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16. Abstract

This document is the culmination of the tenth offering of a Mentors Program at Texas A&M University on Advanced Surface Transportation Systems which was presented in 2000 by the Advanced Institute in Transportation Systems Operations and Management. The Program allows participants to work closely with recognized experts in the fields of intelligent transportation systems (ITS) and traffic operations and management. The highly successful Mentors Program has been available to transportation engineering graduate students at Texas A&M University since 1991. In 2000, the Program was available to state Department of Transportation employees as well.

As part of the Mentors Program six top-level transportation professionals from private enterprise and departments of transportation, were invited to Texas A&M University to present a 1½-day Symposium on Advanced Surface Transportation Systems in early June. Immediately following the Symposium, the participants enrolled in the Program took part in a Forum and a Workshop with the invited mentors and the course instructor. Each participant held numerous discussions with the mentors and course instructor to identify a topic area for a paper. The state DOT participants selected topics that had direct application to the needs of their respective states. Each participant worked with his/her mentor and course instructor to finalize a topic area and objectives for a paper. In addition to discussions with the course instructor, the participants (communicating via telephone, e-mail, fax and mail) worked directly with the mentors throughout the summer while preparing their papers. The mentors and the state DOT employee participants returned to the Texas A&M University campus in late July for formal presentations of the papers.

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COMPENDIUM:
PAPERS ON
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AUGUST 2000

Class Instructor and Mentors (front row, from left) Conrad Dudek, Joseph Lam, Wayne Kittelson, Thomas Hicks; (back row) Leslie Jacobson, William Spreitzer. (Not in photo: Patrick Irwin)

PREFACE

This document is the culmination of the tenth offering of a Mentors Program at Texas A&M University on Advanced Surface Transportation Systems which was presented in 2000 by the Advanced Institute in Transportation Systems Operations and Management. The Program allows participants to work closely with recognized experts in the fields of intelligent transportation systems (ITS) and traffic operations and management. The highly successful Mentors Program has been available to transportation engineering graduate students at Texas A&M University since 1991. In 2000, the Program was available to state Department of Transportation employees as well.

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One important objective of the Program was to develop rapport between the participants and the top-level transportation professionals who served as mentors. The opportunity for the participants to communicate and interact with the mentors, who are recognized for their knowledge and significant contributions both nationally and internationally, was a key element for the participants to gain the type of learning experiences intended by the instructor. Therefore, extra care was taken to encourage interaction through the Symposium, Forum, Workshop and social events.

Thomas Hicks, Patrick Irwin, Les Jacobson, Wayne Kittelson, Joseph Lam and William Spreitzer devoted considerable time and energy to this Program. We are extremely grateful for their valuable contributions to making the 2000 Mentors Program such a huge success.

The opportunity to bring top-level transportation professionals to the campus was made possible through financial support provided by the University Transportation Centers Program of the U.S. Department of Transportation to the Southwest Region University Transportation Center at TTI.

Joan Stapp, Senior Secretary with the Texas Transportation Institute, coordinated the Symposium and Workshop in a very efficient and professional manner.

Congratulations are extended to the participants who completed the Program. Their papers are presented in this Compendium. The transportation professionals who graciously served as mentors in previous years and the participants in the Advanced Institute Program since 1991 are shown in Appendices A and B. A listing of all the papers prepared since 1991 is shown in Appendix C.

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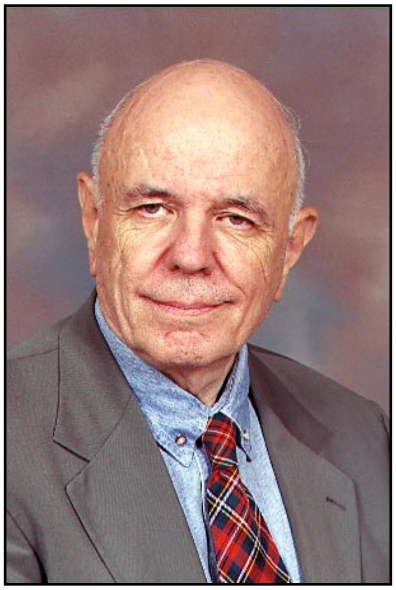
2000 MENTORS



THOMAS HICKS

Thomas Hicks is presently the Director of the Office of Traffic & Safety for the Maryland State Highway Administration, one of six engineering offices reporting to the Chief Engineer. He is responsible for coordinating the work of six Divisions - Traffic Safety Analysis, Traffic Engineering/Design, Traffic Operations (maintenance and operations), Traffic Development Support (studies and research), Motor Carrier, and the Maryland Highway Safety Office. In addition he is responsible for the Highway Sign and Signal Shops and serves as one of 8 members comprising the Board that guides and directs the State's ITS program - CHART.

Mr. Hicks has served as the State Traffic Engineer for the Maryland State Highway Administration since 1968. Under the old State Roads Commission, he served as Assistant Chief Engineer for Traffic Safety, and later Assistant Chief Engineer for Traffic Engineering. In the early 1980s, as some states were cutting back on traffic engineering activities, the Maryland SHA began a significant effort to expand theirs, and Mr. Hicks position was elevated to Deputy Chief Engineer. In 1991, the Office of Traffic Engineering assumed control of the State's safety grant and Motor Carrier programs. The office then became known as the Office of Traffic & Safety. Maryland's traffic engineering program today is one of the most comprehensive in the country.

Prior to his Maryland assignments, Mr. Hicks was the State Traffic Engineer for the Oklahoma Department of Highways, becoming their first in this position. He is a graduate Civil Engineer with a BSCE from the University of Maryland and he completed the graduate school program of the Bureau of Highway Traffic at Yale University. Mr. Hicks taught traffic engineering for three years at the University of Oklahoma.

Mr. Hicks has served in leadership rolls with several professional organizations including ITE, AASHTO, NCUTCD, TRB, ATSSA, and the Safety Council of Maryland. He is currently a member of the AASHTO Standing Committee on Highway Traffic Safety, Vice-Chairman of the AASHTO Committee on Traffic Engineering, and a Member of NCUTCD where he served as Chairman, Construction & Maintenance Technical Committee. He is a member of the Washington DC ITE; served as a member of various TRB committees; and was a Co-Founder and first President of the Oklahoma Traffic Engineers Association. Mr. Hicks is the recipient of the National Safety Award from ATSSA; the 1991 Highway Safety Award from AASHTO; and the Community Transportation Award from the Washington DC Section of ITE. Mr. Hicks is the recipient of the 1999 Theodore M. Matson Award. He is a registered Professional Engineer in Maryland.

PATRICK L. IRWIN

Patrick Irwin was born and raised in San Antonio, Texas. He received a Bachelor of Science degree in Civil Engineering from Texas A&M University.

He began his career with the Texas Department of Transportation in 1974 with an assignment to the San Antonio District Traffic Section in freeway operations. His operations study of I-410 in San Antonio justified the first implementation in the state of turnarounds as well as x-configuration of ramps. An assignment in Atascosa County followed which involved the rural design of I-37. Next came an appointment to the San Antonio Special Design Group where he was the design team leader for several projects including the Fratt Interchange Project that in 1979 and at $67 million was the largest Department contract. A six and a half year assignment as Supervising Resident Engineer for Frio and LaSalle Counties followed. In 1986, Irwin returned to the San Antonio District as District Traffic Engineer, responsible for traffic operations for some 11,800 lane-miles of highways in sixteen South Texas counties. In 1992, he was appointed Director of Transportation Operations for the District. Mr. Irwin is currently responsible for the on going development of the San Antonio Advanced Traffic Management System (TransGuide) that is envisioned to be the most advanced system in the nation. TransGuide was the 1995 recipient of the ITS America Board Chair Award and was selected as a United States DOT Model Deployment Initiative Site.

Mr. Irwin has addressed and participated in numerous national, state and local Transportation groups. He was a primary developer and instructor of the Advanced Traffic Engineering course of TxDOT's Professional Development training program. He also has published papers in the fields of both transportation operations and transportation management.

He is a past Director of ITS Texas. In addition, he has been a guest lecturer at universities, servers as a resource for the USDOT's Peer-To-Peer Program and has provided consultation to 16 foreign counties in transportation management. Mr. Irwin also supports the Texas Transportation Federal Credit Union as a Director, Rotary Club past resident and a Superintendent of the Walter Gerlach Junior Livestock show & sale.

He was honored by TxDOT in 1995 with the prestigious High Flyer Award. This award was given for innovative risks in supporting TxDOT's mission of providing safe, effective and efficient movement of people and goods.

LES JACOBSON

Mr. Les Jacobson is an expert in traffic management systems, especially freeway management and high occupancy vehicle systems. He is a Senior Intelligent Transportation System Specialist with PB Farradyne, Inc.

Prior to this position, he was the Assistant Regional Administrator for Traffic Systems of the Washington State Department of Transportation. He was a member of the Region management team, helped develop the Region's capital program, and managed the Region's operations program. He was responsible for all traffic engineering and electronic maintenance functions in the Region. He was with the WSDOT for over 20 years and spent most of his career dealing with traffic management issues, especially freeway operations, HOV systems, and ITS. He was an integral member of the team that implemented the ramp metering system in Seattle in 1981 and supervised the operation of the Traffic Systems Management Center (TSMC) from 1983 through 1984. It was during his tenure at the TSMC that the first major HOV lane was opened on Interstate 5 in the Seattle area.

Mr. Jacobson was responsible for the operation of the Seattle area's freeway HOV system. He was a member of the WSDOT HOV Policy Task Force and the PSRC (the Seattle area MPO) HOV Policy Committee. He was involved in several HOV planning efforts. He was involved in developing ITS policy for the Northwest Region and was a key member of Washington State's ITS model deployment initiative. He received AASHTO's Alfred E. Johnson Achievement Award in 1996 and the ITE ITS Council's Individual Achievement Award in 1999. He is a registered professional engineer in Washington State. He is a member of the Institute of Transportation Engineers and the ITS Council, and is the secretary of the TRB HOV Systems Committee and a member of the ITS Committee. He chaired the ITS America ATMS Committee from 1994 to 1998 and is a member of the Coordinating Council. He has chaired and been a member of several NCHRP research panels, and teaches Traffic Flow Theory at the University of Washington.

WAYNE K. KITTELSON

Wayne Kittelson is a Principal in the transportation consulting firm Kittelson & Associates, Inc. Throughout his career, Mr. Kittelson has been involved in a wide variety of projects related to transportation planning, traffic engineering, highway design, public involvement, and transportation research. He has also taught transportation related courses, and has developed and applied computer programs to facilitate various analytic procedures.

For over twenty-five years, Mr. Kittelson has been directly involved in a wide variety of applied research activities. Whether as a project participant, Project Manager, Panel Member, or Principal Investigator, he has assisted in the development and application of state-of-the-art techniques for accurate and realistic analyses of traffic operational and safety analyses on all types of facilities. Examples of recent research-related activities in which Mr. Kittelson has had significant professional involvement include: NCHRP 3-46 (development of an unsignalized intersection analysis method); NCHRP 3-49 (Evaluation of the Operational and Safety Effects of Mid-Block Left-Turn Treatments); NCHRP 3-54 (Uniform Display for Protected-Permitted Left-Turn Phasing); NCHRP 3-55(2) (Development of Planning Applications for Estimating Speed and Level-of-Service); NCHRP 3-55(3) (development of a two-lane roadway analysis method); NCHRP 3-55(6) (Development and Delivery of a Year 2000 Highway Capacity Manual); TCRP A-15 (development of a Transit Capacity Manual); and an FHWA-sponsored project to develop a Roundabout Design Guide.

Mr. Kittelson also regularly serves as an instructor in numerous highway capacity analysis and intersection design courses given throughout the United States. He has been associated with the Transportation Research Board's Committee on Highway Capacity and Quality of Service since 1978, when he was a major contributor to an FHWA-sponsored research project entitled *Quality of Flow on Urban Arterials.* He has continued to stay involved in Committee activities since then, serving as both its Secretary and as Chairman of the Subcommittee on Interpretations and User Liaison. He participated directly in the development of the 1985 *Highway Capacity Manual*, the 1994 update, and the 1997 update.

In the area of design, Mr. Kittelson has previously served as an instructor for an FHWA-sponsored course entitled, "Design of Urban Streets." This course was given throughout the United States and in Puerto Rico, and continues to serve as a basic reference on urban street design standards and guidelines. Mr. Kittelson has presented short-courses on urban intersection design and operations issues.

Mr. Kittelson received his Bachelor of Science degree in Civil Engineering from Northwestern University and his Master of Science degree in Civil Engineering with specialization in Traffic and Transportation from the University of California at Berkeley. He has been a member of several professional organizations and served as the President of the Oregon Section of ITE. He is a registered professional engineer in Oregon and Florida.

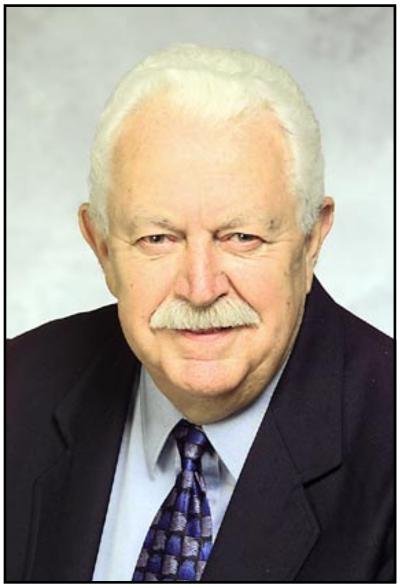
JOSEPH K. LAM

Joe Lam is a Division Vice President and Director of Delcan Corporation.

As a professional, Joe Lam has been active in the ITS (Intelligent Transport Systems) - related field of urban and freeway traffic management and control for over 30 years. Prior to joining Delcan, he spent 11 years in the Metropolitan Toronto Traffic Control Centre, where he held various positions of increasing responsibilities and was involved in the day-to-day administrative and operational activities of the world's first computerized traffic signal system, and also in the research and development of new control strategies and the design and implementation of system enhancements.

As the vice president responsible for the Transportation Systems Division for Delcan, Joe directs a group of traffic, communications and software engineering consulting professionals who contribute significantly to the export of Canadian technology to manage traffic congestion problems around the world, including the United States, South Korea, Taiwan, China, Indonesia, Hong Kong, South America and the Middle East. He was instrumental in the development of the COMPASS ATMS which manages traffic on the Highway 401, the world's busiest freeway, in the Toronto area, and in the implementation of the Tsing Ma Traffic Control and Surveillance System, which monitors traffic in a 17km road network, including a tunnel and three bridges between the New Hong Kong Airport and the mainland. He is currently directing a ITS planning project for the Egnatia Highway, a 600km tollway in Northern Greece. As a Director of Delcan, he is responsible for the Company's operations in the Far East, including Hong Kong, Taiwan and China.

Joe received his engineering degree from the University of St. Andrews in Scotland, and as a part-time associate professor at McMaster University in Hamilton, Ontario, he has taught post-graduate courses in urban traffic management. He has authored numerous reports and papers on the various aspects of ITS, and regularly speak on this subject in seminars and conferences around the world. He is currently the Chairman of ITS Canada, and a member of ITS America Board of Directors. Mr. Lam was also the chairman of the Toronto 1999 ITS World Congress Organizing Committee.



WILLIAM M. SPREITZER

Mr. Spreitzer received his B.Ae.E. in Aeronautical Engineering, from the University of Detroit in 1952 and P.Ae.E., Professional Aeronautical Engineering degree (Honorary) from the University of Detroit, 1957. He is a recognized world leader in Intelligent Transportation Systems (including AHS) and transportation research.

Mr. Spreitzer brings forty-six years of relevant experience to Intelligent Transportation Studies including advanced automotive gas turbine engine development; full-scale and on-the-road concept vehicle development in applications of gas turbines, advanced transmissions and automatic vehicle controls to automobiles (Firebird I, Firebird II and Firebird III), buses (TurboCruiser I and TurboCruiser II), heavy trucks (TurboTitan I and TurboTitan II) and a variety of wheeled and tracked military vehicles; direction of research development programs in advanced transportation systems (U.S. Department of Housing and Urban development Study of New Systems for Urban Transportation) and interdisciplinary studies of transportation systems of the future--public and private/personal and transit and commercial (freight). Mr. Spreitzer retired from General Motors in January 1998 as Technical Director, General Motors ITS Program where he was responsible for planning and coordination of General Motors ITS Programs, corporate-wide and worldwide.

Mr. Spreitzer is active in national and international ITS efforts. He is past Chair of the ITS America Coordinating Council (1994-97); past Chair of the ITS America Futures Group; Chair of the Society of Automotive Engineers Technical Standards Board ITS Division and a member of the SAE ITS Program Office and past Chair of the United States Delegation to the International Standards Organization (ISO) Technical Committee 204, Transport Information and Control Systems (TICS).

CONTENTS

ANALYSIS OF FREEWAY SERVICE PATROL ORGANIZATION AND OPERATION

by

John Denholm III

Professional Mentor
Thomas Hicks, P.E.
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Prepared for
CVEN 677 – 2000 Mentors Program
Advanced Surface Transportation Systems

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College Station, TX

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SUMMARY

Freeway Service Patrols are an increasingly popular public service in cities around the United States. They are used throughout the U.S. to combat congestion on urban freeways, and as a way to provide fast, safe, and free service to the motoring public in times of need. As they become more popular, it becomes desirable for program managers to be able to evaluate their patrols based on what service patrols from other areas of the country are doing.

Nineteen agencies across the U.S. were surveyed to gain information on the current state of freeway service patrol organization and operation. The survey results were used in the development of guidelines for freeway service patrols based on the effective or unique practices identified in the survey. The guidelines were also partly based on information gathered in a literature review of materials relevant to freeway service patrols. These guidelines can then be used as a tool used in the implementation of a new service patrol, or as a tool to evaluate and improve an existing service patrol. The guidelines developed appear below:

- Define the service patrol's goals, and steps to attain them;
- Establish interagency cooperation before operations begin;
- Institute service on short congested routes;
- Ensure service patrol operators are well trained;
- Utilize tow-trucks or quick tow devices when possible;
- Embark on a public relations campaign;
- Budget for the wear and tear on vehicles involved in the patrol; and
- Periodically make a comparison with other patrols around the country

To test the feasibility of using these guidelines to evaluate existing patrols, the Houston Motorist Assistance Program was evaluated and recommendations for improvement were made based on the guidelines and information gathered in the survey.

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INTRODUCTION

Incidents on urban freeways are a major cause of congestion. Many cities are using Freeway Service Patrols as a way to mitigate the congestion caused by both major and minor freeway incidents. A service patrol vehicle can be anything from a pick-up truck to a fully equipped tow-truck capable of removing a vehicle damaged in a collision. Freeway service patrols primarily respond to minor incidents such as property damage only accidents, flat tires, stalled cars, and debris on the roadway. By swiftly removing these minor incidents from the roadway, the risk of further congestion from a secondary incident or rubbernecking is reduced considerably. In addition to minor incidents, freeways service patrols respond to major incidents and offer assistance ranging from traffic control to debris clearance. The quick clearance of a freeway incident also results in a reduction of unwanted traffic and congestion on the local street system.

Problem Statement

Freeway service patrols have been implemented in most major cities, and are integral parts of Incident Management programs in those cities. Freeway Service Patrols are constantly changing and adapting new practices. It is difficult for managers of a freeway service patrol to take a step back and compare what they are doing to the other service patrols around the country. Through an application of this research, program managers can identify characteristics of other freeway service patrols that will then form the basis of their own program's evaluation.

Research Objectives

The overall goal of this research was to develop guidelines to be used in the evaluation of existing freeway service patrols, or in the implementation of a new freeway service patrol, using effective practices identified in a survey of existing patrols. The specific objectives of this research were to:

- Identify freeway service patrol usage around the United States;
- Identify the organizational structure of the various patrols;
- Identify the operational goals of the various patrols;
- Investigate freeway service patrol response to various kinds of incidents;
- Identify characteristics that are unique to freeway service patrols in some areas;
- Develop a set of guidelines for freeway service patrols based on a synthesis of practices identified;
- Analyze an existing Freeway Service Patrol program using the developed guidelines.

Scope

This research was limited to developing guidelines for Freeway Service Patrols in urban areas. The analysis of the existing patrols was limited to their response to freeway incidents (debris, stalls, crashes etc.) and their response or role in special event and weather related emergencies were not considered.

STUDY DESIGN

The procedures followed in developing guidelines for Freeways Service Patrols consisted of four primary tasks: literature review, data collection, data analysis, and application of findings. These tasks are expanded upon in the following sections.

Literature Review

A review of literature relevant to freeway service patrols and their role in incident management was conducted to identify the typical role of a freeway service patrol. Determining the normal operational and organizational characteristics of a typical freeway service patrol was also a goal of the literature review.

Data Collection

To expand on the literature reviewed, a telephone/email survey was developed and conducted. Responses were received from nineteen agencies who operate freeway service patrols in 25 metropolitan areas across the U.S. Information from this questionnaire is the basis for the guidelines for freeway service patrols that are developed later in this research. Information pertaining to the organization and operation of a freeway service patrol was solicited. Survey responses were gathered from the agencies represented in Table 1. A detailed contact list including names and telephone numbers is available in the Appendix of this report, in addition to a copy of the questionnaire used in the telephone/email survey.

Data Analysis

Information gathered from the telephone/email survey was placed into tabular format to facilitate data analysis. Using the information gathered in the literature review and through the telephone/email survey, guidelines for developing a freeway service patrol were developed. These guidelines are applicable both in the development of a new program, and in the evaluation and improvement of an existing program.

Application of Findings

The guidelines that were developed from the literature and survey were then applied to the Motorist Assistance Program in Houston as a case study. Houston is one of the largest metropolitan areas in the country yet has a relatively small program when compared to other metropolitan areas of similar, or even smaller size. Areas of improvement were identified from a comparison of the existing Houston program with the guidelines developed from other effective practices across the country.

BACKGROUND

Congestion

When the traffic demand on a roadway exceeds the capacity, congestion develops. There are five primary reasons why congestion is continually increasing on American roadways. These reasons are (*1*):

- Metropolitan Areas are growing;
- More Americans are working;
- Less people are car pooling, using mass transit or walking to work;
- Commuting patterns are different than in the past, straining previously uncongested routes; and
- More Americans are traveling for social and other non-work related reasons than ever before.

Two types of congestion occur on the freeway system: recurring and non-recurring. Recurring congestion is typically a result of high-volume, peak-hour traffic. Recurring traffic can be planned for both by the motorist and by an incident management program because it is predictable in nature. The motorists will experience the effects of recurring congestion in the same location, at the same time, and for the same amount of time on a patterned basis (*2*).

Table 1. Survey Respondents

Agency	City, State	Freeway Service Patrol Name
New York State Department of Transportation	Albany, NY	Highway Emergency Local Patrol (HELP)
Nevada Department of Transportation	Carson City, NV	Freeway Service Patrol
North Carolina Department of Transportation	Charlotte, NC	Incident Management Assistance Patrol (IMAP)
New Jersey Department of Transportation	Cherry Hill, NJ	Emergency Service Patrol
Illinois Department of Transportation	Chicago, IL	Emergency Traffic Patrol
TRW Transportation Systems	Cincinnati, OH	ARTIMIS/CVS Samaritan
Colorado Department of Transportation	Denver, CO	Mile High Courtesy Patrol
Harris County Sheriff's Department	Houston, TX	Motorist Assistance Program (MAP)
Kansas Department of Transportation	Kansas City, KS	Service Patrol
Los Angeles County Metropolitan Transportation Authority	Los Angeles, CA	Metro Freeway Service Patrol
TRW Transportation Systems	Louisville, KY	Freeway Friends
	Louisville, Indiana area	Hoosier Helpers
Maryland State Highway Administration	Maryland (state wide program)	CHART Emergency Traffic Patrol
Wisconsin Department of Transportation	Milwaukee, WI	Milwaukee County Enhanced Freeway Patrol
		Gateway Patrol (Racine/Kenosha Counties)
		Waukesha County Gateway Patrol
Minnesota Department of Transportation	Minneapolis, MN	Highway Helper Program
Tennessee Department of Transportation	Nashville, Memphis, Chattanooga, Knoxville, TN	Tennessee HELP
Metropolitan Transportation Commission	Oakland, CA	Bay Area Freeway Service
Sacramento Metropolitan Transportation Authority	Sacramento, CA	Sacramento Metro Freeway Service Patrol
Texas Department of Transportation	San Antonio, TX	Courtesy Patrol
Missouri Department of Transportation	St. Louis, MO	Motorist Assist
Virginia Department of Transportation	Virginia Beach, VA	Freeway Incident Response Team (F.I.R.T.)

Non-recurring congestion occurs at a random frequency and is usually the result of a freeway incident such as: debris, stalled vehicle, minor accident, or a major accident. Effective response to these incidents is necessary to minimize the effects that non-recurring congestion have on the motoring public (*3*). Over 50 percent of the total delay on freeways is due to incidents (*3*). In addition to incidents, weather, work zones, and special events all effect traffic flow.

Freeway Service Patrols

A freeway service patrol is one of the primary tools available to an incident management program in combating congestion, through the quick reopening of the freeway to full capacity. Service patrols serve the purpose of incident detection and verification, as well as reducing the amount of impact minor incidents have on the freeway system. For a freeway service patrol to be an instrumental part of an incident management team, there is a need for the patrol to have specialized equipment such as heavy-duty wreckers available to it 24 hours per day, 7 days per week (*4*). A key function of a service patrol is to simply encourage the involved motorists to leave the freeway after a minor accident. If a service patrol operator can instruct the parties involved in an accident to leave the freeway, congestion resulting from the accident is reduced significantly (3). It is of primary importance that once an agency has handled any injuries or material spills from an incident, that next task be the swift re-opening of the closed lanes or roadway (1).

Freeway service patrols exist to assist the motoring public, however they are far more valuable because of their involvement in incident management.

Freeway service patrol vehicles typically are equipped with a variety of equipment to assist a stranded motorist, or to respond to an incident on the freeway system. This equipment includes the following: (5)

- Tools – wrench sets, hammers, screwdrivers, tire gauges, booster cables etc.
- Fluids – gasoline, water, anti-freeze, transmission fluid, oil;
- Safety equipment – first aid kit, fire extinguisher, gloves, safety goggles Haz-Mat guidebook;
- Traffic control – vehicle mounted warning lights, retractable arrow panels, traffic cones, flares;
- Mechanical equipment – air compressors, hydraulic car jacks, push bumpers etc.; and
- Communications – two-way radios, cellular phones.

Freeway service patrols can operate either through a dispatch system, or through a roving patrol assigned to a specific route. In the mid-1970's a research project in Los Angeles operated a freeway service patrol in both ways, and concluded that while both methods were effective, a roving patrol proved to be more effective (6).

SURVEY FINDINGS

Organizational Characteristics

Of the freeway service patrols surveyed, the majority is funded entirely by their respective State Department of Transportation. Some agencies receive partial federal funding, and others are comprised of public-private partnerships such as the arrangements between the Ohio Department of Transportation and CVS Drugstores, or the arrangement that forms the Houston Motorist Assistance Program. Local funding also contributes to many of the freeway service patrols. Transportation authorities, law enforcement agencies, and city taxes are some of the sources for local funding. Other forms of a public-private partnership would be the California freeway service patrol programs, which are 100 percent funded by public agencies, yet all services are contracted out to private agencies. A comparison of the types of funding that different freeway service patrols receive is illustrated in Table 2.

Operational Characteristics

Most freeway service patrols are operated by the same agency that provides the primary funding for the program. In most cases this is the state DOT who operates the patrols, however in many cases a private third party operates the patrol. In two instances, a local sheriff's department operates the service patrol. A large percentage of surveyed patrols use three-quarter ton pick-up trucks as their patrol vehicles. Some patrols use tow-trucks as their primary patrol vehicle. See Table 3 for a comparison of the various vehicles used by the freeway service patrols. The use of a tow-truck enables the patrol to clear a disabled vehicle form the roadway more quickly. The patrols in Sacramento and Los Angeles California, as well as the program in Chicago all use tow-trucks as their primary service patrol vehicle.

Very few of the agencies surveyed operate their freeway service patrols 24 hours a day. The majority of the agencies operate their patrols during the time period of 6:00 A.M. until 10:00 P.M. with most agencies concentrating their services during peak hour traffic. The survey respondents in most cases provided information as to the number of miles patrolled by their vehicles, and the number of vehicles in the fleet,

Table 2. Freeway Service Patrol Funding Sources

Freeway Service Patrol Name	City	Federal	State	Local	Private
Highway Emergency Local Patrol	Albany, NY	X	X		
Freeway Service Patrol	Carson City, NV		X		
Incident Management Assistance Patrol	Charlotte, NC		X		
Emergency Service Patrol	Cherry Hill, NJ	X			
Emergency Traffic Patrol	Chicago, IL		X		
ARTIMIS/CVS Samaritan	Cincinnati, OH		X		X
Mile High Courtesy Patrol	Denver, CO	X	X		
Motorist Assistance Program	Houston, TX		X	X	X
Service Patrol	Kansas City, KS		X		
Metro Freeway Service Patrol	Los Angeles, CA		X	X	
Freeway Friends	Louisville, KY		X		X
Hoosier Helpers	Louisville, Indiana area		X		
CHART Emergency Traffic Patrol	Maryland (state wide program)	X	X		
Milwaukee County Enhanced Freeway Patrol	Milwaukee, WI		X	X	
Highway Helper Program	Minneapolis, MN	X	X		
Tennessee HELP	Nashville, Memphis, Chattanooga, and Knoxville, TN	X	X		
Bay Area Freeway Service Patrol	Oakland, CA	X	X	X	
Metro Freeway Service Patrol	Sacramento, CA		X	X	
Courtesy Patrol	San Antonio, TX		X		
Motorist Assist	St. Louis, MO		X		
Freeway Incident Response Team	Virginia Beach, VA		X		

and the number operational during peak hour traffic. Table 4 provides a comparison of each agency's response to questions about number of miles patrolled and vehicles used.

Response to given incidents

The survey questionnaire contained a set of given incidents in an attempt to identify the typical freeway service patrol response to the given incident. The incidents were: debris on roadway, stall/disabled vehicle in a moving lane of traffic, minor accident (property damage only), major accident (injuries), HAZ-MAT spill, fatal accident, and freeway structural failure. The most commonly given answer will be described in the sections below.

Debris on roadway

The majority of freeway service patrols surveyed stated that their operators would attempt to remove the debris from the roadway by themselves. If unassisted removal is not possible the freeway service patrol operator will either radio another service patrol unit for assistance, or the appropriate DOT maintenance personal. In an instance that removal is not possible the service patrol will provide traffic control until the debris is removed or sufficient backup has arrived.

Table 3. Freeway Service Patrol Vehicles

Freeway Service Patrol Name	City	Pick-up	Van	Tow-Truck	Other
Highway Emergency Local Patrol	Albany, NY	X			
Freeway Service Patrol	Carson City, NV		X		
Incident Management Assistance Patrol	Charlotte, NC	X			
Emergency Service Patrol	Cherry Hill, NJ		X		X
Emergency Traffic Patrol	Chicago, IL	X		X	X
ARTIMIS/CVS Samaritan	Cincinnati, OH		X		
Mile High Courtesy Patrol	Denver, CO			X	
CHART Emergency Traffic Patrol	Maryland (state wide program)	X	X	X	X
Motorist Assistance Program	Houston, TX		X		
Service Patrol	Kansas City, KS	X			
Metro Freeway Service Patrol	Los Angeles, CA	X		X	
Freeway Friends	Louisville, KY		X		
Hoosier Helpers	Louisville, Indiana area		X		
Milwaukee County Enhanced Freeway Patrol	Milwaukee, WI			X	X
Highway Helper Program	Minneapolis, MN	X			
Tennessee HELP	Nashville, Memphis, Chattanooga, and Knoxville, TN	X			X
Bay Area Freeway Service Patrol	Oakland, CA	X		X	
Metro Freeway Service Patrol	Sacramento, CA	X		X	
Courtesy Patrol	San Antonio, TX	X			
Motorist Assist	St. Louis, MO	X			
Freeway Incident Response Team	Virginia Beach, VA	X			

Stalled / disabled vehicle in roadway

Most of the agencies surveyed had freeway service patrol vehicles equipped with push bumpers, but not towing capabilities. Thus the typical response to this type incident would be to push the vehicle either to the shoulder or off the freeway entirely. If this were not a possible solution, most patrols would then notify a local law enforcement agency that would in turn order the vehicle towed off of the highway. This type of incident was easily solved by patrols that posses towing capability. These patrols would tow the vehicle to safety and then arrange for a private tow for the motorist.

Minor accident (property damage only)

Once a collision occurs, a freeway service patrol can no longer resolve an incident unassisted since law enforcement will usually need to complete an accident report. Since this is a traffic accident, the freeway service patrol would notify the drivers to move their vehicles off the roadway either to the shoulder or to an accident investigation site. At this point most patrols will give the parties involved in the accident information exchange forms in order to help speed the accident reporting process for the local law enforcement agency that was summoned to the scene. If for some reason the parties involved cannot move their vehicles to safety, the patrol will set up traffic control until local law enforcement agencies can arrive on scene and resolve the situation.

Major Accident (injuries)

The majority of agencies surveyed did not have freeway service patrol operators who were trained in CPR or basic first aid. Thus for the majority of patrols, their response to a major accident is to simply set up

Table 4. Number of Miles Patrolled vs. Number of Vehicle Comparisons

Freeway Service Patrol Name	City	Miles[1]	# of Vehicles[2]	# During peak hour	Peak hour Veh/Mile
Highway Emergency Local Patrol	Albany, NY	35	3	2	0.057
Freeway Service Patrol	Carson City, NV	30[a]	6	3	0.100
Incident Management Assistance Patrol	Charlotte, NC	55	8	3[b]	0.073
Emergency Service Patrol	Cherry Hill, NJ	44	10	6	0.136
Emergency Traffic Patrol	Chicago, IL	80[a]	35	10[b]	0.125
ARTIMIS/CVS Samaritan	Cincinnati, OH	88	5	5	0.057
Mile High Courtesy Patrol	Denver, CO	45	12	12	0.267
Motorist Assistance Program	Houston, TX	190[a]	18	7[b]	0.037
Service Patrol	Kansas City, KS	1000[a]	4	4	0.004
Metro Freeway Service Patrol	Los Angeles, CA	411[a]	146	146	0.355
Hoosier Helpers	Louisiville[3]	40	2	2	0.050
Freeway Friends	Louisville, KY	40	2	2	0.050
CHART Emergency Traffic Patrol	Maryland (state wide program)	405[a]	N/A	18[d]	0.044
Milwaukee County Enhanced Freeway Patrol	Milwaukee, WI	60	4[a]	4[a]	0.067
Highway Helper Program	Minneapolis, MN	170	9	8	0.047
Tennessee HELP	Nashville, Memphis, Chattanooga, Knoxville	120[c]	36[c]	14[c]	0.044
Bay Area Freeway Service Patrol	Oakland, CA	362	57	57	0.157
Metro Freeway Service Patrol	Sacramento, CA	90	17	17	0.189
Courtesy Patrol	San Antonio, TX	120	6	2	0.017
Motorist Assist	St. Louis, MO	131	14	14	0.107
Freeway Incident Response Team	Virginia Beach, VA	100[a]	24	10	0.100

1. Miles reported is centerline miles reported in survey unless noted
2. Number of freeway service patrol vehicles (not including supervisor or special equipment)
a. Estimated
b. Variable number of vehicles used during peak hour, minimum value is reported in table.
c. Four cities combined
d. Nine vehicles in Washington DC area, eight in Baltimore area and one in Frederick area

traffic control and to notify local police, fire, and rescue personnel. Upon arrival of emergency personnel, many patrols will continue to maintain traffic control. For the few patrols that have first aid / CPR trained operators, the typical response differs slightly in that they would set up traffic control and then begin treating the parties injured in the accident.

HAZ-MAT spill, fatal accident, freeway structural failure.

These incidents are too catastrophic in nature for the freeway service patrols to play a major role in. In most cases, the service patrol will set up necessary traffic control and notify the proper authorities of information relevant to incident response. Some freeway service patrols are more capable of dealing with traffic control and initial response to these catastrophic incidents simply because of the layout of their vehicles, or the training they have received.

Examples of Current Freeway Service Patrols

Freeway Service Patrols are in use in at least 50 cities across the United States (7). While they vary in geographic area covered, number of vehicles used and other basic characteristics, they all serve two primary purposes: 1) To keep the freeway clear of incidents and 2) To assist and serve the motoring public. In the following section, various patrols from around the country will be briefly described to gain a better understanding of what the various patrols are capable of.

Chicago, Illinois – Emergency Traffic Patrol

Created in 1960, the Emergency Traffic Patrol (ETP), or "Minutemen," is one or the preeminent freeway service patrols in the U.S. The Illinois Department of Transportation (IDOT) operates the ETP program. IDOT also provides 100 percent of the funding necessary for the program. Currently the program is responsible for patrolling approximately 80 centerline miles of Chicago area freeways. The ETP program has 35 one-ton ETP vehicles that are equipped with a "quick tow" device that enables the driver of the ETP vehicle to tow a disabled vehicle without ever leaving the ETP vehicle. This allows for the quick and efficient removal of a minor traffic incident, without exposing the operator to the dangers of exiting a vehicle on a freeway. The strength of the ETP program lies in the ability to respond to almost any type of incident in a quick and efficient manner. In addition to the 35 ETP vehicles, the program operates 11 utility vehicles that are usually 4X4 pick-up trucks, three heavy-duty wreckers, a rotating crash crane, a sand spreader, a light command center, and an emergency extrication truck. The heavy-duty wreckers and rotating crash cranes allow this freeway service patrol the unique ability to clear the roadway of incidents involving 18-wheelers in a short amount of time. Average clearance times for an incident depend on its location. The ETP reports an average shoulder incident clearance time of 9 minutes, incidents blocking one lane take 12 minutes to clear, and incidents blocking two lanes take 23 minutes to clear on average. These numbers are a direct result of the equipment and training provided to the ETP operators. Extensive training is also a strong point of the service patrol in Chicago. The operators receive training in basic automobile fire-fighting, extrication of injured people from vehicles, CPR and basic first aid, and they undergo yearly refresher courses to ensure their skills are up to date. The Chicago ETP operates 24 hours a day, seven days a week. Approximately ten to twelve ETP vehicles are operating during the peek traffic periods (8).

Figure 1. Example of an IDOT Emergency Traffic Patrol Vehicle

Los Angeles, California – Metro Freeway Service Patrol

The Metro Freeway Service Patrol was formed in 1991 and is jointly operated by the Los Angeles County Metropolitan Transportation Authority (MTA), California Highway Patrol (CHP), and the California Department of Transportation (CalTrans). In fiscal year 2000 these agencies combined to fund the $20 million annual budget, with $15 million coming from the MTA and $5 million coming from the state agencies. The program in Los Angeles contracts out 100 percent of the service patrol services to local towing companies. Annually, the patrol assists over 350,000 motorists in the Los Angeles area. The Metro Freeway Service Patrol is responsible for approximately 411 miles of freeway in the Los Angeles area. During peak hour traffic the patrol has 146 contracted vehicles on the freeways performing motorist assistance. The service patrol has 125 tow-trucks patrolling in addition to 21 pick-up trucks. The patrol provides service Monday-Friday 6:00 A.M. – 10:00 A.M., 3:00 P.M. – 7:00 P.M. in all areas. In addition, some areas receive service Monday-Friday 10:00 A.M. - 3:00 P.M., with some areas even having service on Saturday and Sunday from 10:00 A.M. – 6:00 P.M. The goal of the Los Angeles program is to move obstructing vehicles out of the lanes of traffic to improve freeway flow. The operators of the vehicles receive safety, operations, and communication training from the CHP before they can begin performing service patrol duties (*9*).

Figure 2. Example of Los Angeles Metro Freeway Service Patrol Pickup Truck

Cincinnati, Ohio – ARTIMIS/CVS Samaritan

Samaritania, Inc. operates the Cincinnati freeway service patrol program under a subcontract to TRW Inc. The Kentucky Transportation Cabinet (KYTC) and the Ohio Department of Transportation (ODOT) contracted TRW Inc. to provide a freeway service patrol in the Cincinnati area. KYTC and ODOT provide 51 percent of the funding for the patrol, while the remaining 49 percent is funded by CVS drugstores. Founded in 1992, this program operates with the intention of providing free assistance to the motoring public and helps minimize the possibility accidents or traffic jams. The organization of the patrol is notable in that a mix of public and private funding, in addition to private contractors are being used to provide the service to the motoring public. The service patrol has five customized one-ton vans that provide service on approximately 88 miles of freeway and two state routes in the Cincinnati area. The patrol is operational Monday-Friday from 6:30 A.M. - 9:30 A.M. and from 3:00 P.M. - 6:00 P.M. All five vans are operating during these hours. The operators of these vans are some of the more trained operators around the country. They are ASE certified mechanics in addition to being trained EMTs. The van drivers are obligated to stop and investigate any disabled vehicle on the side of the road. In these cases the operator will render minor assistance, however, if major repairs are necessary, the operator will call for a tow truck to remove the vehicle from the roadway. The vans are on scene at an incident for an average of 15 minutes before either the incident is resolved, or further assistance is summoned (10).

Figure 3. Example of ARTIMIS/CVS Samaritan Van

St. Louis, Missouri – Motorist Assist

Founded in 1992, the Motorist Assist program in St. Louis, Mo., serves 131 miles of freeways in and around the St. Louis Area. Motorist Assist is completely operated and funded by the Missouri Department of Transportation (MoDOT). Motorist assist has 14 three-quarter ton pickups that are operational Monday-Friday from 5:00 A.M. to 7:30 P.M. In addition to the 14 pickup trucks, MoDOT also owns and operates an emergency response truck. The operators for Motorist Assists all receive training in first aid, CPR, vehicle fire fighting, media communication, hazardous materials, and incident management. The service patrol has an average response time of 15 minutes and typically discovers incidents while patrolling a designated route. Sometimes operators are notified of an incident by a MoDOT dispatcher, or by local law enforcement agencies. The Motorist Assist program exists to reduce traffic congestion and improve traffic flow. Though small, the MoDOT motorist assist program has been well received by the public, and plans are in the works for expanding the current routes and number of drivers.

Figure 4. Example of St. Louis Motorist Assist Pickup Truck

Charlotte, North Carolina – Incident Management Assistance Patrol

The North Carolina Department of Transportation (NCDOT) operates the Incident Management Assistance Patrol (IMAP) in the Charlotte Area. NCDOT fully funds the program which patrols 55 centerline miles of freeway, and has the ability to respond to an additional 50 miles when assistance is need at a major incident. The Samaratania organization also co-sponsors a service patrol with CVS drugstores along 16 miles of Interstate 77 through Charlotte. The IMAP patrol consists of eight three-quarter ton pickups with a utility bed in addition to one supervisor vehicle. The patrol operates Monday-Friday 5:30 A.M. until 9:30 P.M. and 10:00 A.M. through 6:00 P.M. on Saturdays, Sundays and holidays. IMAP typically has three to four vehicles operating during peak hours. If heavy congestion is expected, other vehicles may be called into service. The operators have all received Red Cross first aid training, in addition to a two-day precision driver and operations training from the North Carolina State Highway Patrol. Interestingly, the operators are trained in Hazmat operations, and have the training to contain a diesel fuel spill up to 200 gallons. One of the strengths of the IMAP program is the interagency relationships that have been established. The IMAP operators will typically provide traffic control for minor and major accidents while the Highway Patrol or local law enforcement agencies perform accident investigation duties.

Figure 5. Example of an North Carolina DOT IMAP Pickup Truck

DEVELOPMENT OF GUIDELINES FOR FREEWAY SERVICE PATROLS

Identification of Effective Practices

Through the course of the survey, various practices have been identified as unique, or effective. These are characteristics freeway service patrols that other agencies would be wise to emulate. In the following section, the practices will be identified and expanded upon.

Training

The amount of training that the operators of the service patrol received was highly variable from location to location. However, the need for training was evident when discussing freeway service patrol characteristics with the person surveyed. Some freeway service patrols such as the ETP in Chicago had highly trained operators while others, such as the San Antonio Courtesy Patrol operators had no formal training. It is obvious that the more trained the operator, the better the service offered to the motoring public will be. From the survey of existing patrols, the following types of training were identified as characteristics of a freeway service patrol:

- First Aid / CPR training;
- Basic automotive repair;
- Basic automotive fire fighting skills;
- Haz-Mat identification and procedures;
- Traffic control techniques;
- Incident Management; and
- Public Relations / Communications;

These areas of training all play an important role in the day-to-day operation of a freeway service patrol. First Aid/CPR training is necessary because at many incidents, the FSP operator will the first person on scene, thus they can evaluate the critical injuries and begin primary care. Since the operators are assisting the motoring public who are at many times experiencing car trouble, it follows that basic automotive repair would be a requisite skill for an operator. Vehicle fires and hazardous materials spills are also likely incidents for an operator to discover during a patrol, thus the ability to follow a proper protocol in dealing with the incident makes it safer for everyone involved. Training service patrol staff in incident management and traffic control techniques reinforces the basic ideas and principles that the freeways service patrol is trying to accomplish. Many agencies have semi-annual or annual refresher courses in these topics. Communications and public relations training is included in many programs because negative public relations can be detrimental to the success of any government-funded program, thus it is necessary for the operators to present themselves professionally to the motoring public. Many agencies have very well organized formal training programs. One such agency is the Atlanta HERO program, who's operators receive 316 hours of training. The modules of their training are detailed in Table 5.

Specialized Equipment

A freeway service patrol with access to special equipment such as tow-truck will be more effective in it efforts to keep the roads clear. A service patrol vehicle with towing capabilities does not have to wait for a tow truck to be called to the scene of an incident that can not be pushed from the roadway, this means that the incident will be cleared faster and less congestion will result from the incident. Some of the larger and more effective programs in the country utilize vehicles with towing capabilities. A comparison of all survey respondents is available in Table 6. Directional arrows or retractable arrow panels are also an example of specialized equipment that a service patrol may have at its disposal. These electronic devices allow the patrol vehicle to perform traffic control duties in a safer manner than vehicles without such equipment. Push bumpers seemed to be standard equipment on the service patrol vehicles, yet they are still an example of a type of specialized equipment that enables a patrol to be successful. Access to other types of equipment, such as heavy-duty wreckers and rotating crash cranes would also allow a freeway service patrol to perform a larger role in the incident management program of a location.

Guidelines for Freeway Service Patrols

Define the service patrol's goals, and steps to attain them.

By having a set of definite goals, the patrol operators are more focused and sure of their job. Defining goals will also help in prioritizing the response to incidents. If the freeway service patrol's primary goal is to keep the freeway clear as opposed to assisting the motorist, operating procedures would reflect this philosophy. For instance, an agency may establish a maximum time limit available to assist a motorist before ordering a tow. There is less room for incorrect decisions by the operators when well-defined operating procedures exist and are complimentary to the patrol's stated goals.

Establish interagency cooperation agreements before operations begin..

Service Patrols that cooperate with other local agencies such as fire and law enforcement are more effective in responding to freeway incidents if an formal agreement outlining each agency's responsibilities is established. Formally defining each agency's role in clearing an incident can reduce miscommunication and other problems that may develop at the scene. Support for the agreement from upper management down will help ensure that the staff on scene overcome any previous problems and will work towards fulfilling their responsibilities.

Table 5. Modules of a FSP Training Program (*11*)

Training Module	Presenter	Hours
Course introduction	Moreland Altobelli Associates, Inc	2 hours
DOT Manual of Guidance	Moreland Altobelli Associates, Inc	2 hours
Local police, fire, EMT coordination	Moreland Altobelli Associates, Inc	4 hours
Legal and liability issues	Moreland Altobelli Associates, Inc	4 hours
Public relations/communications	Moreland Altobelli Associates, Inc	8 hours
Defensive driving	Georgia Safety Council	6 hours
Hazardous materials awareness	Georgia Emergency Management Agency and Georgia Fire Academy (GEMA-GFA)	8 hours
Hazardous materials first responder	GEMA-GFA	24 hours
Bloodborne pathogens	GEMA-GFA	8 hours
Personal safety	Georgia State Patrol	8 hours
CPR	Georgia Department of Transportation Enforcement Training Officer	8 hours
First aid - first responder	American Red Cross	44 hours
Traffic control	Georgia Department of Transportation	24 hours
Basic auto mechanics	Georgia Department of Transportation	36 hours
Preventative maintenance	Georgia Department of Transportation	4 hours
Crash victim extrication	GEMA-GFA	16 hours
Commercial driver license	Georgia Department of Transportation	8 hours
Radio and telephone protocol	Georgia Department of Transportation	8 hours
Commercial wrecker training	WreckMaster	48 hours
Certified flagger	Georgia Department of Transportation	8 hours
Standard operating procedures	Moreland Altobelli Associates, Inc	16 hours
Portable variable message sign	Georgia Department of Transportation	4 hours
Sand spreader truck	Georgia Department of Transportation	4 hours
Push bumper training	Georgia Department of Transportation	8 hours
DOT safety standards	Georgia Department of Transportation	6 hours
Total		**316**

Institute service on short congested routes

The service patrol should begin operation on priority routes in an area. By starting small, the patrol, if successful will be more likely to gain more funding allowing it to expand to less congested corridors, or in some cases, even expand off of the freeway system onto secondary routes.

