found no definitive safety improvements that could be attributed to the truck restriction.

Although the lane distribution of trucks changed significantly due to the restriction, no safety effects were found that could be attributed to the truck restriction in terms of the lane distribution of cars, speeds of either cars or trucks, or the time gaps between vehicles. The authors also concluded that even though truck lane restrictions should theoretically improve the capacity and safety of a roadway, the research evidence did not support this assumption *(30)*.

A 1992 study by the Organisation for Economic Co-operation and Development (OECD) regarding truck roads examined operational issues regarding dedicated truck lanes and exclusive truck routes. The authors concluded that truck-only lanes appear to be of limited value because they reduce the operational flexibility of the road. Particular problems may arise when trucks attempt to overtake other trucks or where the road is heavily congested and trucks are traveling faster than vehicles in nonexclusive lanes. Another fear is that designating one lane exclusively for trucks would result in the saturation of that lane by trucks, resulting in little or no operational benefit. Conversely, the lane would receive limited use during holidays and weekends when truck traffic is relatively light *(31)*. A study conducted in the Netherlands found that the designation of a truck lane is feasible only when truck traffic density is in the range of 600-1000 trucks per hour. Densities lower than this would be inefficient lane usage, whereas higher truck traffic densities would result in bottlenecks *(32)*.

In an effort to improve truck safety on Houston freeways, the City of Houston decided to conduct a demonstration project restricting trucks from traveling in the left lane in 1999. The Texas Department of Transportation (TxDOT) and the Texas Transportation Institute (TTI) developed the demonstration project, which consisted of an 8-mile section of IH-10 East Freeway between Waco and Uvalde Streets. The criteria used for site selection included the requirement that the site be a radial freeway section within the city limits of Houston, the minimum length of the section be 6 miles, and the truck volume be at least 4 percent *(33)*. TTI researchers were charged with monitoring and evaluating the restriction for the duration of the demonstration project. In September 2001, the TTI research team published a report outlining and described the monitoring, evaluation, and findings of the study. The research team monitored the following areas: compliance, enforcement, crash records, freeway operations, public perception, and status of the project. The team reported that compliance rates for the restriction were between 70 and 90 percent. The team also found that vehicle crash rates were reduced during the 36-week monitoring period, although several factors including increased enforcement may have contributed to that reduction. Traffic studies conducted during the evaluation revealed that there was no significant impact on freeway operations, travel time, frequency of lane changes, or traffic patterns. Public opinion was extremely positive with 90 percent of automobile users in favor of the restriction *(33)*.

3.2 Safety Issues

The concern for highway safety parallels the historic development of the modern U.S. highway system. As the industrial revolution produced motor vehicles in considerable numbers, the demand for roadways increased, and governments at all levels came to realize that roadway financing, construction, and safety were matters for their concern. Safety was given a new focus with the passage of the National Highway Safety and the National Traffic and Motor Vehicle Safety Acts of 1966. These acts began the development of safety standards and authorities that guide today's transportation manager. As the use of technology increases along with operational concerns such as congestion and increased demand, it is important to remember that safety is paramount. The major safety consideration in implementation of operational strategies can be summed up by the old physician's caution: Primum non nocere, which is loosely translated as "Above all, do no harm."

3.2.1 HOV and HOT Lanes

As in any transportation strategy, safety is paramount for managed lanes. Research has suggested that with the implementation and operation of an HOV or HOT lane, accidents should not increase and that the accident rate should be lower in the HOV lane than on the freeway mainlanes. However, if the creation of the HOV facility results in the narrowing or elimination of mainlanes or shoulder, this may not be a realistic goal. A 1991 TTI study *(5)* found that appropriate safety measures of effectiveness should include a before and after comparison of the number and severity of accidents and the accident rates per million vehicle miles or million passenger miles of travel on both the HOV lanes and freeway mainlanes. In the 1999 study, The A B C's of HOV: the Texas Experience *(3)*, TTI researchers noted that in Texas there were still some locations where the merging of HOV lanes and mixed flow lane traffic occurs. To assure that the interactions in those locations do not become a bottleneck, TTI recommended that the congestion levels, operating speeds, and accident rates on the general purpose lanes adjacent to the HOV lanes be monitored on an ongoing basis.

3.2.2 Busways

Safety problems are an important concern for busways, and like other managed lanes strategies busways can provide a safe mode of transportation. Any type of safety problem may impact the public perception of the busway and, therefore, affect the ridership and efficiency of the strategy. In the Florida International University study, *At-Grade Busway Planning Guide (12)*, researchers identified the following safety concerns regarding at-grade busways:

- pedestrians trespassing on the busway right-of-way where no sidewalk is provided,
- pedestrians jaywalking across at-grade busway right-of-way,
- confusion of motorists and pedestrians about the way the busway vehicle is approaching,
- side-aligned two-way at-grade busways operating on a two-way street may cause motorist confusion,
- motorists making illegal left turns across the busway, unaware of the approaching busway vehicle,
- motorists violating the right-turn arrow, unaware of approaching busway vehicle,
- red time extension for multiple busway preemption makes motorist waiting to cross busways impatient, and
- complex intersection geometry creates confusion.

These and other safety problems should be addressed during the planning and design periods. Monitoring of busways and adjacent roadways by operations personnel will provide indications of potential safety problems *(19)*.