Ensure service patrol operators are well trained

Patrol operators that have a solid understanding of incident management and traffic control procedures are more valuable on the scene of an incident than an operator who is unsure of what to do. In the event of a traffic accident, a patrol operator who is trained in first aid is much more valuable than one who can only block a lane of traffic with a vehicle. The public opinion of the program can be impacted by the perceived knowledge level of the operators.

Utilize tow-trucks or quick tow devices when possible

The time saved in clearing an incident from a busy freeway should necessitate a service patrol having towing capabilities. When a patrol has to wait on law enforcement and or private towing companies, this prolongs the length of time an incident is on the freeway, and in turn increases the amount of congestion that results. Previous research has recommended that freeway service patrols make use of vehicles that have the capability of removing lightweight vehicles from the freeway (6). Push bumpers are useful in this task, however they cannot always be used to remove a vehicle from the roadway.

Table 6. Towing Capabilities of Freeway Service Patrols

Freeway Service Patrol Name	**City**	**Primary FSP Vehicles have towing capability**
Highway Emergency Local Patrol	Albany, NY	
Freeway Service Patrol	Carson City, NV	
Incident Management Assistance Patrol	Charlotte, NC	
Emergency Service Patrol	Cherry Hill, NJ	
Emergency Traffic Patrol	Chicago, IL	Yes
ARTIMIS/CVS Samaritan	Cincinnati, OH	
Mile High Courtesy Patrol	Denver, CO	Yes
Motorist Assistance Program	Houston, TX	
Service Patrol	Kansas City, KS	
Metro Freeway Service Patrol	Los Angeles, CA	Yes
Freeway Friends	Louisville, KY	
Hoosier Helpers	Louisville, Indiana area	
CHART Emergency Traffic Patrol	Maryland	Yes
Milwaukee County Enhanced Freeway Patrol	Milwaukee, WI	Some
Highway Helper Program	Minneapolis, MN	
Tennessee HELP	Nashville, Memphis, Chattanooga, Knoxville	
Bay Area Freeway Service Patrol	Oakland, CA	Yes
Metro Freeway Service Patrol	Sacramento, CA	Yes
Courtesy Patrol	San Antonio, TX	
Motorist Assist	St. Louis, MO	
Freeway Incident Response Team	Virginia Beach, VA	

Embark on a public relations campaign

Sell the freeway service patrols benefits to the motoring public. If the public is happy with the program, then the politicians will be happy with the program as well. Good public opinion can make it easier to secure more funding for route or vehicle expansions.

Budget for the wear and tear on vehicles involved in the patrol

Some agencies may forget to budget for the expenditures necessary for successfully maintaining a fleet of vehicles that in some locations may be driving 500 plus miles a day. One of the greatest concerns for some operators is the condition of their vehicles, and they find it hard to perform their duties in vehicle that is unfit to drive (7).

Periodically make a comparison with other patrols around the country.

Every few years it may be necessary to compare the freeway service program to others around the United States to ensure that the operating characteristics are still in line with what the more advanced or more successful patrols are doing.

CASE STUDY: EVALUATION OF A FREEWAY SERVICE PATROL

Description of Existing Program

The Houston Motorist Assistance Program (MAP) was created in 1986 through a joint partnership of the Texas Department of Transportation (TxDOT), Houston METRO, the Houston Automobile Dealers Association (HADA), Houston Cellular, and the Harris County Sheriff's Department (HCSO). Currently the goal of MAP is to keep traffic flowing, assist the stranded motorist, and generally make Harris County area freeways safer. Funding for the program comes from the aforementioned agencies. In Table 7 below, the amount and percentage of MAP program funding contributed by each agency is detailed. The HCSO operates Houston MAP even though it only contributes funding for 12 percent of the total operating costs. This arrangement is different from most other freeway service patrols that were surveyed because usually the agency that contributed the most funding operated the patrol.

Houston MAP uses 18 mini-vans donated by HADA to patrol approximately 190 miles of local freeways. The patrol operates Monday-Friday from 6:00 A.M. to 10:00 P.M. There are 7-9 vans patrolling during each peak hour period. Since the program is operated by the HCSO, all operators are trained peace officers in the State of Texas and have all associated powers. However, this is the limit of their current training (*12*).

Table 7. Funding of Houston MAP

Agency	Total Contribution	Percent of total operating costs
Harris County Sheriff's Dept.	$165,866	12 percent
Houston METRO	$795,000	56 percent
Texas Dept. of Transportation	$350,812	25 percent
Houston Auto. Dealers Assoc.	$80,000	6 percent
Houston Cellular	$32,700	2 percent
TOTAL	$1,424,378	

Recommendations for Houston MAP

Houston MAP is a very successful program, as its benefit cost ratio is between 6.6:1 and 23.3:1 (*13*) Even though the program is considered a success there are some areas where the program can be improved. An application of the suggested guidelines for freeway service patrols will identify areas where Houston MAP can improve.

Define goals and methods of attaining them.

MAP officers know that the general goal is to assist Harris County Motorists while keeping the freeways clear. MAP officers realize that their primary concern is to remove vehicles that reduce the capacity of the Houston freeway system while ensuring the safety of the motoring public. They also know the steps needed to attain this goal.

Develop formal agreements regarding local law enforcement agencies' roles.

MAP is a model program for interagency cooperation as it relates to funding. MAP funding comes from the local transportation agencies and local law enforcement, as well as local businesses. The MAP program could benefit from a formal written agreement defining the roles that MAP and other local law enforcement agencies will perform on the scene of an incident. MAP's primary purpose is not to write accident reports, their purpose is to keep the freeways of Houston clear and as such, they should arrange for other agencies with legal jurisdiction to make the scene of accidents that have been moved off the freeway by a MAP officer. Immediately upon arrival of another law enforcement officer, the MAP deputy should be free to continue on his patrol route unless assistance is needed for traffic control at the current incident.

Increase number of vehicles or decrease route length.

MAP currently work with a set of routes that originated from smaller routes on the most heavily traveled freeways in Houston. Under the current system, map operates on 190 one way miles of the Houston freeway system. This is a large program, however, Houston only patrols the 190 miles with seven MAP vans during peak hour traffic. This gives a ration of 0.037 vehicles/mile for the program. In comparison, Los Angeles has a ratio of 0.355 veh/mile or roughly 9.6 times the coverage of the Houston Program.

Provide more training to the MAP officers.

While MAP operators are trained Peace Officers, they have little first aid training. In addition, MAP officers rarely receive Incident Management or Traffic Control training, thus at times, even though they are carrying out their duties, they may be compounding the congestion problem due to lack of knowledge of incident management or traffic control. The ability to recognize hazardous materials, life threatening injuries, and incidents that will pose serious traffic problems are a necessity for a freeway service patrol operator, and these skills usually only come through training.

Implement towing capabilities.

The MAP program in Houston utilizes mini-vans with push bumpers. While these are convenient when a vehicle is occupied, if an obstructing vehicle is abandoned, a MAP officer must call for a private tow-truck to remove the vehicle from the roadway, which leads to a longer incident clearance time.

Advertise the program more.

The MAP program has been existence for almost 15 years yet many people in Houston do not know that the program exists, nor do they no how to contact MAP to receive free assistance while on a Houston freeway. If MAP were to advertise more on local television or on billboards along the freeway, it can be presumed that motorist awareness of the program would increase. With increased motorist awareness or the program, public support may increase, thus increasing the chances of gaining increased funding from local governmental agencies.

Secure funding for vehicles, maintenance, and an increased number of operators.

As the previous study indicated this is something that MAP has not planned for accordingly in the past. This could be the result of any number of factors, many of which are out of the control of the Harris County Sheriff's Department who operates the MAP vehicles and is responsible for their upkeep. However, the need to secure funding for more vehicles exists as the current fleet is too small to effectively serve the ever-expanding Houston Metropolitan Region. Because Houston MAP is a model public-private partnership, it is possible that the program could solicit funds from more businesses in the Houston area. In comparison, the budget for the Chicago ETP program is approximately 3.5 million dollars while MAP only has a budget of 1.4 million dollars (7).

Compare MAP to other programs.

To effectively evaluate the performance of the MAP program it may be necessary to compare the freeway service program to others around the United States to ensure that the operating characteristics are still in line with what the more advanced or more successful patrols are doing.

Benefits of Improvements

The first and most obvious benefit of implementing some of these recommendations would be the increased level of service the Houston MAP program could provide for Houston motoring public. With either more vehicles or smaller routes, the MAP operators could come into contact with more motorists before they arrange for private service. In addition to increased visibility and service, a larger fleet would be able to more efficiently and more quickly remove vehicles from Houston's freeway system resulting in less delay due to incidents. The ability to quickly remove vehicles would be further increased if Houston MAP was to implement tow trucks or vehicles with towing capabilities as their primary patrol vehicle. A third effect of a more efficient MAP program would be increased air quality in the Houston metropolitan area. Though this effect is not as measurable or predictable as the benefits from other improvements, less congestion and delay results in fewer emissions from automobiles on the freeway system, thus improving the air quality in the Houston area.

CONCLUSIONS

Freeway Service Patrols have slowly become more popular since their inception in the 1960's. Currently freeway service patrols exist in a wide variety of forms. From very small publicly funded patrols, to medium sized patrols funded by public-private partnerships, to extremely large federally and state funded patrols that help more than 250,000 motorists a year. The primary goals of a freeway service patrol must be to help keep the freeway clear of minor incidents, and to assist the motoring public. As more cities turn to integrated incident management programs, interagency coordination between service patrols and other agencies will become more crucial. As the patrols become more involved in incident management they can evolve from minor incident resolution only, to full-scale catastrophic incident response. Chicago, which has the oldest freeway service patrol in the country, also has the most functional program in that it evolved from serving only minor incidents, into the large-scale response unit that it is today. The Chicago program is a well-suited model for the growing patrols of today. As more patrols are developed, it becomes imperative that newly formed patrols learn from the mistakes of their older counterparts. By following the basic guidelines established in this paper, as well as learning from existing patrols, a newly forming service patrol can quickly become a model program.

Further research into freeway service patrols is needed. An in depth look at the effects training, vehicle choice, and patrol route length have on freeway service patrol effectiveness would be of interest to any agency operating a service patrol.

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- Scott Cole, North Carolina DOT;
- John Corbin, Wisconsin DOT;
- Scott Evans, TRW Transportation Systems;
- Frank Horne, Tennessee DOT;
- Dan Howard, New York State DOT;
- Cory Johnson, Minnesota DOT;
- Teresa Krenning, Missouri DOT;
- Barney Leslie, TRW Transportation Systems;
- Juanita Lowe, Kansas DOT;
- Keith Maki, Nevada DOT;
- Alvin Marquess, Maryland SHA;
- Al Martinez, Los Angeles County Metropolitan Transportation Authority;
- Ryan McCann, New Jersey DOT;
- Jennifer Obertino, Illinois DOT;
- Gilbert Sanchez, Texas DOT;
- Don Schmidt, Illinois DOT;
- Lieutenant W.T. Sparks, Harris County Sheriff's Department;
- Radiah Taylor, Oakland Metropolitan Transportation Commission;
- George Thompson, Virginia DOT; and
- Brian Williams, Sacramento Metropolitan Transportation Authority.

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11. Fenno, David. *Personal Correspondence and Interview.* Texas Transportation Institute, July 2000.

12. Survey response for the Houston Motorist Assistance Program, completed by Lt. Bill Sparks, Harris County Sheriff's Department.

APPENDIX A: FREEWAY SERVICE PATROL QUESTIONNAIRE

NAME: ______________________ DATE: ________
AGENCY: ______________________ TITLE: ______________________
PHONE: ______________________ EMAIL: ______________________
CITY: ______________________ STATE: ______________________

FREEWAY SERVICE PATROL NAME: ______________________________

The purpose of this questionnaire is to gather information on the operation and organization of Freeway Service Patrols around the country. This information will be incorporated into a paper that is being prepared for the summer graduate course *Advanced Surface Transportation Systems* at Texas A&M University. The information presented in the paper may be used as a guide for the development of a new service patrol, or in the evaluation and improvement of existing service patrols. If you have questions please contact John Denholm via email: denholm@tamu.edu or by phone: 979.862.8492.

Please complete and return to John Denholm by Fax (979.845.6006) on or before **July 7th, 2000.**

If return by Fax is not possible please mail to:

John Denholm
CE/TTI 410 E
Texas Transportation Institute
Texas A&M University System
3135 TAMU
College Station, TX 77843-3135

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1) What agencies operate the Freeway Service Patrol (FSP) in your area?
2) What agencies fund the FSP? What percentage of operating costs does each agency absorb?
3) Are any FSP services provided by a private contractor? If so, which?
4) How many miles of freeway does the FSP serve?
5) How many vehicles are in the FSP fleet?
6) What are the operational hours of the FSP?
7) How many vehicles are operational during peak hour traffic?
8) What kind of vehicles does your FSP utilize (e.g. tow-truck, pick-up, van, etc.)?
9) Does your patrol have any special equipment at its disposal? (heavy-duty wrecker, etc.)
10) Do the FSP'S drivers have any special training (e.g. police, fire, medical personal actually driving patrol vehicles)
11) How / Who notifies the FSP of an incident?
12) What are the average incident response and incident clearance times for the FSP?
13) What is the FSP "typical" response or role in the following types of incidents:
    - A) Debris on roadway
    - B) Stalled / disabled vehicle in moving lane of traffic
    - C) Minor accident (property damage only)
    - D) Major Accident (injuries)
    - E) Catastrophic Incident
        - 1) Accident with HAZ-MAT spill
        - 2) Fatal accident
        - 3) Freeway structural failure.
14) What are the goals of the FSP?
15) Does the FSP in its current form meet these goals?
    - A) If not, what improvements need to be made?
    - B) If you could develop the program from scratch, what would be done differently in its implementation?
16) What are the strengths and weaknesses of your FSP?

APPENDIX B: FREEWAY SERVICE PATROL CONTACT LIST

City, State	Agency	Contact	Phone	Freeway Service Patrol Name
Albany, NY	New York State DOT	Dan Howard	518-485-2805	Highway Emergency Local Patrol (HELP)
Carson City, NV	Nevada DOT	Keith Maki	775-888-7446	Freeway Service Patrol
Charlotte, NC	North Carolina DOT	Scott Cole	704-342-6814	Incident Management Assistance Patrol (IMAP)
Cherry Hill, NJ	New Jersey DOT	Ryan McCann	856-795-4747	Emergency Service Patrol
Chicago, IL	Illinois DOT	Don Schmidt	847-705-4157	Emergency Traffic Patrol
Cincinnati, OH	TRW Transportation Sys.	Scott Evans	513-564-6113	ARTIMIS/CVS Samaritan
Denver, CO	Colorado DOT	Jim Blake	303-757-9511	Mile High Courtesy Patrol
Houston, TX	Harris County Sheriff's Department	Lt. W.T. Sparks	713-755-7347	Motorist Assistance Program (MAP)
Kansas City, KS	Kansas DOT	Juanita Lowe	913-677-5963	Service Patrol
Los Angeles, CA	Los Angeles County Metro. Trans. Authority	Al Martinez	213-922-2956	Metro Freeway Service Patrol
Louisville Area	TRW Transportation Sys.	Barney Leslie	937-259-4882	Freeway Friends
				Hoosier Helpers
Maryland (state wide program)	Maryland SHA	Alvin Marquess	410-242-8589	CHART Emergency Traffic Patrol
Milwaukee, WI	Wisconsin DOT	John Corbin	414-227-2166	Milwaukee County Enhanced Freeway Patrol
				Gateway Patrol (Racine/Kenosha Counties)
				Waukesha County Gateway Patrol
Minneapolis, MN	Minnesota DOT	Cory Johnson	612-341-7500	Highway Helper Program
Memphis, Nashville, Chattanooga, Knoxville, TN	Tennessee DOT	Frank Horne	615-532-3462	Tennessee HELP
Oakland, CA	Metro. Trans. Comm.	Radiah Taylor	510-817-3209	Bay Area Freeway Service
Sacramento, CA	Sacramento Metro. Trans. Authority	Brian Williams		Sacramento Metro Freeway Service Patrol
San Antonio, TX	Texas DOT	Gilbert Sanchez	210-615-5863	Courtesy Patrol
St. Louis, MO	Missouri DOT	Teresa Krenning	314-340-4317	Motorist Assist
St. Louis Area	Illinois DOT	Jennifer Obertino	618-346-3275	Emergency Patrol
Virginia Beach, VA	Virginia DOT	George Thompson	757-424-9903	Freeway Incident Response Team (F.I.R.T.)

JOHN P. DENHOLM III

John Denholm III received his Bachelor of Arts degree in Mathematics from the University of St. Thomas in May 1999. He is currently pursuing a Master of Science degree in Civil Engineering at Texas A&M University. He is employed as a Graduate Research Assistant by the Texas Transportation Institute. University activities include active membership in the Texas A&M student chapters of the Institute of Transportation Engineers and the American Society of Civil Engineers. As an undergraduate, he received Certification in Spanish for International Commerce and served as president of the Mathematics Club and as a Senator in the Student Association for two years. His areas of interest include: incident management, traffic operations, and traffic law enforcement.

A COLLABORATIVE APPROACH TO TRANSPORTATION, INCIDENT, AND EMERGENCY MANAGEMENT IN LOUISIANA

by

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SUMMARY

Effective management and operations of our transportation system has been the charge of area and statewide public officials in Louisiana for decades. Over the years, jurisdictional boundaries were established and responsibilities were outsourced legislatively to local transportation management agencies and policing authorities to address the need of providing regionalized public service. This approach resulted in institutionalizing the management of the transportation system creating oftentimes disjointed and ineffective traffic and incident management strategies and operations. Advancement of technology found in automation and telecommunications has given transportation leaders the ability to effectively deliver seamless, safer, and more efficient operations to the public. Building on this technology, the Federal Highway Administration (FHWA) initiated the national Intelligent Transportation Systems (ITS) program to encourage states to automate transportation services, integrate multiple systems across jurisdictional boundaries, and foster a "team" approach to providing transportation, incident, and emergency management services. This team approach allows agencies to maximize delivery of public service with existing and sometimes less staffing capability and financial means.

The Louisiana Department of Transportation and Development (DOTD) with the support of other state and local agencies initiated the state's ITS program with the premise that improved transportation, incident, and emergency management and operations from both a regional and statewide perspective would result. ITS planning studies have indicated that DOTD and other state and local agencies should seek ways to partner with each other to provide seamless transportation, incident, and emergency management services. Such partnering includes pooling of scarce resources (personnel and financial), sharing of information, assuming the lead agency in providing primary responsibilities, and supporting other agencies' functions required in managing recurring and non-recurring events on the transportation system.

The purpose of this research was to identify roles and responsibilities, institutional and organizational change needed, architectural framework, and general deployment strategies required to establish and sustain an interagency, collaborative transportation management and operations program. Those agencies responsible for transportation, incident, and emergency management and involved in this collaboration are the Louisiana Office of Emergency Preparedness (LOEP), Louisiana State Police (LSP), and DOTD. A task force was established comprising key representatives from the three agencies and charged with developing a common mission, objectives, system framework, and mechanics of an interagency action plan.

Best practices and lessons learned were obtained from a research review of ITS and various transportation and incident management programs. Representative state departments of transportation were contacted and traffic management centers toured to document mission and functions played by the DOT in an interagency transportation management and operations setting. Concepts of operation and interagency partnering opportunities and agreements among state and local agencies were also reviewed.

The major finding of this research was that all agencies (DOTD, LOEP, and LSP) could realize significant benefit by pooling resources, sharing common space and function, and maximizing use of transportation information in providing transportation management services to Louisiana. Further, it was felt that a collaborative agreement between the three agencies would solidify support of a statewide transportation, incident, and emergency management program. A common system was identified to support a collaborative program, referred herein as the Louisiana Advanced Transportation Information System (LATIS).

This system will be administered by DOTD through interagency task forces comprised of DOTD, LOEP, and LSP personnel in conjunction with various local, state, and federal transportation stakeholders. The function of LATIS, consistent with the national ITS architecture guidance, is to provide a common framework and repository of data for multiple agencies in Louisiana to analyze, disseminate, and share

information on the state's transportation, incident, and emergency conditions. Multiple agencies and stakeholders should be involved with integration, technology, and communications aspects of LATIS and DOTD should be responsible for facilitating the engineering and integration of the system. To effectively manage this system, it was felt that changes in organizational makeup of DOTD should be explored. Establishing a transportation management and operations group within DOTD that reports directly to the Chief Engineer, exclusive of traditional operations and maintenance services, was recommended to enhance the state's ability to fully leverage administrative and financial support to develop and sustain LATIS for the long term.

- Based on the derived benefits and need of an interagency program among state agencies in Louisiana, a preliminary interagency agreement was developed. Components of this agreement were as follows:

- The DOTD will be responsible for managing and operating the state's transportation system under normal and recurring and regionalized non-recurring traffic conditions. Support functions will be provided by LSP and other local transportation agencies. Regional transportation responsibilities supporting an advanced traffic management system (ATMS) will fall under the authority of the DOTD District office, which can be delegated to local authorities through the form of city-state agreements. The DOTD will remain the authoritative transportation management and operations agency on all interstate highways and expressways.

- LSP will be the lead agency responsible for managing, commanding, controlling, and the enforcement of transportation-related incidents. While they will receive site-related support from DOTD and other agencies under this agreement, the LSP would facilitate all elements of incident management in Louisiana. These elements include establishing incident management teams and plans in the urbanized areas to be coordinated by the regional troop commanders, and providing a source of training and incident management awareness through federally sponsored workshops.

- LOEP will have the authority, as given by the Governor under the emergency operations plan, to command, coordinate, and administer emergency or disaster operations. Such emergencies include natural (hurricanes, flooding), technological (chemical spills), and national (nuclear attack) events. Emergency operations of all affected state and federal agencies should be delegated through the LOEP in accordance with the previously developed plan.

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INTRODUCTION

Efficient management and operations of our transportation system has been a goal of the traffic services community for decades. Over the past 10 to 20 years, advancements in automation, telecommunications, and systems have migrated into the transportation operations arena thus giving engineers and transportation agencies greater ability to effectively manage the freeway and arterial network and share information. Given that multiple agencies (i.e., local transportation agencies, State Departments Of Transportation, State Patrols, etc.) oftentimes have overlapping responsibilities in transportation, incident, and emergency management, technology provides a "glue" by which agencies now can pool resources, share information that has value among multiple agencies, and provide better delivery of transportation services to the public.

The Intelligent Transportation Systems (ITS) program initiated by the Federal Highway Administration (FHWA) is devised to capitalize on benefits that technology lends to transportation. ITS is a tool that comprises a set of technological applications to monitor, detect, and analyze transportation conditions and deploy strategies that focus on improving operational efficiency and safety of the transportation system (*1*). The goal of any ITS deployment is service oriented; to improve system efficiency and provide an agency seamless delivery of transportation services to the facilitator and user. Placing intelligent "eyes and ears" on the transportation network gives public and private agencies capability to be more responsive to changing conditions of the transportation system resulting from normal traffic congestion, minor and major incidents, special events, and regional or national emergencies.

As the ITS program matures, FHWA, state, and local agencies realize potential benefits brought about by interagency and private sharing of resources and information. Thus FHWA along with the Institute of Transportation Engineers (ITE) is placing current emphasis on developing new concepts of transportation management and operations. An ITE-sponsored National Steering Committee on Transportation Operations recently initiated a national dialogue on transportation operations involving 400 transportation professionals in April 2000. One of the core elements discussed, inherent to effective management and operations, was the need for better coordination and more collaboration of resources among state, local, and private agencies. Professionals realize with advanced communications and data collection/dissemination systems, and the specter of diminishing staffing and financial support, pooling of agency resources becomes desirable and often necessary to sustain the level of transportation services expected by the public.

The Louisiana Department of Transportation and Development (DOTD) recently established an Intelligent Transportation Systems (ITS) initiative to aggressively pursue the implementation and operation of advanced technologies managing the state's transportation system. Among the goals of this program is to identify and carry out the state's role in a multi-agency approach, both local and state, to managing and operating transportation systems, incidents, and emergency situations.

This "outside-the-box" concept presents institutional, organizational, and technical challenges to state agencies in Louisiana that must be overcome in establishing a cooperative, collaborative partnership. State and local governmental agencies often operate under rigid, bureaucratic, directives exclusive of sister agency missions and responsibilities. This traditional business practice transcends jurisdictional barriers that produce disjointed, inefficient transportation operations. Often interagency transportation management and operation ventures are unsuccessful because multiple individuals and organizations have differing and potentially unclear roles and responsibilities (*1*). These participants may be acting from incomplete technical understandings of systems and situations with differing motivations and priorities. Nevertheless, multiple agency interaction is necessary to optimize performance of overburdened transportation systems and agencies (*2*).

Regional ITS deployment in Louisiana involving multiple local and state agencies is taking shape. Currently, the cities of New Orleans, Baton Rouge, and Lafayette are developing regional advanced transportation and incident management systems (ATMS) to be coordinated through multi-agency traffic management centers (TMCs). These facilities will house and coordinate communications of personnel and systems that manage and operate the region's freeways, traffic control signals, service patrols, incident and emergency response, and traveler information. Such agencies include local transportation engineering and public works, incident management and emergency response teams, DOTD district transportation operations engineering, and regional Louisiana State Police (LSP) troop personnel. Future systems are planned for the Shreveport and Bossier City, Lake Charles, Monroe, Alexandria, Bayou (Houma and Thibodaux), and Northshore (Hammond and Slidell) urban regions. DOTD statewide ITS functions (i.e., technical support, training, systems development and integration, etc.) will be housed and coordinated out of the Baton Rouge TMC with high-speed communications provided between the regional TMCs to comprise Louisiana's ITS program. A map shown in Figure 1 is provided in the supporting information section of this paper graphically depicting this statewide program.

Certain transportation conditions resulting from a multi-jurisdictional event such as inclement weather (i.e., fog, hurricanes, chemical spills, flooding, etc.) give rise to a macroscopic approach to managing the transportation network in Louisiana. The responsibility of managing these high-level emergencies has been delegated to the Louisiana Office of Emergency Preparedness (LOEP). LOEP is planning to construct a new facility to serve as the focal point of interagency emergency management and coordination for the state. The facility will provide 24 hour, 7 day-a-week coordination and dispatch for all affected state and local agencies and will be interconnected to the statewide ITS communications network provided by DOTD (see Figure 2).

PROBLEM STATEMENT

The need to reduce the effects of recurring and non-recurring roadway congestion has grown with increased levels of traffic demand. These problems are common to Louisiana's highway landscape in the developed areas and rural segments of interstate highways elevated over waterways and natural boundaries. In addition to recurring congestion, the threat of flooding, fog or hurricanes, chemical-related emergencies, and special events pose increasing detriment to normal transportation operations unique to Louisiana.

Aside from road-related problems, state and local agencies in Louisiana are faced with smaller less technically oriented staffing and limited budget resources while sustaining and increasing the level of operational services demanded by the public. A survey of 20 state transportation agencies by Daniels and Starr reported a 20 percent shortfall in both funding and staffing of ITS (*3*). However, new and expanded ITS deployment was expected to increase 300-400 percent in the next 5 years. Half of responding states rated their current ability to operate and maintain these systems as fair to poor and over 70 percent expect future levels to be fair to poor. Research indicates ITS programs that encourage pooling of resources and share information can offset diminishing expenditures while maintaining and often increasing efficiency and effectiveness of agency services (*1*).

Given the benefits derived from ITS, a collaborative, cost-effective interagency approach to managing and operating the state's transportation system is needed by DOTD, LOEP, and LSP. With state's commitment toward developing and sustaining a comprehensive ITS program, an interagency action plan is needed to document roles and responsibilities, organizational makeup, and systems elements required to leverage information sharing opportunities.

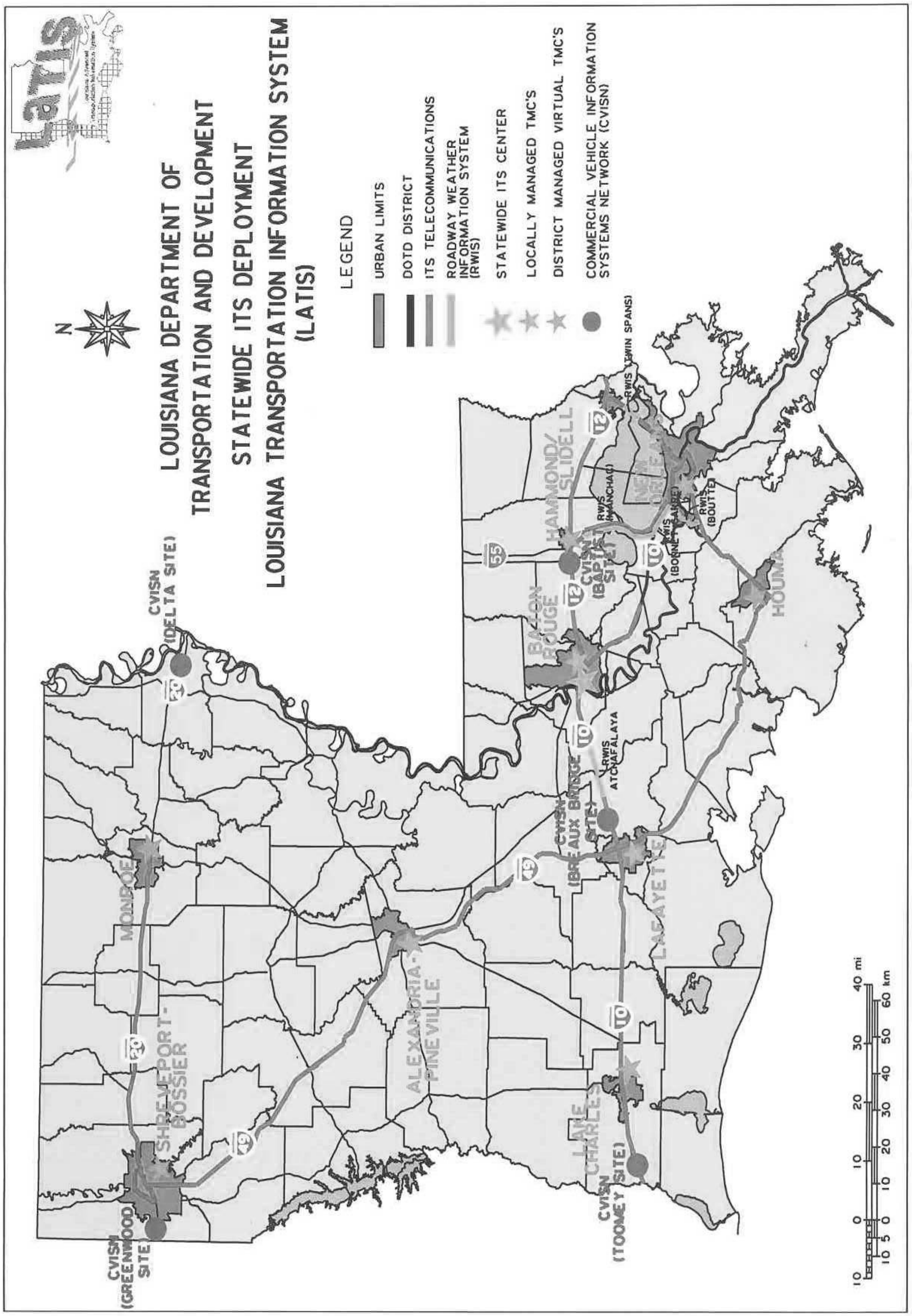

Figure 1. Map of Louisiana's ITS Program

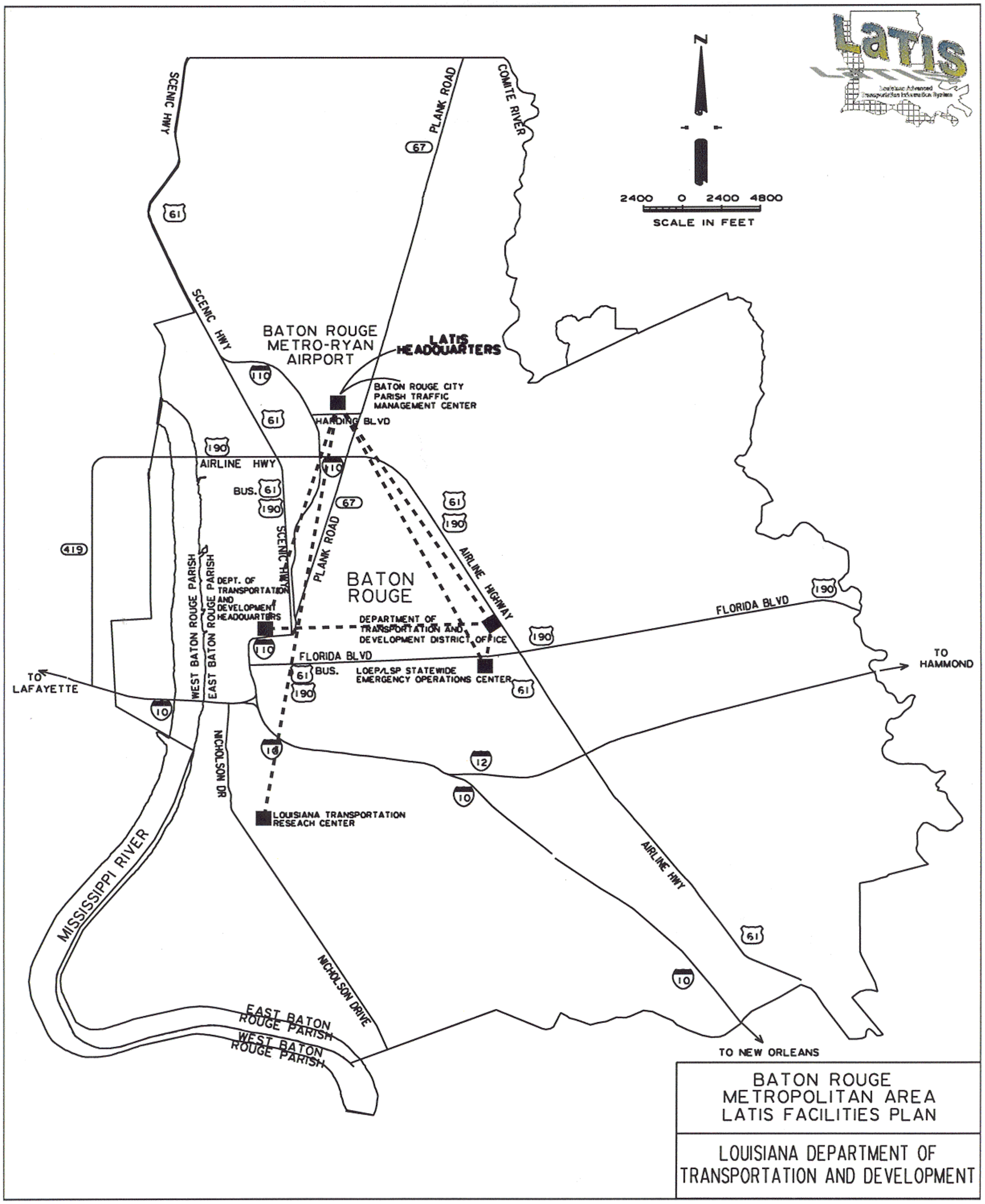

Figure 2. Map of DOTD, LSP. & LOEP Communications Network

PURPOSE AND RESEARCH OBJECTIVES

The purpose of this research is to develop an action plan for Louisiana that supports an interagency effort between DOTD, LOEP, and LSP to manage and operate a statewide transportation, incident, and emergency management program. Best practices and lessons learned from other transportation agencies through research review and interviews with representative state agencies will serve as the basis for developing this plan. Existing management and operations practices within DOTD, LOEP, and LSP will also be documented. A task force comprising representatives of these agencies will be consulted to develop roles and responsibilities of their agency in support of an interagency partnership. Finally, organizational structure and ITS elements required to support this partnership on behalf of DOTD will be explored.

Specifically, the objectives of this research effort were to:

1. Document current practice and lessons learned in developing transportation, incident, and emergency management systems from a four representative state departments of transportation (DOT);
2. Summarize current management and operations practice within Louisiana related to the affected agencies of LOEP, LSP, and DOTD;
3. Identify existing institutional and organizational constraints within DOTD and propose solutions to implementing and sustaining a successful interagency ITS program; and
4. Propose an effective and mutually beneficial action plan in which DOTD, LOEP, and LSP would jointly participate in an interagency transportation, incident, and emergency management program by mapping out:
   - Interagency roles and responsibilities;
   - Organizational structure changes within DOTD to support and maintain presence; and
   - ITS elements required to maximize sharing of information and maintain interagency support.

LITERATURE REVIEW

Mechanisms of interagency partnerships have been well documented by FHWA and ITE as follow-up study of impacts the national ITS initiative had on such programs. This literature review focused on identifying best practices and lessons learned derived from other state and local agencies in establishing and maintaining an interagency transportation, incident, and emergency services program.

Institutional and Organizational Issues

The most important characteristic involving the makeup of any transportation, incident, and emergency management program is institutional coordination (2). Regardless of the agencies' role in an interagency initiative, it was found that close coordination with all agencies should begin in the planning phase of ITS deployment and continue throughout every phase of project development. Before initiating the ITS planning process, management and operational needs of each agency should be clearly defined and agreed to before any project is developed (2). When projects are being developed, operational commonalities should be assessed in systems architecture to maximize the use of information and maintain the level of agency investment. Interagency participation, consensus, and oversight are required in ITS deployment to ensure devices are strategically placed to maximize the utility provided to each agency. On-going resource commitment in personnel and funding among agencies is essential to sustaining adequate management and operations of the program. And finally, interagency participation is essential to effectively integrate multiple functions to provide useful, seamless, and more efficient delivery of transportation services to the public.

An example of cooperative roles of multiple agencies in TMC operation includes the Detroit TMC, which is jointly staffed by Michigan State Patrol (MSP) and Michigan DOT (1). MSP dispatchers provide incident information to the MDOT TMC operations contractor who then provides verification, support responses, and real-time traveler information. Regional and state transportation management, control, and enforcement are not compromised and TMC services include all affected agencies providing transportation management services within the region. Moreover, it is feared by all agencies in the Detroit TMC, that institutional policy restricting any primary functions may preclude integration and coordination of agency functions and will ultimately lead to disjointed and ineffective operation and control of the transportation system.

Benefits of intra and interagency coordination were found to be less confusion and more visibility among the agency's decision-makers, efficient use of staffing and resources through better internal and external control, improved employee motivation and involvement, better coordination among agencies, and reduced costs (*3*). Also, several state and local transportation agencies surveyed found benefit in collocating multiple agency functions in a single building or common communications network to foster strong interagency communication and coordination.

The overriding problem resulting from interagency partnerships is that roles and responsibilities have not been clearly defined at the outset (*4*). Such teaming without a clear vision creates resentment where agencies are indifferent to one another's requirements and often impedes the flow of funding from one institution to the facilitating agency. This creates a cascade of possible problems that can slow the project development to a point where any meaningful progress is difficult (*4*). A core message from interagency partnerships has been that a thorough and effective vision built on commonalities can achieve wonders in supporting project advancement. Key elements include: a thorough knowledge of each partner's roles and responsibilities, understanding each partner's capabilities and limitations, and managing expectations.

Other key elements to developing and maintaining a successful interagency transportation services program depend on two conditions: 1) where the program reports within the agency's hierarchy, and 2) its relationship to regional transportation agencies' responsibilities (*4*). This relationship should be clearly defined and worked out before deploying an ITS program to avoid confusion over whose responsible for its management and operations. Administratively the transportation management and operations program is best located in a state DOT's organizational structure where it can receive the bureaucratic and financial support required to maintain operations (*5*). This support is accomplished at the highest level possible within the agency, which is typically in an exclusive transportation operations department. At the departmental division level the ITS program manager would report directly to an operations administrator to emphasize the importance and compete for funding, equipment, and staffing on equal footing with highway maintenance and construction functions of an agency.

Information Technology and ITS Issues

Among the primary benefits to transportation agencies brought about by advanced technologies is the ability to collect and share valuable information void of jurisdictional constraints. For this reason, FHWA encourages agencies to look for opportunities for joint, integrated operations (*1*). Systems should be configured to allow all transportation agencies to access ITS devices, share and analyze data collected and images generated, and control devices in an organized fashion. Systems should also allow for operation of fixed or portable traveler information systems by other agencies. The integration and operation of ITS should be based on the need to share information among agencies to manage the regional transportation network as a whole rather than a narrow, institutionalized focus of a single transportation agency. It has been shown that agencies can successfully operate common systems in centralized or distributed environments without conflict (*6*). To address interagency operations and integration needs, the ITE National Committee on Transportation Operations developed six activity areas and actions to be taken. These are:

1. Establishing the vision;
   - A vision for transportation beyond the narrow box of traffic operations and perceived traffic engineering activities
2. Building a constituency;
   - Involve emergency response professionals, emphasizing the advantages seamless communications will provide in terms of improved response times
   - Be inclusive of all stakeholders
3. Developing benchmarks of system performance;
4. Identifying sources and levels of funding;
   - Much could be accomplished just by changing the mindset within transportation agencies to take fuller advantage of the flexibility already provided by existing programs
5. Facilitating institutional change; and
   - Change DOT mindset from a builder of a system to an operator of one
   - DOT organizations should rid themselves of superiority complex
   - Get serious about clearing freeway incidents
   - Elevate operations through traditional DOT hierarchy
   - Create new institutional view of agency responsibility
6. Setting the research agenda.

Identifying information sharing opportunities has been shown to provide incentive for interagency partnerships (*6*). ITE suggests that agencies should first look for opportunities and mechanisms to build trust and understanding among each other and share in resources and information rather than shy away from institutional barriers brought about by traditional ways of doing business by state and local bureaucracy (*2*).

Summary of Literature Review

In summary, it was found in this literature research that professionals encourage:

- Identifying interagency coalitions and agency "champions" with specific purposes to address common informational needs;
- Developing an interagency program among local and state agencies to coordinate transportation, incident, and emergency management efforts such as proposed in this research; and
- Developing a team atmosphere among agencies not to monopolize the decision-making process, but rather develop win-win situations in which one agency can gain value from information collected by another.

It was envisioned that information sharing brought about by common ITS communications and platforms would encourage agencies such as DOTD, LOEP, and LSP to pool resources and provide financial support for a common system. Research in this area shows that an honest effort is required by these agencies; however, to operate "outside-the-box" and break down institutional barriers that can impede or stop the migration of advanced technology into the state's transportation system.

CURRENT PRACTICE OF STATE DOT ORGANIZATIONS

Interviews of Representative State DOT Organizations

Transportation professionals of several state DOT organizations were contacted to obtain information on existing management and operations programs and interagency relationships resulting from deployment of their respective ITS program. This information was gathered from four representative state DOT organizations with the purpose of determining how these agencies addressed:

- Focus of the state DOT's concept of operations in developing and maintaining a transportation, incident, and emergency management program (i.e., lead or support agency, and regionalized or statewide approach);
- Roles and responsibilities of the state DOT in an interagency partnership to facilitate statewide transportation, incident, and emergency operations;
- Interagency partnerships (formal and informal) and mechanisms devised to achieve cooperation;
- Changes in DOT organizational structure to sustain effective management and operations;
- Innovative financing mechanisms employed to sustain and expand operations; and
- Policy directives that lead to or result from an interagency partnership.

The four representative states contacted were the Maryland State Highway Administration (SHA), the Minnesota Department of Transportation (Mn/DOT), the Virginia Department of Transportation (VDOT), and the Washington Department of Transportation (WSDOT). Information collected from these state DOT organizations relating to their respective management and operations programs is summarized in Table 1.

Results of this state DOT evaluation summarized in Table 2 showed that the success of each state program was found in the state DOT's willingness to establish and maintain a lead presence and effective working relationships with sister local and state agencies. In every case, state DOTs obtained strong mid-management level support from local transportation, transit, and incident response agencies, and state patrol and emergency operations personnel despite, oftentimes, waning administrative or political support. Although formal operating agreements had been drafted by all agencies primarily for incident and emergency management, most DOTs indicated that good working relationships with other agencies could exist without contracts.

All state DOTs facilitated some form of organizational change to better accommodate interagency transportation management and operations needs and maximize effectiveness gained by advanced technologies. In many cases, management and operations functions were separated from traditional construction and maintenance activities and placed on more stable organizational footing to obtain its fair share of financial support with competing interests. Common to initiating these four programs were agency "champions" with a strong transportation management and operations vision that commanded and gained financial and staffing support in the agency's traditional hierarchy.

Scanning Tour of Texas DOT Transportation Management Centers

On June 13-14, 2000, DOTD administrators conducted a federally sponsored scanning tour of Texas TMCs stationed in the Fort Worth and Houston Districts. These sites were chosen by DOTD based on their function and applicability to regional ITS programs planned in Louisiana.

It was found that Texas DOT varies on its approach to transportation, incident, and emergency management from district to district in terms of a distributed versus centralized concept of operations. Hence, the roles of Texas DOT in management and operations vary widely in each district. Those roles basically include the following:

- The leader for traffic control on the freeways (e.g. lane control signals and ramp meters);
- The leader in establishing incident management programs in urban areas;
- The supporter of local transportation management and operations functions;
- The policy-maker in defining architecture requirements and standards to ensure system commonality and compatibility; and
- The facilitator of information gathering and dissemination for use by other agencies and the private sector.