3.2.3 Exclusive Lanes and Lane Restrictions

In 1984, McCasland and Stokes *(34)* examined truck traffic characteristics and problems on urban freeways in Texas. The study evaluated six truck restrictions and regulatory practices through information obtained from a literature review and a survey of state policies. Results indicated that the restriction of truck traffic to one mixed-flow lane would probably not improve freeway safety or operations based on associated constraints and limitations *(34)*.

One area of particular concern when implementing truck restrictions on urban freeways is the creation of a "barrier effect" in weaving areas. Weaving areas are segments of freeway formed when a diverge area closely follows a merge area. Operationally, weaving areas are of concern because the "crossing" of vehicles creates turbulence in the traffic streams. When trucks are restricted to the rightmost lanes of a freeway and are of significant numbers, a barrier composed of trucks can form in the weaving areas. 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 *(17, 34)*.

3.3 Economic Issues

In recent years, greater scrutiny has been placed on the economic side of transportation. It has become apparent that transportation facilities must provide acceptable service under the strains of increasing demands while meeting the test of financial prudence and limited funding. Aggressive transportation systems management strategies such as managed lanes are estimated to reduce congestion and delay by as much as 25 percent, if properly implemented. This reduction provides a significant impact on demand that translates into sizable savings *(35)*.

3.3.1 HOV and HOT Lanes

Limited resources dictate that HOV and HOT lanes meet the same economic tests to which all transportation improvements are subjected. Benefits of HOV and HOT facilities include a number of different elements including savings from reduced travel time, operating cost savings, fuel consumption savings, and congestion cost savings *(3, 5, 36)*. The benefit-to-cost relationship was analyzed in detail by TTI researchers in the study, An Evaluation of High-Occupancy Vehicle Lanes in Texas *(36)*. The study found that the benefits of the HOV lane include the monetary value of time savings for motorists and bus riders as well as a cost savings from the reduction of fuel consumption. When comparing these benefits to the cost of implementation, HOV lanes had a cost-effectiveness ratio ranging from 6:1 to 48:1 *(3, 36)*.

HOT lane implementation can make the maximum use of available HOV facilities. However, HOV lanes must continue to offer a distinct advantage over adjacent mixed flow mainlanes to be effective and attractive to bus and van pool patrons. Balancing these two objectives form the key to successful HOT lanes. The benefits of HOT lanes, in addition to the previously mentioned benefits for an HOV lane, are the maximum use of an existing facility with little cost of modification and revenue that can be utilized to operate and maintain the facility *(3, 5, 36, 37)*.

3.3.2 Busways

As previously stated, busways act like a surface subway by allowing buses to receive traffic signal preference, thus bypassing stoplights, or by crossing over intersections on overpasses. Exclusive busways improve bus service by increasing travel speeds and improving reliability over conventional bus service. This enhancement of service makes busways an attractive form of commuter transportation. Benefits of busways include savings derived from increased ridership, reduced travel time, reduced congestion, reduced traffic diversion, improved access, lower air pollutant emissions, reduced parking demand, and lower fuel consumption *(38)*.

3.3.3 Exclusive Lanes and Lane Restrictions

As previously stated, when Trowbridge et al. investigated the possibility of using reserved capacity lanes as exclusive truck lanes in the Seattle area, they estimated the benefit and cost of the strategy. Based on current traffic data and simulation, the following economic impacts resulted:

- estimated $10 million in savings in truck travel time,
- estimated 2.5 minutes time savings per average trip (this is less than an 8 percent savings of an average trip), and
- estimated $30 million in savings for SOVs *(26)*.

The economic analysis reflected increased pavement deterioration in the reserved capacity lane and decreased pavement deterioration in other lanes. The net effect would be a modest overall increase in cost due to pavement deterioration and the consequent increased maintenance *(26)*.

When Wishart and Hoel *(39)* investigated exclusive truck facilities in Virginia using Exclusive Vehicle Facilities Simulation (EVFS), they described a list of expected benefits and costs. Broad intended benefits of separating truck traffic from automobiles included improved operations, reduced crashes, less severe crashes, and fewer and shorter delays. Other expected benefits are savings from reduced travel delay, reduced vehicle operation cost, decreased environmental impact from exhaust and fuel consumption, and injury and property damage savings. These benefits are offset by expected costs in engineering, construction, additional right-of-way, signage, enforcement, and maintenance *(39)*. It should be noted that although expected costs may outweigh the benefits, many of the costs are one-time costs, whereas the benefits are recurring.

3.4 Legal and Policy Issues

As previously noted, the tasks of planning, designing, funding, constructing, operating, and enforcing regulations regarding roadways and transportation systems became a governmental responsibility. Policy issues regarding transportation have evolved over the last 50 years as the needs and demands on transportation systems have grown. Legal issues involving managed lanes often cover such varied topics as access, authority, taxation, enforcement, and free trade. It is important to remember that policy and legislative actions are often the result of reaction to a specific issue or public opinion. The following sections include cases describing legislation, court decisions, and policies resulting from management decisions.

3.4.1 HOV Lanes

Policies regarding HOV lane facilities are found at all governmental levels. In most cases the policies regarding these facilities are part of a larger planning and management effort, such as the long- and short-range plans developed by state departments of transportation. HOV lane policies should accurately reflect the goals of both the agency and the community where they are utilized. The policies developed should address land use, economic development, congestion levels, environmental factors, impacts on mixed flow lanes, safety, cost, and support services and facilities *(2)*.