Table 1. Summary of State DOT Organization Transportation Incident, and Emergency Management Programs

Characteristic		State DOT Transportation, Incident, and Emergency Management Programs			
		Maryland's CHART	Minnesota's TMC	Virginia's Smart Travel	Venture Washington
Concept of Operation		• Statewide TMC concept • Regional TMC connection • Functions: • Congestion monitoring • Traffic management • Traveler information • Incident management • Communications • Road-weather information • Systems integration • Service patrols	• Regional TMC concept, statewide connectivity • Functions: • Congestion monitoring • Traffic management • Traveler information • Incident management • Commercial vehicles • Intelligent vehicles • Public transportation • Systems integration • Service patrols	• Regional TMC concept, statewide connectivity • Spot rural safety systems • Functions: • Traffic management • Traveler information • Incident management • Commercial vehicles • Intelligent vehicles • Public transportation	• Regional TMC concept, statewide connectivity • Spot rural safety systems • Functions: • Traffic management • Traveler information • Incident management • Commercial vehicles • Road-weather information • Public transportation • Service patrols
• Agency Involvement		• SHA primary with MSP, MdTA & local agencies support	• Mn/DOT primary with State Patrol, Public Transit & local agencies support	• VDOT primary with local agencies support	• WSDOT primary with WSP support
Roles & Responsibilities	Transportation Operations	• Primary: • Freeway management • Service patrols • Traveler information • Operations staff at SOC • Support: • Urban traffic signals • Public transit	• Primary: • Freeway management • Public transit • Service patrols • Traveler information • Operations staff • Support: • Urban traffic signals • Public transit	• Primary: • Freeway management • Service patrols • Traveler information • Operations staff • Support: • Urban traffic signals • Public transit	• Primary: • Freeway management • Service patrols • Traveler information • Operations staff • Support: • Urban traffic signals • Public transit
	Incident Management	• Primary: • First responder • Traffic management • Traveler information (special events) • Support: • Debris removal • Traffic control	• Primary: • Motorist assistance • Traffic management • Traveler information • Support: • Site/scene management • Debris removal • Traffic control	• Primary: • Emergency coordination • Traffic management • Traveler information • Site/scene management • Support: • Debris removal • Traffic control	• Primary: • Traffic management • Traveler information • Site/scene management • Support: • Debris removal • Traffic control
	Emergency Management	• Primary: • Traffic management • Traveler information • Support: • Traffic control • Public information & comm.	Primary: • Traffic management • Traveler information Support: • Traffic control • Public information & comm. • Hazmat coordination	Primary: • TEOC operation • Public information & comm. • Traffic safety • Damage assessment Support: • Traffic control	Primary: • Traffic management • Traveler information Support: • Traffic control • Public information & comm.
Organizational Structure Change		• Operations Division	• Metro Operations Division	• Traffic Operations Division	• Traffic & Safety Division
Interagency Agreements		• Roadway clearance policy • Incident management plans	• Roadway clearance policy • Incident management plans	• Emergency operation plan • Incident management plans	• Roadway clearance policy • Incident management MOU

Table 2. Summary of State DOT Evaluation

State DOT ITS Program	Program Overview	Successes
Maryland SHA CHART	• Initiated in 1996 • The CHART Business Plan that resulted detailed a 6-year program headed by the SHA in full partnership with the Maryland Transit Authority (MdTA) and the Maryland State Patrol (MSP). • The major thrust of this program was to develop an integrated system of multiple transportation management agencies and operations with the common focus alleviating the impacts of recurring traffic congestion, incident that block the roadway, and emergencies that require regional and statewide movement of people and goods.	• Great reliance placed on agency teamwork and partnering necessary to achieve program objectives. • Development of a roadway clearance policy, which gave SHA authority to reinstate the flow of traffic by clearing incidents from the roadway. • Interagency cooperative effort of SHA, MSP, and MdTA to jointly operate the Statewide Operations Center in Hanover. This centralized SOC supports regional TMCs in Baltimore and other key areas.
Minnesota DOT Guidestar	• Initiated in 1991 • Organizational makeup founded as a partnership of public, private, and academic sectors with Mn/DOT assuming the lead role in development and facilitating systems integration.	• Strong cooperation between local public and private sectors. • Mn/DOT built on regional successes into deploying statewide ITS program. • Great emphasis placed on developing strong organizational framework for management and operations.
Virginia DOT Smart Travel	• Initiated in 1993 • Based on statewide ITS deployment of regional and district TMCs to manage and operate localized systems connected together to form a statewide network. • Future of Smart Travel is to continue deployment with a regionalized focus and connect each of the Smart Travel centers to form a statewide ITS network.	• Participation by local transportation and other state and private agencies is necessary for successful long-term operations • In 1994 Virginia Connections was developed that overcame institutional barriers and focused on provision of interagency delivery transportation services. • VDOT has worked since then to develop advanced technologies in transportation that transcends institutions.
1. Washington DOT 2. Venture Washington	• Initiated in 1992 • Guided by WSDOT and local transportation management agencies • WSDOT in cooperation with local and state agencies efficiently builds, maintains, operates, and promotes safe and coordinated transportation systems. • With regard to incident and emergency management, the WSP is given the authority of Incident Commander. WSDOT's responsibilities to the incident consist of site and scene management and providing traffic control and assistance in debris removal.	• Comprehensive and coordinated traffic management and traveler information systems on the Seattle/Tacoma area freeways, coordinated traffic control signal systems, commercial vehicle information systems, and site-specific road-weather information systems. • A memorandum of understanding developed between WSDOT and WSP that document roles and responsibilities of the two agencies given presence and type of incidents. A focus has been placed on a coordinated, expeditious opening of roadways that were affected by the incident while protecting the incident scene.

It was expressed in both districts that the role of Texas DOT in transportation management and operations should be that of leadership and ownership of those elements necessary to properly operate state-owned highways. Professionals within the organization concede that the core of ITS is locally focused, meaning that the districts should oversee key elements in ITS deployment. Except for those technologies and services that are planned and executed from headquarters in Austin (e.g., commercial vehicle operations), it is generally accepted that Texas DOT districts will represent the state's involvement in ITS. Within the established policy framework, each district will serve as an independent local partner. Statewide divisions in Texas DOT will be responsible for developing issues of statewide significance such as common operating platforms and systems integration, and promulgating (with District involvement) appropriate standards and practices, and monitor overall effectiveness of ITS deployment.

As the state's transportation network connects to locally owned roadways to provide seamless transition, so is the state's ITS program envisioned to function. However, the Fort Worth and Houston districts provide this seamless operation in contrasting methods. The concept of operation in the Fort Worth District takes on a distributed TMC nature in that Texas DOT and local transportation agencies will manage and operate the regional transportation system through a series of TMCs connected by a common communications system for sharing information. The TMC is stationed on the district grounds and currently houses Texas DOT transportation operations engineering and ITS personnel. It is currently connected via high-speed communications infrastructure to the City of Fort Worth TMC. It is planned to virtually connect to other local and state TMCs on a common operating platform to provide seamless transportation, incident, and emergency management and operations services to the Metroplex region.

The Houston Transtar facility operates under a centralized concept. The Transtar structure was developed from a consortium of local and state transportation agencies. The agencies of the City of Houston, Harris County, Houston Metro, and Texas DOT entered into a partnering agreement to collocate agency functions out of a central TMC. The facility is situated near the Texas DOT District and is jointly staffed and operated by the four agencies. A manager is appointed by the Transtar executive committee to coordinate multi-agency functions in a common setting.

The findings of this scanning tour showed that a state DOT can successfully operate common regional systems in centralized or distributed environments. The attractiveness of the decentralized approach followed in Fort Worth is that it avoids major investment in a central facility and allows smaller agencies to avoid creating full-time staffing dedicated solely to ITS. The primary drawback is that it depends on longer, more costly, and less direct lines of communication. Benefits of centralized operations in a common facility similar to the Houston Transtar include information sharing among various agencies, enhanced communication in all aspects of transportation management, and agencies working closely together produce more consistent, unified response to an incident or situation, thus increasing the overall effectiveness of the transportation resources.

OVERVIEW OF TRANSPORTATION, INCIDENT, AND EMERGENCY MANAGEMENT IN LOUISIANA

The next step of this research was to identify current agency roles and responsibilities of DOTD, LOEP, and LSP and recommended changes that would establish and sustain a statewide interagency transportation, incident, and emergency management program. This effort was limited to identifying agency commonalities in management and operations of transportation-related events with the understanding that non-transportation related functions would remain exclusive to that agency.

It was found that the current roles and responsibilities of DOTD, LOEP, and LSP are consistent with the transportation, incident, and emergency management agency functions identified in the national ITS architecture guidance document (7). These primary functions in the architecture include the following roles and responsibilities:

Transportation Agencies

- Plan and coordinate the overall incident management program;
- Provide TMC functions to assist in incident detection and verification; and
- Service patrols assist in accident clearance, determine roadway repair needs, assist disabled motorists, and coordinate response efforts with other agencies.

Incident Management Agencies

- Officers enforce the statutory authority of the Incident Commander (IC) to direct activities of the general public, including motorists and passengers, as well as bystanders. As peace officers they bring the ability to control scene activities and to arrest and remove violators who hamper emergency operations;
- IC utilizes law enforcement in traffic control and direction, bystander and crowd control, perimeter establishment and enforcement, and crime scene management;
- Personnel are often used in non-traditional roles as well such as: first aid, emergency extrication, media relations, coordination with traffic management, and manage evacuations.

Emergency Management Agencies

- Delegated the authority to command any incident, emergency, or disaster involving natural, technological, or national situation; and
- Highest priority situations addressed by emergency management are those affecting life safety, environment, and property damage.

By state law, DOTD is responsible for managing, operating, and providing engineering support on the state's transportation system. The LSP is the state's enforcement arm, responsible for command and traffic control of all incidents and highway-related emergencies. The LOEP is responsible for coordinating and managing all emergencies of regional and statewide significance (e.g., hurricanes, chemical spills, flooding, etc.). Detailed below is the agency's responsibility given the transportation, incident, or emergency agency function included in the national ITS architecture.

DOTD Responsibilities in Transportation Management and Operations

The Louisiana DOTD is responsible for planning, development, operation, and maintenance of nearly 895 miles of Interstate highways and approximately 15,800 miles of state owned roadways. Metropolitan Planning Organizations (MPOs) may also conduct planning for some urban interstate and state highway segments, but DOTD is typically responsible for programming planned improvements in the Statewide Transportation Improvement Plan. DOTD has also developed city-state agreements with municipalities for design, basic operation, and maintenance activities on state highways within urban limits. Such local jurisdictions are responsible for these activities with DOTD generally responsible for transportation management operations on all interstate highways.

Recognizing its role in transportation management and operations coupled with the need to leverage resources to maximize operational efficiency, DOTD initiated an ITS program. It is the mission of the DOTD ITS Program to improve efficiency and safety of transportation on Louisiana's highway infrastructure through the application of advanced technology and interagency cooperation. This program will rely heavily on continued communication, coordination, and cooperation among agencies and stakeholders such as the LOEP and LSP to foster relationships necessary to achieve this mission. In short, ITS will be the mechanism used to facilitate change within the DOTD to make the state more user-service oriented in delivering transportation services to Louisianans. This ideology is consistent with overall mission of DOTD, which is to make the agency a premier service organization.

DOTD's role in ITS project planning and implementation is similar to its responsibilities in general transportation planning. The DOTD ITS Program is responsible for:

- Implementing organizational change within DOTD to capitalize on opportunities for integrating ITS technologies in state and local project planning, design, implementation, and operations and maintenance;
- Providing leadership, expertise, and guidance in implementing planning and operational changes that promote information sharing and uniformity among multiple jurisdictions and local systems;
- Taking lead role in freeway management systems and programs, whether urban or rural;
- Providing appropriate financial, informational, and other support for locally sponsored ITS initiatives. These initiatives should be evaluated on a case-by-case basis and prioritized into DOTD Highway Project Selection Process; and
- Taking the lead role in identifying transportation needs and designing, deploying, integrating, and operating related ITS projects in rural areas.

In carrying out these transportation management and operations responsibilities, DOTD will:

- Establish and coordinate a statewide transportation management and operations function that links urban and rural ITS initiatives and incident and emergency management functions of other state and local agencies;
- Establish transportation management and operations functions in each DOTD District Office;
- Provide planning, design, deployment funding and operational support for ITS freeway and incident management initiatives undertaken by local jurisdictions;
- Fund and operate one or more state seats in all urban transportation management centers (TMCs);
- Design, deploy and operate incident and emergency detection systems in rural areas with links to the urban and statewide TMCs; and
- Develop and operate an advanced traveler information (ATIS) program via the Internet and other communications media that will provide real-time traveler information.

LSP Responsibilities in Incident Management

Incident management involves strategies to initiate immediate response to an incident from detection and verification to dispatch the appropriate personnel, to travel involved, to clearing incidents and re-opening lanes as quickly as possible; while protecting the safety of victims, travelers, and incident response personnel. The statewide incident management program in Louisiana was initiated from a regional program started in the Baton Rouge area in 1994. This early program recognized the overwhelming need to quickly and efficiently respond to incidents on the freeway to mitigate the effects of non-recurring congestion. The Baton Rouge local transportation agency in cooperation with DOTD, LSP, and FHWA established an incident management task force comprised of all local transportation and law enforcement leaders. Results of this effort developed program measures for the incident management team to follow in fulfilling the mission of the program. Among the key recommendations brought forth was to initiate, deploy, and operate a freeway motorist assistance or service patrol and an ITS program in the Baton Rouge area. These programs were envisioned to continue the interagency partnership that was established by the incident management task force; deploy ITS and incident detection devices, service patrols, and integrate cellular call-in programs to quickly detect and verify incidents. And also provide a common system framework in which multiple agencies could share information and pool resources.

DOTD was identified to play a key role in establishing this incident management program along with LSP. Based on the successes and lessons learned from the Baton Rouge initiative, LSP initiated an effort to introduce and deploy like incident management programs in other urban areas of the state (New Orleans, Shreveport/Bossier City, etc.) and ultimately develop a statewide incident management program. The objectives of this statewide incident management program are to:

- Leverage ITS applications in both urban and rural locations to reduce the operational and safety effects of non-recurring congestion from a regional and statewide standpoint;
- Grant authority to LSP and other approved transportation agency and law enforcement personnel to proactively remove incidents and debris from freeway travel lanes;
- Increase public awareness on incident management strategies and removal or lane clearance laws and programs; and
- Establish a common operating procedures and communications framework for regional and statewide incident response personnel.

The key component of this program is to integrate systems and agencies (local, regional, and state) to produce a common statewide incident management program. To date, the LSP troop districts in New Orleans, Shreveport/Bossier City, Lake Charles, and Northshore have established incident management teams. Efforts are underway by LSP to establish similar programs in Lafayette, Monroe, and Alexandria to complete the statewide program. Also, LSP has planned incident management training sessions in these areas as a precursor to initiating regional efforts.

LSP has identified its role as taking the lead in establishing and facilitating a coordinated statewide incident management program. The programs will have a regional focus coordinated out the LSP troops, which coincide with DOTD Districts. The Troop Commanders will be responsible for managing the regional incident management programs, which include:

- Involving all local and state transportation agencies in coordination meetings;
- Establishing a common communications platform for each agency; and
- Identifying an Incident Commander to manage various incident scenarios.

In coordination with DOTD and the local MPOs, LSP will develop Incident Management Plans that define roles and responsibilities of all affected agencies, detail incident scenarios, identify detour routes, and management and operational strategies to handle incidents.

LOEP Responsibilities in Emergency Operations

A Louisiana Statewide Emergency Operations Plan was developed and currently maintained by the LOEP in accordance with legislative mandate and authority given by the Governor. This plan establishes policy for state government response to emergencies and disasters. It assigns responsibilities, tasks, and actions that the state shall take to provide for the safety and welfare of its citizens against the threat of natural, technological, and national security emergencies and disasters. It addresses the need for mitigation, preparedness, response, and recovery activities, which will enhance the state's overall capability to cope with potential hazards.

Louisiana's geography and climate are unique to that compared to other states in that it is situated in the Gulf Coastal Plain and covers an area of approximately 51,000 square miles. Fourteen percent of the land area is covered with water in the form of lakes, rivers, streams, bayous, and wetlands. The overall terrain ranges from flat to gently rolling hills, from below sea level in the southern portion near New Orleans to slightly more than 535 feet above sea level in the northern part of the state. The climate is moderate with normally mild, wet winters and warm to hot summers with high relative humidity. Temperatures range from 100 degrees Fahrenheit in the summer to near or below freezing in the winter. Average annual rainfall varies from 64 inches in the southern portion to 44 inches in the northern portion.

Based in large part to unique climate and presence of petroleum and chemical industries, Louisiana faces a variety of risks, which pose significant threat to the safety and welfare of its citizens whether they are natural, technological, and/or national emergencies or disasters. These risks include:

- Natural - Hurricanes, tornadoes, flooding, dam or levee failures, freezes, winter storms, earthquakes, subsidence, erosion, drought, water shortages, and wildfires;
- Technological - Nuclear power plant incidents, transportation and other hazardous material incidents, and industrial accidents; and
- National Emergencies or Disasters - Nuclear attack, chemical/biological warfare, terrorist incidents, civil disturbances or riots, and resource shortages (utility of energy).

During an emergency or disaster, LOEP will take immediate and appropriate action to determine, direct, mobilize, and coordinate resource needs of state and local agencies. State and local agencies including DOTD and LSP are directed to suspend normal operations and redirect resources to save lives, relieve human suffering, sustain survivors, protect property, and repair essential facilities as directed by the LOEP. Many of the potential risks e.g. floods, hurricanes, and other severe weather, nuclear facility incidents and enemy attack would be preceded by a period of increased alertness, giving public officials time to take precautionary or protective measures to reduce loss of life and minimize damages.

The emergency operations plan is based on the premise that the emergency functions the various state and local agencies perform during emergency operations generally parallel their day-to-day functions. The same personnel and material resources will be employed in both cases. Day-to-day functions that do not contribute directly to the emergency operation may be suspended or redirected for the duration of any emergency or disaster, and efforts that would normally be assigned to those functions will be channeled toward emergency and disaster tasks assigned.

By the direction of the Governor, each state and local agency will have a multi-hazard emergency operations plan and implementing procedure. Authority and responsibility are to be as decentralized as possible to field units and individuals responsible for actual performance of operations. The Governor has the overall responsibility for emergency management and is assisted in these duties by the LOEP Director. Tasks for elements listed in the emergency operations plan are assigned to the state agencies as follows:

- Issue orderly succession of officials for all key positions in each department and every essential sub-departmental office, so that operations can continue when officials are absent or incapacitated;
- Insure the maintenance of safeguarding key records;
- Set up system for internal status reporting on manpower and other resources, estimates of damages, and actions taken for emergencies; and
- Organize, supervise, and coordinate all activities that take place in the functional area of responsibility.

Recommended Agency Primary and Support Roles

Based on state law and legislative mandates, DOTD's responsibilities relate to the safe and efficient management and operations of the transportation system under recurring and non-recurring traffic conditions. Functions include assuming the lead role in developing and sustaining effective operations of traffic management systems including motorist assistance patrols on the interstate highways, traffic control signal systems on state-owned highways, and the collection, dissemination, and integration of traffic-related data necessary to support a statewide traveler information program.

LSP is the lead agency responsible for managing, commanding, and controlling all transportation-related incidents on state-owned highways. The LSP will be responsible for establishing and facilitating regional incident management programs with the support of DOTD toward developing a statewide program. The LSP will be responsible for designating the appropriate Incident Commander and managing and controlling the scene. Their responsibilities transcend regional and statewide incidents.

LOEP, through the statewide emergency operations plan, delegates primary and support responsibilities for each state and federal agency in an emergency event. The plan defines 21 functions required by the state in an emergency or disaster scenario. These functions relate to administrative command and control, information dissemination and management, law enforcement and military response, and public safety and welfare. Table 3 summarizes the primary (P) and support (S) roles and reconciles the 21 emergency operations function to the responsible agency overseeing that function.

Based on this information, Table 4 was developed in this research to summarize the functions (primary and support) and required actions of DOTD, LOEP, and LSP under emergency situations. These functions were derived from the statewide emergency operations plan and matched with the transportation, incident, and emergency agency responsibilities outlined in the ITS architecture and provide the basis for developing an interagency agreement.

COMPONENTS OF AN INTERAGENCY ACTION PLAN

Overview

To develop the components of an interagency action plan, a task force made up of key representatives of DOTD, LOEP, and LSP was established. The charge of this task force was to develop common mission, vision, objectives, and program framework that would comprise an interagency partnership action plan to support a collaborative statewide transportation, incident, and emergency management program.

It was determined through research and input from the task force that Louisiana's state and local agency roles and responsibilities for transportation, incident, and emergency management functions have been well defined and formalized through development of Louisiana's Emergency Operations Plan and the LSP Incident Management Strategies. However, these plans do not address common systems architecture necessary to support communications, information dissemination, and advanced technology required in an interagency partnership. Based on input from the task force and in keeping with the vision of Louisiana's ITS program, it was concluded this interagency action plan would outline an integrated ITS program that drives a DOTD, LOEP, and LSP partnership.

This interagency statewide ITS program is hereinafter referred to as the Louisiana Advanced Transportation Information System (LATIS). The successful implementation and sustained operation of LATIS depends on interagency consensus brought about by a common mission, vision, objectives, and program framework that maximizes the state's investment in LATIS. It is realized that other state and local agencies will play a critical role in system development and their participation should be addressed in future action plan efforts. Considering the common functions of DOTD, LOEP, and LSP in transportation, incident, and emergency management, the LATIS framework focuses on defining institutional and organization structure, integration requirements, and deployment initiatives required to fully implement LATIS. Based on results of discussions with the task force, the following mission, vision, objectives, and framework have been defined.

Mission

The motoring public of Louisiana anticipates and expects the freeway and major arterial network to provide a means of traveling from origin to destination in a safe, efficient, and seamless manner under both normal and extraordinary travel conditions. It is therefore the mission of DOTD, LOEP, and LSP to facilitate effective, seamless, customer-oriented transportation services in Louisiana through a state-level, integrated transportation, incident, and emergency management ITS program. Strategies developed through this LATIS program should work toward this common mission by promoting, developing, and sustaining support of an integrated, interagency concept that focuses on saving the public time, lives, and money.

Table 3. Emergency Function and Responsibility Chart of State and Federal Agencies

State or Federal Agency	Communication & Warning	Damage Assessment	Donated Goods	Emergency Direction & Control	Energy	Engineering & Traffic Management	Fire Fighting	Hazmat	Information Management	Law Enforcement & Security	Legal Issues	Mass Feeding	Medical & Sanitation	Oil Spill	Public Information	Radiological	Search & Rescue	Shelter Operations & Control	Traffic Control & Evacuation	Transportation	Watershed Protection
LOEP	P	P	S	P					P					S	P	S					P
National Guard	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S		S	P	
Agriculture & Forestry		S	S	S			P	S	S	S		S	S	S	S	S	S		S		
Office of Corrections	S			S					S	S		P			S		S	S	S	S	
Culture, Rec. & Tourism	S	S		S			S		S	S					S		S	S	S		
Economic Development		S	S	S					S						S			S		S	
Education		S		S					S						S			S		S	
Environmental Quality		S		S				S	S			S	S	S	S	P					
Division of Administration	S			S					S		S				S						
Elderly Affairs		S		S					S						S			S		S	
Oil Spill		S		S					S					P	S						
Business Advocacy				S					S						S						
Health & Hospitals		S	S	S		S		S	S				P		S	S		S			
Justice				S					S		P				S						
Labor		S		S					S						S						
Natural Resources		S		S	P			S	S					S	S	S					S
Social Services		S	S	S					S			S			S			P			
LSP	S	S		S				P	S	P				S	S	S	S		P		
DOTD	S	S	S	S	S	P			S	S			S		S	S	S		S	S	S
Wildlife & Fisheries	S	S		S			S	S	S	S		S		S	S		P		S	S	
Volunteer Organizations		S	P	S			S		S			S	S	S	S			S			
USA Corps of Engineers		S		S		S			S						S						S
US Coast Guard				S				S	S	S					S		S			S	
USDA-NRCS		S		S		S			S						S						S

Table 4. Primary and Support Functions and Responsibilities of DOTD, LOEP, and LSP

Agency	Primary Functions	Support Functions	Common Required Actions
DOTD	• Traffic Engineering • Freeway and Arterial Traffic Management • Traveler Information • Systems Integration	• Emergency communications • Damage assessment • Donated goods • Emergency direction & control • Energy • Information management • Law enforcement & security • Medical & sanitation • Public information • Search & rescue • Radiological • Traffic control & evacuation • Transportation • Watershed protection	**Primary** • Prepare detailed implementing procedures for all primary functions, to include the procedures by which the agency will be alerted and activated and perform the designated functions when required • Prepare requirements for supporting agencies and initiate coordination of responsibilities **Secondary** • Coordinate with the primary agency & learn what types of support and kinds of actions are required for given scenarios • Develop detailed implementing procedures for support functions consistent with the lead agency's responsibilities
LOEP	• Emergency communications & warning • Damage assessment • Emergency direction & control • Watershed protection • Information management • Public information	• Donated Goods • Oil Spill • Radiological	
LSP	• Law Enforcement & Security • Hazmat Transport • Incident Management • Traffic Control & Evacuation of emergencies	• Communications & warning • Damage assessment • Emergency direction & control • Information management • Oil spill • Public information • Radiological • Search & rescue	

Vision

The vision of the LATIS program should deploy a fully integrated ITS program that enhances safety, mobility, economic viability, and the quality of life for citizens, businesses, and visitors of Louisiana. This integrated system will focus on becoming the central repository of transportation-related information to facilitate regional and statewide functions of transportation, incident, and emergency management administered by DOTD, LSP, and LOEP, respectively.

Objectives

The common objectives of LATIS should be to use applications to:

- Improve the overall safety of the state's transportation network with emphasis on freeway operations;

- Improve effectiveness of transportation operations, and incident and emergency management through reducing the impacts of recurring and non-recurring congestion;
- Become the repository of and more effectively disseminate traffic, traveler, and weather information of traffic conditions during periods of recurring congestion, incidents, and emergency and special events;
- Promote more effective modal utilization by automating public transit operations, toll facilities, and priority facilities; and
- Improve administrative handling and operational safety and productivity of commercial vehicle operations with emphasis on the transport of hazardous materials.

Framework

The LATIS program should include process and technology-based initiatives to improve the operations of the state's transportation network through an integrated transportation, incident, and emergency management system administered collaboratively by DOTD, LOEP, and LSP. These initiatives are covered in four program areas that are designed to maximize the state's investment in ITS. The systems administration, engineering, management, and integration of LATIS will be spearheaded by DOTD with collaborative input from the LOEP and LSP, and future stakeholders. The program areas detailed in this framework and defined below include addressing the institutional and organizational needs, defining the system architecture and information sharing opportunities, and identifying deployment initiatives required to facilitate an integrated statewide LATIS network.

Institutional Structure - Policy directives and institutional arrangements that define roles and responsibilities of the primary agencies of DOTD, LOEP, and LSP are needed to successfully implement an interagency transportation operations and control, incident response, and emergency management system offered by LATIS.

Organizational Structure - It is incumbent upon DOTD administration to position transportation management and operations within the organization where it can best perform for the long-term. This element includes developing a recommended organizational hierarchy to position DOTD as the lead agency to capitalize on technological advancements fostered by the LATIS program.

LATIS Architecture - Among the benefits of LATIS should be the ability to share information collected by the system with other agencies, both state and local. Identifying information sharing needs among agency stakeholders is critical to successfully implementing LATIS operating agreements. To accommodate a common, interoperable system, architecture standards of LATIS must follow national ITS architecture guidance. This element includes addressing basic LATIS architecture and information flow to achieve an integrated system.

Deployment Initiatives - New Orleans, Baton Rouge, Shreveport/Bossier City, and Lafayette are developing or planning to develop TMCs to assist in advanced transportation and incident management and operation of their urban freeway and arterial systems. DOTD District managed TMCs are planned in Lake Charles, Monroe, Alexandria, Houma, and the Northshore region to facilitate a more limited ATMS and incident management program. DOTD is taking an active role in supporting and participating in development, funding, management, and operation of these local initiatives. The purpose of LATIS deployment in local areas is to integrate regional ATMS and incident management systems with a statewide emergency management program. In addition to urban applications, rural transportation needs will be accounted for in the LATIS program. Studies along the rural freeway corridors through Louisiana identify specific safety (e.g., fog and flood warning systems) and other emergency and transportation issues (e.g., commercial vehicle operations, hazardous materials routing) of statewide significance, which lend themselves to LATIS solutions. The LATIS program will include a process for addressing these issues on an as-needed basis.

Institutional Structure

From the existing institutional framework of Louisiana's state government, the following general responsibilities of facilitating and supporting LATIS by each agency is summarized in Table 5.

Table 5. Legislative and LATIS Responsibilities of State Agencies in Collaboration

Agency	Legislative Responsibilities	LATIS Responsibilities
DOTD	• Responsible for planning, construction, operations, and maintenance of highways in the state's transportation system • Lead agency for coordinating and managing transportation engineering, control, and operations under normal and emergency conditions	• Facilitating systems administration, management, engineering, and integration • Developing an ITS Unit to oversee deployment of initiatives • Establishing an ITS Technical Advisory Council • Coordinating with local metropolitan planning organizations (MPOs) to develop regional plans • Identifying a DOTD Headquarters Team comprised of intra- and interagency decision-makers charged with prioritizing regional and statewide ITS initiatives • Establishing a statewide transportation management and operations function within the department's hierarchy and house this function jointly with LSP in the Baton Rouge TMC facility to conduct regional and statewide activities
LOEP	• Responsibility reserved for events leading up to and including emergencies and disasters from a statewide significance • Coordinates emergency operations by facilitating communications, warning issuances, emergency direction and control, emergency information management, and public information dissemination	• Developing an emergency management and operations component to be integrated into the program by overseeing the deployment interagency communications and systems used to support statewide emergency operations • Working with DOTD and LSP and other agencies to develop regional and statewide emergency evacuation plans and traffic control that can be initiated through the program • Facilitating the state's Office of Emergency Preparedness center for interagency coordination during emergency events • Developing communication links between the LOEP center, the LSP center, and the DOTD center for LATIS operations • Actively participating on the ITS Technical Advisory Council and represent state's interest in emergency management
LSP	• Responsible for law enforcement and security on state's transportation system • Regulates and enforces the transport of hazardous materials and control of traffic during high-level incidents and evacuations • Assumes lead role in facilitating regional incident management teams	• Facilitating and managing regional and statewide ITS Incident Management Teams • Developing an Incident Management component to be integrated into the program by establishing an LSP presence in each urban TMC and overseeing the deployment of interagency communications used to support incident management • Actively participating as a support agency in the program to be jointly housed in the Baton Rouge TMC • Actively participating on the state's ITS Technical Advisory Council and DOTD ITS Headquarters Team and represent the state's interest in Incident Management

The institutional makeup of LATIS is based providing collaborative functions managing transportation, incidents, and emergency operations. To effectively define responsibilities, LATIS functions and hierarchy of management responsibilities are set forth. Functions or user services provided by LATIS should focus on satisfying ITS architecture requirements. The following seven functions or user services identified in the national ITS architecture compose the extent of LATIS development.

1. Advanced Transportation Management Systems (ATMS)
2. Advanced Public Transportation Systems (APTS)
3. Incident Management
4. Emergency Management
5. Road Weather Information Systems (RWIS)

6. Advanced Traveler Information Systems (ATIS)
7. Commercial Vehicle Information and Network Systems (CVISN)

The hierarchy of agency involvement, management, and control responsibility for each function should be directly proportional to the condition of the transportation system under normal or special events. That is to say, the authority delegated to each agency should depend on the location, level of severity, and size of response for a given traffic condition, incident, or disaster.

Based on these user services and the responsibility given to each agency, Table 6 summarizes responsibilities of DOTD, LOEP, and LSP both primary and support roles, and Figure 3 depicts the relationship of agency responsibility to condition of the transportation system, in facilitating this action plan. As seen from Figure 3, as the condition of the transportation system worsens from localized, to regional, to statewide significance, local and state agency involvement increases. For the day-to-day transportation management functions, local and DOTD district agencies will be given authority. As incidents occur affecting the transportation system on a regional or statewide basis, DOTD, LOEP, and LSP will take more of a lead role in performing functions. LATIS will provide the “glue” and triggering mechanism that facilitates this hierarchy of control based on the needs of the transportation system.

Organization Structure

Recent legislative actions require the DOTD to operate the following offices and functions in providing transportation services to the public of Louisiana:

- Executive - Administration, control, operations, and general affairs of DOTD;
- Management & Finance - Accounting and budget control, procurement, data processing, and personnel assignment;
- Highways - Engineering, construction, maintenance of highways;
- Planning & Programming;
- Planning and programming of transportation program, pavement management, and safety;
- Operations - Operations of districts and toll facilities; and
- Public Works & Intermodal Transportation - Public transportation, flood control, water resources, soil conservation, and disaster relief.

Currently, transportation management and operations and ITS within DOTD is conducted out of the Maintenance Division under the Office of Highways function overseen administratively by Chief Engineer. Recognizing the need to mainstream advanced technology (ITS) into a transportation agency’s operation, a number of states have established ITS or technology groups within the state DOT and other supporting agencies’ structure as found from the interviews with other state agency personnel. Typically, these groups are responsible for technology transfer and training of employees to operate the automated transportation systems deployed under ITS. Many of these agencies have restructured their transportation management and operations programs to lend importance to the functions, maximize the agency’s receipt of federal funding for operations, and provide a higher voice in the hierarchy to sustain long term funding support for ITS. Such organizational changes include creating a division within its engineering department exclusive of design, construction, and general maintenance and operations. In almost every successful program, a “champion” was identified within the DOT to initiate and become the driving force behind institutional and organizational change for the good of transportation management and operations.

Table 6. LATIS User Services Mapped to Agency Roles and Responsibilities and DOTD Activities

LATIS User Service	Description	Primary Agency	Support Agency	DOTD Activities
ATMS	Includes systems that manage the safe and efficient movement of people and goods on the state's freeway and arterial network (e.g., lane control signals, ramp meters, and traffic signals).	DOTD (Freeways) Local (Arterials)	DOTD (Arterials)	• Traffic engineering flow control and optimization • Traffic flow surveillance and detection • Traffic data sharing
APTS	Automates transit planning, operations, and management. Generally includes fleet management systems and automated passenger message relay.	Local	DOTD	• Support transit schedule reliability and security • Support park and ride information systems • Support flexible transit route strategies
Incident Management	Helps public and private organizations identify the occurrence and nature of a highway incident, initiate the appropriate response, and clear the incident quickly. Usually includes video monitoring and interagency communications systems. Requires establishing policies, incident command & control for all incidents.	LSP	DOTD & Local	• Freeway unplanned and scheduled incident identification, verification, and traveler information • Debris removal • Fog and inclement weather remediation in urban areas • Support response coordination and incident clearance
Emergency Management	Provides management of transportation services in the event of regional or statewide natural or manmade disaster. Typically includes interagency communications systems.	LOEP	DOTD & LSP	• Monitor transportation systems during catastrophic events • Coordinate DOTD response and support multiagency response
RWIS	Provides management of the freeway and other vital transportation services in the event of inclement weather or special event incidents that occur in the rural areas.	LSP	DOTD	• Monitor weather events and flood conditions • Monitor height and bridge loading restrictions • Monitor slow-moving traffic in rural areas • Support control and enforcement of restrictions on traffic flow
ATIS	Provides travelers information to help select the best transportation mode and route, advisories and in-vehicle information for convenience and safety, and simple instructions to reach their destinations. Can be used for day-to-day transportation management and during regional and statewide incidents and emergencies	DOTD	Local, LOEP & LSP	• Provide telephone and Internet traveler information • Broadcast advisories via highway advisory radio (HAR) • Operate dynamic message signs (DMS) • Develop and update electronic state highway map • Support other public and private sector traveler information services
CVISN	Automates domestic and international vehicle monitoring, clearance and enforcement. Typical systems include transponders in vehicles, readers at weigh stations, electronic credential systems, and automated weigh stations.	DOTD	LSP	• Provide transponder readers at weigh stations • Provide mobile weigh stations • Process electronic oversize and overweight permits • Support activities to automate clearance and promote transponders on commercial vehicles • Support other agencies' efforts to automate paperwork for permits, licenses, and fees

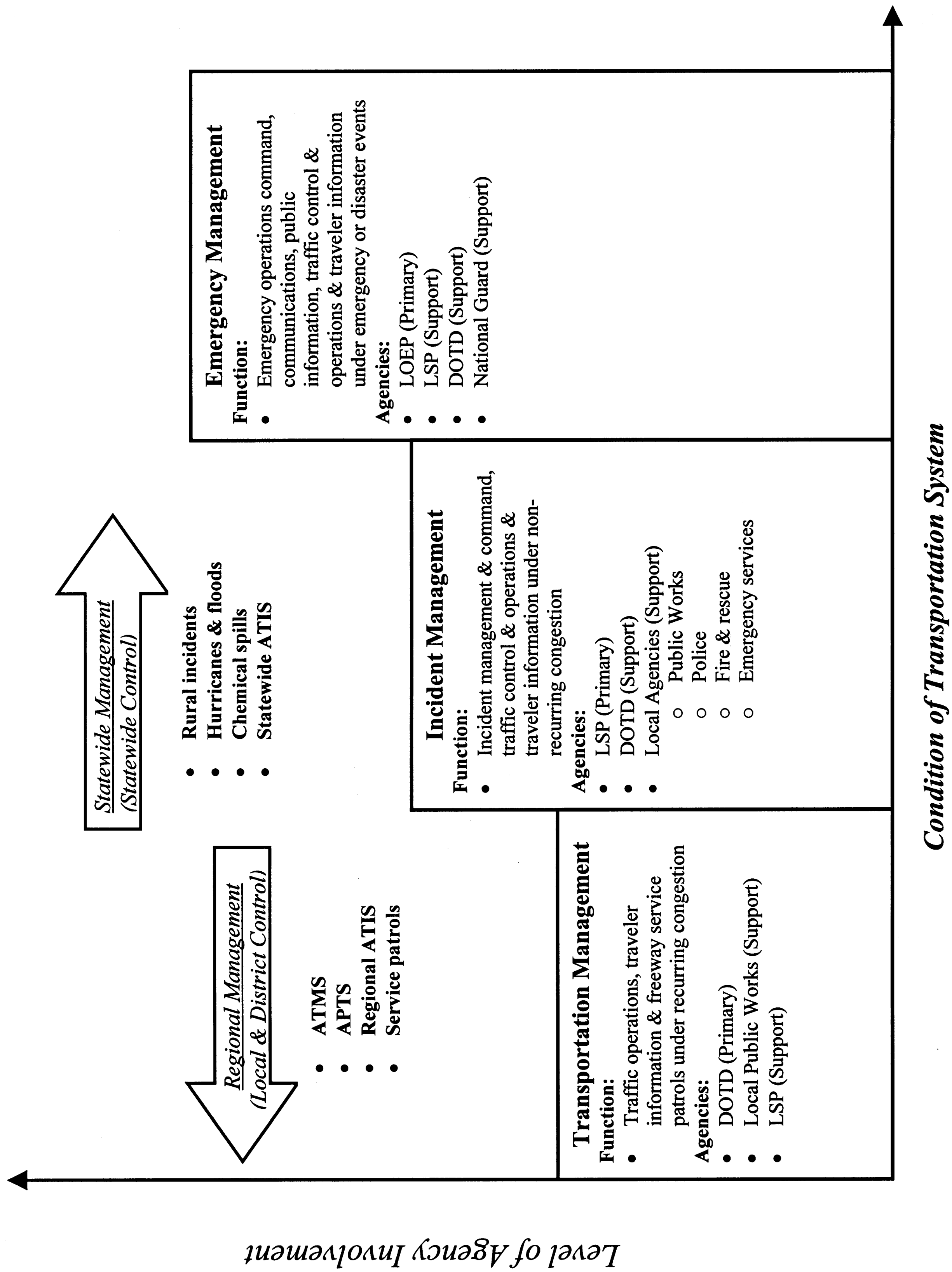

Figure 3. Hierarchy of Transportation, Incident, and Emergency Management

Organizational improvements of DOTD detailed herein are needed to capitalize on the technological opportunities of LATIS and leverage federal funding opportunities available for transportation management and operations.

Recently, DOTD has established an ITS Unit within its Traffic Engineering and Maintenance Section that reports to the general Maintenance and Operations Division under the Office of Highways. The chart shown in Figure 4 depicts the existing hierarchy of command for transportation management and operations and this unit. The ITS Unit was placed in this section to keep traffic engineering and ITS functions together. Traffic Engineering was combined with traffic maintenance (i.e., signals, signs, and markings) under a recent reorganization of DOTD. This function has traditionally been performed under DOTD Maintenance because field operations of traffic services coincided with functions of other sections in Maintenance (i.e., Bridge Inspection, Central Repair, Weight Enforcement Sections, etc.). It was found, however, that most functions conducted out of the traffic maintenance section, other than telecommunications, have little relation to the definition of maintenance, but rather are construction-related (e.g., installation of signals, signs, and markings).

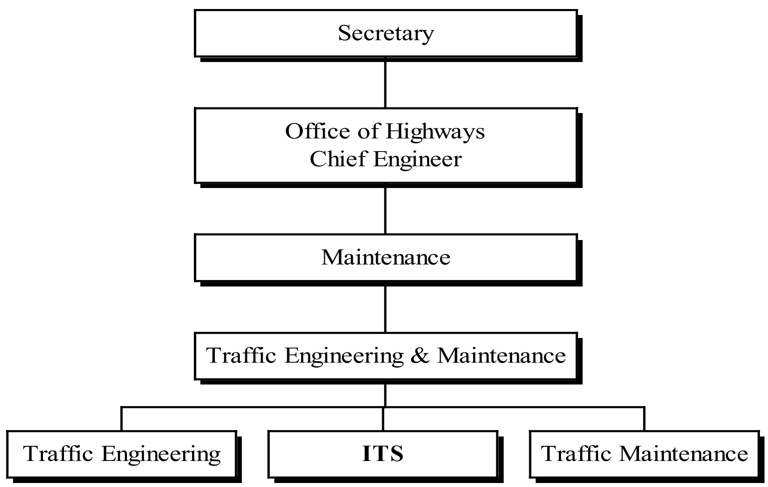

Figure 4. Existing Organization of Transportation Management and Operations and ITS

Operations and maintenance for highways and bridges are clearly defined, and that definition is frequently used for ITS as in this case (*4*). However, this definition is inappropriate for ITS since many of the traditional maintenance items are, in reality, operational readiness items for ITS. In other words, ITS field devices, communications between these devices and the TMC, and the automation in the TMC used to drive these devices constitute the system. If a component fails, the system becomes inoperable. In this case, systems maintenance activities are needed to support ITS operations and not vice-versa.

Also, traditional O&M functions performed out of DOTD Traffic Services (i.e., traffic signal preventive maintenance and upgrade) are funded using mostly state monies. Such O&M as it relates to transportation operations, however, is eligible for federal funding participation at 100 percent by FHWA in most cases. This funding is provided as a result of TEA-21 legislation and changes to the National Highway System Designation Act of 1995, wherein the definition of what constitutes an NHS eligible "project" was amended to include capital and operating costs for traffic control and management facilities eligible for up to 100 percent federal reimbursement. It is apparent that the organizational makeup of transportation management and operations within DOTD can be re-designed and improved to leverage federal funding sources to a greater extent than is currently being done.

The ITS Unit was envisioned to be a source within DOTD to ensure that a core group of employees would be tasked with developing and maintaining the knowledge and expertise required to mainstream advanced technologies into state and local transportation improvement efforts on a coordinated, routine basis. Also, the unit was charged with establishing a transportation management and operations focus within the DOTD business strategy. Specifically, the responsibilities set forth for the ITS effort of DOTD are as follows:

- Direct DOTD resources toward operational issues and ensure that safe and efficient transportation management and operations, a core mission of DOTD, is a key consideration in DOTD policy and program development decisions;
- Ensure that ITS is consistently mainstreamed into DOTD planning and project development;
- Manage and oversee interagency and inter-jurisdictional systems and applications integration;
- Leverage federal and other funding eligible for implementation and sustained management and operations of ITS to the maximum extent possible;
- Provide information, guidance, coordination, financial and other support to state and local ITS planning and deployment efforts;
- Provide a coordinated liaison with LOEP, LSP, and local transportation management agencies and other service providers to effectively manage interagency partnerships and projects;
- Maximize the potential to leverage state and local resources through ITS-related information and infrastructure sharing;
- Task a core group of DOTD employees with developing an on-going awareness and understanding of advanced technology applications to Louisiana's needs;
- Ensure that state and local ITS efforts comply with the national architecture and standards; and
- Work with DOTD Districts and local transportation management agencies to identify appropriate state role in TMCs.

These responsibilities obviously lend themselves more toward planning, coordination, management and operations of advanced transportation systems brought about by ITS deployment rather than preventive maintenance and system preservation activities. Based on information gathered from other state DOT organizations, the core mission of DOTD to provide safe and efficient operations, the operational focus and innovative funding provided by the federal ITS program; coupled with the intra and interagency coordination responsibilities of ITS, it is recommended that DOTD reposition the functions of ITS into the broader area of transportation management and operations. Organizationally, the ITS function would fall under transportation management and operations along with traffic engineering and report to an operations hierarchy managed by the Chief Engineer within the department. The proposed organization chart is shown in Figure 5.

This organizational change would provide the expertise and best position DOTD to maximize its return on ITS investment. Creating a division within the hierarchy would give transportation management and operations sound administrative support and the afford the ability of ITS to leverage sustained financial support for long-term success.

LATIS Architecture

A key component of the national ITS strategic plan is the ability of systems to provide a mechanism and framework for sharing information among a wide array of transportation system managers, transportation and emergency service providers, and transportation system users to improve the safety and efficiency of the existing transportation system. For example, real time traffic data collected by one transportation agency for use in signal timing or incident management could be relayed and used by another agency in an advanced traveler information system to warn traffic of upcoming congestion and recommend

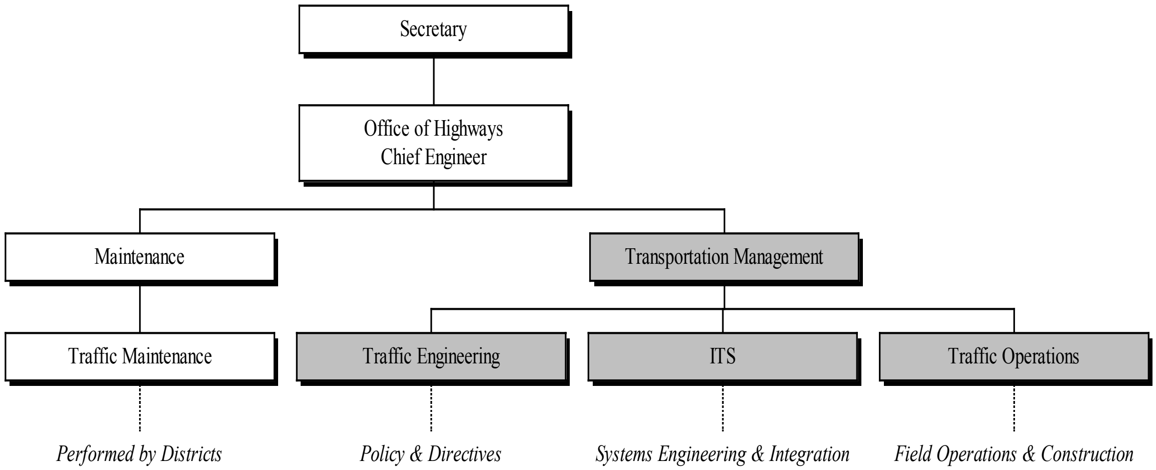

Figure 5. Proposed Organization of Transportation Management and Operations and ITS

alternative routes. Systems integration and interoperability are thus critical to the success of any regional ITS effort for the purposes of information sharing.

DOTD can and should play a lead role in providing the institutional and systems infrastructure required to ensure interoperability, communications, and data exchange among systems under control of multiple jurisdictions. It should be recognized that information sharing needs will change over time, and systems, technologies, and applications will evolve, requiring a process and institutional framework that allows for ongoing integration and expansion of the system. To ensure that information sharing needs among agencies are met by the LATIS architecture, the following actions are required by DOTD:

Establish Integration Task Force - To address the information sharing needs of various state and local agencies, DOTD should establish a task force that meets regularly to discuss integration needs, reporting requirements to ensure that the group is aware of upcoming ITS implementation activities, and an evaluation and implementation process for new integration and interface. Benefits of such an integration strategy maximizes the potential for appropriate information sharing among agencies, systems, and jurisdictions. Electronic data exchange provided by LATIS gives multiple agencies the opportunity to utilize information collected by one agency for improved traffic, transit, incident, and emergency management, and traveler information.

Develop Communications System - Information exchange between devices, systems, jurisdictions, and agencies requires a combination of communications media. High-speed, reliable communications such as fiber optics will be utilized as the baseline trunk medium for LATIS voice, data, and video along portions of the freeway system, connecting DOTD headquarters and district offices, TMCs, LSP troops, and LOEP facilities. A wireless system should be incorporated as backup. To accomplish this requirement, DOTD should pursue franchise agreements with private telecommunication providers and barter such service in exchange for right-of-way use.

Develop Regional Technology Agreements - Regional technology agreements provide a mechanism for ensuring consistency among technologies, standards, and deployment choices with regional significance such as communications electronic fare media. The Integration Task Force should be charged with establishing such agreements with other state and local agencies that may deploy systems to be integrated into the LATIS network.

The system supporting such an integrated concept for LATIS is shown in Figure 6. The diagram depicts the networks supported by the various state and local agencies and the information sharing of information processed by devices deployed in the field. The flowchart also shows the management, decision-making authority, and operations with establishment and support of all the teams and technical task forces to make LATIS work.

LATIS Deployment Initiatives

The state's LATIS deployment initiative for the near term (5-10 years) can be classified into an urban and rural program. The urban LATIS initiative will focus on deployment and integration of advanced traffic management systems (ATMS), advanced traveler information systems (ATIS), incident and emergency management systems, and advanced public transportation systems (APTS). The following outline details the elements of these two initiatives.

Urban ITS Program

Advanced Traffic Management System (ATMS) - Consists of deploying ITS devices for freeway/arterial monitoring and surveillance, vehicle detection, and traffic control to improve urban mobility & safety. Such devices include CCTV cameras, freeway lane control signals, ramp meters, and arterial traffic signal systems.

Advanced Traveler Information System (ATIS) - Consists of deploying and implementing an urban traveler information dissemination program via the Internet, or other public information media. Such devices include dynamic message signs, highway advisory radio, kiosks, traffic information web pages with traffic flow maps and incident reports, and public radio and television. Part of the ATIS effort will be to seek out private partnerships to provide information.

Incident and Emergency Management System - Such a system includes a coordinated and collaborative effort with local transportation and public safety agencies to development of a regional incident management plan for traffic management on urban freeways and major arterials. Field devices to be deployed in support of this regional effort include an integrated emergency 911 computer-aided dispatch with ATMS and ATIS, emergency vehicle preemption devices at signalized intersections, and communications media including video between emergency vehicles and hospitals and centers. This system also involves establishing, where warranted, and continued support for a motorist assistance patrol on freeways and critical major arterials.

Advanced Public Transportation System (APTS) - This system includes the deployment and integration of intelligent routing and fleet management of public transit into the LATIS program. Such devices include global positioning transponders in transit vehicles, and transit vehicle priority systems on specified signalized arterials.

Level of Deployment - The urban LATIS program will consist of deployment and integration of regional systems in the 9 urban areas in Louisiana. It is anticipated that full deployment of urban LATIS will occur in New Orleans, Baton Rouge, Shreveport/Bossier City, and Lafayette. Limited deployment (i.e., ATMS, ATIS, and incident management) is anticipated in Lake Charles, Monroe, Alexandria, Houma, and Northshore region.

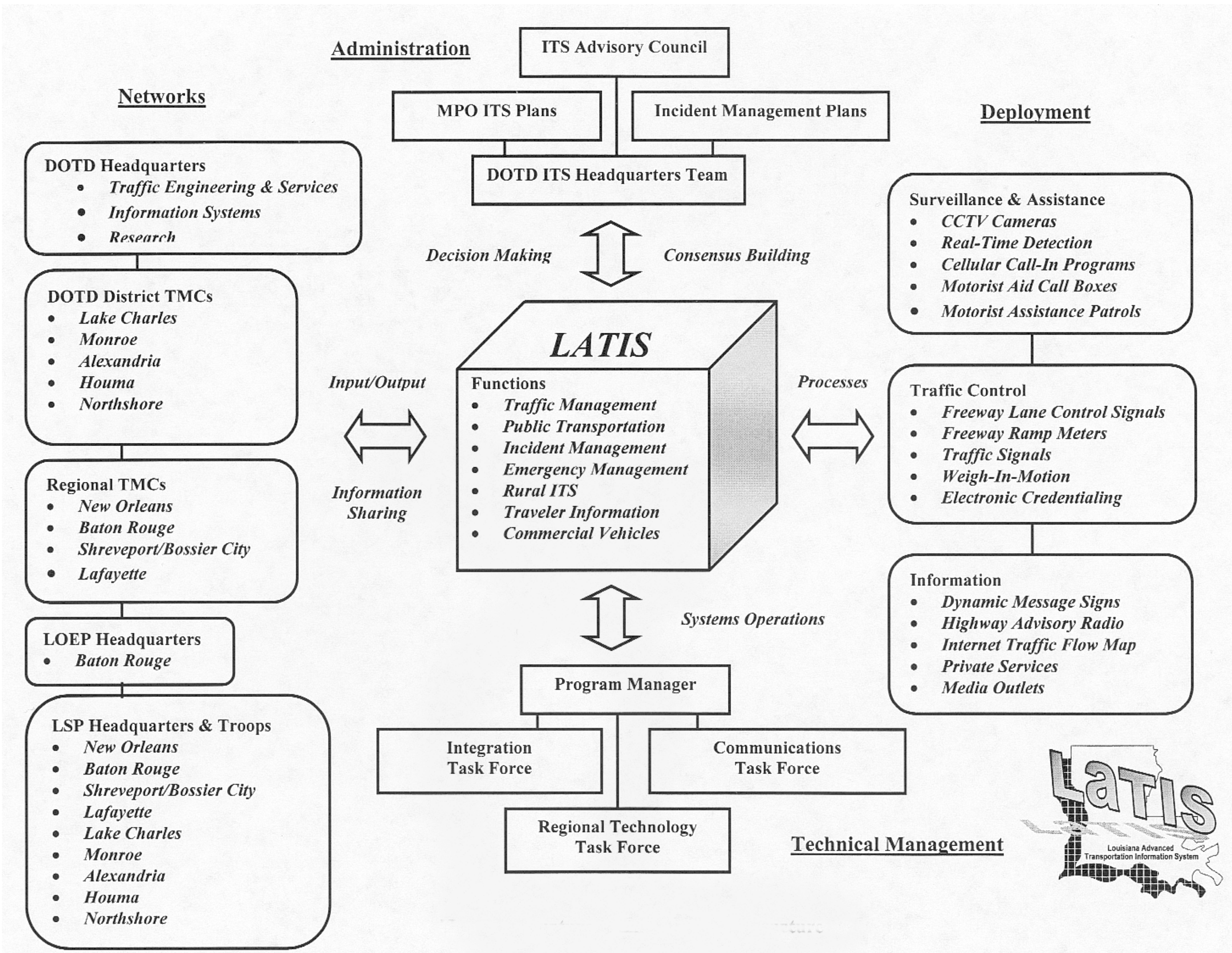

Figure 6. LATIS Architectural Structure

Rural LATIS Program

The rural ITS program will focus on the management, operation, and regulation of commercial fleet movement, the detection, warning and information dissemination of surface weather conditions (e.g. fog, wind, rain, etc.) relating to transportation, a statewide traveler information program stationed at the state borders, a rural incident and emergency management program, and communications and systems facilities to support a joint statewide DOTD, LOEP, and LSP center in Baton Rouge.

Commercial Vehicle Information System and Network (CVISN) - Includes the implementation of weigh-in-motion systems, CVO information, and an electronic credentialing system such at DOTD Truck Weigh Scales along rural interstate highways. Systems will be deployed along I-10 at the Toomey, Breaux Bridge, and Slidell scales, along I-20 at the Greenwood and Delta scales, on I-12 at Baptist, and on I-55 at Kentwood.

Road Weather Information System (RWIS) - Detection and accurate reporting of inclement weather events is vital to Louisiana's incident and emergency operations plan carried out by LOEP and LSP. The ability to effectively manage traffic in such events depends significantly on assessing accurate weather conditions. This system includes the deployment and integration of weather station and roadway sensing equipment to detect inclement weather conditions such as fog, flood, wind, and ice on segments of rural interstate and the ability to control dynamic message signs (DMS) and variable speed limit signs on critical interstate segments.

Advanced Traveler Information System (ATIS) - Similar to the urban ATIS initiative, this system includes development and integration of a statewide traveler information dissemination program via the Internet, kiosks, dynamic message signs (DMS), and public radio for traffic information on congestion, incidents, construction activity, and weather information on fog, ice, rain, and hurricane/severe weather warnings. It is anticipated this system will first be deployed in Louisiana's travel welcome centers at its borders along I-10, I-20, and I-55 and will then be distributed to rest areas and other public points of interest.

Incident and Emergency Management System - Includes the implementation of a statewide emergency and incident management program for major incidents and emergencies requiring evacuations and mitigation. The intent of LATIS under this effort will be to provide traveler information to LOEP and LSP under conditions that the two agencies will be managing and controlling regional and statewide movement of people and goods.

Joint DOTD, LOEP, and LSP Statewide Transportation, Incident, and Emergency Management and Operations Center - The LATIS program is envisioned to operate in a collaborative environment with joint participation between DOTD and the LSP. LOEP will take a supporting role in this collaboration except under conditions of statewide emergencies where they play more of an active role. It is anticipated that a facility will house joint operations of DOTD and LSP forces to accomplish the management of LATIS. Currently, the Baton Rouge Advanced Traffic Management and Emergency Operations Center (ATM-EOC) will house such operations. As LATIS expands, LSP will move its operations to an exclusive facility to succinctly conduct other LSP operations out of meanwhile keeping a presence at the ATM-EOC. DOTD plans to house and sustain its statewide transportation management and operations functions out of the ATM-EOC that will be connected to other regional ITS centers across the state. This effort will support communications needs of the joint statewide operations as depicted in the LATIS Facilities map in the supporting information section.

Level of Deployment - The rural component of LATIS will be deployed and managed along the rural freeway and major highway segments in Louisiana. Critical interstate and highway segments include: I-10 over the Atchafalaya Basin, Bonne Carre Spillway, and Lake Pontchartrain, I-55 over Manchac Pass, I-310 over Bonne Carre Spillway, US 190 over the Atchafalaya Basin, and segments of I-49 in the Shreveport area that are susceptible to ice conditions.

Feasibility of LATIS in Louisiana

In the Early Deployment Plans (EDP) developed for New Orleans and Baton Rouge, benefits and costs were assessed as they relate to the proposed implementation strategy of ITS. For the New Orleans plan, a benefit/cost ratio was quantified based on an analysis of peak traffic condition, accident experience, reduction in delay anticipated, and the value of time. Costs were annualized based on the implementation phase in the study. Results showed the following:

- Benefit/cost ratios ranging from about 10:1 to 20:1 for different phases of implementation; and
- The first implementation phase showed an annual benefit per mile of just over $3 million.

For Baton Rouge, the MPO performed an analysis of benefits using and ITS Deployment model (IDAS) developed in conjunction with the area-wide transportation model. This model allowed the CRPC to implement ITS on a route specific basis and calculated anticipated benefits from an area-wide perspective. Preliminary results showed:

- Surface street systems (i.e., signal synchronization) show benefits that outperform capacity improvements (i.e., adding lanes) for certain arterial systems; and
- A benefit to cost ratio of nearly 20:1 resulted.

RECOMMENDATIONS

Recognizing the need for teamwork and coordination in managing traffic under recurring and non-recurring conditions of the transportation system, it is recommended the DOTD, LOEP, and LSP support a statewide ITS program through management, operations, and agency integration. This agreement maps out the responsibilities of each agency and the functional hierarchy of this interagency system. Efforts to establish and continue funding support, detailed in future efforts, will be shared by all participating agencies at a level consistent with the agency's involvement and responsibility. The following outlines the nature and extent of agency responsibilities of this agreement.

Agency Collaboration and Responsibility

The areas and systems of this interagency agreement include the following functions:

- Transportation Management and Operations - ATMS, ATIS, APTS, and CVISN programs devised to manage and control the flow of traffic during recurring congestion, localized non-recurring congestion, and special events;
- Incident Management - RWIS and incident management coordination, command, and control relating to incidents of a regionalized, rural, or statewide nature; and
- Emergency Management - Emergency operations coordination, command, and control under emergency or disaster events such as natural, technical, or national security situations.

The organizational hierarchy of LATIS shown in Figure 7 depicts these systems and the functional requirements and agency responsibility. All the functions of LATIS will report to an executive group chaired by the Louisiana Secretary of DOTD, the Superintendent of Public Safety and Corrections (LSP Chief), and the Executive Director of LOEP. Each function provided by LATIS will fall under the direction of an administrative-level coordinator appointed by the involved agency. These coordinators will be responsible for assigning staff to conduct operations in fulfilling LATIS common objectives.

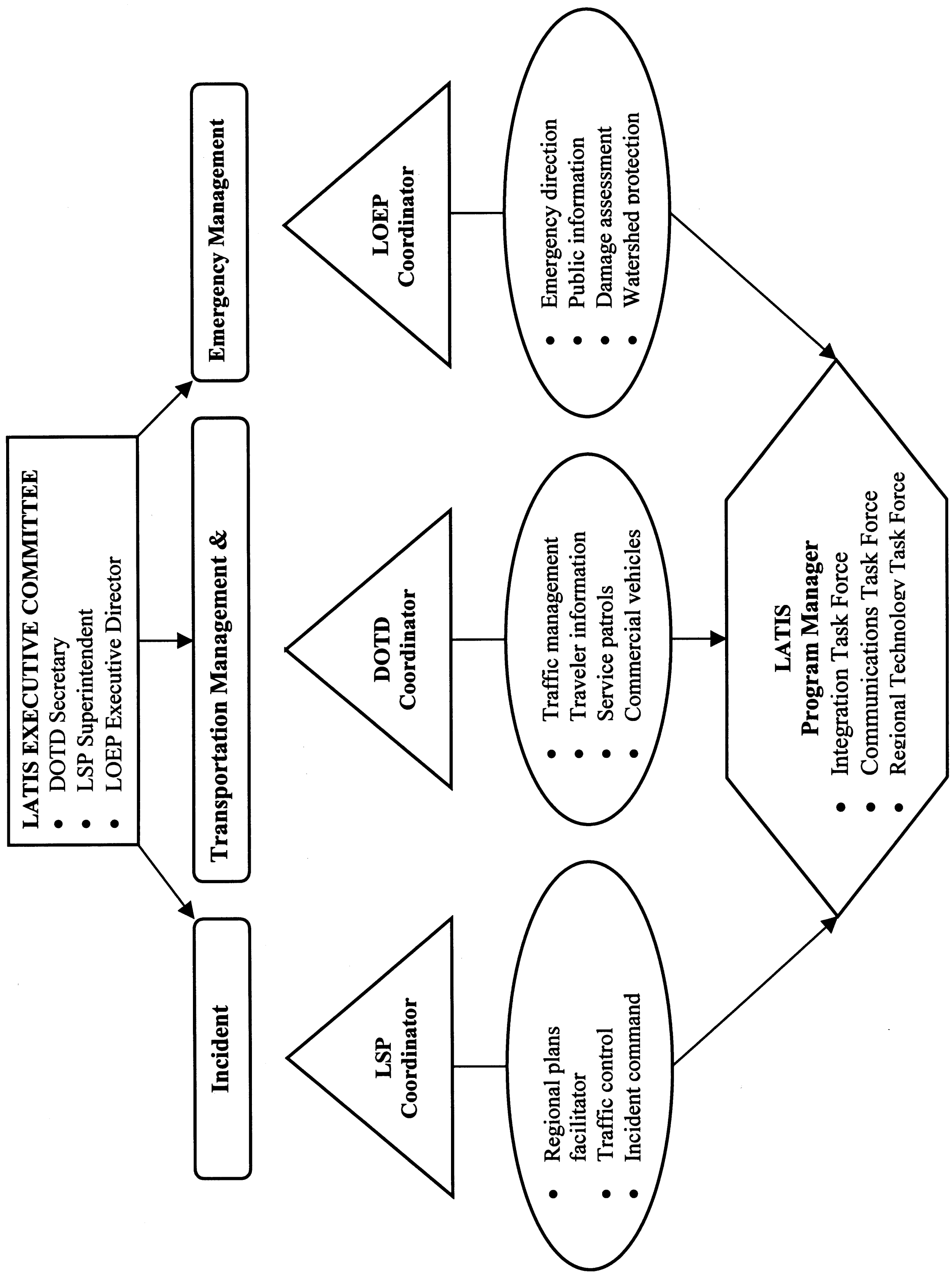

Figure 7. LATIS Functional Organization Heirarchy

conflicts between each function and agency will be handled first at the level from where the conflict originates.

Executive Responsibilities

The executive branch of LATIS will lend all support, both financial and other resource, to ensure the long-term effectiveness of an efficient and integrated program. The executive branch recognizes that Louisiana's public interest is better served by a partnering environment brought about by a common system and agrees to equally assign importance to maintaining system integrity compared to other agency functions.

DOTD Responsibilities

DOTD will be responsible for administering the transportation management and operations function of LATIS. Such responsibilities include deploying ITS devices in the field, being the custodian of the informational database, leading integration efforts and providing systems oversight, developing systems standardization and testing procedures for commonality, scalability, and integrity of LATIS, and operating DOTD elements of LATIS on state-owned highway facilities. During periods of normal traffic operations, DOTD will have control authority over LATIS functions. DOTD may delegate that authority to local transportation management agencies and its own districts. DOTD may direct LSP and other state and local authorities and assign tasks to ensure safe and efficient traffic operations under normal traffic conditions. Other DOTD responsibilities include establishing, supporting, and assigning importance to an ITS and transportation management and operations function within its hierarchy, a statewide ITS Technical Advisory Council comprised of agency stakeholders, an ITS Headquarters Team for decision-making authority, and the technical task forces necessary to support the system. DOTD will also support coordination efforts of the LOEP and LSP by participating in regional Incident Management Teams and the Southeast Louisiana Hurricane Task Force.

LSP Responsibilities

The LSP will be responsible for administering management and command aspects of the state's incident management program. Such duties include establishing and facilitating regional Incident Management Teams, incident scene command, detour plans, traffic and local agency coordination, traffic control, and operating elements of LATIS on state-owned highway facilities. In the event of an incident, control of the LATIS functions needed to support effective incident management will be placed under the authority of LSP (i.e., control of DMS, variable speed limit signs, highway advisory radio, traveler information). LSP may direct DOTD and other state and local forces and assign tasks to ensure safe and efficient traffic operations under incident conditions. Other responsibilities of LSP include supporting DOTD by participating in the statewide ITS Technical Advisory Council and the ITS Headquarters Team.

LOEP Responsibilities

LOEP's responsibility lay with coordinating the state's emergency management plan and operations. LOEP will be responsible for the management and operations of all high-level emergencies involving natural, technical, or national disasters. LOEP will support its functions in LATIS with obtaining necessary support from all involved state and federal agencies and coordinating integration efforts with DOTD.LOEP may direct DOTD, LSP, and other state and local agencies and assign tasks to ensure safe and efficient traffic operations under emergency conditions. Other responsibilities of LOEP include supporting DOTD by participating in the statewide ITS Technical Advisory Council.

CONCLUSIONS

Advancement in technology, whether in devices, systems, and communications, has brought about a mechanism by which transportation management and operations agencies can generate, analyze, manage, share, and disseminate data on a common, integrated platform. Some progressive states with a common interagency vision, have pursued and instituted frameworks for performing agency functions with one another. What has resulted is seamless transportation services afforded to the motoring public.

Recognizing the benefits to agencies and the public of a seamless system, FHWA has taken steps to ensure technical commonality with establishing the national ITS initiative and defining national architecture guidelines. What has often been a hindrance to seeing ITS fully deployed has been the inability of state and local agencies to overcome institutional barriers created by legislative jurisdictions and traditional bureaucracy. In some cases, institutionalizing transportation, incident, and emergency management has been an ITS "show-stopper", preventing the public and agencies from reaping benefits of an interagency partnership.

It found from this research that DOT organizations assume the lead role in developing common systems mechanisms devised to break down institutional barriers and streamline transportation management and operations with the creation of ITS programs. These state agencies have been able to demonstrate benefits of creating workable relationships with sister agencies and identified its own primary and support roles in a system where the DOT did not always need to be the final transportation authority (i.e., "the boss").

Louisiana is faced with a similar challenge. Recently, DOTD created an ITS function to research, plan, deploy, operate, and mainstream advanced technology in the state's transportation system. A commitment exists within all levels of DOTD to aggressively support the advancement of ITS. However, DOTD or sister agencies of LOEP and LSP have no agreement in place to jointly establishing and facilitating a common systems framework, pooling resources toward a common mission, and sharing information freely that crosses agency boundaries and jurisdictions.

This research identified a recommended interagency framework for these agencies to collectively work together under a common mission, vision, and objectives to achieve seamless management and operations of the state's transportation network. The system identified to accomplish this vision is the Louisiana Advanced Transportation Information System (LATIS). The LATIS concept of operation, roles and responsibilities of each agency, information sharing needs, integration needs, and organization structure needs were defined and detailed herein. What resulted were identified components of interagency action plan for DOTD, LOEP, and LSP to pool resources and develop a common, seamless, and most efficient transportation, incident, and emergency management service to Louisiana.

It is envisioned this research will be the first step in establishing the organizational structure, management and operating agreements, and the dedicated recurring financial support necessary to sustain and improve the LATIS program. DOTD, LOEP, and LSP will share responsibility, funding, personnel, and other resources equal to their involvement as identified by future analysis and development of LATIS agreements.

National leaders, along with Louisiana's have concluded that the public cannot build itself out of traffic congestion and the problems it causes. With the advancement of technology and its multiple, proven applications to transportation, state DOT organizations are seizing opportunities to making our highways and streets smarter while returning a more efficient system to the public. With DOTD's commitment to ITS and transportation management and operations, LOEP's commitment to managing emergencies, and LSP's commitment to coordinating and commanding incident response, Louisiana stands poised to gain unprecedented value in delivering greater efficiency and a safer transportation system to its users.

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APPENDIX A: RESULTS OF STATE DOT CONTACTS

The findings of the information collected from the state DOT organizations summarized in Table 1 are categorized by the agency's concept of operations, roles and responsibilities, partnership ventures, and organizational makeup. Listed below are details resulting from state DOT contacts.

Concept of Operations

Most agencies approached transportation management and operations from a regionalized focus with the exception of Maryland SHA, which supports a statewide concept. Most programs were initiated from an early deployment effort that began in a highly developed urban area with the initial focus on localized congestion and incident management. All states interviewed saw the importance of sharing data with other state agencies, but the level of partnering (i.e., sharing common space, financial support, and joint operations) varied greatly. Most state agencies coordinate efforts through communications media rather than being collocated in a common facility. Jurisdictional squabbles over turf seemed to be less of an issue than the problem created with having overlapping responsibilities. Maryland SHA has overcome this problem with facilitating such a joint facility where MSP and SHA Maintenance forces share space with the CHART Operations team. In cases of these shared facilities, formal agreements have generally followed that specifies roles and responsibilities, agency contacts, who pays for what, and who answers to whom.

Roles and Responsibilities

In all states that have a progressive transportation management and operations program with an ITS focus, champions within the state DOT organizations emerged to lead institutional and organizational change in establishing the programs. In these cases, the state DOT organizations were the lead agencies in coordinating deployment and integration efforts and interagency participation the sustained operations and maintenance of the ITS programs. Although multiple agency involvement in the TMCs varies, it is apparent that the state DOT organizations play a lead role in the day-to-day operations of transportation and incident management systems with local and state law enforcement playing a support role. Command of the incident itself, however, usually falls under the policing authority with the state DOT providing maintenance and traffic control support.

With regard to a regional or statewide emergency situation, most state DOT organizations assume a lead role in traffic management and operations while supporting other agencies' needs in areas of public information, evacuation and control, and damage assessment. Virginia DOT, however, has taken the lead role in incident and emergency management by establishing a statewide transportation emergency operations center. An Incident Commander from VDOT is delegated the responsibility and authority for coordinating such high level incidents and emergencies. This type of DOT authority was found to be the exception rather than the norm.

Partnership Agreements

Although formal agreements exist in states where joint operations between agencies are found, most state DOT organizations have an amicable working relationship with agency partners. Mid-level managers and operators within the TMCs do not see the need for developing formal agreements in that seldom is the need to remind agencies of their responsibility. Practically all of the agreements were drafted based on the need identified y upper level managers within the organization that are generally not involved on a day-to-day basis with the operations. The people on the front lines of operations feel enough synergism exists between other agencies to work cohesively without a formal agreement or contract.

Organizational Issues

Progressive ITS states such as those interviewed experienced some type of organizational change to better facilitate improved transportation management and operations brought about by ITS. Practically all of the ITS efforts were born out of traditional traffic engineering and safety programs within the DOT organization that usually reported to a traditional operations and maintenance body. As the ITS programs increased in scope, so did the competition for recurring operations and maintenance funding to sustain the program. Most states found it beneficial to create a separate management and operations function for transportation and ITS on equal footing with general operations and maintenance. This change, in turn, gave credence to such ITS initiatives, provided a long-term funding mechanism, and gave such programs equal voice in justifying increased funding and personnel support. All states interviewed placed top priority on needing organizational change to making ITS initiatives successful for the long term.

APPENDIX B: RECOMMENDED INTERAGENCY AGREEMENT

The Louisiana State Agencies of the Department of Transportation and Development (DOTD), the Louisiana Office of Emergency Preparedness (LOEP), and the Department of Safety and Corrections Office of State Police (LSP) agree to the following:

1. Whereas the state agencies of DOTD, LOEP, and LSP recognize the need for teamwork and coordination in the management and operations of the transportation system under recurring and non-recurring conditions, and
2. Whereas the benefits of ITS are significant to the state of Louisiana in the ability afforded by technology to gather, analyze, engineer, disseminate, and share transportation information among agencies both local, statewide and private, and
3. Whereas significant benefit both financially and functionally can be gained by Louisiana state government of pooling agency resources and sharing responsibility in the management and operations of an interagency transportation, incident, and emergency management program,
4. Be it hereby resolved, the agencies of DOTD, LOEP, and LSP jointly support the establishment and support a statewide ITS program of an interagency transportation, incident, and emergency management referred to as the Louisiana Advanced Transportation Information System (LATIS).

The responsibilities of each agency under this agreement are as follows:

Executive Responsibilities

- Functions of LATIS will report to an executive group chaired by:
  - Louisiana Secretary of DOTD
  - Superintendent of Public Safety and Corrections (LSP Chief)
  - Executive Director of LOEP
- Lend support, both financial and other resource, to ensure the long-term effectiveness of an efficient and integrated program

DOTD Responsibilities

- Administering the transportation management and operations function of LATIS
- Custodian of the informational database
- Lead integration efforts and provide systems oversight
- Developing systems standardization and testing procedures for commonality, scalability, and integrity of LATIS
- Operate DOTD elements of LATIS on state-owned highway facilities during periods of normal traffic operations
- May delegate authority to local transportation management agencies and its own districts
- May direct LSP and other state and local authorities and assign tasks to ensure safe and efficient traffic operations under normal traffic conditions.
- Establish, support, and assign importance to an ITS and transportation management and operations function within its hierarchy
- Develop a statewide ITS Technical Advisory Council
- Develop an ITS Headquarters Team
- Support coordination efforts of the LOEP and LSP by participating in regional Incident Management Teams and the Southeast Louisiana Hurricane Task Force.

LSP Responsibilities

- Administering management and command of the state's incident management program
- Establish and facilitate regional Incident Management Teams
- Command incident scenes
- Develop detour plans
- Coordinate traffic and other local agencies in incident events
- Operate incident management elements of LATIS on state-owned highway facilities
- Control of LATIS during incidents
- May direct DOTD and other state and local forces and assign tasks to ensure safe and efficient traffic operations under incident conditions
- Support DOTD by participating in the statewide ITS Technical Advisory Council and the ITS Headquarters Team

LOEP Responsibilities

- Coordinate state's emergency management plan and operations
- Administer management and operations of all high-level emergencies involving natural, technical, or national disasters
- Support emergency functions in LATIS
- Coordinating integration efforts of emergency operations with DOTD
- May direct DOTD, LSP, and other state and local agencies and assign tasks to ensure safe and efficient traffic operations under emergency conditions
- Support DOTD by participating in the statewide ITS Technical Advisory Council

______________________	______________________	______________________
Secretary of DOTD	Executive Director of LOEP	Superintendent of LSP

STEPHEN W. GLASCOCK

Stephen Glascock is currently with the Louisiana Department of Transportation and Development (DOTD) and manages the state's Intelligent Transportation System (ITS) program. He was appointed by the DOTD Secretary to this technical position to lead Louisiana's ITS effort. He is responsible for planning and coordinating all ITS deployments in the state's nine metropolitan areas, the commercial vehicle information systems network (CVSIN) program, and special ITS deployments along the state's freeway system in rural areas. Among these activities are the implementation of Advanced Transportation Management Systems, Surface Street Control, Incident Management, Advanced Traveler Information, and Road Weather Information Systems. He chairs the state's ITS Advisory Council, a body of public and private stakeholders responsible for developing, prioritizing, and mainstreaming ITS projects into DOTD's Highway Program. Additionally, he manages activities of the statewide ITS Consultant and Systems Manager.

Prior to his employment with DOTD, Mr. Glascock was the Transportation Planning/Traffic Engineering Manager with Gulf Engineers & Consultants, Inc. (GEC) in Baton Rouge, Louisiana. He was responsible for all transportation engineering-related activities that involved an array of public and private clients. He served as project manager for the Louisiana Traffic Control Systems Design and Implementation project and the I-10 (Baton Rouge) Major Investment Study. He also provided expert testimony and traffic engineering services for the Greater New Orleans Expressway Commission.

Prior to his involvement with GEC, Mr. Glascock was employed as Traffic Engineer for the City of Baton Rouge and Parish of East Baton Rouge. He was responsible for planning, designing, and implementing advanced traffic control systems and devices throughout the Baton Rouge metropolitan area. He also, coordinated consultant activities for the Baton Rouge Closed-Loop Traffic Signal System.

Mr. Glascock received a bachelor of science degree in civil engineering from Louisiana State University in 1987 and a master of science degree in civil engineering from Texas A&M University in 1991. While at Texas A&M, Mr. Glascock was employed with the Texas Transportation Institute under a graduate research assistantship. His research was in the area of geometric design consistency and accident analysis. He also performed systems management services for the Civil Engineering Department's Interactive Graphics Roadway Design System. While in graduate school, he became a member of Texas A&M University's Chi Epsilon and Institute of Transportation Engineers student chapters. In 1991, he received the Texas ITE Outstanding Student Award for outstanding accomplishments as a student of transportation engineering. Mr. Glascock, registered since 1992, is a professional engineer licensed to practice civil engineering in the state of Louisiana.

QUANTIFYING THE LEVEL OF SERVICE ON CONGESTED SEGMENTS OF URBAN FREEWAYS

by

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SUMMARY

For years, the amount of traffic on our nations' highways has dramatically increased, while the funding for the improvement of these roads has not been able to keep the pace. With an aging infrastructure and this demand increase, local and state agencies are finding it hard to determine where improvements need to be made. This paper proposes that an increased level of service F regime, defined by the amount of diversion from the freeway and parallel arterials, would be the most appropriate way of ranking the need of the improvements.

Some industry experts believe that the level of service system should be abandoned, though the author of the paper feels that most of the opposition to the system lays in the perceived deficiencies in the current level of service. Especially deficient would be the fact that LOS F has been crudely defined in the past. In this report, though, the LOS F regime is looked at, and broken into 3 pieces, to help give a greater clarity and definition.

This paper details the thought process behind why the level of service system should be expanded, and how it would be expanded. Also discussed is the methodology of how this data would be collected, by using origin-destination studies. Covered in the latter portion of this paper is the numerous ITS technologies that can be used in the collected of the data. As congestion is relative to the area of the country that one is in, no concrete definitions of the expanded level of service system can be given in this paper, but a groundwork is laid down on how to determine the values in question.

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INTRODUCTION

Traffic, it is what we live with today as users of the national road network. For years, the severity of traffic has been defined through the Highway Capacity Manual's description of level of service (*1*). The level of service of a freeway segment reads like a student's report card ranging from an A for an exceptional roadway that has free-flowing traffic to an F for a complete failure or breakdown. As traffic volumes continue to increase on roadway segments across the nation, severe congestion has become more and more commonplace. With this increase, more road segments are within the F, or failure range, some for many hours in the day.

Problem Statement

As the population of the United States continues to grow in the 21st century, a commensurate growth in traffic volumes along the Nation's highway system is expected. At the same time, however, the technology pursuits to combat this growth in traffic flow is anticipated to advance, affording transportation engineers the means and opportunities to mitigate growing traffic congestion. In Maryland alone, the vehicle miles traveled are expected to increase by 60 percent in the next 20 years (*2*). With the roadway infrastructure in the United States being 50 years or older in some locations, and being that highway funding and other resources will not be able to match the booming vehicle miles traveled, congestion is going to become even more commonplace on the nations' highways. It is recognized that state highway agencies are going to have difficult decisions to make regarding highway improvements to relieve congestion, given limited public support and resources to do so. It is imperative that there be a way to determine the difference between acceptable and unacceptable congestion. With these thoughts in mind, it is proposed that this research will develop a procedure for quantifying in greater detail the levels of service on congested segments of urban freeways, particularly those at the more congested levels.

Research Objectives

The primary concern with this research is to quantify the congestion levels of segments on urban freeways. This concern was met through the following objectives:

1. Review and assess, through literature and agency interviews, the current methods for estimating level of service on urban freeways, and compare these methods with newly developed aerial surveillance techniques that are being used or considered for use in quantifying congestion;

2. Characterize the distinctly different conditions that can exist within the currently defined level of service F, as viewed from the perspective of the agency(ies) responsible for maintaining and operating the urban freeway; and

3. Propose a rational re-structuring of the current level of service F range that will better meet the existing and future needs of urban freeway planners and responsible agencies.

Scope of Project

The author of this paper focused mainly on urban freeways in major metropolitan areas. While congestion can occur along any stretch of road, urban or rural, the author prefers to dwell on the roads that carry the most amount of traffic with the most severe, reoccurring congestion. The reason being that the agencies in these areas that are prone to congestion should have explored different areas on how to deal with the problem of quantifying congestion and correcting the resultant congestion problems. Though a discussion on the topic of the potential of using a gradation of level of service F for the prioritization of highway agency contracts will be broached, specific recommendations of where, when and how to fix certain roads will not be discussed.

Tasks

Literature Review

During this task, a literature review was conducted. Literature in the following areas was determined to be pertinent to this research project.

- Level of service determination for freeway segments;
- Emerging technologies in level of service determination;
- Techniques for characterizing the level of service F regime;
- Differing ways to quantify congestion; and,
- Use of level of service data for highway improvement prioritization.

Development of Survey Questions

To gather specific information from various agencies about their current state of practice for dealing with congestion, telephone interviews were conducted. The questions asked helped to ascertain a state or local municipality's views on congestion mitigation. During the interviews, the following topics were discussed:

- Locations of reoccurring congestion in his/her region;
- How his/her agency defines congestion;
- Use of emerging or advanced technologies for LOS determination;
- How severity of congestion effects the funding of highway projects; and
- Value of LOS use in setting priorities.

Conduct Phone Interviews

Once the questions for the survey were determined and a phone contact list finalized, the phone interviews were conducted. Following is the list of questions asked during each interview.

1. Which urban freeways in your area are prone to reoccurring congestion?
2. How and by what methods does your agency define and measure congestion (level of service, aerial surveillance techniques, other)?
3. If your agency uses level of service as its primary quantification of congestion, has your agency tried or heard about newer, emerging technologies? If so, which ones? If you've employed them, what has been your experience (good and bad)? If you have not utilized them, which one(s) are you intending to experiment with?
4. To what extent is the degree of congestion a factor in the prioritization of highway improvement projects?
5. Does your agency recognize more than one LOS F value? Would this concept be helpful?
6. In your professional opinion, where should the break lines for level of service F be?
7. Do you feel that LOS is an antiquated system that should be replaced with some other measure of how the roadway is performing?

Compile and Analyze Data

After conducting the surveys, the results were compiled and analyzed. With the analysis of this level of service survey data, the major portion of this research paper was undertaken. At this point in the research project, the comparison of current states of practice for level of service determination took place. This research was completed under the guise of developing the quantification of the level of service on a congested freeway, i.e. the various levels of F and its effectiveness/usefulness as a tool in highway improvement program prioritization.

Results and Recommendations

Upon the completion of the analysis, the results of the comparison between the agencies were tabulated, the use of emerging technologies is noted, and the use of gradation of the level of service F is discussed. From these results, a rational restructuring of the current level of service F is proposed. With this restructuring complete, recommendations were made on how highway agencies (planners, designers, and operations people) can use this information.

BACKGROUND

The following is an overview of the background literature that is important to the understanding of this topic. This section is not as extensive due to the relatively small amount of literature published at the writing of this report on level of service F. The discussion will begin with a quick overview of the different ways to measure congestion. What follows that is a detailed talk about the history of level of service and proposed revisions to the level of service classifications.

Measuring of Congestion

Depending on the area of the country that you are in depends on how a local or state agency would measure congestion. As was shown in the Dudek and Huchingson study in 1986 (*3*), congestion is relative depending on where the congestion is located. For example, a stop and go condition on a freeway in Boston would be considered commonplace, especially on the Central Artery. Compare this to Bryan-College Station where stop and go traffic would be considered a major breakdown of the road network, and the local traffic agency would field calls for months over a traffic anomaly. Below is a bulleted list, describing some of these differing techniques.

- Baton Rouge, Louisiana. The Remote Sensing and Image Processing Lab (RSIP) at Louisiana State University (LSU) conducted a multi-year study to collect speeds along Baton Rouge freeways using the Global Positioning System (GPS). These data were reduced into speed data over a segment, usually 0.2 miles. From here, color coded speed classification bars (a green bar for above 50 mph, etc.) were overlaid on the freeway network were compiled for both the morning peak and the evening peak for an approximate 3 to 4 month span of time. With these maps, one could easily see where the congestion was located in Baton Rouge. (*4*)

- Chicago, Illinois. This Internet web site, http://www.travelinfo.org, was set up for the Gary-Chicago-Milwaukee Corridor, with help from the University of Illinois - Chicago. Accessing this website, gives a traveler in the Southern Wisconsin, Northern Illinois, and Northern Indiana region, a quick and easy way to determine the traffic bad spots via a color-coded traffic speed map. Also on this map, travel times from various locations within Cook County are listed to the Loop (most likely the Circle Interchange at I-290 and I-90/94) in downtown Chicago. (*5*)

- Houston, Texas. Much like Chicago, Houston has a website at http://traffic.tamu.edu, which allows a traveler to access a color-coded speed map of the Houston freeway network. This map, like Chicago's, gives a user a quick and easy way to determine the areas of avoid on Houston freeways. (*6*)

- Seattle, Washington. Also in the same breath as Chicago and Houston is the Seattle, Washington website at http://www.wsdot.wa.gov gives travelers easy access to a color-coded traffic map. Differing from Chicago and Houston, though, the Seattle site allows the user to view camera locations throughout King County and the surrounding areas to get a near real time look at traffic conditions. (*7*)

History of Level of Service, 1950 to 2000

The purpose of the following sections on the history of level of service are meant to draw light to the main goal of this research project, being the stratification of the region level of service F.

Background of Level of Service

During the work for the 1950 version of the Highway Capacity Manual, the groundwork began to be laid for the level of service that we have today. Through these meetings, three basic definitions of capacity were formulated. These classifications of capacity were denoted as basic capacity, the maximum vehicles that could pass a given point in one hour during the most ideal of conditions, possible capacity, the maximum number of vehicles that could pass a point in one hour under prevailing conditions, and practical capacity, the maximum number of vehicles that could pass a given point in one hour, without causing undue delay or hazard to the motoring public.

By the time that the 1965 Highway Capacity Manual was in the process of being drafted, many felt that there were deficiencies in the capacity definitions, and that this system needed to be expanded. During the meetings for the 1965 HCM, the first level of service system was devised. This system includes five thresholds, ranging from A to E, with a sixth category of F being a catch all category. Though this system is the first attempt at the level of service rankings of modern day, it borrowed a lot from its predecessor, the capacity definitions. Level of service E was supposed to be parallel with the definition of possible capacity. Level of service D was practical capacity as seen on freeways in California. Level of service C was intended to be practical capacity by the 1950 HCM definition. Level of service B was practical capacity along rural highways. Level of service A, though, was defined a level above practical capacity, because Charles Noble, Chief Engineer of the New Jersey Turnpike, believed that since his roadway was tolled, he had to give better service than the practical capacity. (*8*)

Level of Service Now

As the years have advanced, the definition of level of service for freeway sections has changed. In 1985, the methodology the Highway Capacity Manual used to define the level of service of a freeway section is shown in Table 1, assuming ideal conditions and 70-mph design speed.

As can be seen here, the level of service F was still considered to be a catchall category.

In 1994, a revised edition of the Highway Capacity Manual came out. In it, there was a revised table showing the new thresholds of the level of service. Tables 2 through 5 show the 1994 definitions of level of service.

Table 1: 1985 HCM Definition of Level of Service (*9*)

Level of Service	Flow Conditions	V/c limit	Service Volume (veh/hr)	Speed (miles/hr)	Density (veh/mile/ln)
A	Free	0.35	700	>= 60	<= 12
B	Stable	0.54	1100	>= 57	<= 20
C	Stable	0.77	1550	>= 54	<= 30
D	High Density	0.93	1850	>= 46	<= 40
E	Near Capacity	1.00	2000	>= 30	<= 67
F	Breakdown	Unstable		< 30	> 67

Table 2: 1994 HCM Definition of Level of Service, 70 mph Free Flow Speed (*10*)

Level of Service	Maximum Density (pc/mi/ln)	Minimum Speed (mph)	Maximum Service Flow Rate (pcphpl)	Maximum v/c ratio
A	10.0	70	700	0.29
B	16.0	70	1120	0.47
C	24.0	68	1632	0.68
D	32.0	64	2048	0.85
E	45.0	53	2400	1.00
F	Var			

Once again, in the 1994 edition, the level of service F category was viewed as the pit that the rest of the values fell into. Yet, as traffic and traffic theory rocketed towards the 21st century, many believed that something should be done to quantify this value, F.

Proposed Changes to Level of Service

2000 Highway Capacity System

Much like in previous additions of the updated Highway Capacity Manual, there were some slight changes in the break points between differing level of service in the undersaturated region (A through E). In Table 6, these new points are listed.

Table 3: 1994 HCM Definition of Level of Service, 65 mph Free Flow Speed (*10*)

Level of Service	Maximum Density (pc/mi/ln)	Minimum Speed (mph)	Maximum Service Flow Rate (pcphpl)	Maximum v/c ratio
A	10.0	65	650	0.28
B	16.0	65	1040	0.44
C	24.0	64.5	1548	0.66
D	32.0	62	1984	0.84
E	45.0	52	2350	1.00
F	Var			

Table 4: 1994 HCM Definition of Level of Service, 60 mph Free Flow Speed (*10*)

Level of Service	Maximum Density (pc/mi/ln)	Minimum Speed (mph)	Maximum Service Flow Rate (pcphpl)	Maximum v/c ratio
A	10.0	60	600	0.26
B	16.0	60	960	0.42
C	24.0	60	1440	0.63
D	32.0	58	1856	0.81
E	45.0	51	2300	1.00
F	Var			

Notice in the above chart that the density is now being computed in passenger cars per kilometer per lane, which changes the computed value of density, somewhat. Table 7 shows Table 6, along with the equivalent density measure of passenger cars per mile per lane.

Through these past 35 years of using level of service to rank how well our roadway performs, undersaturated flow has always had several breakpoints within its scheme. It has only been until recently that some thought has been put into how to describe oversaturated flow (over and above level of service F).

In the May study, three suggestions are proposed on what to do with the level of service F question. These options are given in the following bulleted list (*11*):

Table 5: 1994 HCM Defintion of Level of Service, 55 mph Free Flow Speed (*10*)

Level of Service	Maximum Density (pc/mi/ln)	Minimum Speed (mph)	Maximum Service Flow Rate (pcphpl)	Maximum v/c ratio
A	10.0	55	550	0.24
B	16.0	55	880	0.39
C	24.0	55	1320	0.59
D	32.0	54.5	1744	0.78
E	45.0	50	2250	1.00
F	Var			

Table 6: Proposed HCM 2000 Level of Service (*11*)

Level of Service	Maximum Density (pcpkmpln)
A	9
B	17
C	22
D	26
E	28

Table 7: Proposed HCM 2000 Level of Service with Both Density Values

Level of Service	Maximum Density (pcpkmpln)	Maximum Density (pcpmpl)
A	9	14.5
B	17	27.4
C	22	35.4
D	26	41.8
E	28	45.1

- Maintain a single region for LOS F;
- Maintain a single region for LOS F but report one of the performance measure results with the LOS F designation; and
- Divide the LOS F region into subregions.

In the section that follows, a discussion on the very last point made in the May paper has been expanded, since the issue was not able to be resolved in time for the 2000 Highway Capacity Manual.

Expansion of the System

As the years have gone by, the congestion seen on freeways across the United States has seen a vast increase. In fact, in 1996, William Baumgaertner wrote (*12*):

"In the past 30 years, urban populations have expanded significantly, vehicle ownership per household has increased, average trip length per person has grown, average number of trips per person has gone up, and not surprisingly, traffic volumes have risen steadily. Consequently, urban vehicle miles of travel have more than tripled. Travel conditions that would have been viewed as intolerable in the 1960s are considered just normal by today's motorists, especially commuters. Reported LOS F in the 1990s is different from reported LOS F in the 1960s. Today's failure periods have gotten worse and are lasting longer".

In this paper, Mr. Baumgaertner devises a new level of service (LOS) classification for signalized intersections and arterials. This LOS classification is similar to the 1985 and 1994 HCM methods, except he adds designations for LOS G, LOS H, and LOS I. Though Mr. Baumgaertner opens discussion for the expansion of the level of service classification, he did not touch upon freeway level of service.

In a 1996 entry into the ITE journal, Ron Cameron described the expansion of the level of service system. In his paper, Mr. Cameron said that the current system of defining level of service is quite inadequate. This was primarily due to the fact that LOS F covers quite a broad area. For example, a freeway, which is operating at speeds of less than 30 miles per hour, is defined at level of service F. The same can be said true for speeds around 5 miles per hour. He stated that the current level of service structure does not define how serious the level of F really is, as there is a vast difference between a freeway operating at 30 miles per hour, and a freeway operating at near 5 miles per hour. Mr. Cameron discussed the expansion of the system for signalized intersections, arterials, and freeway segments. His paper also focused on the duration of a particular level of service, say if an F condition existed for seven hours, the level of service for that roadway would be F7. (*13*). Below, in Table 8, his new level of service definitions is shown.

Current Methods of Determining Different Levels of LOS F

Throughout the literature and Internet searches, the author found no system currently utilized to determine the different levels of level of service F, concretely.

STATE OF PRACTICE INTERVIEWS

This section of the paper deals with the industry surveys conducted during the research of this paper. Agencies from several states, including Maryland, Missouri, Georgia, Virginia, and California were contacted during the interview process. Each interview is developed within its own subsection in this portion of the paper.

Table 8: Proposed Expansion of the LOS Scheme for Freeways (*13*)

Level of Service	Existing	Proposed	Description
A	> 60		Free flow
B	> 50	> 50	Stable flow
C	> 47	> 47	Stable flow
D	> 42	> 42	Approaching Unstable Flow
E	> 30	> 30	Unstable Flow
F	< 30	> 25	Forced Flow
G		> 15	Super Forced Flow
H		> 10	Ultra Forced Flow
I		> 0	Superultra Forced Flow

Maryland (*14*)

Utilizing the interview questions, written about in the first section of this report, the author conducted an interview with Bill Richardson of the Maryland State Highway Administration.

Mr. Richardson reports that many freeways have reoccurring congestion on them during the peak periods. Some of these freeways would include the Baltimore Beltway, the Washington Beltway, and Interstate Highway 95 between Washington and Baltimore.

He said that the Maryland State Highway Administration uses the Highway Capacity Software to determine the level of service along freeway segments.

The Maryland State Highway Administration has utilized some newer technologies to determine the level of service, though Mr. Richardson was unaware if SkyComp, a company that measures the level of service by aerial surveillance techniques, used different levels of F.

At one time in Maryland, congestion was a major factor, along with safety, with the way that contracts were once funded. Even though safety is still a major concern for the prioritization of projects, congestion is not a major as it used to be. Maryland has taken the stance that they will not be able to pave their way out of congestion, and now use congestion mitigation techniques, such as HOV lanes and the possible use of shoulders.

At this time, Maryland does not recognize more than one level of service F. When the roadway begins to perform at a LOS F, it is just operating at F. Though, personally, Mr. Richardson would be interested in seeing an expansion of the level of service F. His thoughts ran parallel with the ideas in the May paper, where the Highway Capacity Software would be used to determine these F levels (*11*). For example, F-1 would be the level of congestion that where is just surpasses LOS E, F-3 would be where the Highway Capacity Software would no longer give an answer, and F-2 would be some intermediate value. He also gave another way to gradate the level of service F, by using an origin-destination study where F-1 would be normal, congested traffic conditions, F-3 would be a point at which users of the system would divert, and F-2 would be an intermediate value.

Georgia (*15*)

Utilizing the survey questions listed in a previous section of the paper, Mr. Marion Waters, a state traffic engineer was interviewed by the author to determine his views on the multiple level of service F system. The interview was not as informative as the other interview that was administered as Mr. Waters believes that the level of service system is an antiquated ranking system, and there should be some new way to describe the severity of congestion.

Though the interview was not as informative towards the goal of the paper, an interesting similarity to the Maryland interview. Mr. Waters believed that congestion should stay with on the freeway system. He believes that it is dangerous to divert traffic onto surface streets that can not handle the traffic that a normal freeway would carry.

To this end, the parallel can be drawn. Mr. Richardson spoke in his interview that one way to stratify the levels of F would be an origin–destination study. If there were significant diversion of vehicular traffic from a congested freeway onto surface streets, this would be defined as LOS F-3. (*14*).

Other Interviews and Closing Thoughts

Though only two interviews were talked about at length in the section above, more interviews took place. Yet, much like the Georgia interview, most congestion experts believed in moving towards a system of quantification of traffic using terms that the public would understand, such as travel time or average speeds.

From these interviews the author believes that much of the complaints about the level of service debate center around the belief that there are deficiencies in the current system. Through background literature reviews, the author did find certain parts of the level of service system that are lacking, such as the regime of level of service F.

Also, the author is not one to believe that the public is not able to understand the level of service system and need something concrete as travel times or average speeds. Yes, travel times posted on the Internet or dynamic message signs are helpful to the traveling public, yet these systems have not been implemented nation wide. While the transportation profession is awaiting this implementation, the author believes that an expansion of the level of service system is needed. Not only would this expanded system be helpful to the traveling public, but also it would be helpful for transportation agencies to help determine the need for the location of transportation improvement projects. Furthermore, in the age where multi-national engineering consulting firms exist and do business around the world, this lays the groundwork for what is and is not an acceptable level of congestion. For example, a firm based outside the area of Houston could not readily discern if a 30 minute travel time on the Katy Freeway is acceptable or not, though, if this same firm was to see that the Katy Freeway operated at LOS F-3 for several hours a day, they could easily see that this is not an acceptable travel condition.