In 1976, the California Department of Transportation began a demonstration project, which reserved a diamond lane in each direction on the eight-lane Santa Monica Freeway for exclusive use of buses and carpools. This was the first attempt to create preferential use lanes from existing freeway mainlanes. The first day of operations was disastrous, featuring traffic operations problems, accidents, an outraged public, and poor press. After 21 weeks, a U.S. district court judge ordered a halt to the project until additional studies could be made *(40)*.

In 1986, the Virginia DOT (VDOT) planned HOV lane facilities for Route 44 and Interstate 64. The Route 44 HOV lanes were concurrent-flow lanes, while the IH-64 lanes were planned as reversible-flow lanes. The Route 44 lanes were completed first, and a decision needed to be made by VDOT as to whether or not to open the Route 44 lanes as the planned HOV concurrent-flow lanes or as mainlanes until the IH-64 lanes could be built. VDOT decided to restrict the lanes as HOV 3+ lanes. Once operational, few motorists elected to take advantage of the short 5 mile HOV facility. During the first month of operation the facility had 50 vehicles per hour usage, and after one year the usage had only grown to 200 vehicles per hour, including violators. Public opinion grew against the HOV lanes, and the Virginia General Assembly passed a law rescinding the HOV concept in the Hampton Roads Area. These legislatively mandated restrictions were in place for four-and-a-half years *(40)*.

In 1998, 20.2 miles of concurrent HOV lanes were completed on IH-287 in New Jersey. The lanes were open to two or more occupants during rush hours and to all vehicles during nonrush periods. The HOV lanes were underutilized due to a variety of factors, and public opinion of the lanes plummeted. The New Jersey DOT (NJDOT) undertook a study to analyze the HOV lanes using the following criteria:

- Do the HOV lanes encourage carpooling?
- Do the HOV lanes carry 700 vehicles per hour for usage, while carrying as many people in the HOV lanes as the average of the mainlanes?
- Do the HOV lanes reduce the current level of congestion and air pollution *(41)*?

NJDOT found that the IH-287 lanes failed two out of the three criteria, and shortly thereafter Governor Whitman announced the elimination of the HOV lanes. The state intended to remove the HOV lanes in November 1998 *(41)*.

A search by a member of the Texas A&M University Office of General Counsel found one lawsuit related to an HOV lane. In 1993, an accident involving a driver driving the wrong direction on a reversible HOV lane on US 290 in Houston, Texas, resulted in two fatalities and two people severely injured. Survivors filed suit against TxDOT, METRO, the City of Houston, and Harris County for negligence and gross negligence. A jury trial found that METRO and the other driver, who was not a defendant, were negligent and that TxDOT and the City of Houston were not negligent. However, the jury found that TxDOT and METRO were engaged in a joint enterprise on the date of the accident and ordered TxDOT to pay restitution as well. TxDOT appealed the ruling to higher courts. Both the First District Court of Appeals and the Texas Supreme Court upheld the initial court ruling *(42)*.

3.4.2 HOT Lanes

Although HOV legal and policy issues often have revolved around operational issues, HOT lanes face legal and policy issues about specific authority to assess tolls, social inequities, and double taxation. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 specifically authorized congestion pricing programs in Section 1012(b). The Transportation Equity Act for 21st Century (TEA-21) of 1998 reauthorized these programs. To collect tolls on HOV lanes, specific legislative action is often necessary to criminalize nonpayment of tolls or other unauthorized use of the HOV lane. In jurisdictions, legislation may also be required to provide the operating entity specific authority to assess tolls *(37)*.

State of Texas statutes include four chapters in the Transportation Code *(43)* that address toll roads and implementation authority for toll roads. Chapter 257, Road Districts, and Chapter 441, Road Utility Districts, address the establishment of districts that may act to have a toll road become part of the state highway system or road system in a county or municipality. Chapter 365, Road District Toll Roads, pertains to the establishment, construction, financial provisions, and authority for toll roads. Chapter 366 of the Transportation Code, Regional Tollway Authorities, addresses the creation of regional toll authorities and the power to acquire, design, finance, construct, operate, and maintain a turnpike *(43)*.

3.4.3 Busways

Researchers found no specific legal or policy issues regarding busways in the reviewed literature.

3.4.4 Exclusive Lanes and Lane Restrictions

Truck restrictions have been implemented by a number of states in an attempt to increase safety, decrease congestion, and improve operations. The most prevalent form of restriction, by far, is lane restrictions. State transportation officials usually have the authority to implement lane restrictions. In many instances, local jurisdictions have the authority through existing legislation to implement restrictions on state highways.

It should be noted that the Surface Transportation Assistance Act (STAA) in 1982 and Tandem Truck Safety Act (TTSA) in 1984 established a national network of highways as a designated large truck network. The law is insistent that state regulations should not interfere with interstate truck movements, as long as the trucks conform to size and weight limits established by STAA and TTSA *(44)*.

In May 1997, the 75th Texas Legislature passed legislation that permits a local municipality to request lane restrictions on certain highways within the municipality's jurisdiction. The request for a lane restriction must be approved by TxDOT. Specific criteria must be met prior to TxDOT approval of a municipality's request. For example, the highway must be a state-maintained controlled access facility with at least three through-lanes in each direction, and an engineering study must be conducted by TxDOT to determine the feasibility of the proposed lane restrictions. To comply with this legislation, Jasek et al. developed guidelines to aid TxDOT in the implementation of requested truck lane restrictions in urban areas. The guidelines provide TxDOT with the necessary information to evaluate a municipality's request for lane restrictions. Researchers recommended a 12-step process to provide guidance on information related to the proposed lane restrictions that must be contained in the ordinance. The process would include conducting a traffic study, removing/installing the appropriate traffic control devices, and periodically reviewing the lane restrictions to prevent any negative impacts that may result from the lane restrictions. Researchers recommended that TxDOT monitor the extent to which municipalities request truck lane restrictions *(29)*.