PROPOSED GRADATION OF LEVEL OF SERVICE F

This section of the paper will help describe the level of service the author has devised. Also, this section will help to define certain systems that could be utilized to determine the different levels of F.

Level of Service F regime

Level of service A through E is very easily defined. In the past, traffic density, traffic volume, traffic speed, and volume capacity thresholds have been used to describe these categories. Level of service F, though, has been a catchall category. Once a traffic flow had breached the maximum value of level of service E, the roadway segment was level of service F, no matter how poor the traffic on the roadway was. This paper, through literature review and industry interviews, has come up with a framework system that can be used to describe level of service F. Through this study, the author has concluded that there should be a three level gradation of the level of service F, which are F-1, F-2, and F-3.

The author believed that this three tiered system would be best for the stratification of LOS F. Since the current LOS scheme only has one value for F, and since this was considered deficient, it was determined that a larger value than one be utilized. The author came upon the idea of three, since this allows for a gray area in between acceptable and unacceptable congestion.

During the literature review and industry interviews, two systems were discovered and described that could help in the classification of the level of service F regime. These two systems were the use of the Highway Capacity Software and the use of origin-destination studies. The Highway Capacity Software method will be described in short, as this approach was already discussed in the 1997 NCHRP study completed by Adolf May. The origin-destination study approach will be discussed in detail later in this section.

Highway Capacity Method

For agencies that are strapped for funds in the traffic study area, the method that should be used to describe the level of service F is the use of the Highway Capacity Software. Currently, this software does not give a direct value such as LOS F-3, yet there are ways to attain these answers. For example, the value of F-1 could be the value that the value attained as the level of service value given by the Highway Capacity Manual Software when the LOS value has just barely F. The value of F-3 could be the point in time in which the program stops giving a value for level of service. The intermediate value, F-2, would be some value in between, determined by either the local agency that is running the analysis or through continued research, using the Highway Capacity Manual Software. (*11*)

Origin – Destination Approach

A common point in the interviews that the author conducted, local and state agencies want the congested traffic to stay on the freeways because signalized arterials are not designed to carry the amount of traffic that a freeway can. This is especially true in urban areas that may or may not have the infrastructure to support freeway traffic on their urban or downtown streets. Diversion was discussed as detrimental for a traffic network as it takes the traffic off the roads that can handle the large volumes and puts this traffic on secondary roads, increasing the delay and decreasing the level of service. Using the information from the interview process (*14, 15*), the origin-destination approach was created by the author of this paper.

There are several ways to conduct this origin-destination study. These methods are listed in the bulleted list below:

- Origin-destination surveys;
- AVI antennas and AVI tags; and,
- License plate-matching techniques.

Using one of the above-mentioned methods, traffic volumes would be classified by the following stratification. F-1 would be when the freeway segment has just gone to F, from E. The freeway is just barely F and not a severe enough traffic condition to which the average vehicle, usually a commuter, will not divert from the freeway. F-3 would be a severe congestion condition. This would be a point at which a large number of travelers are starting to divert off the freeway. This number would need to be decided by a local agency (-ies). This would be done by evaluation of the alternative routes into a central business district or other areas in which congested freeway segments run. For example, if there are good alternatives that can handle traffic, an F-3 grade would be harder to get, while an area that has poor or already heavily congested alternatives, an F-3 grade would be readily attainable. The region of F-2 would be an in between value that is also determined by local agencies through there analysis. This would be a region where some users are starting to divert, while some users are continuing to stick it out on the congested freeway.

This leads to a less than concrete system of ranking by level of service, which is the exact opposite of the level of service designations, A through E. This makes sense, though, as roadway users definition of congestion vary throughout the country. For example, 1-hour of congestion in Bryan/College Station on Texas State Highway 6 would be seen as unacceptable, while a 1-hour congestion window on the Kennedy Expressway (Interstate Highway 90/94) in Chicago would be seen as very acceptable congestion. This makes the LOS F region much less computationally clear, though, it makes the system much more user interactive. It may help local transportation agencies key in on where people feel the worst travel sections of an urban freeway are located, and where their transportation network funds should be spent.

SUGGESTIONS FOR IMPLEMENTATION OF THE LEVEL OF SERVICE SYSTEM

In the following sections, each one of the origin-destination techniques listed in the previous section are discussed in how they would be used and how local agencies should use them in attempting to utilize the level of service F gradation.

Origin-Destination Surveys

For origin-destination surveys, surveys are mailed out to potential users of the roadway system. These surveys would ask basic questions about the users opinion of the roadway system in question that has attained a LOS F rating through HCM calculations. Questions about the route taken, if they use any other routes than the freeway to divert the congested areas, if they plan to divert off the freeway, and at what point would the congestion be so unacceptable that diverting off the freeway seems to be the only alternative. These surveys would have to be returned to the highway agency, so that the data from the surveys could be analyzed. From this analysis, the local agency could determine whether or not there is a tendency of diversion from the congested freeway segments. The agency could then decided from that where to do traffic volume counts along stated diversion routes to determine the severity of diversion. From the traffic volume counts, this data would be complied and compared against the normal traffic flow pattern on the diversion routes from historical data. If historical data does not exist, this trend would need to be tracked over several months to a year to determine if there is diversion or if the traffic patterns are normal.

Once the above process has been completed, the transportation agency can then compile the data. Once the data has been complied, the roadway can be graded on the new level of service F system using the diversion criteria determined in the preliminary stages of this study, as described in the previous section.

Inherently, there are some advantages and disadvantages with this system. The major advantage to using origin-destination surveys would be the relatively low cost of the surveys (cost of postage) and the data collection equipment (pneumatic tubes, hand held counters, labor, etc.). Other advantages would include the ease of data collection and data analysis. The main thrust of the disadvantages has to deal with the persons who take the survey. Sending out a survey does not insure its return. Also, it is almost impossible to pin point who uses what route to go to work without first talking to the person or persons.

Just assuming that someone lives on one side of a town does not assure that this person takes the route or routes in question to work. Also, there may be some surveys that are filled out with a lesser degree of honesty than is expected, thereby throwing off the results of the survey.

AVI Antennas and AVI Tags

With the increased use of intelligent transportation systems along the nations' roadways, it has become easier to collect data that used to be very labor intensive such as travel times. In fact, now commercial vehicles can not be tracked to make sure that they are not off schedule or off route. Some cars are also now equipped with global positioning system receivers, so that they can be located if the driver has trouble with his or her vehicle. Also, all vehicles can now pick up small, thin boxes that can be affixed to the windshield of the car, which can be read by antennas that can automatically pay a person's toll without even without stopping at a toll booth. The technology spoken about here uses an instrument called AVI to determine which car has passed under an AVI antenna, and through that, their account can be debited for the amount of the toll.

AVI is not exclusively used for toll collection, though. AVI also has applications for determining speed and travel time along arterials and freeways that are equipped with these AVI antennas. A vehicle equipped with an AVI tag can pass under the AVI antenna, which can read the identification number imbedded within the tag, which then has its number stored within a computer for data collection purposes. Futher down stream, the tag can be read again, and from this, a travel time or average speed over a freeway or arterial link can be determined.

Using this information, this AVI system can be implemented along congested freeways in an urban area, as well as parallel arterials. To determine diversion, AVI antennas would have to be installed well before the congested area to make sure that as many diverting vehicles can be captured as possible. This system would have to be quite vast to cover the area to be able to track all diverting vehicles along almost all-possible routes. Routes that are not known as diversion routes can be eliminated easily. These routes can be determined either through volume counts or the origin-destination survey mentioned in the previous section. As a vehicle travels under the AVI antenna, the AVI tag is read. The tag reads would be sent to a central computer, which could map the traffic, and determine if there is diversion taking place and the severity of the diversion. The local transportation agency once again should determine the amount of diversion that would constitute whether the roadway is at LOS F-1, F-2, or F-3.

Much like the surveys, the AVI method also has some advantages and disadvantages. The advantages, in this case, are many. The AVI system can allow real time data collection and a real time level of service grade for the roadways in question. Also, this system allows for the electronic collection of data. Without this system, it would take a large number of data collectors to be able to hope to collect a tenth of this data. Also, this data can be collected twenty-four hours a day, seven days a week, three hundred and sixty-five days a year. Another advantage would be that this system, once installed, is not labor intensive. The upkeep of the system along with the coding so that real time level of service classification can occur is the only real cost of maintenance of the system. The major disadvantages have to be the initial cost. To insure that the area that needs to be covered by the AVI system is covered, a myriad of AVI antennas would have to be installed along both the freeway within and outside of the congestion area, and along the arterials determined to be diversion routes. Not only does the area need to be saturated with AVI antennas, as well as having to be interconnected to allow for a central computer to collect data, vehicles and other users of the roadway system would have to contain the AVI tags. This leads to another disadvantage, which is that people could perceive that having these tags in their cars is compromising their privacy, and that the government is tracking them. This fear could be allayed somewhat by a positive public service campaign by the local transportation agency responsible for collecting the data.

License-plate Matching

Much like the AVI antenna system, this is also a tracking technique that can determine the amount of diversion by reading the license plate of a vehicle passing a specific point. Cameras positioned over lanes on a freeway or arterial can be focused upon the license plate holder on a vehicle, and record this information. This system would have to be as wide ranging as the AVI system. License plate matching cameras would have to be positioned within and outside the congestion zone, as well as on the parallel diversion routes to make sure that all the data necessary is collected.

The advantages and disadvantages mirror those of the AVI system, though the privacy concern would be more so here, than with the AVI, as license plates can be traced to a unique vehicle. AVI tags on the other hand, can not be tracked as readily. This system would also have to be interconnected and linked to a central computer. The data will not be as real time as the AVI system, if there is not recognition software available, and would take more labor than the AVI system.

THEORETICAL EXAMPLE OF IMPLEMENTATION

This section discusses the implementation of an ITS system that would be used to determine the level of service on a congested freeway.

United States Highway 290, which runs through Houston, is a major urban freeway, funneling traffic from northwest sections of Harris County, as well as a vital link between Austin and Houston. During morning and evening peaks, congestion is very heavy, causing major delays. Running parallel to this highway is Hempstead Road, which used to carry US 290 until the Northwest Freeway was completed. On both Hempstead Road and US 290 AVI systems have been installed to measure the average speeds and travel times. This system is interconnected to a central computer at TransStar, where the data is collected and compiled.

The city of Houston would come together and need to determine the point at which diversion from US 290 onto Hempstead Road is too much diversion. US 290 is a 6 to 8 lane freeway from Interstate Highway 610 to the Sam Houston Tollway, which is the area in which Hempstead Road is a viable alternative road. Hempstead Road currently is an underutilized signalized arterial, which is pushed as an alternative to the congestion of US 290. In this case, a good bit of diversion is considered to be okay, since Hempstead Road can handle the traffic, though the maximum amount of diversion may be close at hand. It would all depended on the consensus on how much diversion would cause a problem.

Data from vehicles carrying toll tags along US 290, sent to the central computer would need to be cross-referenced with the data from the AVI readers located along Hempstead Road. Data points that remain after this query would be compiled and it would be determined if this is diversion, or if the diversion seen is just a normal trip. This would be done if a certain toll tag identification number appears more than once on the alternative route, here Hempstead Road. Using the information, US 290 can be graded on the stratified level of service spoken of earlier in this report.

This is the only freeway in Houston that this could be conducted, as at this time, the only arterial in Houston that has the AVI systems on it is Hempstead Road. This could be conducted in San Antonio as Bandera Road in the northwestern section of San Antonio also has AVI installed. In this section of town, Interstate Highway 10 is the primary route, and Bandera Road would be considered the alternative diversion route.

CONCLUSIONS

In conclusion, the author determined that there should be an increased level of service F, as the current system, as well as the historical system, has never dealt with the subject. It was decided that there should be 3 strata of level of service, F-1, F-2 and F-3. From the research and interviews completed, diversion should be the measuring factor for this LOS F regime. Each local agency would have to set their own standards, as congestion is a relative entity. This would be done through historical data and/or origin-destination surveys.

Further research in this area would be warranted, in the author's opinion. A wider array of interviews would be helpful, as very few interviews could be used in this study. Also, a more in depth look at this subject could be useful. It would also be of help to take the findings of this report and test it in a real world application, and also to gain the insight of the traffic industry once they can see how this system would work.

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DEVELOPMENT OF PORTABLE VARIABLE MESSAGE SIGN USER GUIDELINES FOR COMMON APPLICATIONS

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SUMMARY

The use of Portable Variable Message Signs (PVMSs) has increased dramatically over the last few years. In a 1996 research paper, David Halloin identified several impediments to the efficient operation of a PVMS. One of the impediments identified was the lack of signing guidelines. A review of state departments of transportation (DOT) internet sites has revealed that many states own and operate PVMSs. However, few states have any guidelines in place to aid in the operation of the signs. User guidelines would be used to guide PVMS operators on such issues as whether or not to use a PVMS, where to place a PVMS, and how to design a PVMS message. A simple list of suggested messages to display would not cover the variety of traffic conditions that can occur.

The intended audience is primarily a technician rather than an engineer. This person would be responsible for setting up the PVMS on site and programming a message. Although the desired location and message may be selected off-site, unknown conditions on-site may require modification to the message or location. The development of the PVMS User Guidelines will be guided by the following process,

1. Determine the audience
2. Determine the purpose of the User Guidelines
3. Include a foreword or preface
4. Determine a format
5. Follow a logical order
6. Include a visual inspection

The User Guidelines will provide an operator basic knowledge on how to create and display an effective message informing drivers of abnormal road conditions associated with commonly occurring applications. The application chosen was incidents and accidents. The guidelines will also provide the field operator guidance on placement of a PVMS for visibility and legibility

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INTRODUCTION

Problem Statement

The use of portable variable message signs (PVMSs) has increased dramatically over the last few years. In a 1996 research paper, David Halloin identified several impediments to the efficient operation of a PVMS. One of the impediments identified was the lack of signing guidelines (*1*). Halloin states that, "Insufficient standards in the area of PVMS operation make it difficult to find documentation on operating the signs unless the agencies have developed or adopted an official policy and references to be used…." A review of state departments of transportation (DOT) internet sites has revealed that many states own and operate PVMSs. However, few states have any guidelines in place to aid in the operation of the signs. A 1997 state-of-the-practice paper surveyed twelve state departments of transportation. Only four responded that their department had a written set of user guidelines (*2*). User guidelines would be used to guide PVMS operators on such issues as whether or not to use a PVMS, where to place a PVMS, and how to design a PVMS message. A simple list of suggested messages to display would not cover the variety of traffic conditions that can occur (*3*)

Research Objectives

The primary objectives of this paper were to:

- Gather information on researched guidelines;
- Gather information on state DOT operators' manuals;
- Compare state DOT PVMS Operators' Manuals to guidelines established through research;
- Determine to what degree the State Manuals and Guidelines agree or follow the research guidelines; and
- Produce a draft set of user guidelines based on the existing manuals and research guidelines.

Scope

The research only covered the development of user guidelines for portable variable message signs. The guidelines are intended to assist a user with the proper placement of the PVMS, message display and development in commonly occurring applications. The guidelines are not intended to replace proper training in the use of PVMSs or cover every possible scenario that could develop. The research did not cover policy on who may use PVMS, what may or may not be displayed on PVMS (i.e. advertisements), or PVMS specifications.

PORTABLE VARIABLE MESSAGE SIGNS

Definition and Application

Portable Variable Messages Signs (PVMSs) are traffic control devices used to inform motorists about recurring congestion, non-recurrent congestion, weather related problems, congestion due to special events, routes, speed restrictions, and other changing conditions or requirements (*4*).

Types

There are numerous types and manufacturers of PVMS (*5*). Three classifications exist for PVMS, Light-reflecting, Light-emitting, and Hybrid. A hybrid display is one that combines both light reflective and light emitting materials (*6*).

Light reflecting PVMSs may use rotating drums or reflective disks to display a message. The rotating drum appears much like a conventional highway sign. Typical rotating drum signs have no more than four drums and display up to twelve unique messages. A reflective disk sign can use circular, rectangular, or dimensional square disks. The disks are rotated electronically to provide either a reflective face or a black face to compose a message. Light-emitting signs may use incandescent bulbs, fiber optics, or light-emitting diodes (LED) to display a message (*6*).

Components

The general components of a PVMS control cabinet, central processing unit (CPU), sign face, and power plant. The control cabinet contains the controls for operating the sign. The CPU translates the operators commands into an actual display shown on the sign face. The sign face is used to display the message to motorists (*5*). Text messages are displayed and can be flashed or static in appearance. Typical character heights range from twelve to eighteen inches. Portable VMS (PVMSs) typically have three lines of text with eight characters per line (*6*). Most PVMS run off batteries. The batteries are continuously charged by either a diesel generator or a solar panel. PVMS also have a line power option to run on existing commercial electrical service (*5*).

Impediments to the Effective use of PVMSs

In 1996, David Halloin identified twelve impediments to effective PVMS operation. Eleven of the impediments are presented. The filtering of LED emissions by sunglasses has been corrected.

1. Message length

   If a message is too long, motorists will be unable to read and understand it. The benefit of using the PVMS is greatly reduced (*1*).

2. Signing guidelines, references, and operator training

   PVMSs are operated by persons with varying degrees of experience and various backgrounds. Operators have difficulty designing brief messages that still relay the necessary information to the motorist. Many agencies also lack a sufficient number of personnel with proper PVMS training.

3. Methods of monitoring site conditions and messages

   To maintain an effective message, accurate information is needed about roadway conditions and activities (*3*). Acceptable sources and methods include credible traffic reporters, police, and visual inspection by agency personnel. Telephone calls from motorists can often be misleading and inaccurate (*1*).

4. Authority for speed control

   Agencies surveyed by Halloin reported that use of PVMSs for speed control had a limited effect. The reduction in speed was typically 5 mph and in some instances only occurred when there was a police presence. If the sign were in place for an extended period of time speeds would return to normal (*1*).

5. PVMSs for marking lane changes

   The use of PVMSs for lane closures and lane shifts is a valid use. However, agencies may be over-using PVMSs for this function. Some agencies in Halloin's survey actually reported using PVMSs as arrow boards. PVMSs may be used to supplement arrow boards but should never be used in place of an arrow board (*1*).

6. Use of a message to alert motorists of future changes in conditions.

   The problem associated with the use of PVMSs for notification of future events is the length of time the message is displayed. If signs display the same message for extended periods, motorists become familiar with the sign and begin to ignore its presence. If the message is changed, the familiar motorists may not notice the new message (*6*).

7. Displaying Default Messages

   Some agencies feel that PVMSs should display messages at all times, even if the message is only the "normal traffic" conditions exist. This assures that motorists know the sign is working. Researchers postulate that the display of trivial information can lead motorists to ignore the sign and possibly miss important information.

8. Operator Boredom

   Operator boredom is a potential problem when PVMSs are operated through a traffic management center. The operator is waiting for conditions to change so that he or she may update the sign. The operator is not actively dealing with the sign and may become bored. The appropriate message may not be displayed promptly when conditions change (*1*).

9. Outdated or high maintenance equipment

   Lamp and equipment failures can impede the effective operation of PVMSs. Older equipment can be very costly to operate. Signs that cannot be operated remotely require an operator to drive out to the sign to change the message (*1*).

10. Cost and manpower necessary to operate system

    Lack of manpower limits the timely updating of messages, especially with remotely located signs. Remotely located signs may require an operator to remain on site to update the message display and monitor site conditions. If the operator cannot remain on site, then he or she must drive back and forth checking the conditions. Either option is time consuming and costly.

11. Motorist recognition of abbreviations and symbols

    Abbreviations are typically used to display word longer than eight characters or to aid in fitting a message to one or two screens. Problems occur when the abbreviation used is not understood by motorists (*1*).

GUIDELINES DEVELOPED THROUGH RESEARCH

Proposed MUTCD Guidelines

The 2001 edition of the Manual on Uniform Traffic Control Devices (MUTCD) will contain standards and guidance for the use of PVMSs. These standards are currently in a review process. Part 6, Temporary Traffic Control, of the MUTCD will contain the revised standards and guidance (*7*). The standards list what a VMS is and typical uses of VMS. It states that PVMS should be used as a supplement to and not as a substitute for conventional signs, markings and lighting.

Message Development

Message development should consider the following guidance:

- No more than two displays within one message cycle;
- Each display should convey a single thought;
- Line 1 should be a problem statement, line two should give location or distance, and line three should give the recommended driver action;
- Messages should be as brief as possible;
- When abbreviations are used, they should be easily understood; and
- The entire message cycle should be readable at least twice at the posted speed.

The MUTCD guidance on message components location is difficult to accomplish with PVMSs. A typical PVMS had only three lines of text of up to eight characters (*6*). The problem statement of "Right Lane Closed" would take up all three lines of text. However, the appropriate action, in this case move left, can be implied by the message.

As mentioned in Halloin's report, abbreviations can cause problems when they are not understood by the motorists.

The guidance of reading the message cycle at twice can be difficult to accomplish, especially for messages requiring multiple displays. The reading time of the motorists is dependent on many factors, one being speed and distance to the PVMS. Other factors can contribute to failure, such as large vehicles blocking the view of the sign (3).

Message Display

The MUTCD will contain the standard that messages shall not scroll or travel horizontally or vertically across the face of the sign (see Figure 1) (7).

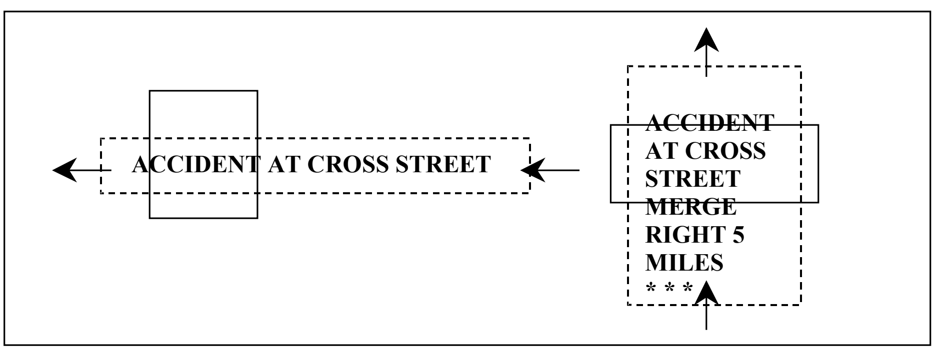

Figure 1 Scrolling Messages

Sign Placement

Placement of the PVMS should follow the following guidance:

- Where used for route diversion, PVMS should be placed in advance of the diversion to allow drivers time to exit;
- PVMS should be placed on the shoulder of the roadway or, if practical, farther from the traveled lane;

- When two signs are required to convey a message, they should be placed on the same side of the roadway, 1000 feet apart;
- Should be visible from ½ mile under day and night conditions;
- Message should be legible from a minimum of 650 feet; and
- PVMS should be sited and aligned to ensure legibility.

The MUTCD will also require that the PVMS be mounted such that the bottom of the display panel is a minimum of seven feet above the roadway when operating.

Existing Research

Message Development

An effective Advisory VMS message is constructed using four components: problem statement, effect statement, attention statement, and action statement. A Guide sign VMS message is composed of a destination affirmation statement and route affirmation and direction statement. Advance signs are composed of an information alert, nature of information, destination, and location statements (6).

The order of the message is important and unnecessary information must be avoided. Unnecessary information may include a component of the message. The component can be implied by the phrasing of the message. Words like street or boulevard also qualify as unnecessary; the important information is the name of the street. Removing unnecessary information will conserve space and free room for more important information.

Order refers to the order of the lines and the order of the display. Drivers expect to see the word “accident” first in a message. Placement elsewhere in the message becomes confusing. A message may require more space than is available on the PVMS. The user can split the message onto two separate, sequential displays. A potential problem occurs when a motorist begins viewing a message in the middle of its display. The message must make sense in any order that a driver may see it (3).

The use of the word “ahead” in place of a distance is redundant in the sense that drivers expect that the message is about an activity that is ahead of them on the roadway (6). However, the repetition of key words in the message is an important element (6). It will help motorists relate message screens to each other and increase driver understanding (see figure 1).

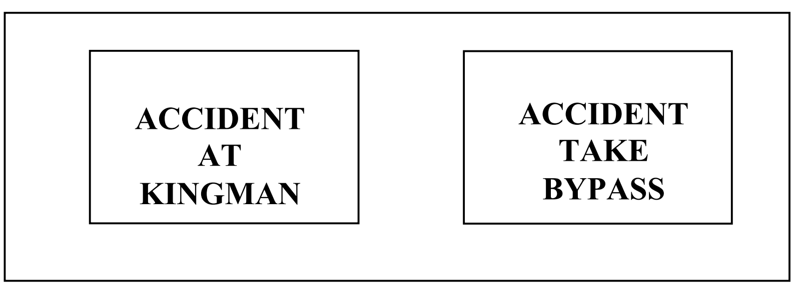

Figure 2 Keyword repetition

Operators should exercise care when using the words “detour” and “alternate route”. Research has shown that “detour” implies that an alternate route has been thought out and is signed to guide motorists. “Alternate route” on the other hand implies that drivers must determine their own route (3). Whether route diversion messages are optional or mandatory should be also made clear to motorists (3).

Message Length

The reading time is the time required for a driver to read a message. The reading time is a product of the length of the message. Research has shown that messages of eight words in length approach the processing limits of drivers at high speed (6). Dudek has suggested a minimum exposure time of one second per short word or two seconds per unit of information whichever is larger.

Message Display

VMS should display messages using single stroke fonts and capital letters. Studies have shown that double stoke lettering has a 25 percent reduction in legibility distance. Miller references research by Mace, et al, which determined that the gains in legibility by using lower-case letters were small: typically fifty feet for high-contrast materials and sixteen feet for low contrast materials (8).

No more than two screens or displays should be used to convey a message. A discrete message is one that is displayed all at one time. The compact and chunk extended formats are recommended for discrete displays. Messages that require more than one screen are known as sequenced messages. Three methods exist for displaying sequenced messages. Word sequencing is the display of one word per sequence, line sequencing is the display of two words per sequence, and chunk sequencing is the display of four words per sequence. Messages with four words or less may use any of the three methods. Eight word messages should use either chunk or line sequencing (6).

Chunking a message is accomplished by splitting the message into compatible units of information. “McQueeny Traffic” and “Use Exit 725” are compatible in the sense that the action statement refers to the intended audience (6).

Sign Location

Advisory signs should be located using the following guidelines (6):

- Upstream of bottleneck and high accident locations;
- Upstream of major “decision points”;
- In advance of freeway to freeway interchanges; and
- Should not be within a major interchange.

Advisory PVMS should be spaced a minimum of three-quarters of a mile from each other in bottleneck areas. With respect to exit ramps and advance guide signs, advisory VMS must be located upstream of the exit direction sign used for diversion (6).

Summary

A synthesis of the existing research and guidelines is given in the following bulleted lists. This will be used as the basis for comparing the state DOT manuals.

Message Development

Message Development should follow these guidelines:

- A message should not use more than two screens in one cycle;
- Each display should convey a single thought;
- Problem statement, location/distance, and recommended driver action format;
- The entire message cycle should be readable at least twice at the posted speed; and
- The message must make sense in any order that a driver may see it.

Message Length

The length of the message should follow these guidelines:

- Messages should be no greater than 8 words in length;
- Design for no more than two displays within one message cycle; and
- Minimum exposure times of one second per short word or two seconds per unit of information whichever is larger.

Message Display

The display of a message should follow these guidelines:

- No more than two screens should be used to convey a message;
- Eight word messages should use either chunk or line sequencing;
- PVMS should display messages using single stroke fonts and capital letters
- Visually check message operation; and
- PVMS should be blank when not in use and turned away from traffic until it can be removed.

PVMS Location

The location of a PVMS generally follows these rules:

- Where used for route diversion, PVMS should be placed in advance of the diversion to allow drivers time to exit;
- PVMS should be placed on the shoulder of the roadway;
- When two signs are required to convey a message, they should be placed on the same side of the roadway, 1000 feet apart;
- Upstream of bottleneck and high accident locations;
- Upstream of major "decision points";
- In advance of freeway to freeway interchanges; and
- Should not be within a major interchange.

CRITIQUE OF STATE DOT OPERATOR'S MANUALS AND GUIDELINES

North Carolina Department of Transportation

The North Carolina Department of Transportation has developed a set of guidelines titled, "Operational Guidelines for the Use of Changeable Message Signs" (5). The guidelines and cover many aspects of changeable message sign operation and installation. The topics include;

- Policy and applications;
- Sign placement and installation;
- Security;
- Message development;
- CMS programming; and
- Maintenance .

The guidelines list levels of message priority. The highest level, level one, is Emergency. Emergencies are described as "unplanned events where extreme traffic diversions are required." The next level is Hazardous Conditions. Messages at this level constitute the majority of messages shown to drivers. It includes extreme weather conditions such as snow or fog, traffic accidents, and congestion. The third level is Short Term Detour. This level covers things such as over-night ramp closures and temporary weight restrictions on bridges. The next level is Traveler Information. It covers real-time traffic conditions and displays messages related to expected delay and alternative route suggestions. The fifth level is Advance Notice. Advance Notice is for planned events such as sporting events and scheduled lane closures. The last and least important category is Public Information pertinent to Highway Safety. The messages displayed under this level require an action to be taken by drivers and covers license, seat belt, and vehicle weight checks. Existing messages may only be replaced by messages of a higher priority level and the message being displayed must be the highest priority information required by the majority of motorists.

The North Carolina guidelines contain extra information concerning VMS and PVMS. Some of this information is policy related. It deals with who has authority over the use of VMS and what message types will not be displayed. The PVMS guidelines are not separated from the VMS guidelines and the majority of the extra information is related to the operation of PVMS. One section gives a brief description of the physical components of a PVMS. It describes each component and it's function or operation. The guidelines have an overview of VMS programming and the use of a cellular phone to remotely program a sign. A section on maintenance is also included. It suggests a list of basic tools and spare parts that should be kept on hand when operating a PVMS unit. A preventative maintenance checklist, broken down by component and system, and trouble-shooting list are included. Each of these sections refers the operator to the service manual for the exact operating instructions. Although this information is relevant to operating a message sign, it is specific only to portable signs. With the exception of Maintenance, it would be best if this extra information were removed and compiled in a separate document.

Oregon Department of Transportation

The Oregon Department of Transportation has also released a set of guidelines. Titled "Guidelines for the Operation of Variable Message Signs on State Highways" (*9*) it is very similar to the NCDOT's guidelines. ODOT's guidelines address the following:

- Definition of VMS;
- Types of VMSs;
- Conditions warranting message display;
- VMS authority;
- Operation;
- Message selection;
- Displaying, altering, and removing a message;
- Restrictions on VMS use;
- Permanent variable message sign computer use; and
- Record keeping.

The areas of interest for this report are Conditions Warranting Message Display, Message Selection, Displaying Messages, and Restrictions on Use. The ODOT guidelines also have a message priority hierarchy, similar to NCDOT. There are eight levels of priority as follows:

1. Drawbridge operations, road or ramp closures, and emergency situations;
2. Incident or accident;
3. Construction of maintenance operations;
4. Adverse weather or environmental conditions;
5. Traffic operations information for special events;
6. Travel-related information directed to individual vehicles;

7. Travel-time information; and
8. Public service announcements.

Message selection begins with the determination of whether or not the message is routine. A routine message is composed using Supplements C of the guidelines: Sample Message for Display on Portable Variable Message Sings. Non-routine or special messages are composed from a list of guidelines. The guidelines list things such as the components of an advisory message, suggest that the operator display compatible units of information in “chunks”, and to limit the length of the message to eight words of four to eight characters each. The correct method for displaying distances is also addressed. The use of PVMS is covered in a supplement to the guidelines, Supplement B: Use of Portable Variable Message Signs.

Virginia Department of Transportation

Virginia Department of Transportation (VDOT) has two separate Operator’s Manuals. The first is specific to permanent VMS and the second is specific to portable VMS (*10*). The manuals use modules to step the operator through a decision process. The PVMS manual contains seventeen modules, which are

1. Should a CMS be used?
2. What is the purpose of the CMS?
3. Where should the CMS be located?
4. What is the maximum number of screens that may be used?
5. What is the message type?
6. What is the message? (current incident or work zone advisory)
7. What is the message? (route diversion)
8. What is the message? (guidance for a special event)
9. What is the message? (advisory for a future event)
10. How should distances and locations be conveyed?
11. Are the words “TRAFFIC” and “AHEAD” used only as necessary?
12. Is the word “NEXT” used only as necessary?
13. How should the CMS message be sequenced?
14. Is the message acceptable?
15. How should the message be displayed?
16. Does the CMS pass the drive through test?
17. When should the message be updated or discontinued?

The manual is a systematic process for using a VMS. The operator begins with module one and proceeds to answer several questions. The modules use a true or false system for answering questions. Each item or question in the module must be answered before moving on to the next module. Both manuals include a foreword detailing the purpose and intent of the manual. Four statements in the foreword are important to note. The first states that the manual is to serves as a training and reference tool. The second is a requirement that the manual be updated. Operators are given a contact for suggestions on improvement. The next says that VDOT requires anyone who will operate a VMS on the highway system within the Commonwealth of Virginia must read the manual at least once. The last states that the manual does not replace existing standards set forth in the MUTCD or the Virginia Work Area Protection Manual.

COMPARISON OF GUIDELINES TO RESEARCH

Tables

The following tables (Tables 1 through 4) compare the state DOT guidelines and manuals to the guidelines developed from research. The comparison is separated by Message Development, Message Length, Message Display, and PVMS placement. A "YES" or "NO" is given based on the inclusion of each guideline.

Table 1. Message Development

Researched Guidelines	NCDOT	ODOT	VDOT
1. No more than two displays within one message cycle.	NO	NO	YES
2. Each display should convey a single thought.	NO	NO	NO
3. Problem statement, location recommended action.	YES	YES	YES
4. The entire message cycle should be readable at least twice at the posted speed.	NO	NO	NO
5. The message must make sense in any order that a driver may see it	NO	NO	YES

Table 2. Message Length

Researched Guidelines	NCDOT	ODOT	VDOT
1.Maximum of 8 Words	NO	YES	NO
2. No more than two displays within one message cycle	NO	NO	YES
3. Minimum exposure times of one second per short word or two seconds per unit of information whichever is larger	NO	YES	YES

Table 3. Message Display

Researched Guidelines	NCDOT	ODOT	VDOT
1. No more than two displays within one message cycle	NO	NO	YES
2. Chunk or line sequencing for messages with 8 words.	NO	YES	NO
3. Use single stroke fonts and capital letters	YES	NO	YES
4. Visually check message operation	NO	YES	YES

Table 4. VMS/PVMS Placement

Researched Guidelines	NCDOT	ODOT	VDOT
1. Where used for route diversion, PVMS should be placed in advance of the diversion to allow drivers time to exit.	YES	NO	YES
2. PVMS should be placed on the shoulder of the roadway	YES	YES	YES
3. When two signs are required to convey a message, they should be placed on the same side of the roadway, 1000 feet apart.	YES	YES	YES
4. Upstream of bottleneck and high accident locations	YES	NO	YES
5. Upstream of major "decision points"	NO	NO	YES
6. In advance of freeway to freeway interchanges	NO	NO	NO
7. Should not be within a major interchange.	YES	NO	NO

Results

The comparison of the research to the manuals suggests that the use of published research to aid in the development of user guidelines will vary by agency. Some agencies appear to have used the MUTCD exclusively, others a combination of the MUTCD guidance and research.

DEVELOPMENT OF AN OPERATOR'S MANUAL

Key Lessons

While developing a set of operator's manuals for the Virginia Department of Transportation, Miller, et al identifies six important lessons for the operation of a VMS.

1. VMS operators need a manual

   An operator's manual will assist operators but not replace them. A manual is superior to a static list of messages. An operator is able to respond to unforeseen conditions and still have an effective message.

2. VMSs should be used to advise motorists of changed traffic conditions

   VMSs should only be used to give information about abnormal conditions. Motorists typically ignore greeting messages and generalized safety statements.

3. VMS must meet motorists information needs

   A VMS message must tell motorists what action is required. Messages should tell specifically which lane is closed and where the closure begins.

4. VMS have limited information capabilities

   VMSs provide more effective guidance when used in combination with other information mediums such as highway advisory radio and other static signs.

5. Credibility is crucial

   Messages must be confirmed and updated. Drivers will ignore VMS messages if they believe they are incorrect. It would be better to display less information or no information at all if the user is unsure of the traffic conditions (*6*).

6. VMS should have no more than two message screens

   It is difficult for drivers to read more than two screens of text at high traffic speeds.

Use of Modules

The VDOT guidelines use modules to determine the message to be displayed on the VMS. A module outlines a single, distinct thought process in the development of the message. Each module serves as a checkpoint ensuring that the proper decisions have been made. The logical flow of decisions points allows the inexperienced operator to become familiar with the use and operation of VMS.

Modules offer many advantages over a simple list. Modules make the manual easier to update, they streamline the decision process, and present information in a user-friendly manner.

Separate VMS/PVMS Manuals

Miller stressed that separate manuals should be used for portable and permanent VMS. VDOT uses two separate manuals for operating VMS. There are three differences between the manuals: the PVMS manual includes a module for the placement of PVMSs, the calculation of unreadable distance is different between permanent and portable VMS, and the display format for the two signs may vary. The other sixteen modules are essentially the same between manuals. The ODOT guidelines also separate out PVMS guidelines. The guidelines are attached as a supplement to the permanent VMS guidelines. The supplement repeats much of the permanent VMS guidelines and contains a section for determining the location of the PVMS. The NCDOT guidelines do not separate out guidelines for PVMS. The Maryland guidelines only cover permanent VMS.

Use of Sample Messages and Abbreviations

Pre-approved messages designed for common situations and a list of abbreviations to use and not to use are important (*1*). With the exception of the Maryland Guidelines, each manual and set of guidelines uses sample messages. The VDOT Manuals illustrate message components using sample messages. NCDOT and ODOT both have an appendix or supplement that lists several sample messages. The guidelines ask the operator to refer to the list when composing a message. The same three manuals also include a list of recommended abbreviations.

Consistency and Readability

An operator's manual must be simple and effective. In the development of operator's manuals for the VDOT, Miller made each page similar in form and content. Decision boxes for each module are located in the same place one each page regardless of the amount of text on the page (3). All questions are in a true-false format. In determining the number of message screens required for a message, the manuals started with equations for the computation of legibility distances and reading. This was then changed to a system of tables which then morphed into a single, simple statement, "One screen is ideal, two screens are acceptable, and three should be used only under extreme circumstances."

RECOMMENDED GUIDELINES

Process

The development of the PVMS User Guidelines will be guided by the following process,

1. Determine the audience;
2. Determine the purpose of the user guidelines;
3. Include a foreword or preface;
4. Determine a format;
5. Follow a logical order; and
6. Include a visual inspection.

Audience

The intended audience is primarily a technician rather than an engineer. This person would be responsible for setting up the PVMS on site and programming a message. Although the desired location and message may be selected off-site, unknown conditions on-site may require modification to the message or location.

Purpose of User Guidelines

Scope

The User Guidelines will provide an operator basic knowledge on how to create and display an effective message informing drivers of abnormal road conditions associated with commonly occurring applications. The application chosen was incidents and accidents. The guidelines will also provide the field operator guidance on placement of a PVMS for visibility and legibility

Basic Knowledge

The guidelines will include information on message composition, verbiage, and message display. Verbiage will include guidance on “words” to avoid using and definitions of some common terminology (i.e. “detour” vs. “alternate route”). Preferred methods of displaying the message (i.e. flashing words, scrolling text, chunking) and preferred methods of displaying distance will also be included.

Foreword

The foreword is specific to each agency that operates PVMS. Generally, it should include a description of why PVMSs are used and the limitations of PVMS. The purpose of the Guidelines should be mentioned to help focus the user. Any clauses and statements regarding the proper use of the guidelines and use of the guidelines in relation to other standards should be included in this section.

Format

Formatting is important. A consistent formatting scheme will assist in making the guidelines simple to use and apply. Each page should have similar wording and sentence structure. The format style used is a combination of the module approach used by VDOT Operator’s Manuals and the section format used by NCDOT and ODOT User Guidelines. Sections organize the information within the User Guidelines. Within each section, the user is focused on a single idea such as message display or PVMS placement. Guidelines are applied using the True/False or Yes/No question scheme. Each question has a definite answer and all questions must answer positive. A negative response indicates a need to make a modification.

Logical Order

A logical order to the guidelines is important. Order helps to prevent confusion. The user is more likely to use the guidelines if they are not confusing and are presented in a clear, orderly manner. The suggested order for this research is

1. Foreword
2. Is a PVMS required?
3. PVMS Location
4. Message Creation
5. Message Display
6. Updating/Terminating the Message

Is the PVMS Required?

This simple question has a lot of impact. PVMSs are not to replace existing static signing or to be used where static signing would work better. PVMS are only used to supplement static signing. The criteria for using PVMS are

1. The message will not tell drivers something they already know.
2. A static sign(s) would not effectively convey the message.
3. A response by the driver is required.
4. The accuracy of the message can be maintained.

PVMS Location

General location of PVMSs is based on visibility, legibility, and accessibility. Visibility and legibility of the PVMS should follow MUTCD guidance. The MUTCD standards and guidance are:

- PVMS should be visible from ½ mile under both day and night conditions;
- PVMS should be legible at 650 feet;
- PVMS should be placed on the shoulder of the roadway or, if practical, further from the traveled lane;
- When two signs are required to convey a message, they should be placed on the same side of the roadway, 1000 feet apart; and
- The bottom of the message sign panel shall be a minimum of 7 feet above the roadway when operating.

In addition, visual clutter in the area should be avoided and view of the sign should not be obstructed by signs, poles, or other objects. PVMS should not be placed within a major intersection or in an interchange.

The PVMS should also be located where it accessible by maintenance vehicles at all times. The maintenance vehicles should not pose a danger to traffic, nor should the user be in danger while operating the sign.

Driver decision time is an important factor. PVMS should be placed in advance of major decision points such as intersections and interchanges. It should also be placed in advance of expected traffic queues so that drivers are aware of the downstream situation. When used for route diversion, PVMS should be placed in advance of the diversion to allow drivers time to exit.

Message Development

The section for message development is tied to the scope of the guidelines. In this case, the guidelines for message development will cover Incidents and Accidents. A message-programming sheet, similar to the sheet in the NCDOT guidelines is included at the beginning of the guidelines, after the forword. The message is written in the sheet and then the guidelines are applied.

A typical Incident/Accident advisory has three components, the problem, the location, and the instruction. Each component is not always needed and may be implied by the message selected. The MUTCD offers guidance on the placement of the components. Line one should be the problem, line two the location or distance, and line three the driver action. This may be difficult to accomplish with the limited size of PVMSs.

The problem statement is the first piece of information (as suggested by the MUTCD). This statement must be clear and comprehensible. The problem statement describes the specific traffic condition. The figure below gives two example of showing the use of a problem statement. The first gives a simple, effective statement and avoids flashy or excitable language. The second uses an implied problem statement. The ultimate message is still clear and comprehensible; the left lane will be closed in five miles.

The location component indicates where the traffic incident occurs. It may be an exit number, a distance, or a landmark. Consideration for the location description should include the familiarity of the motorists.

ACCIDENT 5 MILES MERGE RT	**LEFT LN CLOSED 5 MILES**

Figure 3. Problem Statement

When the majority of motorists are unfamiliar with the area, distances should be given in miles, rounded to the nearest half-mile. Exit numbers may be used when the exits are numbered sequentially. When the majority of drivers are familiar with the area street names and exit numbers may be used.

The driver action is an instruction that describes what the motorist should do, such as change lanes, exit the freeway, slow down. The driver action may also be implied. The figure below illustrates two messages. The first has a driver action statement, the second an implied statement. Again, the message is clear and comprehensible; the left lane will be closed in five miles.

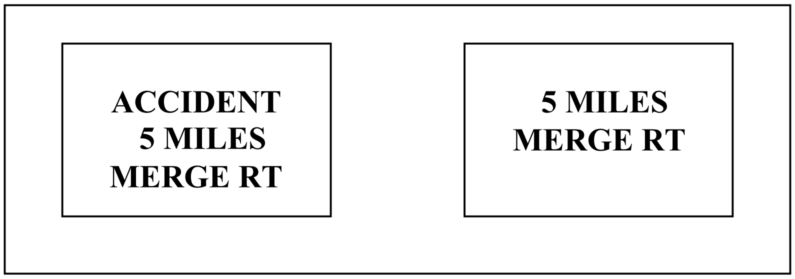

Figure 4. Driver Action Statement

Abbreviations can be used to shorten words and conserve space. However, abbreviations must be understood by drivers to be effective. A list of standard accepted abbreviations may be included with the guidelines. Acceptable abbreviations will differ between agencies.

Care should be taken when using the words “detour” and “alternate route”. “Detour” implies that an alternate route has been thought out and is signed to guide motorists. “Alternate route” on the other hand implies that drivers must determine their own route

The use of the word “ahead” in place of a distance is redundant in the sense that drivers expect that the message is about an activity that is ahead of them on the roadway.

Message Display

Message display covers the several items, including:

- sequencing of the message;
- the number of screens or displays that may be used;
- the use of flashing text;
- screen display time; and
- font.

Message sequencing should follow the following guidance:

- Messages screens must be compatible and make sense when read separately;
- The message must be understood in any order that the driver may read the message; and
- The maximum of two message screens shall be used.

Flashing text may be used to grab motorist attention. Flashing large amounts of text is impractical and impairs the drives ability to read the message. A single line, such as Accident, may be flashed, with the remainder of the screen non-flashing.

Display time is a function of many factors. The screen display time shall follow the guidance of a minimum exposure time of one second eight character word or three seconds per screen

The message will use single stroke fonts and upper-case letters. Single stroke fonts have longer legibility distance and lower-case letters are difficult to display on PVMS.

Visual Inspection

Visual inspection of the PVMS after installation is necessary to insure the message is displaying correctly, the meaning is understood by drivers (and is being followed), and that the message is visible. The best way to accomplish this is to perform a drive by before leaving the sign. Closed circuit television cameras may be utilized to observe the sign operation and as a signal to update or terminate the message.

Terminating and Updating a Message

The procedure for updating and terminating a message will vary by agency. In any case, when the conditions that required the PVMS change, the sign must change. This may mean changing the message to reflect different lane closures or moving the PVMS to a new location, further upstream or downstream. The following guidance should be used to determine when to update or terminate the message.

- Message is no longer accurate;
- Information is still unknown to majority of drivers;
- Drivers are not ignoring the message;
- The driver response is still accurate;
- Incident/accident continues to affect traffic flow; and
- The message can be displayed more effectively with a static sign.

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APPENDIX A

DRAFT

User Guidelines for the Operation of Portable Variable Messages

INCIDENT AND ACCIDENT MANAGEMENT

August 2000

FOREWORD

Definition and Applications

Portable Variable Messages Signs (PVMSs) are traffic control devices used to inform motorists about recurring congestion, non-recurrent congestion, weather related problems, congestion due to special events, routes, speed restrictions, and other changing conditions or requirements.

Variable Message Signs are also referred to as Changeable Message Signs and Dynamic Message Signs

Purpose of the Guidelines

These User Guidelines are intended to aid a user in creating and displaying an effective PVMS message for Incident and Accident Management and the preferred placement of a PVMS.

Proper Use Statement

Statement is specific to each agency. An example statement might be,

“It is required that any PVMS operator read these guidelines in their entirety at least once before operating a PVMS.”

Relations to other standards Statement

Statement is specific to each agency. An example statement might be,

“These guidelines do not replace existing standards such as the *Manual on uniform Traffic Control Devices* (MUTCD)”

Instructions

The first step is to fill out the Programming Sheet. A maximum of two screens may be used.

IMPORTANT: It is not a requirement to use two screens.

The guidelines are applied by answering several yes or no questions. Each question has a definite answer. A negative or “No” response indicates a need to modify the message, display, or location. Supplementary suggestions may also follow the guidance. This is additional information that may be of assistance when designing a message or locating the PVMS.

MESSAGE PROGRAMMING SHEET

Programming Sheet for
Portable Changeable Message Signs

PVMS Location: ______________________________

Date/Time Used From: ____ / ____ / ____ at ____________ AM / PM

To: ____ / ____ / ____ at ____________ AM / PM

Message Programmed by: ______________________________

Screen 1

Screen 1 Timing is: __________ seconds

Screen 2

Screen 2 Timing is: __________ seconds

IS THE PVMS REQUIRED?

1. A response is required by the driver	YES	NO
2. The message will not tell drivers something they already know	YES	NO
3. A static sign(s) would not convey the message more effectively	YES	NO
4. The accuracy of the message can be maintained	YES	NO

If any question above was answered **NO**, a PVMS should not be used.

LOCATING THE PVMS

Guidance

1. Is the PVMS is visible from ½ mile under day and night conditions?	YES	NO
2. Is the PVMS message is legible at 650 feet?	YES	NO
3. The bottom of the message sign panel is at least 7 feet above the roadway?	YES	NO
4. Can the PVMS placed on the shoulder or farther if practical?	YES	NO
5. When using two signs, are they placed on the same side of the roadway, at least 1000 feet apart?	YES	NO
6. The PVMS is not within a major intersection or interchange	YES	NO
7. The PVMS is placed in advance of expected traffic queues	YES	NO
8. The PVMS is placed in advance of major decision points	YES	NO

If any question above was answered **NO**, modify the location of the PVMS.

Supplement

- The PVMS should be located where it is accessible by maintenance vehicles at all times.
- Areas of visual clutter should be avoided when possible.

DEVELOPING A MESSAGE

Guidance

1. The Problem Statement has been included or implied?	YES	NO
2. The location statement has been included or implied?	YES	NO
3. When the majority of drivers are non-local, distance has been given in miles, rounded to the nearest ½ mile.	YES	NO
4. Exit numbers have been used to denote location when exits are numbered sequentially.	YES	NO
5. The Driver Action statement has been included or implied?	YES	NO

If any question above was answered **NO**, modify the text of the message.

Supplement

- The problem statement describes the traffic condition
- The problem statement must be clear and comprehensible
- The location statement indicates where the incident occurs
- The driver action describes what the motorist should do
- Flashy or excitable language should be avoided

ex. ACCIDENT instead of **TRUCK FIRE**

- When it is known that the majority of drivers are familiar with an area, street names and exit numbers may be used to denote locations.
- Abbreviations may be used to shorten words and conserve space. Consult Appendix A for a list of accepted standard abbreviations
- "Detour" implies that an alternate route has been thought out and is signed to guide motorists.
- "Alternate route" on the other hand implies that drivers must determine their own route
- The use of the word "ahead" in place of a distance is redundant in the sense that drivers expect that the message is about an activity that is ahead of them on the roadway.
- A particular statement or action may be implied within the message

ACCIDENT 5 MILES MERGE RT	**LEFT LN CLOSED 5 MILES**

The message on the left contains a problem statement **ACCIDENT**. The message on the right implies that a problem exist. The ultimate message is still clear and comprehensible; the left lane will be closed in five miles.

DISPLAYING A MESSAGE

Guidance

Message Sequencing

1. A maximum of two screens or displays has been used?	YES	NO
2. The message is understood in any order displayed?	YES	NO
3. Message screens or displays are understood separately?	YES	NO

If any question above was answered **NO**, the display setting should be modified
If more than two screens or displays have been used, the message will need to be re-developed.

Message Display

1. Single stroke fonts and upper-case letters have been used?	YES	NO
2. No more than a single line of text per screen is set to flash?	YES	NO

If any question above was answered **NO**, modify the message display.

Supplement

- Flashing text may be used to grab motorist attention. A large amount of flashing text is impractical and impairs the drivers ability to read the message.
- Screen display time shall follow the guidance of 1 second per 8 character word or three 3 seconds per screen.

VISUAL INSPECTION

Guidance

1. The PVMS can be seen clearly?	YES	NO
2. The message is understood?	YES	NO
3. Drivers are following the instruction	YES	NO

If any question above was answered **NO**, modify the message, display or location as appropriate.

Supplement

- Visual clutter should be avoided
- The view of the sign should not be obstructed by signs, poles, or other objects.

TERMINATING/UPDATING A MESSAGE

Guidance

1. The message is still accurate?	YES	NO
2. The information is still unknown to the majority of drivers?	YES	NO
3. Drivers are not ignoring the message	YES	NO
4. The driver response is still accurate	YES	NO
5. The incident/accident continues to affect traffic	YES	NO
6. The message cannot be displayed more effectively with a static sign?	YES	NO
7. The message accuracy can still be maintained	YES	NO

If any question above was answered **NO**, update or terminate the display.

APPENDIX A: STANDARD ABBREVIATIONS

The list of standard acceptable abbreviations will vary by agency or region.

APPENDIX B: TROUBLESHOOTING

Refer to the servicing manual for in-depth servicing problems. The following is a brief summary of some common problems and their possible causes.

Before attempting any troubleshooting, the following basic checks should be made.
1. The voltage of the sign battery bank is above 12 VDC
2. The engine battery voltage is above 12 VDC
3. LED1 on the CPU board flashes

Problem: The generator turns over but does not start.
Possible Causes:
1) The engine battery is dead
2) The engine fuse is blown.
3) Broken wire to oil pump or connector

Problem: The amp meter does not show charging current with generator running.
Possible Causes:
1) If the Power LED on the CPU board is on steady, then the battery is probably fully charged and is taking no more current.
2) Alternator switch is in OFF position.
3) Alternator is not receiving +12VDC on its yellow terminal. (See manual.)
4) Engine may be running slow. Check the RPM. (See manual for making adjustments.)

Problem: The cursor does not work on the laptop.
Possible Cause:
1) The number lock is on; turn it off.

Problem: Sign face shows yellow/black horizontal stripes on all three lines.
Possible Causes:
1) If the top row is yellow, the CPU board is not receiving -30volts DC.
2) If the top row is black, the CPU board is not receiving +30volts DC.

Problem: An entire column, from top to bottom, of the sign does not flip correctly.
Possible Causes:
1) Column triac on the CPU board has shorted or opened. (Replace)
2) Column driver transistor on the CPU board is bad. (Replace)
3) A chip has gone bad. (Replace)

Problem: Sign does not show message.
Possible Causes:
1) If the Power LED on the CPU board is flashing:
    a) The battery needs recharging.
    b) Check the cable that provides the voltages necessary for the CPU board to monitor for proper connection.
2) If the 30-volt LED on the CPU board is on:
    a) If not, the +/-30 volts is not present.
    b) Make sure the power cord is firmly plugged into the inverter.
    c) Check F1 in the control cabinet.

Problem: Entire row across sign does not flip correctly.
Possible Cause:
1) A bad transistor pair. To determine the correct transistor pair to replace, note which row is bad. (If the first row remains yellow, the negative driver corresponding to that row is bad, or vice versa)

Problem: The engine will not start from remote laptop or time implemented command (TICs).
Possible Cause:
1) There is an open circuit line on the backside of the start relay.

Problem: The battery chargers are not registering, although the engine is running.
Possible Cause:
1) The wires running from the alternator to the alternator casing could be shorting out due to insulation breakdown, wear or a loose wire connection.

Note: If the sign is equipped with a battery backup compartment, disconnect the negative lead to the backup and turn off the main circuit breaker (CBI) anytime maintenance is performed in the backup battery electronics compartment.

Problem: One or more dots on the sign are not flipping.
Possible Causes:
1) The flip dot holder is not seated in its magnet slots.
2) The flip dot coil burnt out.
3) The diode on one of the dot modules is open (if all three rows on the same column are not flipping.)
4) The coil wires are not making good connection under the screws which mount the coil bracket.

Problem: Not sensing 120v, 30v or engine on/off.
Possible Causes:
1) The alternator wires are shorting to the case, causing the sense lines to the CPU to be inoperable.
2) One or more of the 1/4 amp slow-blow fuses in the AC sense circuitry is blown.

Problem: There is a comm time out error when trying to start sign remotely.
Possible Causes:
1) The telephone line connection to the modem is loose, not making a good connection.
2) The modem speed is incorrect between the laptop and sign.
3) The modem in the PC central is too fast for the sign modem.

APPENDIX C: PREVENTATIVE MAINTENANCE

PREVENTATIVE MAINTENANCE

Refer to the maintenance manuals for in-depth maintenance instructions. The following is a brief summary of preventative maintenance requirements to keep the CMS generator, hydraulic lift, batteries and trailer in good working condition.

Generator

Task	Frequency
Check Oil	Weekly
Clean Air Filter	Weekly
Check Fuel Level	Weekly
Check Sediment Bowl (fuel transfer)	Weekly
Change Oil	100 hr
Clean Sediment Bowl (fuel transfer)	100 hr
Tighten Delivery Unions	300 hr
Replace Fuel Filter	300 hr
Replace Oil Filter	300 hr
Inspect Battery Terminals and Fluid	300 hr
Check Hydraulic Fluid	300 hr
Check Brake Fluid & Lube Jacks and sign pole	300 hr
Clean Cooling Fins	300 hr
Set Rocker Arm Clearance	300 hr
Set and Clean Injectors	300 hr

Hydraulic Lift

With the sign lowered, periodically check the hydraulic fluid reservoir and add transmission fluid as necessary. The suction filter and valve protection filters should be cleaned periodically, and if not cleanable, they should be replaced. The panel raising mechanism should be greased periodically.

Batteries

Periodically inspect the battery terminals, clean and tighten as necessary. The battery fluid level should be checked monthly and filled with distilled water, if necessary.

Trailer

Check brake fluid, tires and lug nuts, and lubricate the jack. Tire pressure should be 55 to 60 PSI. Periodically inspect for loose connections and hardware and tighten as required.

CPU Cabinet

Ensure all connections are seated.

Controller Cabinet

It is convenient to keep spare fuses in the controller cabinet. Placing labels on switches and key positions is generally helpful. Placing warning labels such as KEY TO OFF POSITION TO AVOID BATTERY DRAIN can avoid some unnecessary maintenance.

Miscellaneous

For signs that are attached to line power, it is suggested that the sign generator be run at least twice a month to keep the engine lubricated and in good working condition. In addition, the sign should have the oil, oil filter, air filter and gas filter replaced if it has not been done prior to connecting the electrical power.

ANDREW JAMES HOLICK

Andrew Holick earned his Bachelor of Science degree in Civil Engineering at Texas A&M University in December 1999. As an undergraduate, he spent three semesters working for the City of Missouri City Public Works Department as a cooperative education student. He worked in a variety of areas including traffic counts, traffic control plans, drainage analysis, residential street design, drafting, and field inspection. Andrew has also interned with the City of College Station Public Works Department. He worked on updating the City's Specifications and Construction Details and produced cost estimates for City capital projects. Andrew currently works at the Texas Transportation Institute as a Graduate Research Assistant in the Traffic Operations Program and is pursuing a Masters of Engineering degree in Civil Engineering. He is a member of the Texas A&M Student Chapter of the Institute of Transportation Engineers and the national and student chapter of the American Society of Civil Engineers. Andrew's career interests include traffic operations and design, geometric highway design, and project management.

PLANNING GUIDELINES FOR IMPROVING TRAVELER INFORMATION IN NORTH CAROLINA

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SUMMARY

"The information revolution has affected virtually every sector of human activity, and transportation is no exception".([1]) Research, both Nationally and in North Carolina, has shown that travel information is very important to the users of the transportation system. It is also important to operators of the transportation system. Informed travelers make better choices that ultimately lead to better use of available roadway capacity. USDOT states "Providing timely traveler information to the pubic has become a tenet of good public policy. Information can help travelers make more informed decisions and can lead to a more efficient and better functioning transportation system". (*1*)

The North Carolina Department of Transportation (NCDOT) recognizes traveler information as an important component of NC SMARTlink, the Department's Intelligent Transportation Systems program. NC SMARTlink currently provides both pre-trip and en route traveler information. With the advent of improved communications and other technologies, and the increasing capabilities and reliance on the Internet, now is the appropriate time to look at improving NCDOT's Traveler Information program. This paper assesses the needs of our system users and recommends tasks and approaches that should be undertaken to meet these goals, all in a way that can be easily understood by NCDOT Senior Managers.

Traveler information consists of pre-trip and en route information given to travelers, either by public entities or private providers. This information typically focuses on information about events or incidents that cause travel delays. Providing this information to travelers allows them to make decisions about trip time and route to help them avoid congestion and the resultant frustration it creates. Travelers may come from three different groups: Locals, Visitors, or Passers-Thru. Each of these groups must be looked at individually to assess what types of information they may need and what mechanism might be best used to get that information to them. Based on this categorization and the fact that most travelers are between the ages of 25 and 54, local TV and radio and the Internet appear to be logical delivery mechanisms to concentrate our efforts on. While local radio and TV traffic reporting is a mainstreamed function in urban areas, using the Internet for traveler information is not yet as routine therefore continuous publicity must be undertaken to increase awareness of this resource. Also emerging technologies such as 511 and in vehicle navigation should be explored and implemented as appropriate and as market forces allow.

NCDOT's current traveler information program, a component of NCSmartlink, is a good foundation for future efforts and appears to be focusing on the most important needs in traveler information and should continue based on the recommendations contained herein.

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INTRODUCTION

Information is important. Having information about a situation, especially a stressful situation, makes one feel more comfortable. Traveler information is no different. Information about the condition of the transportation system is important to system users. It is also important to transportation agencies as informed travelers can make travel choices that lead to better use of available roadway capacity.

Why Traveler Information?

The current trend of commercial and residential growth continues in the beautiful state of North Carolina. Several major highway construction projects are currently underway in areas where highway capacity is lagging development. Daily congestion is a reality during the AM and PM rush hours in North Carolina's urban areas where incidents frequently occur in areas where demand already exceeds capacity. Significant freeway incidents are unfortunately becoming more frequent. Natural disasters can swiftly and severely impact our transportation facilities. All of these conditions unavoidably lead to periodic lane reductions and resultant delay on major transportation facilities. All of these factors contribute to the need to use technology to improve traffic flow.

As a society, at the same time as we are recognizing that these mounting traffic management challenges contribute to some of our worst congestion, our sensitivity to the environmental impacts of our actions, especially those of highway projects, is growing. When area roadways get congested projects to build new or widening existing highways are difficult projects to get through the environmental impact minimization and permitting process. Using ITS to use the full capacity and improve the operations of our existing infrastructure is a more practical means to improve the experience of system users. Recognizing this, DOTs are starting to shift their focus from traditional design and construction based organizations to those that see the value of truly operating their systems to move traffic. One of the components of operating a transportation system, and one of the elements of ITS is that of most visible to our system users, is that of providing traveler information.

Traveler information has two primary benefits; first, the "Customer Service" aspect and secondly the "Travel Demand Management" aspect. Providing traveler information as a form of "Customer Service" is much like that of any public or private entity that uses a Customer Service Phone Line or Internet Website to provide additional information to their customers. In the Information Age information "on demand" is a very common and realistic customer expectation. Secondly, traveler information also helps DOTs help travelers help DOTs in reducing congestion. Providing information to travelers allows them to make travel choices that typically will allow them to avoid, and thereby not further contribute to, congestion. The choices made will often include changing the route or timing of a trip, when those flexibilities exist. This information allows travelers to better plan their trips to reduce delay and frustration as well.

As the owner and operator of over 78,000 centerline miles of highways as well as Rail, Ferry and Public Transportation and Aviation services, North Carolina transportation system users look to NCDOT to provide traveler information. North Carolina's current and planned ITS program has a strong traveler information component. Methods of traveler information range from pre-trip sources, such as a website and Customer Service Phone Line, to en route methods such as Highway Advisory Radio (HAR) and Variable Message Signs (VMS).

As part of developing the vision for NC's ITS Architecture recent "ITS Summits" were held across the state. These summits brought together diverse stakeholders in each of 10 areas of North Carolina and included major employers, chambers of commerce, emergency service providers, elected officials, citizens, etc. This ITS outreach asked over 1000 system users what they would like to see in the future of intelligent transportation in North Carolina. Although formal documentation of the results of these summits are forthcoming, discussions with those attending the summits revealed that North Carolina's stakeholders consistently and overwhelmingly cited "more traveler information" as a primary need.

Research in Texas strove to quantify the importance that travelers place on travel information. When given an imaginary $100,000 to be applied to improvements to an existing urban freeway, 95 percent of all respondents allocated funds to "Real-time Information". This was chosen over additional guide signs and over other forms of improvement in freeway communications. (*2*)

Another example of the demonstrated demand for traveler information in our state, was the very positive response to NCDOT's Hurricane Floyd Road Condition web site. This site listed the over 1500 road closures in North Carolina after the storm in September of 1999. The media gave great praise to our website and served as a valuable partner in getting the word out that it existed. This publicity, in addition to the hard work of the Department's Public Information Staff, led to the over 2 million hits to the website that followed the storm. Considering a normal week's web site usage is about 100,000, hits this first attempt at providing real time traveler information led to a 500 percent increase in website usage in the month following the storm.

What is Traveler Information?

Recent proliferations of Intelligent Transportation Systems (ITS) and communications technologies have allowed transportation agencies to provide more and better information to travelers. ITS America defines traveler information as the process of information "acquisition, analysis, communication, and presentation" and the use of that information "to assist the surface transportation traveler in moving from origin to destination in the way that best satisfies the traveler's need for safety, efficiency and comfort."(*3*)

Most of the components of a typical ITS system contribute to or are in some way linked to the traveler information function. Incident Detection and Verification, Road-Weather Information Systems and multi-modal (i.e. non-highway, especially transit) ITS applications are often the source of the data that is converted into the information given to travelers. Commercial Vehicle Systems and Intelligent Vehicles use traveler information to bring "hands-on" traveler information to the end users. Traveler information is applicable in both urban and rural settings, although the methodologies involved in gathering and disseminating data may be quite different.

Although Intelligent Transportation Systems (ITS) is a relatively new program, traveler information is not a new function to DOTs. Transportation system operators have been providing traveler information as a fundamental service well before the advent of ITS. Static signs, from permanent STOP and SPEED LIMIT signs, to more temporary Work Zone signing are all a form of traveler information. In the last 30 years this effort has expanded to include more "condition responsive" forms of traveler information including Variable Message Signs (VMS), both portable and permanent, and Highway Advisory Radios (HAR). While these devices are successful in communicating "real-time" traveler information, they are limited by their placement in terms of how much advance notice they can provide. They can also be limited by having adequate detection in place, whether automated or manual, to provide good data to use in creating messages for these devices to give to travelers. If an incident has occurred and it goes undetected than the availability of traveler information devices is irrelevant. Similarly, if an incident has occurred and there are no devices located strategically enough nearby to tell travelers of an alternate route than the information is much less effective. Another shortcoming of some en-route traveler information devices is that often times they function more in the "Customer Service" mode, by informing travelers that delays are occurring, rather than in the "Travel Demand Management" mode by giving them information they can use to avoid problem areas entirely. Again this may be caused by the placement (i.e. not giving the information in such a location that an alternate route can be chosen) or the detection (i.e. the device operators may not be aware that an incident warranting additional traveler information has occurred).

Many DOTs provide some type of pre-trip traveler information via Press Releases or other notifications of major work zones or severe incidents. For example, NCDOT spent considerable effort advising travelers of a severe rockslide that occurred on Interstate 40 in the western part of North Carolina in 1997. This effort informed local travelers and those in adjacent states, since the detour route affected travel into and out of those states as well. Efforts like this in the past have been effective, although major incidents warranting this level of traveler information have been fortunately rare. As the volumes on our freeways continue to grow it is statistically likely that events of this magnitude, and the number of travelers affected by them, will continue to increase as well.

Although DOTs' roles as pre-trip traveler information providers have been relatively limited, private sector entities, including television and radio stations, have traditionally been media sources from which system users obtain pre-trip traveler information. Radio and TV traffic reporting began in the 1970's and since then has become a staple in newscasts in most urban areas. These groups gather traffic information from various sources. Realizing that state DOT's often have good access to source data for traveler information, and the media have a delivery mechanism and an audience firmly in place, many states have begun to work with the media to improve the information travelers are able to obtain.

ITS America has recently undertaken significant work in determining what critical traveler information the traveler information "market" is looking for. The research found that "consumers' needs are tied to more and better data and that current data collection falls short of meeting the consumers' needs, in content, coverage and quality".*(4)* Recognizing that traveler information is important and a well documented need in North Carolina, that some successful means of traveler information exist today, but that Nationally high quality comprehensive traveler information is still lacking, where does North Carolina go from here in the improving traveler information?

Objectives

The primary objectives of this paper were to:

- Discuss the concepts and evolution of traveler information and describe the uses and value of the service;
- Consider the varied users of North Carolina' highway system and assess their needs for traveler information focusing on what types of information they desire and what are the most appropriate mechanisms/methods for delivering this information to these users; and
- Recommend guidelines to improve traveler information in North Carolina.

Scope

The scope of this paper was limited to pre-trip and en route methods of highway traveler information, but did not address VMS and HAR.

Traveler information was defined as information about road conditions including incident (i.e. major crashes, work zones, special events, natural disasters, etc.) information, the status of snow and ice clearing efforts, transportation related evacuation information, etc.

This paper did not address the traveler information needs of emergency responders or emergency service providers. These needs are best looked at within the parameters of a multi-agency Incident Management strategy.

FINDINGS

After having addressed what is meant by the term "traveler information" and demonstrating that a need for traveler information exists and why it is in our best interest to provide it to our system users, the next logical questions to address are "Who uses traveler information?" and "What information do they want?". The answers to these questions are interesting both from a National and a North Carolina perspective. The answers to these questions must be factored into the decisions made by public and private entities as to what type of data is collected and what type of information is distributed. Once these conclusions are reached the next logical question is "What mechanisms should we use to provide travelers with traveler information?". Since this effort has been done in the past by both private and public entities it makes sense to explore opportunities to work together to combine the skills and resources of these diverse groups to provide the traveling public with the information they need by the mechanisms that are most effective.

Who Are Our Customers?

A large and truly diverse set of users depends on the highway system in the United States. Medical advancements and socioeconomic betterments have allowed the population to grow. Improvements in communications technologies have allowed areas outside of traditional "Central Business Districts" to become more accessible as locations for commerce. These factors, and many others, contribute to the increasing distances between the locations where people live and work. In many areas the only feasible way to make the trips that people need to make in their daily lives are via the highway system. Who are these users of our system?

A study of users of the highway system in Texas revealed that users fit into the following categories in the following proportions:

Table 1: Texas Drivers by Age Group (5)

Age Group (years)	Percentage of Drivers (percent)
Less than 25	15
25 – 39	35
40 – 54	28
55 – 64	10
Over 64	12

Table 2: Texas Drivers by Education (5)

Level of Education	Percentage of Drivers (percent)
No High School Diploma	28
High School Diploma	26
Some College	23
College Degree	23

From this data it can be noted that the majority of Texas drivers (a total of 67 percent) are between the ages of 25 and 54. The educational level of these drivers appears to be almost equally split (each falling between 23-28 percent).

Texas and North Carolina are similar in many ways. Both are large Southern states, both have a mix of mostly rural areas with some dense urban development, and Texas and North Carolina have the largest and second largest state highway networks, respectively, in the United States. Based on these similarities it would be reasonable to infer that these driver characteristics would be substantially the same in North Carolina.

To try to obtain more North Carolina specific information a survey was conducted among a varied group of fifteen employees of the North Carolina Department of Transportation (See Appendix). The groups of survey respondents included employees from the following Units:

- Chief Engineer's Office,
- Construction,
- Customer Service,
- Information Systems Technology,
- Office of the Secretary of Transportation,
- Public Information,
- State Attorneys Office (for Transportation), and
- Structure Design.

These employees work with citizens and elected officials on a daily basis. The NCDOT's Public Information Office handles over 500 calls each week from system users asking for some form of traveler information. The employees were asked to name groups of users that might use North Carolina's highway system. The following groups were defined:

- North Carolina Citizens,
- Visitors to North Carolina (ultimate destination = North Carolina), and
- Passers-Thru (ultimate destination = place other than North Carolina).

Understanding that these diverse groups exists will allow NCDOT's traveler information efforts to create the most appropriate messages and use the most logical methods to reach the group or groups that a given piece of traveler information may be needed by.

ITS America has recently showcased additional researcher on traveler information customers. The research found that traveler information customers typically:

- Are employed commuters,
- Drive mostly freeway miles,
- Have trip route and time flexibility,
- Frequently lose drive time to congestion,
- Have better than average education level,
- Have slightly higher incomes, and
- Are between 26-46 (i.e. working age) (*6*).

While these characteristics are helpful to know and somewhat intuitive, one of the biggest conclusions drawn from this study was that the use of traveler information was based more on situational or location factors than personality characteristics. Thus it makes sense to consider the situational and locational factors of travel in North Carolina as well as the user types.

What Information Do Our Customers Want?

Information is a necessity when traveling. Information has been traditionally provided to travelers by signs, markings and signals placed by public agencies on streets and highways to make travel safer and more efficient. If roads and highways were static systems than this static information may provide all of the information travelers would need. While these sources of static information give travelers the most basic facts they need to know while traveling, DOTs are increasingly focusing on improving the operations of transportation facilities, and using ITS to accomplish this goal. This new focus often means that public agencies are striving to provide more useful types of information to improve the quality of their users' travels.

One way in which to do this is to provide more "real-time" information about the condition of a route. But what are the most important and most useful types of real time information that our system users want? When the above mentioned NCDOT survey group was asked, the following types of information were identified as being needed by our system users and prioritized as follows:

1. Incident (Construction, Accident, Special Events, etc.) Information
2. Including: severity, duration of impact, alternate route info
3. Prevailing Travel Times
4. Directions
5. Weather and Service (Gas, Food and Lodging) Information (TIED)
6. Prevailing Travel Speeds

Research conducted in Dallas and Houston, Texas found similar results. Information about an incident itself, degree of congestion, and reason for congestion were rated as the most preferred information ratings respectively, while prevailing travel speed was rated of lower importance.(*3*)

Departments of Transportation typically have access to some of the information that we believe system users need. One of the most common types of information DOTs provide is locations of planned construction projects. While this is a good start, the information provided is sometimes too general to be of use to the traveler. For example, a notice about a project that states that a roadway will be under construction from Point X to Point Y during the summer of 2000 may be good to know. Further information may state that motorists can expect periodic lane closures during the duration of the project. While this is good pre-trip information to have, this alone does not allow a traveler to decide whether or not this construction project should cause him to take a different route or change the time of his trip due to this project on the day he is wanting to travel. Assuming that most travelers take the most direct route on the highest type facility (i.e. freeway over arterial, arterial over collector, etc.) they will have to decide for themselves if the presence of this construction project warrants seeking a different (presumably lower type) facility or less direct route. As operators of the transportation systems DOTs could make more of an effort to provide more real-time information to system users. This information could be timely enough to give real time, or least daily, route specific condition information that would allow travelers to decide if switching their route or trip time is warranted.

How Do Our Customers Want To Get Their Traveler Information?

Knowing who our system users are and what types of information they want are fundamental to understand when exploring the topic of traveler information. A final critical piece is the mechanisms and methods used to provide travelers with this information. If this information is not provided in a manner that is useful and convenient than the information may go unused. It will be helpful to consider the methods of distributing the information as a function of the types of users and the information they desire.

The NCDOT survey respondents were asked to identify the methods of transmitting traveler information that they believed travelers most wanted. The respondents ranked the options as follows:

Table 3: Methods of Delivery of Traveler Information

Method of Delivery	Score (Out of a Possible 100 Points)
Local Radio	91
Internet	84
Local TV	82
Kiosk	47

This data shows that reliance on more traditional methods are still quite high (local radio and local TV), while the growing popularity of the Internet has made it a competitive choice as well. The very low score for kiosks may be a function of bad past experiences with these devices.

The Internet is a relatively new and not yet mainstreamed way of getting traveler information. An obvious benefit being the degree of personalization of the data that the Internet allows, while drawbacks continue to be the costs of purchasing a computer and Internet service and the accessibility of that data while travelling or preparing to travel. Although almost every state provides some form of traveler information on the World Wide Web (*7*), and most large urban areas such as Boston, Washington, D.C. and Los Angeles also have private providers such as Etak and TrafficStation that provide internet traveler info, this seems to be far from reaching the general traveling population. Even in the late 1990's while living in Washington, D.C., by many reports the second most congested urban area in the United States, the author did not know of any users, not even those in the ITS or transportation industry that had routinely mainstreamed Internet traveler information into their travel behavior. In the San Francisco Bay Area of California, fewer than 12 of every 100 commuters use the Internet for traveler information, although 83 percent of commuters have access to the Internet (*8*).

The value and usefulness of kiosks for traveler information is a subject of mixed sentiments. The current sentiment in the ITS Community in the United States appears to be somewhat against the use of kiosks. Past kiosk deployment experiences have tended to yield the perception marginal usefulness. Even the inclusion of kiosks in the above mentioned NCDOT survey led to a comment in the margin of "What Are These?". In the past kiosks often had to rely on data that was "confined" within the kiosk, making real time information almost impossible. The information had to be updated and maintained in order to be relevant. With the advent of the Internet this aspect of kiosk limitations can easily be overcome. Users can access most anything available from the Internet on a kiosk. According to market research done by the firm Frost & Sullivan, global "Interactive Kiosk Markets" are expected to grow by more than 20 percent by 2006.(*9*) While kiosks have many applications other than traveler information, as they become more prevalent and mainstreamed into everyday life, their success as sources of travel information will likely grow as well.

Recent research outlines some recommended points to consider when deploying kiosks. These include insuring that kiosks are:

- Attractive,
- Obvious as to what information they are providing, and
- In a location likely to generate pedestrian traffic (*10*).

CONCLUSIONS

Traveler information must be suited to our users in terms of both types of information provided and the methods in which it is delivered. The users of North Carolina's transportation system and of our traveler information appear to be predominantly:

- Between the ages of 25-54,
- Equally split between educational levels,
- Locals, Visitors and Passers-Thru, and
- Wanting real time incident as well as more static traveler information .

When traveling using the highway system there are a limited number of decisions a driver has about taking a trip. Because of this fact the type of information wanted and needed by the travelers are less dependent on user characteristics and methodology of delivery. Assuming no other mode of transportation is available, there are only three variables that a traveler has control over. The first is when the trip is made, the second is which routes the traveler will take, and the third is the speed at which the driver can drive. We will assume that the driver typically drives at the speed limit and therefore this variable does not have any further impact on a trip. This leaves trip time and route as the remaining trip variables. Both of these can be influenced by good traveler information. Again, in addition to giving our travelers an increased sense of control of their situation by having good, accurate and timely information, DOTs are helping travelers by not adding congestion to already congested areas.

The information rated by the survey respondents as being most important to travelers is real-time information. As stated earlier, since the transportation system is not static, it was not surprising that real time information was rated as being most important. Incident information pertaining to such types of events as construction projects, accidents, special events, etc. was rated as the most critical traveler information need. The types of things that were stated as needed to know about these incidents match the two variables that are available in trip planning. The Severity and Duration of an incident and Prevailing Travel Times should all be factored into trip time decisions. Alternate route information is critical in two ways. First to suggest possible ways around an incident or a congested area for those travelers that are not familiar enough with an area to do so unaided. Secondly travelers should have confidence that when DOTs suggest alternate routes that they are aware of the real time conditions on that route and are suggesting a path that will be more expedient than trying to use the route that the incident has occurred on. Information that can assist travelers in making route and time of travel decisions and therefore should be provided whenever possible.

As a part of NC SMARTlink NCDOT's existing Traveler Information Management System or TIMS (found at www.dot.state.nc.us – then click on Real Time Travel Info (TIMS)) currently provides severity ratings and expected duration information for every incident in the system. Alternate route information is provided when available. Travel times are not currently in the system and should be considered.

Other more static types of information were also cited as being important to travelers. Directions and Weather and Service (Gas, Food and Lodging) Information were ranked with equal importance. TIMS currently provides limited weather and service information. These should be expanded to be more comprehensive and directions should be included. As many commercial sites exist with this information links should be created to allow users to select the format of this information that most appeals to them.

Prevailing Travel Speeds were perceived to be the least needed piece of travel information. This may have been due to the fact that this data is not currently given as traveler information in North Carolina, so unfamiliarity may have contributed to the perception of this information being less important. Also, travel speed may be considered as a factor already inherent in determining travel time. For example, if a traveler's destination is 65 miles away and a traveler has 1 hour to make it to that destination the necessary speed of 65 miles per hour can be derived. However, if a lower prevailing speed is occurring, i.e. 45 mph, the traveler must factor this into his travel time decision if no other route is feasible. Without instrumentation detection of this variable is very difficult. This variable may warrant further research as to its usefulness.

Age

Traveler information strategies must be based on delivery methods that would appeal to the age groups that represent a majority of the drivers (25-54). The popularity of and reliance on the Internet as a fundamental source of information, especially among those in the 25-40 range makes it a most logical choice as a traveler information mechanism. Due to the increasing amount of E-Commerce and reliance on computers in global business today, the Internet is also likely to reach drivers in the upper end of the 25-54 age band. All of these reasons make the Internet a logical choice as an area on which to concentrate our traveler information efforts.

For those who have not embraced the Internet for whatever reason, including those for which a computer may be economically unfeasible, radio and TV broadcasts continue to have a widespread appeal and are accessible to many. These services are essentially free (after initial purchase of the TV or radio). Another benefit of these methods of traveler information is that they are accessible and "likely to be accessed" whenever trips might be made. Most travelers are not yet in the habit of checking the Internet before embarking on each and every trip they make, but radio and TV are much more infused into most American's daily lives, and therefore are more "likely to be accessed".

A combination of the three technologies might be the most beneficial to the largest number of users. This combination allows for both passive and active types of traveler information. The information on a web site is continuously supplied, awaiting a user's query. Radio and TV traffic broadcasts are "fed" to the consumer (when their radios and/or TV's are on) at pre-set broadcast times or intervals, or when an event has occurred that warrants an update. An Internet web site that contains comprehensive traveler information that could be accessed by users directly, and used as a source for information given in radio and TV broadcasts seems to benefit from the strengths of each approach.

Educational Level

As the educational level appears to be essentially evenly split between four commonly used educational levels (No High School Diploma, High School Diploma, Some College, College Degree) it does not appear that this factor can be used to dictate the benefits of any given traveler information method over any other method. It seems to make a compelling case for the need for multiple diverse methods that may appeal to differing educational levels of travelers.

Types of Users

North Carolina system users are split between three diverse groups. Each one should be given a method and a message of traveler information that meets their needs.

Locals

This group of users can be targeted by traveler information methods that reach them in their home, such as the Internet, TV, and radio. NCDOT has a website and existing relationships with all of the major media outlets across the state, as well as the Associated Press. Some of the work that remains to be done is that of publicizing the sources of this information, especially for the website information. Regardless of how good and comprehensive information may be on NCDOT's traveler information website, if users are not aware that it exists than its value is significantly diminished.

Visitors

This group of users is slightly more difficult to target with traveler information. As their trip origins are more diverse it would be more logical to provide them with en route traveler information. Tourism is a vital part of North Carolina's economy and attracts many visitors to the state. The North Carolina Department of Commerce has expressed a willingness to partner with NCDOT to provide traveler information. As many tourists may take a more leisurely travel pace this may allow them time to stop at Welcome Centers and Rest Areas to obtain tourism and traveler information. Combining these two services may be beneficial. For example, a kiosk could be used to select a travel destination then query the system to be made aware of any traffic disruptions that may be occurring between them and their chosen destination.

NCDOT's existing relationship with the Department of Commerce has already proven to be most helpful in promoting the TIMS website. Before NCDOT made any formal announcement of the availability of this website the Department of Commerce included a link to the site from their excellent www.visitnc.com site. This link generated over 1500 hits per day for the TIMS website before any NCDOT publicity was done. This shows the value of continuing to work with the Department of Commerce due to the inherent link between tourism and transportation.

A pilot project using kiosks is planned for a Welcome Center along I-95 in North Carolina. Rather than deploying these kiosks and trying to determine whether or not they are useful after they are installed, a pre-planned evaluation program should be developed before the kiosks are constructed so that the experience can be evaluated and conclusions can be drawn as to the benefits gained by their installation.

Passers-Thru

This group appears to be the users where the ability to determine travelers trip origins and destinations is much more difficult. Even once they are determined either or both of those locations may be outside of North Carolina. It appears that radio broadcasts and Welcome Center kiosks would be the most accessible method of traveler information dissemination to this user group.

As technology evolves In-Vehicle navigational devices are becoming more mainstreamed. These devices provide an excellent opportunity to improve traveler information. This method would appear to be particularly well suited to "passers-thru" as the device could seek out the traveler information being provided by NCDOT without the user having to be aware of local radio stations or the locations of kiosks as they pass through the state.

Also the use of the newly designated national 511 Traveler Information number would be a logical source for information for travelers that are not familiar with other sources. A comprehensive look must be taken at this capability and what functions it should include. North Carolina currently has a "***HP**" (**H**ighway **P**atrol) number available for highway emergency calls, although this number is not usable statewide. NCDOT also currently operates "877 DOT 4 YOU" as a Customer Service Hotline. As 511 would be a nationally recognized number, perhaps it would make sense to use this number for a combination of these services. The service could offer the options of selecting between

- Emergency Assistance (current *HP function),
- Traveler Information (text to voice application of the TIMS system), and
- Customer Service (live assistance – existing 877 DOT 4 YOU service).

This must be further discussed with the current operators of each of these systems to determine their willingness to participate and ensure that these functions meet the intent of the 511 program.

RECOMMENDATIONS

The North Carolina Department of Transportation's plan for Traveler Information should include:

1. Improve the TIMS System to
   a. Include more links to Weather and Service (Gas, Food & Lodging) Information.
   b. Include more alternate route information (when available).
   c. Explore the benefits/detection needs of providing prevailing travel speeds and times.

2. Maintain primary focus on the Internet, Television and Radio as distribution mechanisms

3. Work with existing media entities to publicize the TIMS system and explore opportunities to further work together to give traveler information.

4. Continue to work with the Department of Commerce on efforts combining tourism and traveler information.
   a. Use kiosks in a pilot program to determine effectiveness of kiosks before pursuing further. Insure that the kiosks are attractive, easily identifiable as to content and in areas likely to generate pedestrian traffic.
   b. Continue to work with the Department of Commerce to promote our traveler information website.

5. Further explore the possibilities of In-Vehicle Navigational Devices. Insure that traveler information applications that are developed in the near future do not preclude their use in some type of in-vehicle device.

6. Further explore the opportunities and constraints associated with using 511 as a traveler information number. Work with NCDOT Public Information and the State Highway Patrol to evaluate combining Customer Service and Motorist Assistance services as well.

ACKNOWLEDGEMENTS

The author would like to thank Mr. Joseph Lam and Mr. Les Jacobson for their guidance and assistance. The author further wishes to thank Dr. Conrad Dudek for sharing his knowledge on the topic of traveler information and for making the Advanced Transportation Mentors Program at Texas A&M University possible. The additional support and help from the other program participants was also much appreciated.

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APPENDIX:TRAVELER INFORMATION SURVEY … NCDOT PERSONNEL

Name:
Position:

I am doing a research project that will help us improve Traveler Information in North Carolina and I need your input.

Please think for a minute about the many travelers that use
North Carolina's highway system…
These include

1. North Carolina citizens (locals),
2. those who come from somewhere else (visitors), and
3. those who just pass through our state en route to somewhere else(passers-thru).

Can you think of any other users that do not fit in one of these categories?

Common types of trips made by these highway users include:
Commuting (locals)
Business Travel (local, visitors and passers-thru)
Pleasure Travel (locals, visitors and passers-thru)
Errand Travel (locals and visitors)
Deliveries (locals, visitors and passers-thru)
Can you think of a type of trip that does not fit into one of these categories?

IN YOUR OPINION…

Please rate on a scale from 1-5 (low – high) how much you think travelers want the following information:

- ___ Incident Info (ie construction, accident, special events)
  - ___ Severity of Impact to Traffic
  - ___ Likely Duration of Traffic Impact
  - ___ Detour / Alternate Route Info
- ___ Prevailing Travel Speeds
- ___ Prevailing Travel Times
- ___ Directions
- ___ Weather Info
- ___ Service Info (ie food, gas, lodging, roadside assistance)

Other:

When do they want to get it?
(Please rate: 1-5 (low – high))

___ Before a Trip ___ During A Trip ___ Both

How do they want to get it?
(Please rate: 1-5 (low – high))

___ Kiosk ___ Highway Advisory Radio
___ Internet ___ Variable Message Signs
___ Local Radio ___ Local TV

Other:

Why do they want these kinds of traveler info

KELLY E. HUTCHINSON

Ms. Hutchinson is the ITS Operations Unit Head for the North Carolina Department of Transportation. This Unit was created in April of 2000 with the goal of improving the operations of NCDOT's existing and planned ITS statewide infrastructure. A first order of business for the Unit will be to deploy a Traveler Information Management System (TIMS) website to provide real time statewide incident information. The Unit will be responsible for defining and implementing statewide ITS Operations policy issues and procedures, including oversight of the Incident Management Program.

Originally from Massachusetts, Ms. Hutchinson graduated from The George Washington University in 1991 with a B.S. in Civil Engineering. She spent 8 years with the Federal Highway Administration, first at various locations around the United States on the Highway Engineer Training Program, then for 5 years in the Maryland Division. As an Area Engineer she was responsible for design and construction oversight of many large Federal-aid projects including many complex Interstate interchange projects. She worked on the controversial Woodrow Wilson Bridge Project, including serving on the ITS Steering Committee for the project.

Ms. Hutchinson joined the North Carolina Department of Transportation in September of 1999 as the Statewide Incident Management Engineer. She is a registered Professional Engineer. Her transportation interests include measuring the effectiveness of ITS operations and traveler information.

APPLICATIONS OF INTELLIGENT SPEED ADAPTATION IN SPEED-SENSITIVE PEDESTRIAN AREAS IN THE UNITED STATES

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SUMMARY

There is a demonstrated need for slowing the speed of traffic in sensitive areas where vehicles and vulnerable road users have the chance to mix. It has been shown that pedestrians suffer more serious injuries when struck by vehicles traveling at higher speeds and therefore it is logical that reductions in vehicle speeds can have a positive influence on pedestrian fatalities and injuries.

Intelligent speed adaptation (ISA) is a new speed management technology being developed in Europe that has the potential to be applied in the United States to help reduce speeds in areas determined to have vulnerable pedestrians. ISA consists of processes that monitors and compares the vehicle's current speed and the posted regulatory speed. If the vehicle is travelling above the posted speed, the driver is either informed of this violation or limited in their acceleration.

This research is an attempt to summarize the existing speed control methods used for pedestrian areas in the United States. Surveys were administered to United States cities or counties that are implementing traffic calming methods to gain an understanding of current practices and any need for new methods. It was necessary to compile the European research efforts in development of ISA. Using the results from the literature review and the surveys, the applicability of ISA in the United States was investigated and a recommended procedure ISA research and testing was developed. table of contents

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INTRODUCTION

Problem Statement

It is desirable to have lower operating speeds especially in pedestrian areas. However, with the years of efforts to reduce vehicle speeds there is still a demonstrated need to slow the speed of traffic in areas where vehicles and vulnerable road users have the chance to mix. Reductions in vehicle speeds can have an influence on pedestrian fatalities and injuries. It has been shown that pedestrians suffer more serious injuries when struck by vehicles traveling at higher speeds. Many pedestrian crashes may be entirely prevented had the vehicle speed been reduced (*1*). Intelligent speed adaptation (ISA) is a technology being developed in Europe that has the potential to be applied in the United States to help reduce speeds in areas determined to have vulnerable pedestrians or in areas determined critical. ISA consists of processes that monitors and compares the current speed of the vehicle and the posted regulatory speed. The system can either inform the driver that he/she is exceeding the speed limit by a sound or a light signal or the system can physically reduce or limit the speed of the vehicle. Research is necessary to compile and assess the European efforts in the development of ISA.

Research Objectives

The purpose of this research project is to investigate the applications of the ISA technology to speed-sensitive pedestrian areas in the United States. The research was accomplished through performance of the following specific activities:

1. Assess the need of newer speed control methods in the United States by documenting the existing speeding problem and speeding issues;
2. Summarize the existing methods for speed control in the pedestrian areas of the United States with a literature review and survey of city transportation engineers;
3. Synthesize the ISA research and ISA applications being conducted in Europe;
4. Identify key issues related to implementation of ISA in the United States; and
5. Develop a recommended research and testing procedure for exploring the potential to implement ISA in the United States.

Scope

This study was limited to compiling the developing ISA technologies in Europe and the existing speed control methods used for pedestrian areas in the United States. It is not in the scope of this study to examine the advantages and disadvantages to traffic calming techniques. To accomplish the research objectives of this project, United States cities or counties that are implementing traffic calming methods were identified and responsible staff was surveyed to gain an understanding of current practices and any need for new methods. Along with an extensive literature review, these surveys were used as the basis for investigating the applicability of ISA in the United States and as the basis for developing a recommended procedure for implementation.

Study Methodology

The following tasks outline the procedure and approach methodology developed and followed to reach the project objective.

Task 1. Literature Review.

The primary source of information for this paper was a review of current literature regarding the ISA technology in Europe. The purpose of the literature review was to examine the details of this developing technology, their needs for ISA technology, results of the ISA field trials in Europe, and any evaluations of the technology.

The second part of this task involved the review of current literature regarding the United States methods and efforts of traffic calming. This effort was conducted for the purpose of assessing the existing approaches and determining the feasibility of ISA in the United States. The literature review supplements a survey of transportation engineers.

Task 2. Develop a Candidate List of Survey Contacts.

An attempt was made to select a representative set of cities and counties that are using speed control practices. The main source of contacts was derived from the traffic calming programs featured in a Federal Highway Administration paper entitled, *Traffic Calming: State of the Practice (2).* These cities and counties were included since they were willing to previously participate in a traffic calming research project and since their jurisdictions are currently participating in traffic calming practices. Other contacts were provided though state Department of Transportation participants in the Advanced Surface Transportation Systems Program at Texas A&M University and Texas Transportation Institute employees.

Task 3. Develop the Survey Questions.

A brief introduction explaining the ISA technology and the survey questions were developed, a copy is provided in the appendix. The survey was constructed to find what methods of traffic calming is being used, how "need" for traffic calming is determined in the communities, and any foreseeable barriers to implementing ISA in the United States.

Task 4. Collect Survey Data.

Transportation engineers from a variety of city and county agencies actively using traffic calming methods were contacted by phone and asked if they would be willing to complete the survey. After agreeing to participate, these contacts were provided with a copy of the survey questions by fax or e-mail.

Task 5. Evaluate Survey Results.

The collected information was complied and summarized to find existing speed control methods used in the United States.

Task 6. Assess Potential Application of ISA at Pedestrian Crossings in the United States and Develop Guidelines for Implementation.

The key issues to the potential application for ISA at pedestrian crossings in the United States were explored and guidelines for an ISA research and testing plan were developed.

BACKGROUND

This paper is concerned with the need and the methods to reduce speeds of vehicles through pedestrian areas. First, there was an investigation into the problems with speeding in general.

The Speeding Issue

Speeding is defined as driving at an unsafe speed. Unsafe is determined by the existing conditions, i.e. presence of pedestrians, weather conditions, presence of construction, etc. The driver's choice of speed is influenced by many factors such as roadway design, roadside environmental characteristics, traffic control devices, enforcement strategies and speed zoning practices, and vehicle performance. Speed is also influenced by public attitudes, driver education and behavior, and training of all road users (3).

It is thought that the public does not view speeding as a serious safety problem, despite the potential pain and suffering. Poor compliance may be the result of design inconsistency, inconsistent enforcement, and poor public knowledge of speeding issues (3). The *Roadside Design Guide* published by the American Association of State Highway and Transportation Officials (AASHTO) states that on roadways where the design speed is 70 miles per hour (mph) or greater, the average vehicle operating speeds were less than the design speed; however, on lower speed roadways (design speed equal to or less than 40 mph) the average operating speeds were greater than the design speed (4).

Speeding Kills

Speeding is cited as one of the most prevalent factors contributing to crashes. Speed is a factor in 31 percent of fatal crashes, killing an average of 1,000 Americans each month. In 1998, 12,477 people died in speed-related crashes (5).

Consequences of Speed

The negative relationship between speed and crashes has been proven in several studies. It is reasonable to believe that a better compliance with speed limits would provide significant safety improvements. The general speed limit is rigid and set to reflect the highest allowed speed in normal road and visibility conditions. In many critical situations (pedestrian zones, adverse weather, work zones) that demand adaptation below the posted speed limit, it is indicated that drivers do not lower their speeds (6).

Simple physics explains how all accidents are speed-related because kinetic energy is equal to the mass of the vehicle and its occupants times the speed squared. The greater the speed of the vehicle is at the crash increases the kinetic energy exponentially. With the increase of speed at crash, the severity is also increased. Other consequences of speed include: greater distances traveled during driver reaction time due to less time to perceive and react to traffic and roadway conditions, increased stopping distances, and reduction in the effectiveness of occupant protection devices. (3).