3.5 Environmental Issues

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.

3.5.1 HOV and HOT Lanes

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.

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 the vehicle capacity of the roadway *(40)*. One prime example of environmental opposition to the implementation of an HOV lane was the Cross-Westchester HOV Plan. In the mid-1990s the New York Department of Transportation announced plans to build a high occupancy vehicle lane in the median of IH-287, also known as the Cross-Westchester Expressway. Strong opposition quickly formed by a group known as the Tri-State Transportation Campaign (TSTC). Groups including Scenic Hudson, the Sierra Club, the Environmental Defense Fund, the National Resources Defense Council, Federated Conservationists of Westchester County, and the Regional Plan Association and Transportation Alternatives later joined TSTC in opposing the project. The main arguments against the project were that the highway widening and resulting HOV lane would encourage a greater dependence on the automobile, would exacerbate inefficient land use, were not a sustainable solution to the Lower Hudson Valley transportation problems, and would hinder expansion of public transportation. A massive television campaign was mounted, and in October 1997, Governor Pataki ordered the DOT to end project planning *(45, 46, 47, 48, 49, 50, 51)*.

3.5.2 Busways

Busways 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.

3.5.3 Exclusive Lanes and Lane Restrictions

A study by the OECD *(31)* examined the impact of truck facilities and truck lanes on the environment. The environmental issues considered were noise and vibration pollution, fuel consumption, and air pollution. According to this study, the air pollution produced by trucks is quite different from the pollution produced by cars. Trucks are primarily powered by diesel engines that operate with higher air/fuel ratios than the gasoline engines that power most cars. Diesel engines produce less carbon monoxide and unburned hydrocarbons than gasoline engines. However, diesel engines produce more smoke and solid particles due to the rich fuel/air mix than automobile engines. Vehicle emissions and energy consumption increase with traffic congestion and speed variations. Speed variations can increase both emissions and fuel consumption by 25 to 40 percent, whereas traffic congestion can increase emissions and fuel consumption by 50 to 100 percent *(31)*.

The European Conference of Ministers of Transport held a special conference on the environment in 1989 *(52)*. The reports presented to 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 *(52)*.

3.6 Social and Public Opinion Issues

Societal and public opinion regarding the implementation of a managed lane strategy may be the single most important nonoperational factor. 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 lane strategy.

3.6.1 HOV and HOT Lanes

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 *(2)*. Under the sponsorship of the FHWA, a comprehensive HOV Marketing Manual *(40)* was developed in 1994. The authors of this manual provide a comprehensive discussion and case studies of both successful and unsuccessful marketing attempts involving HOV lanes. The major reasons for public involvement and a successful marketing strategy during the planning and implementation of an HOV facility include:

- heighten awareness of issues,
- obtain input on HOV alternatives during the implementation and design process,
- heighten public awareness of the selected HOV alternative,
- build constituencies, partnerships, and support for the selected alternative,
- increase public confidence in the HOV facility,
- develop accurate expectations for use of the HOV facility,
- promote and educate all groups on the use of the HOV facility,
- create awareness of support facilities and services,
- enhance support of future HOV initiatives, and
- meet federal, state, and local requirements *(2)*.

As previously noted in the sections concerning legal and policy issues and environmental issues, poorly thought out strategies combined with insufficient public education can lead to implementation problems. In the case of the Santa Monica Expressway demonstration project, which was the first time that an HOV or preferential lane was created from a preexisting mainlane, it became quickly apparent that the conventional marketing and public education strategy was insufficient. The reduction of an already busy expressway by one lane provoked an emotional and hostile reaction, which resulted in an eventual court order to halt the project. Although the California Department of Transportation (CALTRANS) was aware of the potential problems of reducing one of the busiest freeways in the U.S. by one lane only, a conventional public education and marketing strategy was implemented. A different marketing strategy, in all likelihood, would not have prevented the negative opinions; however, it may have allowed the demonstration project to run its course *(40)*.

The Hampton Roads/Route 44 HOV lane in Virginia fell victim to project delays within a broader system; additionally, little time was allotted to plan and execute a marketing campaign. The 5-mile stretch of newly built HOV facility, which lacked support facilities such as park and rideshare lots, fell prey to underutilization. Public acceptance of an underutilized, highly visible facility created outrage and frustration. During the four-and-a-half year temporary rescission of the HOV strategy, a marketing and public awareness campaign was carefully planned and executed. Measures implemented, which led to the eventual successful implementation of the facility, included:

- the formation of an HOV steering committee, which included local and regional public officials and representatives;
- the development of a long range marketing plan;
- the design of several rideshare support facilities, such as computer ride matching, employer outreach programs, additional park and ride lots, promotion of rideshare lots, express bus service, and a program utilizing subsidized transit fares for participating employees; and
- the redefinition of initial occupancy requirements from HOV-3 to HOV-2+ *(40)*.

In some instances public relations campaigns and marketing strategies do not work. One of the main issues that led to the removal of the HOV facility on IH-287 in New Jersey was poor public opinion due to under utilization. In January 1998, 20.2 miles of concurrent HOV lanes were completed on IH-287 in New Jersey. The lanes were open to two or more occupants during rush hours and to all vehicles during nonrush periods. The HOV lanes were underutilized due to a variety of factors, and public opinion of the lanes plummeted *(41)*. Despite an aggressive public relations campaign and marketing strategy, the task of increasing carpooling on IH-287 HOV lanes failed. In addition to the resistance to carpooling, an aggressive public relations campaign against the HOV lanes was waged *(53)*. On November 30, 1998, less than one year after completion, Governor Christie Todd Whitman opened the HOV lanes to all traffic. The Governor noted that the HOV lanes failed to meet their original goals and added to the congestion, poor air quality, and safety problems *(54)*.

In the case of the IH-287 Cross-Westchester Expressway HOV plan, a good public education and marketing strategy in the planning stages may have been able to counteract a sophisticated campaign mounted by environmental interest groups. As previously noted, in the mid 1990s the New York DOT announced plans to build a high occupancy vehicle lane in the median of IH-287, also known as the Cross-Westchester Expressway. Strong opposition quickly formed by a group known as the Tri-State Transportation Campaign (TSTC). Groups including Scenic Hudson, the Sierra Club, the Environmental Defense Fund, the National Resources Defense Council, Federated Conservationists of Westchester County, and the Regional Plan Association and Transportation Alternatives later joined TSTC in opposing the project.

Although the HOV facility was still in the planning stages, groups opposing the facility released their own "environmental impact" papers, which rejected the proposed facility for the following reasons:

- chaos during construction, in which motorists would be subjected to lane closures, detours, and massive delays;
- no immediate relief to congestion since the project would take five to seven years to complete;
- a return to pre-construction congestion, which would be created by continued growth of vehicular traffic;
- road network congestion, by increasing highway capacity;
- induced traffic and threats to environmentally sensitive open space, by encouraging development on undeveloped lands;
- threats to economic revitalization of existing urban centers, by allowing decentralization of businesses; and
- waste of scarce public resources with a cost of $444 million *(55)*.

In addition to rebuttals to planning documents, groups opposing the Cross -Westchester facility launched a series of television spots urging viewers to call the governor and urge him to call off the project *(56)*.

HOT lanes also pose some potential public relations challenges, even though they improve utilization of existing HOV lanes. The *Maryland DOT 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 increase *(9)*.

In 1999 and 2000, Urban and Transportation Consulting conducted a series of commuter focus groups to explore public acceptance of the implementation of value express lanes (HOT lanes) in the Denver metropolitan area. The focus groups consisted of commuters who utilize US 36, IH-25, and E-470 *(57, 58, 59)*. These in-depth group sessions produced the following findings:

- Most participants accept the concept of value pricing as a means of better utilizing existing HOV facilities.
- Fewer participants accept the concept of applying value pricing to a new or proposed HOV facility.
- Many participants recognize value pricing as a temporary strategy that "will go away" as congestion increases.
- The most effective marketing strategy or method of selling the concept of value pricing is through real examples.
- The least effective marketing strategy or method of selling the concept of value pricing is through theory on managing demand.
- Most participants could imagine a reason for utilizing a value-priced lane if it were available.
- There were a number of "hot" or sensitive issues regarding value pricing including double taxation, limited capacity, and the short-term value of the lanes.
- The potential use of the funds varied among the participants.

- Although opinions were mixed regarding whether operation of the value-priced lanes should be operated by a public or private organization, just over two-thirds preferred public management *(58, 59)*.

In May 2001, the final reports of the Colorado Value Express Lane Feasibility Study were published *(60, 61)*. The researchers found that value express lanes were technically feasible and publicly acceptable for the IH-25 and US 36 HOV facilities in the Denver metropolitan area. However, the study conclusions urged that a plan for public education on value pricing and its concepts be implemented to forestall any misconceptions about the strategy *(60, 61)*.

Stockton et al. reported in *Feasibility of Priority Lane Pricing on the Katy HOV Lane: Feasibility Assessment (37)* that the critical steps to achieving public acceptance to HOT lanes were:

- understanding historic public feedback nationally,
- understanding local opinion,
- developing a public education/information campaign, and
- developing support among public officials.

3.6.2 Busways

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 *(62)*. 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)*.

3.6.3 Exclusive Lanes and Lane Restrictions

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. 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 *(26)*.

The OECD report on truck roads *(31)* 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 *(31)*. 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 *(31, 63, 64)*.

3.7 Enforcement Issues

Enforcement, as defined in *Webster's New Collegiate Dictionary (65)*, provides five definitions. The fifth definition, *to carry out effectively* <~*laws*>, provides the key thought of the role of enforcement in managed lanes. Once operational requirements are decided for a managed lane strategy, enforcement becomes the means by which the strategy is implemented and effectively carried out *(65)*.

3.7.1 HOV and HOT Lanes

The HOV Systems Manual *(2)*, asserts that enforcement is critical to a number of elements in a successful HOV operation. These elements include:

- ensuring that operating requirements including vehicle-occupancy levels are maintained;
- discouraging unauthorized usage;
- maintaining a safe operating environment; and
- providing a visible means of promoting the fairness and integrity of the facility, thereby assisting in gaining public acceptance of the strategy *(2)*.