The idea of controlling speed has evolved from assuming that a reduction in speed will eliminate some crashes and reduce the severity of other crashes (7). Speed management consists of employing engineering, enforcement, and education methods for the purpose of reducing speed-related crashes and promoting the orderly movement of road users (8).

Motor Vehicle Collisions with Pedestrians

Pedestrian zones of concern include schools zones, residential neighborhoods, downtown areas, retirement areas, shopping areas, hospital areas, and recreational/park spaces.

Pedestrians have represented 13 to 17 percent of all motor-vehicle deaths since 1975 (9). The National Highway Traffic Safety Administration estimates that a pedestrian is killed every 101 minutes and is injured every eight minutes (5).

In 1998, there were 5,220 pedestrian fatalities from motor vehicle collisions, and approximately 69,000 pedestrian injuries. Pedestrian deaths constitute one-fourth of traffic deaths in 5 to 9 year olds and eighteen percent of traffic deaths among people 75 years and older. It is interesting to note that males are 68 percent of pedestrian deaths (5). Although the child pedestrian rate is decreasing steadily, it may be due to the decline in number of children walking, rather than the effectiveness of prevention efforts (10). It is not know what percentage of these collisions are due to excessive speeds.

Younger pedestrians are generally less susceptible to serious injuries; as age increases, pedestrians are much more likely to suffer serious injuries and death. Overall, pedestrians age 65 and older are five times more likely to die in motor vehicles crashes than pedestrians age 14 or younger (1). In 1998, children under 15 years old accounted for 30 percent of pedestrian injuries, 11 percent of pedestrian fatalities, but only 23 percent of the United States population. The population greater than or equal to 55 years of age accounts for 21 percent of the United States population, 13 percent of pedestrian injuries and 32 percent of pedestrian fatalities in 1998. This relationship between age and death/injury is supported with Figure 1, the National Highway Traffic Safety Administration pedestrian death and injury rates in the United States in 1998 (5).

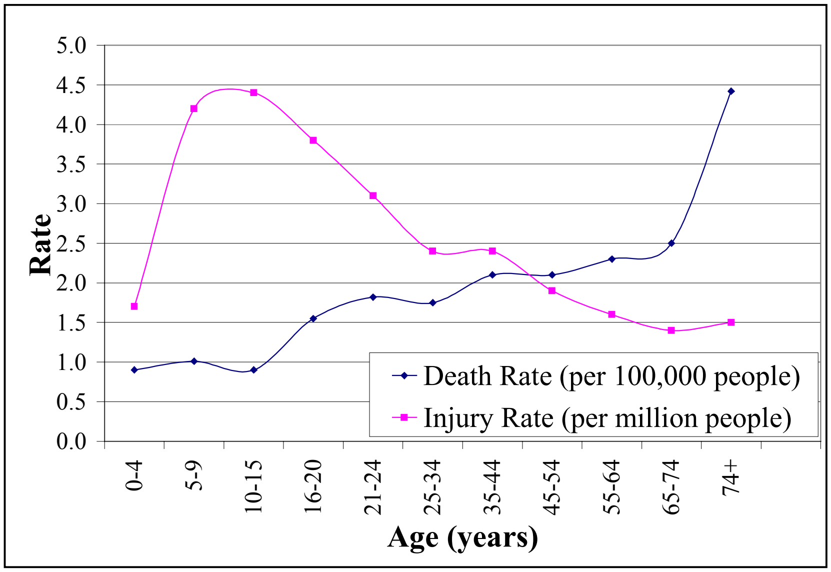

Figure 1. Pedestrian Deaths and Injuries in the United States in 1997 (1)

In Sweden, in 1994, the child pedestrian injury rate was just 45 percent of that in the United States, despite Swedish children walking more than American children. Denmark, Germany, and the Netherlands are some other countries noted for their leadership in and views with traffic calming; all have shown child pedestrian death rates lower than the United States (10).

Higher vehicle speeds are associated with a greater chance of collision with a pedestrian and a more serious pedestrian injury. The relationship between higher vehicle speed and the greater pedestrian severity resulting has been documented in a number of studies. Table 1 is a summary of the National Highway Traffic Safety Administration's statistics on speed and pedestrian fatalities; estimates are from a literature review and existing data sets (1).

As the statistics illustrate, motor vehicles create a significant hazard to all pedestrians (10). Children require special attention because the nature of children hinders their ability to handle traffic situations. Children up to the age of 11 or 12 years have weaker cognitive, perceptual and behavioral abilities such as: their field of vision is one-third narrower than adults, difficulty determining the distance and direction from which sound comes, difficulty judging safe gaps in traffic and safe places to cross (assessments of speed, distance and time), difficulty processing several items of information at the same time, and lack knowledge or understanding of complex traffic situations (10,11).

Table 1. Speed of Vehicle at Collision and Chance of Pedestrian Fatality (1).

Speed of Vehicle at Collision (mph)	Percent Chance of Fatality (%)
<= 20	5
30	40
40	80
50	Nearly 100

United States' pedestrian collision types in 1998 are shown in Table 2. Crossing at intersection includes pedestrian dash-outs, turning vehicle conflicts, and motorist violating traffic signal control (5).

Table 2. Pedestrian Crash Types in the United States, 1998 (5)

	Crash Type	Percentage of Crashes
Fatal	Intersection	22.1
	Non intersection	77.5
Injury	Intersection	38.1
	Non intersection	57.1

Vehicles Speeding Through Sensitive Areas

In a study that examined the immediate neighborhood environments of 39 children injured in the same block of their homes, five variables were considered: vehicle volume, vehicle speed, parked vehicles, total pedestrians, and multiple family housing. The researchers were able to concluded that it is more important to control speed than vehicular volume to prevent child pedestrian injuries on residential streets. The difference between a narrow escape and a crash is often the speed of the vehicle. (10).

A study of 40 school zones in Washington state was done by the Washington State Department of Transportation. The data for this study was vehicle speeds in school zones 30 minutes before the start of school and 30 minutes after school dismissal. Results of the research found that a significant proportion of vehicles were measured traveling at excessive speeds through school zones during times when children were likely to be in proximity to traffic. The findings are summarized in Table 3. It was also found that excessive speeds predominately occurred at schools with faster (greater than 25 mph) approach speed limits. School-zone speed limit signs with "flashing lights" were effective in slowing vehicles on roadways with higher approach speeds; the average speed at schools with these "flashing light" signs was about 5 to 7 mph slower than other types of school-zone speed limit signs (12).

All of the research in the literature review supports the relationship between higher vehicle speed and increased severity of pedestrian injury and fatality. Furthermore, there is documentation that vehicles are speeding through sensitive areas such as school zones and residential areas. The studies and the research have fueled the search for innovative traffic control practices with the objective of slowing traffic in sensitive areas.

Table 3. Washington State Vehicles' Speeds through School Zones (*12*)

Vehicle Speed (mph)	30 minutes before school (%vehicles in speed range)	30 minutes after school (%vehicles in speed range)
0-25	55.5	52.9
26-30	18.7	19.4
31-35	13.7	15.1
36-40	8.2	7.9
41+	3.9	4.8

TREATMENTS FOR SPEEDING

Literature Review of United States Speed Reduction Methods

The traditional emphasis of speed control in the United States has been by reducing posted speed limits, increasing enforcement, and installing traffic control measures such as stop signs or traffic signals at intersections. Education has also been used to inform the public of the dangers of excessive speed and/or the presence of police (*1*). There are conflicting opinions that the pedestrian can be educated to adapt to traffic, or that the traffic environment can be adapted to accommodate pedestrians through various measures to reduce vehicle speed (*10*).

Speed management techniques generally fall into four categories: roadway design, roadway surface, traffic control, and enforcement.

1. Roadway design techniques
   - Chicanes - curb extensions or islands that alter the linear progression of a vehicle so that the driver's path forms a S-shaped curve in the roadway;
   - Neckdowns, bulbouts and chokers - curb extensions at intersections to reduce the width of the traveled path;
   - Central island narrowing - islands located along the centerline of the street to reduce the width of the road and provide refuge to pedestrians during the crossing maneuver;
   - Roadway narrowing – narrow the roadway visually by using geometric features, pavement markings, or landscaping;
   - Full closure – barriers placed across the street to completely close the through traffic by diverters, cul-de-sacs, or signing;
   - Diagonal diverters – barriers placed diagonally across intersections to prohibit through movement;
   - Half closure and semi-diverters– barriers that close travel in one direction for limited distances on otherwise two-way traffic streets;
   - Entrance features – the use of textured pavements, curb extensions, raised crosswalks, landscaping, or entrance signs; and
   - Traffic circles – islands placed in the center of an intersection; and
   - Roundabouts – raised islands that create counter-clockwise traffic flow (*7*).

2. Roadway surface techniques
   - Speed humps – rounded, raised areas of pavement placed across the road, perpendicular to traffic flow;
   - Speed tables – flat topped speed humps (plateaus) often constructed with textured material;
   - Raised intersections – elevation of the entire intersection;
   - Speed cushions – smaller raised area within a traffic lane;

- Crosswalks – roadway parts designated for pedestrian use;
- Widening sidewalks – sidewalks that provide additional pedestrian space;
- Rumble strips – pavement undulations that cause the vehicle to vibrate and rumble (7).

3. Traffic control techniques
   - Signs such as speed limits, stop signs, warning signs, and other regulatory, informational, warning, and guide signs – inform the driver of the law or warn drivers of conditions;
   - Pavement markings – used to reinforce the message displayed by signs;
   - Flashing beacons – are used to gain drivers' attention; and
   - School speed zones – to alert drivers of the sensitive speed zone by using combinations of signing, crosswalks, pavement markings, flashing beacons, and/or traffic signals (7).

4. Enforcement techniques
   - Citizen speed watch – public awareness programs that involve residents, agency staff, and motorists;
   - Increased enforcement – the most common enforcement technique, an increase in the presence of law enforcement and the issuing of speeding citations in target areas ;
   - Speed trailers – mobile roadside radar devices that display the speed limit and the speed of the approaching vehicle to inform the driver; and
   - Automated enforcement – a radar device, processing unit, and camera to record vehicle speeds and photograph those exceeding the speed limit. (7).

The above speed reduction methods have been successful in some situations; however, transportation engineers are still developing different techniques because every location's characteristics and needs are different. There are positive and negative results to each type of traffic calming technique. The method selected should be dependent on the specific site or area.

Survey Results of United States Speed Reduction Methods

This section contains a summary of the survey conducted for this research project. a copy of the background information explaining ISA and the survey is provided in the appendix. A total of 17 people were contacted, 12 surveys were distributed, and 6 surveys were completed and returned. Table 4 shows the cities and counties that returned a survey. The quality of answers returned on the survey varied; however, the majority of the respondents appeared to put time and thought into their answers. Overall, 4 cities supported the idea of ISA and other ITS technologies.

Table 4. Cities and Counties Represented in the Survey

City/County	Contact
Austin, Texas	David Gerard
Bellevue, Washington	Karen L. Gonzalez
Charlotte, North Carolina	Michael J. Eads
Gainesville, Florida	Brian Kanely
Howard County, Maryland	George E. Frangos, P.E.
San Diego, California	Allen Holden, Jr.

In general, these communities are continually implementing new methods for speed control in an attempt to lower vehicle speed and all communities are concerned about pedestrian safety. Table 5 is a summary of the of the current methods being used to slow traffic, how the communities determine which areas

Table 5. Summary of Surveys Received

City/County	Current Speed Reduction Methods	Determination of "Need" for Speed Control Methods	Potential ISA Barriers
Austin, Texas	Traffic circles, speed humps, speed cushions, semi diverter, chicanes	Fatal accidents and pedestrian/bicycle accidents are reviewed yearly	Acceptance by public
Bellevue, Washington	Speed humps, traffic circles, curb extensions, medians, slow points, partial closures	Citizen input Traffic data Field reviews	FHWA approval, community/political acceptance
Charlotte, North Carolina	Road humps, special signing mid-block of pedestrian crossings	Charlotte DOT has a section committed to accident review	State legislation
Howard County, Maryland	Choked school crossings, raised intersections, humps, roundabouts, medians, rumble strips, chicanes, pavement markings, eyebrows, raised crosswalks	Uses AIMS software to review pedestrian/bicycle accidents Traffic calming program involves community interaction process that serves to develop appropriate treatment	ISA should develop through ITS programs at local levels
Gainesville, Florida	Speed humps	Program to look at traffic signals	Safety, legal, privacy, public acceptance
San Diego, California	Road humps, traffic circles, median diverters, bulb outs, traditional measures, one-way streets, closing medians, turn prohibitions	Enforcement Engineering (traffic engineering analysis and corrective measures) Education	Public acceptance (feeling of intrusion into personal freedom)

"need" speed control measures, and the representatives' opinions of potential barriers to implementing ITS technologies, such as ISA, to reduce speeding.

The following sections are a summary of the all the answers received by the five cities and one county. Where available, additional information from the communities' homepages is included.

Austin, Texas

Current methods of physical used for traffic calming in Austin include traffic circles, speed humps, speed cushions, semi diverters, and chicanes. Austin also uses speed trailers. The public likes the traffic calming methods Austin implements; however, the representative from Austin feels that they have little effect on the speed of vehicles. Pedestrian safety is a big issue in the community's subjective opinion; however, Austin's accident statistics do not indicate a real problem with pedestrian crashes. To assess safety needs, all fatal accidents and all pedestrian/bicyclist accidents are reviewed. The top 25 intersections are reviewed annually. Austin's representative replied that Texas needs photo radar to become legal (currently pending in the state legislature). Speed cushions were also mentioned as a new method to help reduce speeds in pedestrian areas.

The representative from Austin believed that technologies, such as ISA, are an acceptable solution to reducing speeds. Potential barriers Austin mentioned included public acceptance.

Bellevue, Washington

Current methods used for traffic calming include speed humps, traffic circles, curb extensions, medians, raised crosswalks, slow points, and partial closures. Bellevue also has a citizen speed watch program. Improvements to the traditional types of speed control include the use of speed trailers for informational purposes to heighten driver awareness of the speed limit and their speed. The speed trailers are used in areas experiencing frequent speed. These are noted as school zones and neighborhoods (*13*). Public acceptance is judged as very positive from survey feedback.

Pedestrian safety ranks among one of the top concerns of the city. Citizen input, traffic data, and field review help assess and prioritize safety needs in Bellevue. Public and driver education is provided through educational material. A pamphlet for neighborhoods desiring traffic calming measures was included in the survey return. This material was very informative about what methods Bellevue does and does not implement and why. In the educational pamphlet, it is explained that "Children at Play" and "Slow Children" signs are not used (even if requested) because these signs do not increase driver's attention to the potential children. It is also explained that stop signs as speed control devices are not used (*13*).

The representative from Bellevue is aware of the technologies such as of radar trailers, variable message signs and flashing crosswalks. The representative believe that technologies, such as ISA, are an acceptable solution to managing speeds. Potential barriers mentioned include Federal Highway Administration (FHWA) approval, community acceptance, and political acceptance.

Charlotte, North Carolina

Current methods used for traffic calming include road humps citywide (450 humps by August 2000) and special signs mid-block advising motorists that they must yield to pedestrian crossings ahead. The city of Charlotte, North Carolina and Howard County, Maryland have implemented the most design treatments that are improvements to the traditional types of speed control (signing, markings, and signals). Charlotte uses a combination of crosswalk and road humps. The city even has a speed table at one intersection with a high volume of pedestrian traffic. And a traffic circle with some pedestrian friendly features is planned to replace a signal in a newly renovated area of the city. Public acceptance is assessed from voluntary calls made to the public service division and is judged positive overall. Pedestrian safety is very much a concern of the citizens of Charlotte and safety initiatives are supported by the city council.

To assess safety needs, Charlotte Department of Transportation (CDOT) has a section in their Department committed to reviewing accidents; it receives a copy of all accident reports. CDOT makes recommendations to the City Council Transportation Committee and then that committee prioritizes the needs. Public and driver education is provided by the school system. As a new technology, photo enforcement is an option in Charlotte to help reduce speeds in pedestrian zones and has implemented red light running cameras.

The representative from Charlotte expressed that technologies, such as ISA, merit examination and expressed that it would be very beneficial in a school zone setting. Potential barriers mentioned included the state legislation. Charlotte has had success in using photo enforcement for red light running; however, it was an "uphill battle" in the state legislature. Many lawmakers were concerned with the "big brother" concept and ISA would probably face the same criticism.

Gainesville, Florida

Current methods used for traffic calming are road humps. Gainesville has not implemented any design treatments that are improvements to the traditional types of speed control.

Pedestrian safety is very much a concern because the University of Florida produces many pedestrians walking to and from classes. Transportation needs of the community are prioritized by consensus. Public and driver education is provided through the school board and safety council.

The representative from Gainesville has "serious doubts" that technologies, such as ISA, are an acceptable solution to reducing and managing speeds in pedestrian areas. Potential barriers mentioned included safety, legal, privacy, and public acceptance issues. Gainesville has had no success passing red light cameras enforcement in the state legislature and therefore it is thought that ISA has "no chance" in Florida.

Howard County, Maryland

Enforcement is the primary means of speed control in Howard County (*14*). Other methods used for traffic calming include raised intersections, humps, roundabouts, medians, rumble strips, chicanes, pavement markings, eyebrows, and raised crosswalks as deemed appropriate to each site. School crossings in the immediate vicinity of schools are choked. Howard County has found that automated enforcement systems for red light running have reduced the number of violations, the number of accidents, and the approach speeds to intersections with the systems.

Pedestrian safety is a concern at the local neighborhood level. This concern is the primary issues that prompted the formulation of the traffic calming program over a decade ago. Accident information management system software (AIMS) is used to assess safety needs by identifying high accident locations. Howard County's traffic calming program involves a community interaction process that serves to develop the appropriate treatment for each area in concern. School crossings, school routes, and high accident locations have the highest priority.

Public and driver education is provided by a multi-entity organization that promotes traffic safety in Howard County through media and public function activities called TAGS (traffic action group for safety). Also, to heighten public awareness to reduce speeds in residential communities there is an ongoing campaigned called the Traffic Safety Awareness Campaign. A community speed watch program allows individuals and community groups to take an active role in reducing speed in their neighborhoods. The aim of the community speed watch is to reduce speeds through peer pressure and awareness. At the beginning of each school year, the police department institutes a special speed enforcement program on the roadways surrounding the county's school zones with the purpose to cite speeding violators. This program serves to remind drivers that school is back in session and conformance to the speed limits is critical for the students' safety. This program is accompanied by news releases to educate drivers of its existence (*14*).

The representative from Howard County believes that technologies, such as ISA, may be acceptable in school zones, local residential streets, and work zones. The term "acceptable" was questioned as to whom and where. This type of technology should evolve through the developing ITS programs at local levels. There may be a reservoir of public support for such technology. Howard County is currently testing speed and tailgating systems based on digital technology.

San Diego, California

Current methods used for traffic calming in San Diego include physical measures such as road humps, traffic circles, median diverters, bulb outs; traditional measures such as signing, pavement markings, and traffic signals; and roadway design techniques such as one-way streets, closing medians, and turn prohibitions. Radar speed trailers for education and feedback to the drivers are also used in San Diego. The public has had good reactions; however, these reactions are not measured in San Diego. They are just anecdotal.

Pedestrian safety is one of the biggest concerns for San Diego. To assess safety needs, San Diego uses enforcement, engineering (traffic engineering analysis and corrective measures), and education. Needs are prioritized based on accident rate in addition to public and political input. Public and driver education was used most in San Diego; Bellevue, Washington; and in Howard County, Maryland. In San Diego, television, public meetings, handouts, school-targeted bicycle rodeos, and the *Safe Route to School* program provide education for the public. As a new technology, San Diego is investigating flashing lights imbedded in crosswalks to help reduce speeds in pedestrian crossings.

The representative from San Diego believed that technologies, such as ISA, are not an acceptable solution to speed related problems. Potential barriers mentioned include not being able to gain public acceptance. Another concern was that the public would feel ISA was an intrusion into personal freedoms.

Analysis of US Experience with Traffic Calming

Even with the advances in vehicle safety (air bags, anti-locking brakes, etc.), mobile and air emergency medical service, and other similar techniques and technologies, the total volume of fatalities and injuries remains basically constant because of the continuing increase in exposure by the increasing amount of travel. The percentage of drivers speeding indicates that speed limits need to be supported by other measures. For this support, new methods of speed control are continually being developed. This suggests that current speed reduction methods are not enough for every speed sensitive pedestrian area or every situation.

The question remains: Does the United States “need” ISA to reduce speeds? The answer may be that speeds do need to be reduced in pedestrian areas and ISA is a potential technology that may help drivers reduce their speeds.

INTELLIGENT SPEED ADAPTATION

As an alternative method to traditional traffic calming techniques, a few European countries are developing a technology called intelligent speed adaptation (ISA). The goals of ISA are to reduce speeds above the posted speed limits and to reduce the frequency of speed related crashes. ISA allows agencies to directly or indirectly influence the speed of vehicles equipped to receive the signal while in a target area. ISA consists of processes that monitor the relationship between the current speed of a vehicle and the posted speed limit (*15*).

There are two types of ISA systems. First is a warning system called the informative or advisory system. This system informs the driver of changes in the speed limit by setting off an audio or visual alarm or even a display of the speed limit. Figure 2 is a picture of a vehicle in Sweden equipped with the informative ISA system (without display capabilities) (*16*).

The second type is called the automatic or active system. This system does not allow the driver to accelerate over the posted speed limit (*17*). Both informative and automatic systems are being used in field tests in Sweden, the Netherlands, the United Kingdom, and Spain.

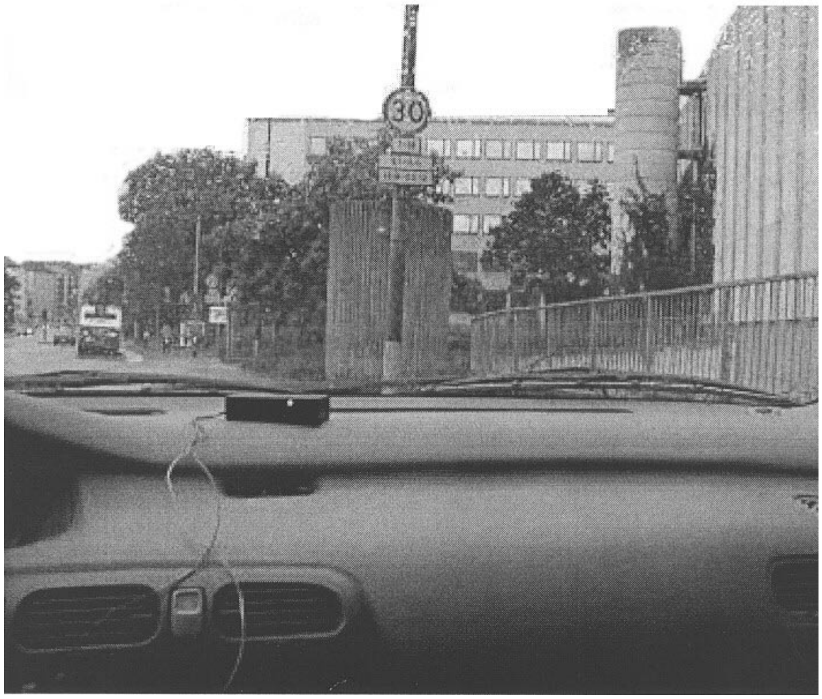

Figure 2. Vehicle with Informative ISA System (<u>*16*</u>)

In-Vehicle Unit

The informative system's in-vehicle unit consists of a small box (4 by 2 by 1 inches),an example unit is on the dash in Figure 2. This unit consists of two light emitting diodes (red for speeding and green for on), microprocessor, radio receiver, and a buzzer. This device is linked with the vehicle's pulse emitter (cruise control) to measure distance and speed. This device is also linked with the vehicle's battery for power (<u>*16*</u>).

The active system's in-vehicle unit is an after-market installed device that links the vehicle's power train (the throttle, ignition, fuelling system, gearbox, and/or brakes) to intervene and restrict fuel injection and limit the speed of a vehicle so that the driver is not capable of driving faster than the posted speed (<u>*17*</u>).

Communication Infrastructure

ISA requires some form of communication between the vehicle and the ISA infrastructure enabling the vehicle to "know" the speed limit. The communication can be in the form of an integrated roadside ISA system where information from a roadside beacon is transmitted to the vehicle as illustrated in Figure 3. Alternatively, this communication can be provided by a global positioning system (GPS) where information from a digital map is stored in the car and a GPS receiver relates the position of the vehicle. (<u>*17*</u>, <u>*18*</u>).

All of the European field trials in found by the author are using the roadside beacon transmitters.

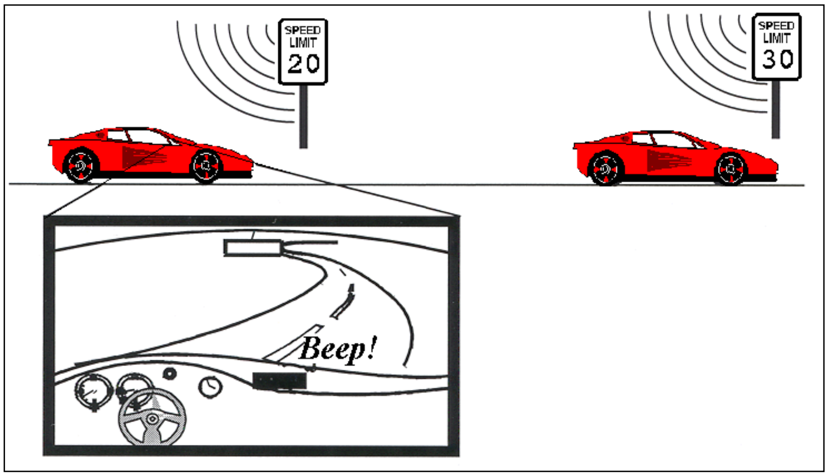

Figure 3. Schematic of Roadside Beacon Infrastructure and Informative ISA System (8)

There are three choices of the types of speed limits ISA can support:

1. *Fixed* speed limits where the limit is set to the maximum legal posted speed for the stretch of road or area of the city;
2. *Variable* speed limits where local speeds could be adjusted to change during the stretch of road where "dangerous" places are present; and
3. *Dynamic* speed limits that take into account changing speed zoning by time of day, road surface conditions, weather, and visibility (17).

All of the European field trials in found by the author are using fixed or variable speed limits.

European Experience

Overall, European countries running trials are using ISA in urban areas with speed limits set at 20 or 30 mph. The are not applying ISA to specific spots.

Simulator Runs – Leeds, Sweden

At the Institute for Transport Studies in Leeds, Sweden, ISA research has been conducted for the last ten years. The hypothesis of their research is a reduction in injury accidents when 100 percent of vehicles will be fitted with a speed limiting system (17). The Leeds facility has run two experiments (1995, 1996) with a complete car simulator using the active system where the simulator's speed was physically limited in certain situations and not limited at other times.

In general, the results showed that driver behavior does change when ISA as a speed limiter is used. It was concluded that in car following scenarios less time was spent at short headways, indicating safer following behavior. The speed limited condition showed a lower average approach speed to intersections (mean = 22.42 mph) than non-speed limited (mean = 24.08 mph). A chi-square test for independence revealed that frequency of traffic signal violations decreased when the speed limiting function was on. The studies found that the automatic ISA system of physical speed limiting had a calming effect on drivers. However, subjective mental workload measures indicated that driver's feelings of frustration increased when their speed was limited. This frustration was also reflected in the shorter gap acceptance observed when limited (mean = 46.69 seconds) than when not limited in speed (mean = 54.15 seconds).

The results of additional experiments contrasted with the first. In the second simulator trials, drivers drove at shorter headways. This inconsistency between driver behavior in experiments led to the conclusion for the need for studies of long-term behavioral adaptation. Also in the second experiment, drivers expected the system to be all knowing; this was evident from drivers not slowing in poor visibility fog conditions (*17*).

Demonstration Projects – Umea and Enslov, Sweden

Approximately SEK 30 million (approximately 3.4 million United States dollars) has been invested by Sweden for ISA research, most of this money has been used for two demonstration projects. In Umea, Sweden, the vehicles in the trials are equipped with the informative ISA system with the information transmitted to vehicles by a roadside beacon. It has been found that drivers are willing to change their behavior, with help from ISA. The simple in-car unit device helps drivers keep under the speed limit without the need for physical measures for traffic calming, which the city views as expensive and an obstacle to emergency vehicles and buses. Umea has shown that drivers appreciate the technology and 90 percent express that they want the system to extend to more areas of the city. ISA has increased road safety by lowering speeds, especially in urban areas where vehicles and vulnerable road users have the chance to mix (*15*,*17*).

In Enslov, Sweden, the vehicles in the trials were equipped with the automatic ISA system with 25 vehicles driven by the same drivers for a two-month duration. Radio transmitters at the entrance and exit roads to the city turn the ISA function on and off in the test vehicles. The test area comprised all of the urban area of the city, approximately 2.7 miles squared. The speed of the vehicles was automatically limited to the city-mandated speed of 30 mph. The driver experienced this limiting in the form of resistance in the accelerator and the fact that it was not possible to increase the speed of the vehicle. After experiencing the automatic speed limiting ISA system, drivers viewed the system as a safety measure and not as an unpleasant control or source of irritation with 66 percent of drivers expressing that speed limiters would make "traffic safer" (*15*).

The results of both studies unanimously suggest driver acceptance and understanding of the ISA systems in areas with a 20 or 30 mph speed limit, and even a willingness to pay for the system. Further results of both studies showed that:

- The percent of drivers adhering to 20 mph speed limits on roads increased from just over 20 percent to 80 percent;
- More than 50 percent of the users felt that the level of comfort increases and the mental pressure is less;
- Almost 100 percent felt that the introduction of these systems will lead to "safer traffic"; and
- The interaction with other road users improved (*19*).

The United Kingdom

The ISA research project in Great Britain predicts that automatic ISA systems can significantly reduce the number and severity of accidents, particularly among vulnerable pedestrians. The research in Great Britain has included household surveys and focus groups in Phase I and a study of driver behavior using a driver simulator and road trials in Phase II (*20*).

For the field trials, roadside beacons will communicate with vehicles equipped with the automatic ISA system. The field trial test route was approximately 42 miles long, speed limits varied from 30 to 70 mph, and a high number of pedestrians. The automatic system was successful in reducing excessive speeds. There was the option for drivers to turn "off" the system at locations where speeding was the normal for the surrounding traffic. With the mixed traffic (some vehicles not equipped with ISA), drivers preferred to be in control of the vehicle when they felt pressure from other drivers.

The results from observation indicated that no negative behavior was occurring, in fact, the vehicle headways increased. Drivers felt they had more time to make driving decisions because of their lower speeds and reported mental workload decreased with driver familiarization of the system.

Large-Scale Trial - Sweden

A large-scale field trial involving 5,000 vehicles is being conducted in four, primarily urban environments in Sweden. This trial based on voluntary driver participation started in 1999 and is set to conclude in 2001. The budget is SEK 75 million, or approximately 8.4 million United States Dollars. This trial is experimenting with variations of the informative and automatic ISA systems. First, is the informative ISA system which two variations are used: one that uses a visual and audio warning or one that displays the posted speed limit. The second system, called the ISA system for quality assurance, is being used for quality assurance of transports such as school buses, taxis, and transport for the disabled. With this system, after a warning, if the driver fails to reduce speed in 10 to 15 seconds, a violation is registered. Last, Sweden is experimenting with the active ISA system.

The goals of this trial are to provide knowledge of the potential obstacles associated with a general introduction of ISA; provide knowledge of the effects on traffic safety, the environment, accessibility, and transport costs; act as a catalyst in creating a public market for ISA; and attempt to study the impact on long term use (*8*).

The Netherlands

In the Netherlands, an experiment is being carried out during 1998 through 2000. The infrastructure in the Campenhoef district will be equipped with the roadside radio transmitter beacons. Twenty vehicles have been equipped with the active ISA system. The vehicles will be driven by varying teams for approximately one year. The research plan assumes that the ISA system can only vary by being turned on and off, thus using a fixed speed limit (situation and/or time dependent changes in the borders), and that the recognizability of the ISA vehicles will not be encouraged or varied.

The Netherlands is looking to evaluate the operation and ergonomics of the system, the attitudes of drivers, the effects of ISA on speed behavior before and during the study, the effects on groups other than ISA users such as neighborhoods and pedestrians, and the effects of ISA on speed behavior compared to the speed behavior of non-ISA users (*18*).

Conclusions about ISA

ISA is becoming an acceptable means to reduce speeds in sensitive areas in Europe and the United States needs to seriously evaluate its potential for application. In general, it can be concluded from the experiments that informative ISA systems appears to have less effect on driver's speeds than intervening active systems. Active systems have reduced mean speed and speed variance more significantly; however, driver acceptance appears to be higher with the warning system (*6*,21).

ISA Compared to Physical Methods

ISA is a positive alternative to current physical methods of traffic calming used in the United States because of easier snow clearance and maintenance; smoother, more straightforward operation for public transport and rescue vehicles; greater comfort and less risk of damage to vehicles; and more flexible "road bump" locations (*19*). Other possible problems with implementing physical traffic calming methods include the liability with raised crossings, curbs as fixed objects, lowering the design standard by narrowing the roadway, and any other measure viewed as counterproductive to safety (*3*).

Police enforcement is the widest used speed reduction method in the United States and in Europe; however, there are also long-recognized limitations to police enforcement. Speed enforcement is most effective if: drivers believe it is likely to occur, the violation is costly to the drivers, not associated with varying locations or times of day, or not associated with any specific cues. Most studies show that drivers slow only in the area of enforcement only during the time of enforcement (*1*).

KEY ISSUES RELATED TO APPLICATION OF ISA IN THE UNITED STATES

Thus far, ISA research is returning positive results; however, it is not guaranteed that any safety improvements will be secured. Sweden has discovered a lot about the potentials with ISA and much about driver short-term acceptance and support. However, we know very little about long term driver acceptance, the potential impact on society, and the long term effects on road safety. Further research is needed to assess the long-term benefits, behavioral adaptation issues, effects on the environment, and the accessibility of ISA on a large scale. Other potential problems with ISA include human factors such as possible complacency and loss of vigilance, loss of driving skills, loss of information about the current situation, and change of the driving task to a task of monitoring (*17*,*21*).

There are many issues regarding the application of ISA in the United States. The following sections explore these key issues.

Recognition of Cultural Differences

There are cultural differences between Americans and Europeans that need to be explored before the United States can simply apply European technology, such as ISA.

An important factor to consider when evaluating the implementation of European traffic control practices in the United States is the widespread use and support of public and multi-modal transportation as well as the increased number of people walking for transportation purposes in Europe. Europeans are not as reliant on the automobile as Americans are and this is probably the most significant cultural difference that affects transportation. Europeans also appear to have a generally greater respect for authority than Americans and therefore a higher compliance with traffic control devices and regulations. (*15*).

A few engineering differences noted by the FHWA team are that European transportation agencies appear to be more accepting of new technologies and the use of ITS solutions appear to be more readily accepted by European engineers and their countries (*15*).

Effectiveness

To make it possible to introduce ISA systems in the United States, the trials underway in Europe must demonstrate that ISA systems have a positive effect on the road traffic system.

Results have been generally positive suggesting the potential for dramatic improvements in safety; however, it is not guaranteed that those improvement will be secured and more time is necessary to fully understand the implications of ISA technology (*17*).

Public Attitudes and Acceptance

Public acceptance and legislation support are two key issues the survey determined to be of concern to implementation of ISA in the United States.

First, who should pay for the in-vehicle unit of the ISA system? The research programs in Europe are purchasing the units for the field trial. At the end of the field trials, drivers have the option to buy the unit. Should this purchase be mandatory for the drivers to purchase or car-manufactures to implement or should the purchase be voluntary? European consumers are expressing interest in purchasing and using ISA; however, would American consumers have that same interest?

ISA would be best introduced and marketed as a means to increase pedestrian safety and therefore first be implemented in pedestrian zones such as school zones, residential neighborhoods, downtown areas, retirement areas, shopping areas, hospital zones, and recreational/park spaces. It is desired that any ISA program be reactive and a response to accident levels or citizens complaints to help with support of the systems. Then, only after widespread acceptance and demonstration of improvements by reduction in the number of vehicles speeding through pedestrian areas and in the number of motor vehicle collisions with pedestrians, the technology could be applied to other areas.

Rural applications of ISA could be but is not limited to: isolated stop locations on high-speed roadways, on sharp curves, locations of poor skid resistance, railroad crossings, and other locations involving high numbers of incidents. Urban applications other than just pedestrian sensitive areas include: hazardous intersections, neighborhood speed restraints, areas where sight restrictions are due to vertical crest curves subject to queuing, and construction and maintenance work zones.

In Europe, acceptance by the driver of ISA increases after use of and familiarization with the technology.

Human Factors

There is a difference between the human factor issues for the informative and automatic systems.

The informative ISA system may become annoying to speeding drivers that are not going to slow their speeds. There is the possibility that the driver would choose to simply turn off the system or ignore the warnings.

The automatic system presents the issue of human expectancy and reliance. Over years of use, drivers may become accustomed to the speed limiter. What would happen if the system would fail and the driver does not realize that he/she is speeding because they are used to the automatic speed limit? It is difficult to anticipate how humans will react and long-term behaviors, one cannot assume that behavior is constant.

In Europe, before and after subjective driver surveys are attempting to quantify the human factor issues.

Legal Issues

The newness of this developing technology possibly presents more barriers because the public and the legislators are uninformed of the dangers of vehicles speeding and the vulnerability of pedestrians. Before this technology can be considered further, there needs to be an intensive look into the legal issues that are currently unclear.

As the surveys for this research predict, the process to legalized ISA may be a battle with legislatures because new legislation may be required.

The automatic ISA system seems to present more legal and liability issues because the local jurisdiction would gain control over the speeds of vehicles. The issue of accident liability is complex. Would the driver or the system manufacturer be responsible? There is the issue of potential system failure, the conditions for "fail safe" must be defined.

Research and Testing Procedure for the United States

It is important to note that the target years for implementation of ISA technology in Europe range from 2010 to 2020; ISA is not ready for widespread implementation in Europe.

The following has been developed by the author to address the essential issues addressed.

Estimate Potential Benefits of ISA

To begin with, the estimated potential benefits of ISA should be quantified to help assess the feasibility of the ISA system for the United States before money is spent on further research. The benefits of the system must considerable outweigh the costs. The prediction of accident savings would be based on the interaction between speeding vehicles and pedestrians and the probability of accidents. Research is necessary to quantify the number of deaths/injuries due to speeds greater than posted speed limits in sensitive areas.

In the large scale field trial in Umea, Sweden (5,000 vehicles), the cost of the informative in-vehicle unit (cost to driver) is approximately 200 United States dollars. It is estimated that with large-scale implementation the cost will drop to around 46 United States dollars. The cost of the roadside transmitter for these trials (150-200) is approximately 1300 United States dollars. It is estimated that the cost would drop to approximately 830 United States dollars with widespread implementation (*16*).

Address Legal Issues

The concern of legality and acceptance by legislatures was expressed through the survey conducted for this research and expressed in several European ISA literatures. Before it can be determined that ISA is applicable to the United States' pedestrian areas, the potential implementations need to be thoroughly evaluated.

A survey of legislators across the country could be done to find the legal concerns, possible barriers, and opinions of the lawmakers. From the survey results, a plan of action could be determined. The survey could be included with information carefully explaining the possible ISA systems and that ISA is a future technology that is developing. .

Further Research and Testing

Further research is required on the technological aspects including communication options; reliability of the system; acceptance by the public and relevant authorities; and driver behavior issues.

Monitoring the European efforts and information sharing between the European researchers and American researchers should be established. It would be beneficial to explore the research methods used in Europe and the lessons learned from their research efforts in detail.

First, surveys and focus groups can assess driver opinions of the technology. The goals of the surveys and focus groups would be to predict biases to the technology and potential barriers to be addressed by marketing.

Second, the details of the technology should be explored with simulator runs and the system to be proposed for the United States could be suggested. Field trials with preset driving routes would be next. The goals of the simulator runs and preset route trials would be to measure average driving speeds, variations in speed, vehicle headways, and to observe interaction with other drivers and pedestrians.

Finally, long-term (at least one year long), field trials could be conducted to gather information in an attempt to address the long-term driver behavior issues of expectancy of the system and reliance on the system. All trials and simulator runs would be followed with surveys to help determine driver behavior issues and attitudes about the technology after driving. The after surveys could aid in determining the willingness for American consumers to purchase the ISA equipment. Then the issue of whom should purchase the systems and the issue of if purchase would be voluntary or mandatory could by examined with more information relevant to American consumer opinions.

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INCIDENT MANAGEMENT: INFORMATION EXCHANGE AMONG OPERATIONS CENTERS OF PUBLIC SAFETY AGENCIES

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SUMMARY

Incidents are the leading cause of congestion on the highways. Managing these incidents requires cooperation, communication, and coordination of a number of public and private partners including transportation agencies, emergency management agencies, and the media. While managing an incident is not the core function of any one agency, it is important to all. Managing incidents in an effective and efficient manner can save lives, save costs, save time, and improve the quality of life.

In this paper, a recommended action plan is presented for implementing or improving the exchange of incident information among transportation and public safety agencies. The recommended action plan was based on responses of surveyed transportation agencies and literature review, which included the National ITS Architecture.

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INTRODUCTION

Incidents are a major cause of congestion (*1*). Congestion has two components: recurring congestion where the predictable increase in traffic volume reaches or exceed the available capacity of the highway facility; and non-recurring congestion, which is the unpredictable delay, caused by incidents. Incidents include accidents and a vast array of small events, such as debris on the road, vehicle stalls, and maintenance work.

The detection, verification, response, and clearance of the incident can take as little as minutes to as long as hours. During peak congestion periods, minutes can result in hours of vehicle delays. By managing these incidents in an effective manner, the delay to motorists and the impact to public safety can be reduced. The time saved by an incident management program depends on how well the detection, verification, response to, and clearance of an incident are managed.

Communication is the essence of many operations and programs, not unlike incident management. When public safety and transportation agencies are notified of an incident, they are most likely in need of communicating to one another in some manner. The safety of any affected motorist and response personnel can be greatly degraded by the lack of, inefficient, or inaccurate exchange of information. When operation centers for the responding agencies, such as police and transportation departments, are unaware of an incident affecting their operations, then communication and coordination has failed. A Transportation Management Center can serve as a hub for collecting and disseminating traffic and incident information with the public, other transportation departments, and public safety agencies. Although it is imperative that operation centers communicate and exchange information, the amount, type of, and how incident information is exchanged varies among agencies.

Research Objectives

The primary objectives of this study were to:

1. Investigate current practices of incident information exchange among the operation centers of Public Safety agencies and Transportation Management Centers;
2. Identify the advantages and barriers to the exchange of incident information;
3. Develop an Action Plan for the exchange of incident information between the Public Safety Centers and Transportation Management Centers; and
4. Apply these recommended practices to a pilot Incident Management program in St. Louis, MO.

BACKGROUND

Traffic Congestion and Impact of Incidents

Incidents are a major cause of congestion (*1*). Congestion has two components: recurring congestion where the predictable increase in traffic volume reaches or exceed the available capacity of the highway facility; and non-recurring congestion, which is the unpredictable delay, caused by incidents. Incidents include accidents and a vast array of small events, such as debris on the road, vehicle stalls, and maintenance work. Table 1 shows typical capacity reductions due to several incident types (*2*).

Table 1. Typical Capacity Reductions (2)

Incident Type	Capacity Reduction (percent)
Normal Flow (three lanes)	None
Stall (one lane blocked)	48
Noninjury Accident (one lane blocked)	50
Accident (two lanes blocked)	79
Accident on Shoulder	26

The detection, verification, response, and clearance of the incident can take as little as minutes to as long as hours. During peak congestion periods, minutes can result in hours of vehicle delays. The delay caused by incidents can be quantified by Figure 1 (2). By managing these incidents in an effective manner, the delay to motorists and the impact to public safety can be reduced. The time saved by an incident management program depends on how well the detection, verification, response to, and clearance of an incident are managed.

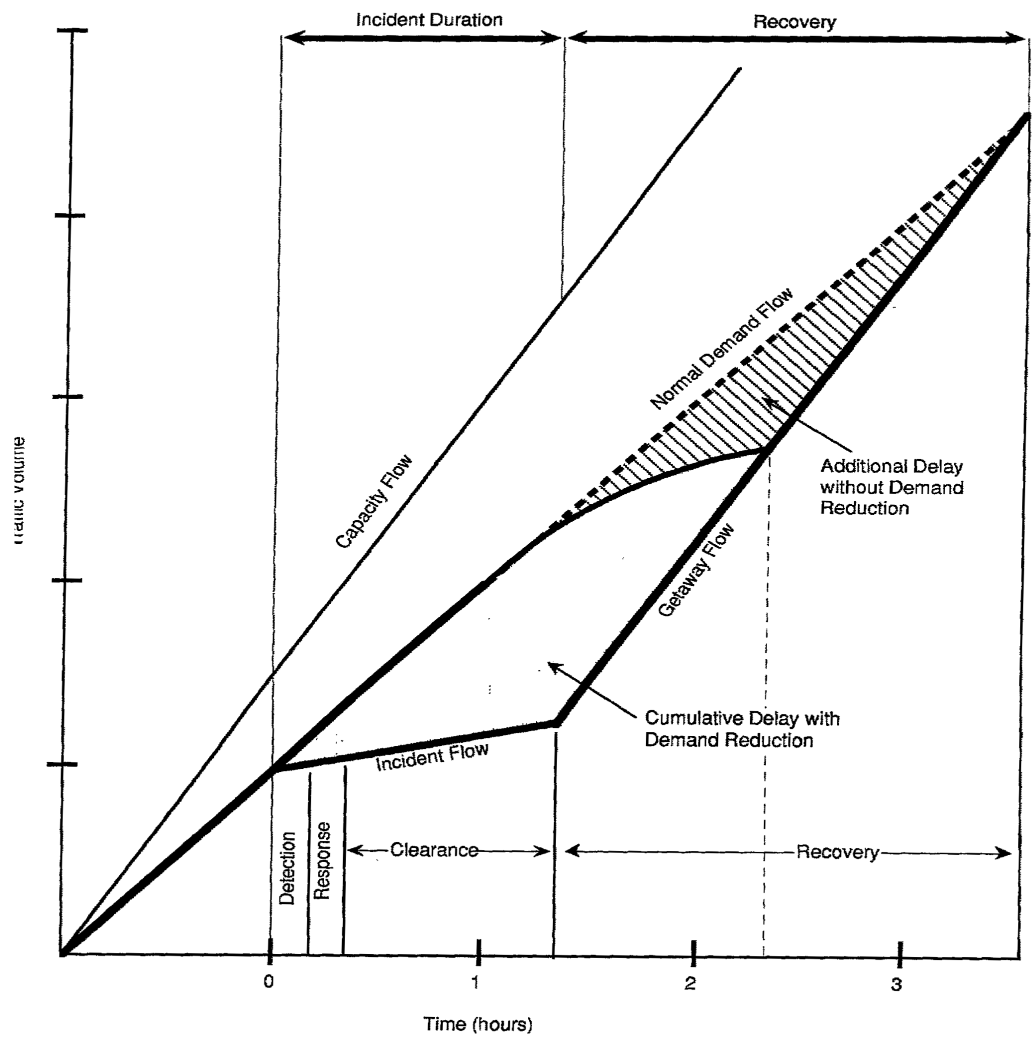

Figure 1. Quantifying Incident Delay

Incident Management

Incident management is the process of managing multi-agency, multi-jurisdictional responses to incidents. Since it includes coordinating the operations of many agencies to respond to incidents, incident management poses a significant institutional and management challenge. Efficient and coordinated management of incidents reduces their impact on public safety, traffic conditions, and the local economy.

Incident management yields significant benefits through reduced vehicle delays and enhanced safety to motorists through the reduction of incident frequency and improved response and clearance times. Across the nation, incident management programs have delivered measurable benefits. Some of the benefits relative to their unique features as part of its incident management program are shown in Table 2 (*3*).

Table 2. Incident Management Programs Benefits (*3*)

Program Name	Measured Benefit
Minnesota Highway Helper Program	8 minute reduction in vehicle stall duration
San Antonio, TX TransGuide System	Average response time reduced by 20% Accident rate reduction of 41%
Houston, TX TranStar System	Average delay savings of 572,095 vehicle-hours
Atlanta, GA NaviGAtor System	Average clearance time reductions from 6.25 hours to 1.5 hours during first 3 weeks of operation
Maryland CHART Program	Average 2 million vehicle-hours of non-recurrent congestion delay savings per year

Many agencies are involved in managing incidents and restoring the highway in a manner to allow vehicle travel. These agencies are state and local transportation departments, state and local law enforcement, fire and rescue departments, hazardous material clean up services (HAZMAT), towing and recovery companies, traveler information services, and the public. Each has their own responsibility and role in the detection, verification, clearance, and recovery of an incident scene.