For an enforcement program to be successful, a number of components must be present. These components include legal authority, fines and citations, enforcement strategies, enforcement techniques, funding, and communication. The first component, simply put, is that for enforcement to be successful, the agency responsible for enforcement of the rules and regulations of the HOV lane must have the legal authority to enforce those regulations. Successful HOV enforcement strategy should also include fines and citations that are appropriate for the various violations that are encountered and that the amount of the fines are high enough to deter violators. There are generally four types of enforcement strategies for HOV lanes: routine enforcement, special enforcement, selective enforcement, and self-enforcement. Self-enforcement is usually accomplished by a program that allows drivers to report violators of the HOV requirements. An example of self-enforcement is the HERO program that has been used in multiple cities including Seattle, Houston, and Washington, D.C.

There are also specific enforcement techniques and methods such as video surveillance and roving patrols Funding is also of primary importance for successful enforcement. State and local police have many responsibilities besides enforcement of HOV lane operational requirements. Therefore, enforcement of these requirements may not be a high priority. If, however, exclusive funding is made available for HOV patrols, police enforcement may become a higher priority. Communication is also an important enforcement tool. The public must become educated about the requirements for using the HOV lanes and the consequences for violations. A good communications program may prove to be a deterrent in its own right *(2)*.

In 1998, Turner *(66)* analyzed technologies for enforcement for HOV lanes. After a qualitative assessment of video, automatic vehicle identification (AVI), and infrared machine vision technologies, the study focused on video technology. The high occupancy vehicle enforcement and review (HOVER) technology was developed and assessed. Turner found that video could potentially be used for the following purposes: mailing HOV information to suspected violators, enforcement screening, and ticket-by-mail enforcement. The latter application could not be used in Texas because it is currently illegal *(66)*.

As is the case with HOV lanes, enforcement is the key for effective implementation and operation of an HOT lane. The concept of the HOT lane strategy is the controlled usage of the facility. Without effective enforcement this control is not possible, because everyone must be assured that there is no free ride *(37)*. In the case of an HOV lane, when a vehicle that does not meet occupancy requirements "uses" the facility, the driver misuses a "free" facility. When a violator misuses a HOT facility, the violator is stealing a service. Although users of the HOV facility may be unhappy with facility misuse, HOT users will not tolerate someone stealing service. Therefore, enforcement is paramount to success *(37)*. One way of enforcing proper HOT usage is stationing an officer to check occupancy or toll tags at the end of a barrier-restricted facility. Video enforcement of violators of HOT lanes has also been suggested *(8)*. Video enforcement is currently being used on the California State Route 91 express lanes for toll enforcement.

3.7.2 Busways

Researchers found little to no enforcement issues associated with busways.

3.7.3 Exclusive Lanes and Lane Restrictions

Mannering, Koehne, and Araucto conducted a study in the Puget Sound region that considered lane restrictions as a means of increasing roadway capacity, improving highway operations, improving the level of roadway safety, and encouraging uniform pavement wear across lanes *(67)*. The study region has a truck volume of approximately 5 percent of the total traffic volume. The portion of the in-depth analysis that addressed enforcement issues focused on violation rates. Researchers found that the violation rate for trucks during the restriction was 2.1 percent, which was the same as the proportion of trucks in that lane prior to the restriction. Increased enforcement did not alter the percentage *(66)*.

The New Jersey Turnpike Authority was one of the first jurisdictions to impose restrictions for trucks. On the dual-dual portion of the turnpike from Interchange 8A to Interchange 14, trucks are restricted to the right outer lanes, and 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 NJTA rates compliance for truck lane restrictions as high *(67)*.

The truck bypass facility on a section of northbound I-5 near Portland, Oregon, at the Tigard Street interchange requires trucks to stay in the right lane, exit onto a truck roadway, and reenter traffic downstream of the interchange. Observations of trucks traveling northbound indicated that nearly every truck uses the truck bypass, with little to no need for additional enforcement *(17)*.

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8.0 APPENDIX B

GLOSSARY OF TERMS

GLOSSARY OF TERMS FOR MANAGED LANES

-A-

Advanced Traffic Management System (ATMS) – remotely operated traffic management system for monitoring and managing operations of a freeway system including HOV lanes and arterial streets. Major elements of the system include surveillance, communications, and controls.

Automatic Vehicle Location (AVL) – the use of advanced technologies such as Global Positioning Systems (GPS) to monitor the location and movement of vehicles.

Average Daily Traffic (ADT) – a measure of traffic. The average number of vehicle trips generated over a specific time period.

Average Vehicle Occupancy (AVO) – the number of people divided by the number of vehicles (including buses) traveling past a specific point over a given time period.

-B-

Barrier Separated – an HOV lane separated from the regular lanes of traffic by a concrete barrier. The facility may be one-lane/reversible or a two-lane bidirectional.

Benefit-Cost Ratio (B/C) – estimate of the anticipated dollars of discounted benefits achievable to a given outlay of discounted costs.

Bidirectional HOV Facility – preferential facility in which both directions of traffic flow are provided for.

Buffer-Separated – a facility in which the HOV lane is separated from the general-purpose lanes by a designated buffer.

Bus Priority System – means by which transit is given preferential treatment or advantage over other traffic.

Bus Rapid Transit (BRT) – a term describing a bus operation that is generally characterized by operation on a separate right-of-way that permits high speeds.

Busway – a preferential roadway designed exclusively for use by buses.

-C-

CBD – Central Business District – commonly referred to as downtown.

Change of Mode – transfer from one type of transportation vehicle to another.

Commute Trips – trips that are taken on a daily or regular basis to work.

Concurrent Flow Lane – an HOV lane that is operated in the same direction as the adjacent general-purpose lanes.

Congestion Pricing – the policy of charging drivers a fee that varies with the level of traffic on a congested roadway. Congestion is designed to allocate roadway space, a scarce resource, in a more economically feasible manner. Synonym: congestion-relief tolling.

Contraflow Lane – an HOV lane operating in the opposite direction of the normal flow of traffic, designated for peak direction travel.

Continuous Access – an HOV lane separated from the regular lanes of traffic by a painted stripe only.

Cost – resources used to produce a good or service.

-D-

Deadheading – segment of a trip made by a transit vehicle not in revenue service.

Delay – the increased travel time experienced due to circumstances that impede a desirable movement of traffic.

Demand-Side Policies – policies aimed at reducing congestion by reducing the demand for travel either overall or by targeted modes.

Differential Pricing (Variable Pricing) – time-of-day pricing and tolls that vary by other factors like facility location, season, day-of-week, or air quality impact.

Direct HOV/HOT Ramps – freeway entrance ramps set up as restricted use ramps for HOV/HOT facility-eligible vehicles.

Directional Split – the distribution of traffic flows on a two-way facility.

Dynamic Pricing – tolls that vary in response to changing congestion levels, as opposed to variable pricing that follows a fixed schedule.

-E-

Electronic Toll Collection – this refers to electronic systems that collect vehicle tolls, reducing or eliminating the need for tollbooths and for vehicles to stop.

Enforcement – function of maintaining the rules and regulations of a preferential treatment to maintain the integrity.

Enforcement Area – designated space on which enforcement can be performed.

Environmental Assessment (EA) – study to determine the potential impacts on the environment from a project.

Environmental Impact Statement (EIS) – comprehensive study of all the potential impacts of a project funded with federal dollars.

Express Bus Service – bus service with a limited number of stops, usually at a high speed.

-F-

Fees for Entering – tolls charged to vehicles entering a particular facility or an area, but which do not depend on the distance traveled on the facility or in the area.

FHWA – Federal Highway Administration.

Fixed Guideway – transportation system composed of vehicles that can operate only on their own guideways.

Freight Lane – a facility or lane restricted to authorized truck types.

FTA – Federal Transit Administration.

-G-

General-Purpose Lanes – lanes on a freeway or expressway that are open to all motor vehicles.

Grade Separation – the vertical separation of an intersecting transportation facility.

-H-

High Occupancy Vehicle (HOV) – a passenger vehicle carrying more than a specified minimum number of passengers, such as an automobile carrying more than one or more than two people. HOVs include carpools and vanpool as well as buses.

High Occupancy Vehicle System – development and operation of a coordinated approach of physical improvements such as HOV lanes, park-and-ride lots, and supporting services and policies.

HOT Lanes (High Occupancy Toll Lanes) – HOV facilities that allow lower occupancy vehicles, such as solo drivers, to use these facilities in return for toll payments, which could vary by time-of-day or level of congestion.

HOV Lane – an exclusive traffic lane or facility limited to carrying high occupancy vehicles (HOVs) and certain other qualified vehicles.

HOV/HOT Freeway-to-Freeway Connectors – special freeway-to-freeway ramps restricted to HOV/HOT lane-eligible vehicles.

-I-

Incentive Programs – policies and techniques aimed at a specific behavior.

Ingress – the provision of access into a roadway.

Inherently Low Emission Vehicles (ILEV) – alternative fueled clean air vehicles. Related terms include Zero-Emission vehicles (ZEVs), Ultra-Low-Emission (ULEV), and Super-Ultra-Low-Emission (SULEV) vehicles powered by alternative fuels.

Intelligent Transportation Systems (ITS) – the application of advanced technologies to enhance the operation and management of a transportation system.

Interchange – the system of grade-separated ramps connecting two or more roadways

Intermodal – facility connections between transportation modes.

-J-

Jitney – privately owned vehicle operated on a fixed or semi-fixed schedule for a fare.

-K-

Kiss-and-Ride – facility whereby transit riders are dropped off and picked up.

-L-

Level of Service (LOS) – qualitative measure that describes the operational conditions of a roadway or intersection.

Light Rail Transit (LRT) – mode of transit that operates on steel rails and is powered by overhead electrical wires.

Limited Access – access management used to restrict entry to a facility based upon facility congestion levels or operational condition, such as the presence of an accident or maintenance activities. Typically, access is not restricted by type of user.

Line Haul – portion of a commute trip that is nonstop between two points.

Local Bus Service – Bus routes and service characterized by frequent stops and slow operating speeds.

-M-

Main Lane – general-purpose lane on a freeway that is open to all motor vehicles.

Main-Lane Metering – regulating the flow of vehicles on general-purpose lanes or on freeway-to-freeway connections through the use of traffic signals that allow vehicles to proceed at a predetermined rate.

Major Investment Study (MIS) – detailed study and assessment of the various options available for the purpose of selecting one for implementation.

Managed Lane – a lane or lanes that increase freeway efficiency by packaging various operational and design actions. Lane management operations may be adjusted at any time to better match regional goals.

Mileage-Based Fee – the fee charged for using a vehicle based on the vehicle miles traveled (VMT) in the jurisdiction.

Mode – means of travel.

Mode shift – the change from one means of travel to another.

Motor Vehicle Fuel Tax – pricing of gasoline and other fuels.

Multi-Modal – facilities serving more than one transportation mode.

-N-

Non-Attainment Area – a geographic area in which the level of air pollution is higher than the level allowed by nationally accepted standards for one or more pollutants.

National Environmental Policy Act (NEPA) – legislation enacted in 1969 that requires that federally funded projects conduct an EIS to evaluate potential impacts.

-O-

Off-Peak Direction – direction of lower demand during the peak commuting period.

On-Line Station – mode transfer facility located along an HOV lane or a fixed guideway system.

Origin-Destination Study – analysis of the starting and ending points or zones of people or vehicles.

-P-

Park-and-Pool Lot – facility where individuals can park their private vehicles and join a carpool or vanpool. This lot is not normally served by public transportation.

Park-and-Ride Lot – facility where individuals can park their private vehicles and access public transportation.

Parking Management – strategies aimed at making better use of available parking supply. Parking management strategies include preferential parking or price discounts for carpools and/or short-term parkers, and disincentives for those contributing more to congestion.

Parking Surcharges – users who park in congested areas during the most congested periods are charged fees higher than those normally associated with the facilities they use.

Peak Direction – direction of higher demand during a peak commuting time.

Peak Hour – the hour in which the maximum demand occurs on a facility.

Peak Period – period in which traffic levels rise from normal levels to maximum levels.

Preferential Parking – incentive to encourage ridesharing. Usually located closer to the destination.

Price – the direct costs borne by users for consuming a good or service.

Price Elasticity of Demand – a measure of the sensitivity of demand for a commodity to a change in its price. It equals the percentage change in consumption of the commodity that results from a 1-percent change in its price. The greater the elasticity, the more price-sensitive the demand for the commodity.

Priority Lane – lane providing preferential treatment to HOVs.

Priority Lane Pricing – concept of using congestion pricing on an HOV lane.

-Q-

Queue – a line of vehicles or persons.

Queue Bypass – an HOV facility that provides a bypass around a queue of vehicles delayed at a ramp or mainline traffic meter or other bottleneck location.

-R-

Ramp Metering – procedure used to reduce congestion by managing vehicle flow from local-access on-ramps. The entrance ramp is equipped with a traffic signal that allows vehicles to enter the freeway at predetermined intervals.

Ramp Meter Bypass – preferential treatment at a ramp meter in which a lane is provided for the exclusive use of HOVs to bypass the queue.

Revenue Neutral – revenue-neutral pricing strategies involve rebating some or all of the revenue generated by pricing to toll payers, where raising money is not an objective of congestion pricing.

Reverse Commute – travel time between work/school and home in the opposite direction of the peak direction of travel.

Reversible HOV Lane – facility in which the direction of traffic flow can be changed at different times of the day to match the peak direction of travel.

Road Pricing – an umbrella phrase that covers all charges imposed on those who use roadways. The term includes such traditional revenue sources as fuel taxes and license fees as well as charges that vary with time of day, the specific road used, and vehicle size and weight.

-S-

Signal Preemption – an interruption of the normal operation of a signal in order to immediately serve a particular movement.

Signal Priority – technique of altering the sequence or timing of traffic signal phases using special detection in order to provide preferential treatment.

Special Use Lane – lane restricted for specific uses only.

Support Facility – a physical improvement that enhances HOV operations.

-T-

Time-of-Day Pricing – facility tolls that vary by time-of-day in response to varying congestion levels. Typically, such tolls are higher during peak periods when the congestion is most severe.

Toll Road – a section of road where motorists are charged a use fee (or toll).

Transit Center – mode transfer facility serving buses or other modes.

Throughput – the volume of vehicle or passengers passing a specific point during a predetermined period of time.

Traffic Assignment – the planning and modeling process of allocating trips by different modes and to different origins and destination and routes.

Traffic Assignment Zone – the division of a study area into subunits or zones allowing for a more detailed level of analysis.

Traffic Volume – the number of vehicles on a roadway.

Transponder – an electronic tag mounted on a license plate, built into a vehicle, or placed on the dashboard. The tag is read electronically by an electronic tolling device that automatically assesses the amount of the user fee.

Transportation Control Measure (TCM) – series of vehicle trip-reduction measures focusing on reducing travel by SOVs and increasing alternative modes.

Transportation/Travel Demand Management (TDM) – a variety of strategies, techniques, or incentives aimed at providing the most efficient and effective use of existing transportation services and facilities. Road pricing is one category of TDM.

Transportation System Management (TSM) – actions that improve the operation and coordination of transportation services and facilities.

Travel Time – the length of time it takes to travel between two points.

Travel Time Reliability – term referring to the lack of variability in travel time that can be expected using different facilities.

Travel Time Savings – time saved by using an HOV facility rather than the general-purpose lanes.

Trip Generation Rates – number of vehicular trips to and from a development. These rates are used to identify the potential impacts of new projects.

-U-

User Management – which types of users can utilize a facility. HOV lanes are prime examples of user-managed facilities. Restrictions may vary by time of day or day of the week.

-V-

Value Pricing – a system of fees or tolls paid by drivers to gain access to dedicated roadway facilities providing a superior level of service compared to the competitive free facilities. Value pricing permits anyone to access the managed lanes, and the value of the toll is used to ensure that the management goals of the facility are maintained.

Vanpool – prearranged ridesharing function in which groups of people travel together on a regular basis in a van.

Vehicle Miles Traveled (VMT) – the total distance traveled in miles by all motor vehicles of a specific group in a given area at a given time.

Violation Rate – number of vehicles that do not meet the minimum occupancy requirements of an HOV facility.

Volume to Capacity Ratio – the ratio of demand flow rates to capacity for a given type of transportation facility.

-W-

-X-

-Y-

-Z-