Transportation management centers can function as information management centers in support of multi-agency operations. Their focus typically is in restoration of normal traffic flow and minimization of delays. Law enforcement agencies are focused on responding to the aid of the involved motorists and investigating the incident. Few agencies continue to coordinate with the local transportation management center once they are at the incident scene.

Inter-agency Coordination

Greater inter-agency coordination can result in significant improvements to the efficiency of incident response, clearance, and recovery. This is accomplished by improving working relationships among incident management agencies responsible for transportation, law enforcement, fire and rescue, environmental monitoring, and safety from multiple jurisdictions.

Features of inter-agency coordination may include the following (*3*):

- Agreement of common goals prior to incident occurrence;
- Adoption of cooperative policies;
- Joint inter-agency training opportunities;
- Development of inter-agency incident management handbooks;
- Creation of inter-agency memorandums of understanding;
- Resource sharing among participating agencies;
- Collocation of core incident management personnel;
- Frequent interaction among partner agencies;
- Prior joint planning for on-scene staging and traffic management;
- Incident data collection and dissemination of incident information; and
- Periodic incident management program review and regular evaluation.

Benefits of inter-agency coordination may include the following (*3*):

- Promote better understanding, trust, respect, and communication among incident management agencies;
- Improved detection, response, and clearance times;
- Promote the sharing of resources among agencies;
- Allow for better on-site management of incidents;
- Promote better incident management policies;
- Allow for improved sensitivities to each other's organizational needs and extended faith in each other's abilities;
- Allow agencies to gauge expectations;
- Allow for improved safety resulting from more efficient response/incident clearance processes;
- Allow for improved public awareness through better communication and real-time updates about incidents to the public;
- Consolidated dissemination of information;
- Promotes unified command structure; and
- Enhances the cooperative efforts of field responses and activities.

As relationships and trust among agencies is developed, regional integration develops. The first phase of regional integration is the exchange of incident information. When transportation management centers and public safety agencies, or emergency management centers, exchange incident information, each performs its primary focus more effectively.

SURVEY RESULTS

One of the objectives of this paper was to investigate current practices of incident information exchange among operation centers of public safety and transportation agencies. The following agencies were contacted.

1. Arizona Department of Transportation, City of Phoenix
2. Hawaii Department of Transportation, Island of Oahu
3. Minnesota Department of Transportation, City of Minneapolis
4. New Jersey Department of Transportation, City of Trenton
5. Texas Department of Transportation, Houston District
6. Texas Department of Transportation, San Antonio District

7. Utah Department of Transportation, Salt Lake City
8. Washington State Department of Transportation, City of Seattle
9. Wisconsin Department of Transportation, City of Milwaukee

The survey presented to the state transportation management centers was to determine the following:

1. What incident information was being exchanged
2. Who was exchanging the incident information
3. How were they exchanging the incident information
4. When were they exchanging the incident information

The surveyed agencies notified the public safety agencies of incidents and were contacted by the public safety agencies of incidents. More specifically, the local police or state highway patrol centers were the public safety agencies in communication with the state transportation management centers. Table 3 shows how, when, and what information being received by the Transportation Management Centers and Table 4 indicates the current practices of distribution of the incident information to the public safety agency.

Arizona Department of Transportation (*4*)

The Arizona Department of Transportation has a response team available 24 hours a day, 7 days a week. The teams are dispatched from the operations center with an average response time in the Phoenix valley of 13 minutes. The Department of Transportation's operation center is integrated with the county operation center, allowing exchange of information among transportation agencies. However, the public safety agencies do not have Computer Aided Dispatching at this time to interface electronically directly with their 911 dispatching center.

Hawaii Department of Transportation (*5*)

The Tunnel Operations Center in Hawaii has the primary purpose of managing the H-3 Freeway tunnel on the Island of Oahu, including the dispatch of emergency services, emergency call boxes, and motorist information and assistance. The tunnel has closed circuit television cameras (CCTV), carbon monoxide detectors, traffic loop sensors, intrusion detectors on the fire hose cabinet doors, call boxes, and the 911 police dispatch reports for incident detection and verification. An area-wide freeway management system is currently under development and included is an interface with the emergency 911-dispatch center.

Initially, security and confidentiality were barriers in the coordinated exchange of incident information among the Hawaii Department of Transportation and the state patrol and police agencies. The Department has addressed these concerns by educating the public safety agency on the benefits of information exchange and developing accepted solutions for their concerns.

Minnesota Department of Transportation (*6*)

The Minnesota Department of Transportation has the Highway Helper program that operates from 5:00 A.M. to 8:00 P.M., Monday through Friday with limited coverage on the weekends. The Highway Helper vehicles are dispatched from the Traffic Management Center. However, there is close coordination and communication with the Minnesota State Patrol, along with joint policies and procedures. They currently send electronic messages to the State Patrol dispatch, but are migrating to Computer Aided Dispatch (CAD) and 911 systems to be located in the transportation management center. The Highway Helper operation will also be integrated into the CAD system.

Table 3. How the Transportation Management Center Receives Incident Information

Agency Name	Time Elapse Before Notification Made By Police/Patrol	Method Of Notification By Police/Patrol	Real Time Electronic Interface Between DOT And Police/Patrol	Information Received from Police/Patrol
Arizona Department of Transportation, Phoenix	<= 5 minutes	Telephone	No	Route, direction, milepost, needs, and type of incident
Hawaii Department of Transportation, Island of Oahu	<= 5 minutes	Telephone	No (currently)	Location, nature of incident, and injuries involved
Minnesota Department of Transportation, Minneapolis	<= 5 minutes	Telephone	No (currently)	Incident type, location, direction of travel, response type needed (tow, fire, ambulance, etc.)
New Jersey Department of Transportation, Trenton	10 - 20 minutes	Telephone	No	Location, direction, vehicles involved, spills, HAZMAT, damage to state property, and duration of incident
Texas Department of Transportation, Houston District	<= 5 minutes	Computer	No (currently)	Location, severity of incident, and equipment needed
Texas Department of Transportation, San Antonio District	<= 5 minutes	Computer, person, and telephone	Yes	Incident status, date/time of incident, section working the incident, severity, coordinates and cross street for location of incident
Utah Department of Transportation, Salt Lake City	<= 5 minutes	Radio	Yes	Location and nature of incident
Washington State Department of Transportation, Seattle	<= 5 minutes	CAD terminal located in TOC or Telephone	Yes (State Patrol only)	Information on the CAD report
Wisconsin Department of Transportation, Milwaukee	<=5 minutes	Telephone	No (currently)	Location, severity, type, anticipated duration, and lane closures

Table 4. Transportation Management Center Distribution of Incident Information

Agency Name	Time elapse before notification is made	Information given by DOT	Method of exchanging information	Which of these does Police/Patrol have access 1. CCTV 2. Web Site 3. AMTS Real time map
Arizona Department of Transportation, Phoenix	<= 5 minutes	Route, direction, milepost, needs, and type	Telephone	2 and 3
Hawaii Department of Transportation, Island of Oahu	<= 5 minutes	Location, nature of incident, other agencies involved, equipment needed	Telephone	Not known
Minnesota Department of Transportation, Minneapolis	<= 5 minutes	Incident type, location, direction of travel, response type needed (tow, fire, ambulance, etc.)	Telephone and computer	1, 2 and 3 CCTV is preferred method
New Jersey Department of Transportation, Trenton	<= 5 minutes	As much as they have	Telephone	No
Texas Department of Transportation, Houston District	<= 5 minutes	Location, severity, and equipment needed	Computer and Telephone	1, 2, and 3
Texas Department of Transportation, San Antonio District	<= 5 minutes	Exact location of incident (direction & cross street), vehicles involved, fire truck needed, and wrecker evaluation	Computer, Telephone, Fax, In person, etc.	1, 2, and 3
Utah Department of Transportation, Salt Lake City	<= 5 minutes	Incident details of where, what, who, when, and why	Radio and shared CAD system	1, 2, and 3
Washington State Department of Transportation, Seattle	<= 5 minutes	Location, type, and severity	Radio Communications	1, 2, and 3
Wisconsin Department of Transportation, Milwaukee	<= 5 minutes	Location and type	Telephone	1, 2 and 3

When major incidents occur, the transportation management center notifies the Minnesota State Police, traveler information service providers, television stations, and county and city engineers. The Minnesota Department of Transportation is working on providing closed circuit television video on their web page, allowing the towing agencies to better check the incident scene for proper recovery equipment dispatching. In summary, joint policies and procedures, annual incident conferences, and routine incident debriefing meetings have improved their incident management processes and effectiveness.

New Jersey Department of Transportation (*7*)

The New Jersey Department of Transportation in partnership with the New Jersey State Patrol has a team of responders for major incidents. Improvement to the incident management operation would benefit by the real-time incident information exchange. The Incident Management Program has improved the communications, working relationships, and the coordination of incident response and clearance.

Texas Department of Transportation, Houston (*8*)

The Houston TranStar Division of the Texas Department of Transportation provides a coordinated regional effort between law enforcement agencies, planning services, telecommunications, and special event coordination. Metro's TranStar Division is composed of an Incident and Emergency Management Section, Dispatch Section, and a Traffic Management Systems Section. The Incident and Emergency Management Section provides coordination for inter-agency support and telecommunications services during critical incidents on the freeways.

The Houston TranStar Division is proposing the development of a Regional Computer Aided Dispatch that would integrate and share databases between the regional public safety agencies and TranStar. It would also involve agencies such as, METRO police, Houston police, Harris County Law Enforcement, Texas Department of Public Safety, Houston Fire Department, Harris County Emergency Management, City of Houston Emergency Management, Texas Department of Transportation, and other local city police and fire Departments. This project would demonstrate the potential benefits of inter-agency interconnected systems.

Texas Department of Transportation, San Antonio (*9*)

The Texas Department of Transportation has a Courtesy Patrol section that assists with incident verification, traffic control, incident clearance, and recovery. Information regarding incidents can be quickly exchanged because of computer access to the San Antonio Police communications dispatching system and the presence of a police traffic dispatcher co-located in the transportation management center. Inter-agency cooperation is greatly increased because of the co-location of the traffic police dispatch.

Utah Department of Transportation (*10*)

The Utah Department of Transportation has an Incident Management Team that consists of Utah Department of Transportation, Utah Highway Patrol, Dispatch Center, Fire and Emergency Medical Services, and other response agencies. The Utah Highway Patrol has a presence within the Department of Transportation's operation center. The shared radio frequency and Computer Aided Dispatch system allows real-time exchange of incident information. The ongoing efforts of the Incident Management Advisory Board promotes teamwork among the state, local, and response agencies.

Washington State Department of Transportation (*11*)

The Washington State Department of Transportation has a team responding to incidents 24 hours a day, 7 days a week. The presence of the State Patrol Computer Aided Dispatch terminal in the operations center allows nearly real-time exchange of incident information. The major barrier in the free exchange of information was the development of relationships with the emergency service providers and the tow operators. This has been addressed by the concerted efforts of all agencies to maintain communications at all levels of the organizations, common training programs where appropriate, development of joint mission statements, and agreements of common understanding.

Wisconsin Department of Transportation (*12*)

The Wisconsin Department of Transportation Traffic Operations Center in Milwaukee has an incident response team during the hours of 6:00 A.M. – 9:00 A.M. and 2:00 P.M. – 6:00 P.M., weekdays, and peak weekend hours. Their task is to help with traffic control during an incident, clearance and recovery of the incident area. They currently are designing an InterCAD network to link the MONITOR Freeway Traffic Management System with the Emergency 911 (PSAP) system. The lack of real-time data links with the public safety computer aided dispatch center systems has been a barrier in improving the traffic management efforts more.

The results of the surveys were utilized in the development of the recommended action plan for incident information exchange among the transportation agencies and emergency management centers specifically law enforcement agencies. The surveyed agencies agreed to the importance of exchanging incident information with the state and local law enforcement agencies in a timely and accurate manner. However, there were a variety of methods or technologies used to exchange information, each having their own effectiveness and application. Many of the surveyed transportation agencies have plans to integrate with police Computer Aided Dispatch systems, improving the coordination and communication among the agencies. The experiences and recommendations from the surveyed agencies provided significant input in the development of the recommendations.

NATIONAL ITS ARCHITECTURE REVIEW

The Federal Highway Administration requires agencies to be in compliance with the National ITS Architecture if approval of funding for ITS related projects can be granted. The implementation and operation of an incident management program must have adequate funding. Therefore, to ensure continued funding, transportation stakeholders across the nation have begun developing regional ITS Architecture plans in their regions. This section briefly describes the National ITS Architecture and its benefits; and discusses and identifies the specific portions relevant to incident management and the exchange of information among the transportation and emergency management centers, referred to as Incident Management Architecture.

Overview of Architecture

Transportation systems are becoming more complex and sophisticated. There are more stakeholders to satisfy and the need to integrate is increasing. An architecture simply does three things; 1) identifies boundaries and participants; 2) describes activities or functions; and 3) provides a framework for planning, defining, and integrating ITS. The National ITS Architecture is an important tool that provides a framework to identify components and interconnections both externally and internally (*13*).

Some of the benefits of using National ITS Architecture are:

- There are potential lower development and deployment costs;
- Reduced development time and risk;
- It allows for future system expansion; and
- It fosters information exchange among agencies.

There are two components of the National ITS Architecture, Logical Architecture and Physical Architecture.

The Logical Architecture defines:

- Architecture boundary;
- Functions to be performed; and
- Relationships between functions.

It does not define where the functions are performed or how the functions are implemented.

The Physical Architecture:

- Defines physical entity interfaces;
- Distributes functionality; and
- Consists of three layers
  1. Communication layer – how information is transferred between transportation agencies,
  2. Transportation layer – what transportation systems transfer what information,
  3. Institutional layer – supporting institutional structure, policy, and strategies.

As shown in Figure 2 (<u>13</u>), there are four subclasses of subsystems. The figure also shows the connectivity between them.

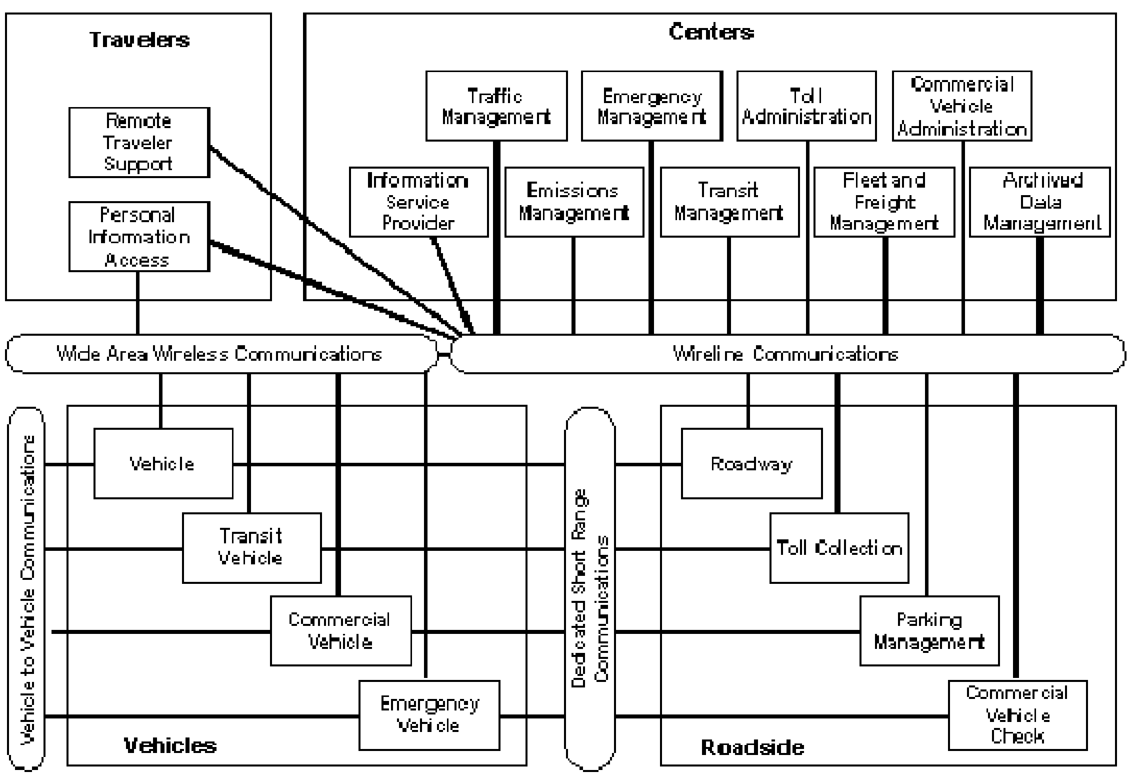

Figure 2. Physical Architecture and Subsystems and Interconnects

Incident Management Architecture

The Traffic Management Subsystem operates within the Center subclass. This subsystem communicates with the Roadway Subsystem to monitor and manage traffic flow. Incidents are detected and verified and incident information is provided to the Emergency Management Subsystems. These subsystems can communicate with other Traffic Management Subsystems to coordinate traffic information and control strategies in neighboring jurisdictions.

The Emergency Management Subsystem may represent any collection of Public Safety Agencies or Private concerns dealing with Public Safety. The Emergency Management Subsystem provides the capability to manage emergency vehicles and exchange information with other such agencies. It also provides an interface between existing emergency telephone support and E911 centers. It may be combined in the same location as a traffic management subsystem to provide integrated incident management.

Incident Management Action Initiated by Traffic Management Subsystem

The Traffic Management Subsystem continually collects data from the following:

1. Traffic sensors from the Roadway Subsystem
2. Probe data from an Information Service Provider
3. Weather service data
4. Event promoter data
5. Incident alerts from other Traffic Management Subsystems

Based on the collected data, the Traffic Management Subsystem detects, classifies, and verifies incidents. When the incident is verified, an appropriate incident response is prepared and messages are sent to Roadway Subsystems (e.g., to set Dynamic Message Sign messages), and Emergency Management and other Traffic Management Subsystems to alert them of the incident.

On receipt of the incident information message, the Emergency Management Subsystem will notify other Emergency Management Subsystems, such as police, fire, and medical services.

Incident Management Action Initiated by Emergency Management Subsystem

The Emergency Management Subsystem may receive Incident Notification messages from the Emergency Telecommunication System or other subsystems. This information can be processed and a determination made to forward the incident information message to the Traffic Management Subsystem. The Traffic Management Subsystem receives the incident information and, after possibly validating the incident, processes an incident response plan accordingly.

Data Flows between Traffic Management Subsystems and Emergency Management Subsystems

There are several physical architecture data flows among Traffic Management Subsystems and Emergency Management Subsystems. Table 5 lists the typical data flows from the Traffic Management and Emergency Management Subsystems to one another in reference to incident management (*13*). These data flows are used as guidance for determining what data is exchanged between the subsystems and for developing the necessary interfaces.

The process of developing a complete regional ITS Architecture plan requires participation by many agencies and organizations. The review of the National ITS Architecture for this report was to identify typical incident information exchanged among the traffic and emergency management subsystems in an Incident Management Architecture, as shown in Table 5. The results of the review were incorporated into the recommendations, Step 2, determining the incident information needs.

Table 5. Physical Architecture Data Flows (*13*)

Traffic Management Subsystem	Emergency Management Subsystem
Current Network Conditions • current traffic information, road conditions, and camera images	Emergency Traffic Control Request • special request to preempt the current traffic control strategy in effect at one or more signalized intersections or highway segments (e.g., all signals to red-flash, emergency route preemption, or another special traffic control plan)
Emergency Traffic Control Response • status of the special traffic signal control strategy implemented in response to the emergency traffic control request	Incident Information • notification of existence of incident and expected severity, location, time, and nature of incident
Incident Information • notification of existence of incident and expected severity, location, time, and nature of incident	Incident Response Status • status of current incident response including traffic management strategies implemented at the site (e.g., closures, diversions, traffic signal control overrides)
Incident Information Request • request for incident information, clearing time, and severity	Remote Surveillance Control • the control commands used to remotely operate another center's sensors or surveillance equipment
Resource Deployment Status • status of traffic management center resource deployment identifying the resources available and their current deployment status	Resource Request • request for traffic management resources to implement special traffic control measures, assist in clean up, verify an incident, etc.

RECOMMENDATIONS

The most effective and efficient Incident Management Programs are those that coordinate and communicate among agencies responsible for detecting, verifying, responding, and clearing the traffic incidents. The coordination and communication involves the exchange of incident information. This section is a summary of the survey of current practices across the nation and literature research.

In every urban area, agencies already perform some type of incident response, even without formal incident management programs. The goal of an incident management program is to create a more effective response for all cooperating agencies.

Recommended Action Plan

The recommended action plan is based on the results of the survey questionnaire of current practices and research literature discussed in previous sections. The purpose of the action plan is to help agencies answer the questions of who is involved, what information is exchanged, when is the information exchanged, and how is it exchanged. Furthermore, the action plan focuses on the incident information exchange among operations centers of transportation and public safety agencies, primarily state and local police.

Step 1 Assessment of Current Practices

Regional integration requires the development of trust and relationships among agencies. This step would include organizing the group of potentially affected public safety agencies and defining the operational objectives and any functional requirements for managing traffic incidents. Many centers already share some form of information during incidents. However, there may not be a formal process in place or the process may need to be improved.

An important part of this step is to define how the transportation and public safety agencies will manage incidents. Operational procedures and practices are determined and the responsibility for each function in managing incidents is identified. The current level of integration among the operation centers of the transportation and public safety agencies must be determined.

Items addressed in this step would include the following:

1. Determine police and transportation agencies involved in incident response;
2. Develop flowchart of existing process of incident information exchange, including who is exchanging incident information, how is the incident information being exchanged, and when the incident information is being exchanged;
3. Define police and transportation agencies responsibilities in incident management;
4. Define functional requirements of the incident management program relating to the operation centers of the agencies involved; and
5. Develop operational procedures and practices necessary for the inter-agency cooperation, communication, and coordination of incident information exchange.

This step lays the ground rules for the incident management program relative to incident information exchange and sets the stage for the next step, identifying incident information needs.

Step 2 Determine the Incident Information Needs

Each agency will have different needs for incident information, at different times, and in different methods of exchange. Once these needs are determined by each public safety and transportation agency, commonalties and differences can be sorted out. Information or data flows necessary to address the individual agency needs will be determined. The use of the National ITS Architecture will facilitate this process by providing the framework for data flows related to incident management.

Based on specific National ITS architectural data flows for Incident Management, recommendations from existing transportation operations centers, and the author, a listing of recommended incident information considered beneficial for effective incident management was derived.

Incident information should include the following:

1. Location and direction (e.g. route and milepost or cross-street);
2. Estimated severity and nature of incident;
3. Estimated incident duration and clearance time; and
4. Recommended response equipment needed (e.g., sweeper, HAZMAT service, etc.).

Additionally, valuable incident information to be exchanged could include the following:

1. Status of resources available and their current deployment status;
2. Specific traffic control strategies (e.g., signals to flash, preemption, etc.);
3. Status of current traffic control strategies (e.g., lane closures, diversions, etc.);
4. Closed circuit television camera footage; and
5. Congestion, construction, and maintenance activities status.

It is important to note that the above information would benefit the agencies if provided in real-time. This list is not inclusive of all the incident information to be exchanged among agencies. However it represents types of incident information deemed to be beneficial by the National ITS Architecture and officials from existing transportation operations centers. There may be additional types of incident information desired by specific agencies for specific reasons not identified in this list, but would improve the incident management program. Other types of information could be exchanged with less urgency, but still provide valuable input for maintaining or improving the management of incidents. This type of information might consist of:

- Incident response agencies information (e.g., contact names, numbers, and resources);
- Post incident debriefing documentation;
- Standard operating procedures and practices (e.g., incident management response plans and accident investigation sites);
- Training (e.g., materials and course dates); and
- Legislation updates (e.g., quick clearance laws).

Once incident information needs are determined and prioritized by each participating agency, the information collected and available by each agency is recognized. Generally, more data or information is available than can be utilized effectively. A flow chart that illustrates the specific incident information to be exchanged among the agencies should be developed.

Step 3 Method of Exchange

Establishing the incident information needs is a critical step in improving incident management. The next step would be to determine the method in which the incident information will be exchanged. There are many methods or technologies possible for exchanging incident information, some simple, some more complex. For example, the telephone offers the simplest and most economical method. Whereas, an integrated Computer Aided Dispatch system is more complex and costly. Agencies with available funding have implemented the exchange through shared Computer Aided Dispatching computer terminals or shared radio frequencies. This allows the real-time exchange of incident information without an additional task for the operator to relay the information.

A transportation management center may have multiple methods of exchanging incident information with public safety agencies because of various funding levels, technical abilities, and desires. No matter what method or technology is used to exchange incident information, critical information should be exchanged immediately to reduce the incident duration, clearance, and delays to the motorists.

Typical actions taken during this step would include:

- Establishing funding levels and sources;
- Defining desired level of integration;
- Evaluating current technologies in operation at each agency;
- Researching available technologies, such as Computer Aided Dispatching; and
- Obtaining appropriate approvals for chosen or preferred methods.

Once the method or methods are selected, the next step would be implementing the recommendations.

Step 4 Implementation of Methods

The implementation step is dependent on the methods chosen. The more simple methods do not require much effort by the agencies. Some methods will require technical expertise and significant funding. The implementation step can include tasks such as, developing a work plan for implementation and a timeline or schedule.

Step 5 Evaluation

Agencies should routinely assess and evaluate the management of incidents. More than likely, when an incident is not managed properly, the exchange of information was insufficient. This could be due to inefficient, inaccurate, or lack of information. Evaluations can be beneficial by recognizing the efficiencies and identifying areas for improvement.

Agencies should develop policies and practices on how their incident management programs will be evaluated, including the communication, cooperation, and coordination among the agencies. This could include reporting on incident management statistics, such as, incident detection and response time. In general, agencies conduct post-incident debriefing meetings with the agencies involved in the incident. These are an effective means of getting each agencies perspective on the incident and the events surrounding it. They can identify when and what incident information was exchanged, and how effective or ineffective the exchange was.

The practice of conducting post-incident debriefing meetings should be guided by mutually agreed upon criteria. These criteria would include determining under what circumstances would a meeting be conducted, who would be involved, where and when the meetings will be held, and how they will be conducted. Agencies should also agree to what types of incident records and information will be collected and used during a debriefing meeting, such as, closed circuit television camera video of incidents.

Above all, the evaluation step is the most important. Inefficiencies and ineffective processes or practices are identified and improvements are recommended. Successful incident management programs cannot be deemed successful without continual evaluation, specifically in the exchange of incident information.

In summary, the recommended action plan provides a logical process for implementing or revisiting the current incident information exchange practices among transportation and emergency management agencies in a region.

APPLICATION OF RECOMMENDED ACTION PLAN

The St. Louis Metropolitan area is the largest urbanized area in the state of Missouri. The challenge of developing and implementing an integrated incident management program is complicated due to the multiple incorporated municipalities within the metropolitan limits. The application of the recommended action plan will be to target a pilot area along the interstate system. In addition, the action plan is focused only on the exchange of incident information with the law enforcement agencies.

Background

The pilot area involves four municipalities that have jurisdiction over the interstate system within their city limits along with the state highway patrol. Currently, there are no traffic sensors or closed circuit television cameras in operation for detecting and verifying incidents remotely at a transportation management center. The existing Missouri Department of Transportation (MoDOT) Motorist Assist Program or cellular 911 calls placed to the Missouri Highway Patrol detects incidents. The city dispatch centers do have computer aided dispatching capabilities at this time.

The pilot area has two complex directional interchanges, portions of one-way and two-way outer roads, a major river bridge, and high traffic volumes. Obtaining accurate and sufficient incident information from the motorists is critical for proper response to incidents.

The Missouri Department of Transportation is developing and deploying the first phase of an ITS system that includes the installation of traffic sensors, closed circuit television cameras (CCTV), dynamic message signs, an integrated Advanced Traffic Management System (ATMS) software program, traffic information telephone hot line, and traffic information web site. The roadway device installations will be completed by fall 2000, with the other software-related items to be completed by summer 2001. In addition to the phase 1 field and software deployments, a new Transportation Information Center (TIC) will become operational by fall 2000. This will serve as a hub for traffic and incident management for the metropolitan area.

Assessment of Current Practices

At this time, coordination between the operations centers is limited and unstructured. The field coordination and cooperation levels are much more advanced than the operations centers due to the Motorist Assist program and the working relationships with the operators and police officers. Typically, the Motorist Assist operator contacts the Missouri Highway patrol or local police dispatchers of an incident if they are the first responders to an incident. Often, the MoDOT dispatcher and customer service representatives are only aware of significant incidents that have lane closures.

When the city police agency or state patrol are first notified of an incident, they do not contact MoDOT of the incident in all cases. However, the Motorist Assist operator is generally on the scene already. It is obvious that the notification process and incident information exchange is very unstructured and needs improvement.

Determine the Incident Information Needs

Some of the incident information identified in Step 2 of the recommended action plan is available already and can be exchanged. Once the TIC becomes operational, MoDOT will have limited capabilities to detect and verify incidents in the pilot area. The incident information that is collected can be exchanged with the patrol and police agencies.

To initiate early communications and cooperation among the operations centers, a standard Incident Information Report can be developed for use by MoDOT, the state patrol, and the city dispatchers. The basic report will assist the dispatchers in collecting the appropriate incident information to provide to the response units. The completed Incident Information Report would have the following information:

- Date, time of notification;
- Location by route, direction, milepost, and cross street;
- Nature of incident, severity of incident, and number and type of vehicles involved;
- Recommended response equipment needed; and
- Notification made by.

Method of Exchange and Implementation

The initial method of exchange would be by telephone. Common radio frequencies are not established between MoDOT and law enforcement. Again, once the TIC system is operational, the dispatchers will have access to the CCTV, the ATMS real time map displays, and the web site for continual information on the traffic information. Direct computer interfaces with public safety agencies are being developed and will be implemented in the near future.

Continual Evaluation and Improvement

As the St. Louis metropolitan deploys ITS technologies, integration with the public safety agencies will improve. Initial efforts will be technically challenged. However, with a concerted effort by MoDOT and the public safety agencies in the pilot area, incident management improvements will be made. Post-incident debriefings will be conducted for major incidents such as, those blocking more than 2 lanes over a 30-minute period or whatever criteria all agencies agree upon.

CONCLUSIONS

Every day there are incidents that affect the lives and safety of motorists as they travel the transportation system. There are proven benefits to managing incidents and part of that process is the exchange of information among public safety and transportation agencies. Some of the greatest challenges of incident management are institutional. The technical challenges are attainable and can be overcome. The development of standards, automation of systems, and interoperability are current issues being addressed worldwide and will simplify the technical challenges.

The importance of effectively and efficiently managing incidents is self-evident. Appropriate coordination and communication among agencies can save lives, save costs, and improve the transportation system.

ACKNOWLEDGMENTS

The author would like to extend a special thanks to Dr. Conrad L. Dudek for allowing participation in the program for the first time by state department of transportation employees. The opportunity afforded to the author and the fellow participants was above expectations. The author would also like to note appreciation to Les Jacobson and Pat Irwin for the expertise and guidance that they provided. Lastly, the author would like to express her gratitude to all the professionals, which included John O'Laughlin, Blaine Kawamura, John Corbin, Dave McCormick, Patricia Ott, Captain Tim Kelly, Ritchie Taylor, Dottie Shoup, Sue Groth, and David Rodrigues, for being very helpful and taking the time to share their experiences and knowledge.

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APPENDIX A - QUESTIONNAIRE

Agency Name:___________________**Type:** DOT FIRE POLICE

1. Does your agency have a team that responds to highway incidents as their primary job to help with traffic control, incident clearance, and recovery? Yes No

2. If yes, what are the hours of operation?_____________________

3. Are they dispatched? Yes No Where are they dispatched from?_____

WHEN AN INCIDENT OCCURS ON THE HIGHWAY…

4. How are you notified? ____________________________

5. Do police and/or fire agencies notify you of the incident?______________

6. If so, When do they notify you? Immediately (within 5 minutes)

   5 – 10 minutes

   10 - 20 minutes

   20 + minutes

7. How do they notify you (computer, phone, fax, etc.)?_________________

8. Is there a real time electronic transfer of incident information from the primary Emergency 911 center?

   Yes No

9. If not, why?________________________________

10. What information is received?________________________

11. Do you verify the incident? Yes No If so, how?____________

12. Do you receive information that is not needed or used? Yes No

13. If so, what?________________________________

14. What information does your center need?____

15. Who does your center notify or contact?________________________

16. Does your agency notify the police/patrol? Yes No

17. If yes, When are they notified? Immediately (within 5 minutes)

    5 – 10 minutes

    10 - 20 minutes

    20 + minutes

18. What information is given?____

19. How is the information given (computer, phone, fax, etc.)?____

20. Do you give information that is not needed or used? Yes No

21. If so, what?________________________________

22. What format does the information need to be in to exchange with the police and fire?____________________

____

23. Do you have a standard format or form for exchanging information? Yes No

24. Does police and/or fire agencies have access to the following?

    CCTV Web Site ATMS real time map

25. What information would improve the detection/verification/response/clearance of incidents?______________

____

26. Are there institutional barriers restricting the exchange of information with the police and fire?

    Yes No

27. If so, What are they and have you overcome them and how?______________________________________

    ____

28. How has the exchange information benefited your operation?_______________________________________

    ____

29. What problems or disadvantages do you have in exchanging information?_____________________________

    ____

30. Have you addressed these and how?____

    ____

If agency is TMC:

Referrals for additional research with Police/Fire:

____

TERESA A. KRENNING

Ms. Krenning is the Transportation Operation Center Manager for the Missouri Department of Transportation, St. Louis Metropolitan District. In this role, she is responsible for managing the operation of the Advanced Transportation Management System (ATMS). This will include contract administration for the contracted staffing in the center, as well as any contracts for the Information Service Providers. Her responsibilities other than managing the center include planning and coordinating all ITS deployments and developing and maintaining an Incident Management Program in the region.

Ms. Krenning started her employment with the Missouri Department of Transportation in the Traffic Department 1990 after graduating with a bachelor's degree. Her duties included studies and recommendation of traffic control countermeasures, such as, speed limit reductions and traffic signal installations. She has been involved with the development of an ATMS system for the district office since 1996. In addition, Ms. Krenning has managed a very successful Motorist Assist program for most of its existence.

FUNCTIONAL REQUIREMENTS OF ADVANCED TRAFFIC MANAGEMENT SYSTEMS FOR IMPROVING WORK ZONE TRAFFIC FLOW

by

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SUMMARY

The overall goal of this research was to develop recommendations for Advanced Traffic Management Systems (ATMS) to improve traffic flow through work zones. The recommendations were created for general development of an ATMS and then applied to a future work zone.

A detailed accident analysis was completed to determine common causes and types of accidents for a segment of Virginia's I-81. As a result of this analysis, it was determined that most accidents in the study area consisted of run off the road accidents, rear end accidents, and sideswipe accidents. Many of these accidents may be avoided by providing motorists with accurate information about roadway conditions using an ATMS.

In order to develop these recommendations, six ATMS facilities were contacted. By making contact with currently operating ATMS facilities, the varied experiences of the personnel provided detailed information on traffic problem identification and resolution using ITS technologies. The information was gathered using a survey questionnaire which was completed by e-mail, fax, or telephone interview.

The advice and recommendations from the different ATMS facility contacts were reviewed and evaluated in developing recommendations for an ATMS and in applying the same recommendations to an ATMS in a work zone. Many of the survey responders offered specific accounts of how the ATMS was helpful for improving traffic flow in work zones or during incidents. From the research, the following recommendations were made for developing an ATMS:

- Determine coverage area for the ATMS;
- Identify existing traffic management resources;
- Establish central point of coordination;
- Select information dissemination methods;
- Choose incident/queue detection method;
- Specify system functional characteristics;
- Develop and test ATMS software;
- Implement the ATMS; and
- Evaluate the ATMS.

To illustrate the use of the recommendations, they were applied to future construction proposed for a 16-mile segment of I-81 in Virginia.

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INTRODUCTION

Work zones typically impact motorists and traffic flow in a variety of ways. "Today, the majority of highway funds are being used on system preservation (resurfacing, restoration, rehabilitation, and reconstruction) type projects on the existing highway system (*1*)." On practically any trip of considerable length, the motorist can expect to travel through at least one work zone, ranging from short, temporary maintenance operations to longer construction zones which are often in place for months or even years. This often applies to commuting motorists as well. "It has been estimated that the majority of our nation's population travels through a work zone at least once every day (*1*)."

Motorists traveling through work zones are faced with both routine and unexpected tasks of driving coupled with additional distractions provided by the work zone. Distractions may include slow or stop and go traffic, narrow or reduced number of lanes, and entering and exiting traffic. In addition, a portion of the driver's attention is often focused on the road work being performed outside the travel way.

"As congestion builds, crash rates increase and as crash rates increase there is more congestion. The safe and efficient flow of traffic through construction and maintenance work zones is a major concern to transportation officials, the highway industry, the traveling public, and the Congress (*1*)." Advanced Traffic Management Systems (ATMS) can improve traffic flow by identifying traffic related problems and notifying motorists and appropriate personnel to address and lessen the impacts of the problems. An ATMS can be beneficial to motorists on roadways with or without work zones by helping to maintain normal traffic flow.

PROBLEM STATEMENT

There are many Advanced Traffic Management Systems (ATMS) in operation throughout the United States and other countries. The experience of the personnel operating these systems, particularly in the United States, can provide detailed information on traffic problem identification and resolution. Advantages and disadvantages of ATMS current operations can also be identified based on the experience of others. Research of these issues will provide background for a set of recommendations for an ATMS that may be applied to improve traffic flow through work zones along Interstate 81 in Virginia's Roanoke Valley. Although the recommendations are specifically for this area, they may be applied and/or modified to match conditions for other affected locations.

Research Objectives

The primary objectives of this paper were to:

1. Examine common traffic related problems along 16 miles of the Roanoke Valley section of Virginia's Interstate 81, including work zone areas and non-work zone areas. Especially there is concern how such problems may be affected by terrain, weather, and high truck volumes.
2. Obtain information from a minimum of six existing Advanced Traffic Management System operators to address specific concerns identified for I-81 in Virginia.
3. Develop principles for addressing work zone problems using ATMS.
4. Apply the principles and data gathered to develop recommendations for a proposed Advanced Traffic Management System for the Virginia Department of Transportation's Salem District.

Study Scope

The scope of this paper is limited to developing recommendations for functional requirements of ATMS for improving work zone traffic flow for both maintenance and construction work zones. It does not include an investigation into the detailed technical capabilities of equipment that may be part of an

ATMS. However, the intent is to show how effectively the advanced technology can be used to improve operations. The study will specifically address how freeway work zone traffic flow can be improved through coverage by an ATMS.

Work Plan

The following tasks were performed to fulfill the objectives of this research:

Task 1: Literature Review

A review of current literature was conducted in order to examine available research concerning traffic management through work zones using ATMS. Several Internet pages were also reviewed.

Task 2: Identify Traffic Problems

Common traffic related problems along the study section of Virginia's Interstate 81, including work zone areas and non-work zone areas, were examined. This was accomplished by reviewing the accident history for a segment of Interstate 81, 16 miles long, in the Virginia Department of Transportation's Salem District. The data were used to identify certain types of accidents common to the area. Particular attention was given to terrain, weather, and truck volume factors leading to accidents.

Task 3: Develop Telephone Interview Guide

A telephone interview guide was developed to obtain information from operators of ATMS. Some responders preferred to reply to the questionnaire by fax or e-mail. A copy of the interview questions may be found in the Appendix.

Task 4: Conduct Telephone Interviews

Using the interview guide, six ATMS operators were contacted to discuss their specific operations. A list of the contacts that were made is shown in Table 1 of the Appendix. Each narrative discussion was reviewed for accuracy by the appropriate contact person.

Task 5: Evaluate Telephone Interview Results

Responses given during telephone interviews and in writing were analyzed to determine advantages and disadvantages of various capabilities of each ATMS.

Task 6: Develop Recommendations

Based on the literature review and the results of the telephone interview, recommendations were developed that may improve traffic flow through work zones using ATMS.

Task 7: Apply Recommendations in a Case Study

The recommendations developed were used in a case study for a 16-mile segment of Interstate 81 in Virginia.

BACKGROUND

Interstate 81 in the Virginia Department of Transportation's Salem District is a four lane limited access facility with rolling and mountainous terrain and both urban and rural related travel. The Salem District is centered around the Cities of Roanoke and Salem as shown on the map in Figure 1. The original facility was constructed in the early 1960s with interchanges built to serve the rural land uses surrounding the interstate (2).

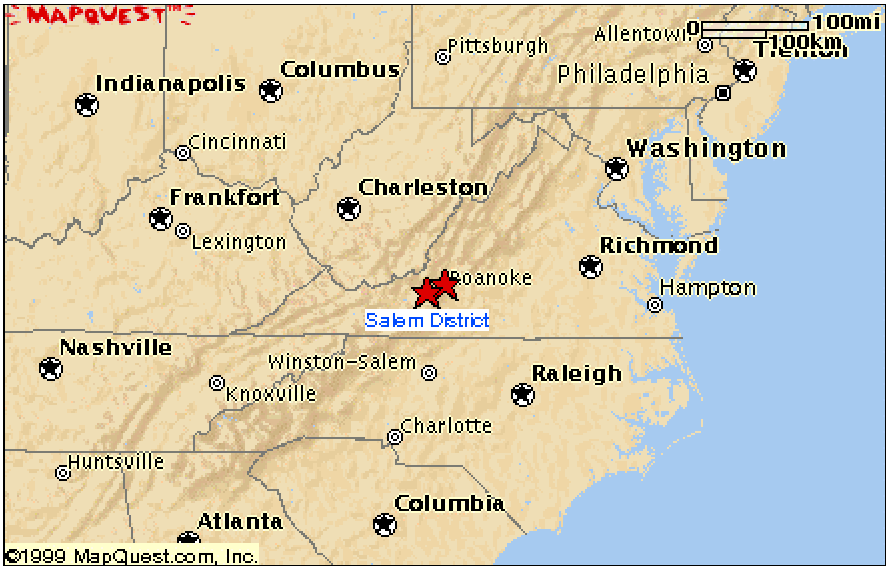

Figure 1. Salem District (3)

Interstate 81 is a major heavy truck route linking the raw materials generated in the south and the finished products manufactured in the industrial northeast (2). The facility was designed to handle 15 percent truck traffic. Depending on the location, the interstate now carries from 19 to 40 percent truck traffic, which is expected to increase in the future (4).

The rolling and mountainous terrain present additional challenges for the driver. Heavy trucks often have difficulty navigating curves and maintaining constant speed both up and down grades. This speed variance can also lead to accidents.

Work zone accidents on I-81 in Virginia steadily increased from 1991 to 1995 (5). The trend since 1995 has been a steady increase after a low of nine work zone accidents in 1996 (6). The top two causes of work zone accidents are attributed to driver inattention and exceeding the safe speed limit (5).

The terrain, traffic volume, truck traffic, adjacent development, and accident history have all contributed to the need to redesign and improve Virginia's Interstate 81. Weather has also contributed to accidents on the roadway. The area of interest is a 16-mile segment in the Roanoke Valley from milepost 136.4 to milepost 152.4. The project area, which runs from just south of Route 112 to just north of Route 220, is shown on the map in Figure 2. This 16-mile segment has been divided into six smaller segments on which design began during the spring of 2000. Construction is expected to begin in the next three to five years.

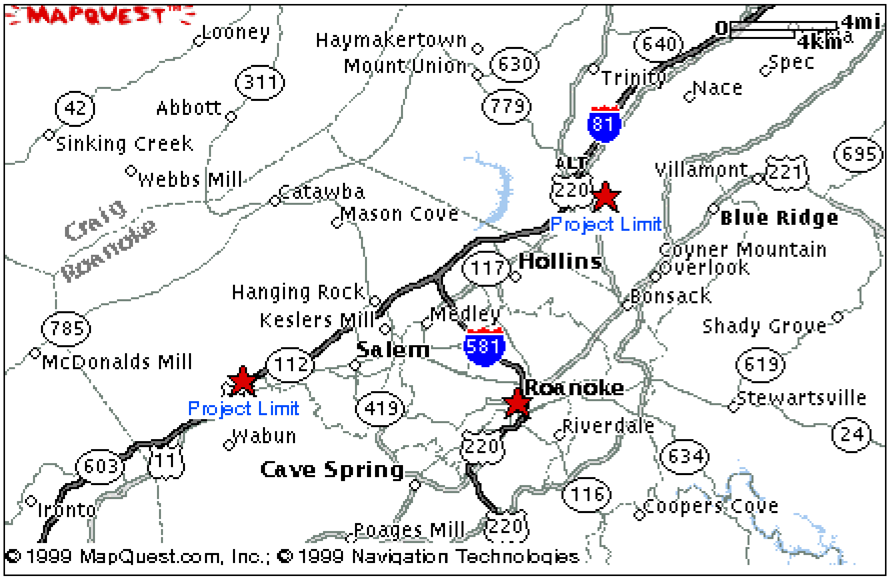

Figure 2. Project Area *(3)*

Accident Analysis

The 16-mile segment that has been identified for design was also chosen for the accident review. Individual police reports were reviewed to determine alignment, vehicle type, pavement condition (dry, wet, snow, or ice), and accident type. The alignment data are based on the police officer's interpretation of the actual geometric conditions such as curve/straight and grade/level. It is reasonable to understand that some reports indicated as straight or level alignment may have actually been on sections with slight curves or grades that are difficult to perceive. The accident data are summarized in Table 1 below.

The segment from milepost 136.4 to milepost 152.4 had 803 reported accidents over the five and one half year period from January, 1995 through June 2000. The data did not specifically identify accidents occurring in work zones. However, over the last four years, data for the entire 325-mile length I-81 in Virginia range from a low of nine work zone accidents in 1996 to a high of 46 accidents in 1999. Statewide work zone accidents generally follow the same trend of increasing since 1996.

Most accidents occurring in the study area, over the review period, involved one of three different collision types. Vehicles hitting fixed objects off the roadway, rear end accidents, and sideswipe accidents involving vehicles traveling in the same direction made up 85 percent of all reviewed accidents. The accident review indicated that during a period of five and one half years, accidents occurring in the 16-mile section mostly occurred on level, straight alignment, dry pavement, and did not involve heavy trucks. Of the 803 accidents reviewed, only 23 percent involved heavy trucks. Truck percentages often reach as high as 40 percent on I-81 in the study area, indicating that heavy truck accidents are proportionally less than the number of heavy trucks using the roadway. Motorists often perceive trucks as being involved in high percentages of accidents in the area. This may be due to the severity of heavy truck accidents and the media exposure often given to such occurrences.

Run off the road accidents, rear end accidents, and sideswipe accidents may be caused by driver inattention and/or exceeding the safe speed. An ATMS may be beneficial in reducing these types of accidents by providing drivers with more information about roadway conditions. By knowing conditions ahead, drivers can make decisions to avoid potential accidents. Also, secondary accidents may be reduced through quicker incident management as a result of ATMS coverage.

Table 1. Accident Summary

Direction	Collision Type									Pavement		Alignment				Vehicle	Total
	Fixed Object Off Road	Rear End	Sideswipe/Same Direction	Sideswipe/Opposite Direction	Deer/Other Animal	Non-Collision	Angle	Object in Road	Other	Wet	Snow/Ice	Curve	Straight	Grade	Level	Heavy Truck	
Northbound	147	90	72	0	27	18	2	1	4	88	30	69	289	182	279	80	361
Southbound	152	132	89	2	24	34	1	3	5	93	44	64	373	206	226	105	442
Total	299	222	161	2	51	52	3	4	9	181	74	133	662	388	505	185	803
% of Total	37	28	20	<1	6	6	<1	<1	1	23	9	17	82	48	63	23	

Freeway Management

Freeway management should encompass all activities undertaken to operate a freeway facility in a manner consistent with predetermined goals and objectives of that facility including those related to the impacts on and the influence of surrounding communities. One of the major goals of freeway management is the control, guidance, and warning of motorists in order to improve the flow of traffic on limited access facilities (*7*).

Many freeway management strategies are extensions of traffic engineering and control tools that have been used in the past but are now being expanded and supported by the Intelligent Transportation Systems (ITS) program. It is apparent that steps taken to reduce or mitigate congestion will positively effect the community. A freeway management program is intended to provide this relief from congestion. Although little data are available to prove the benefits of an effective management plan, there is little question that a well-planned program will significantly reduce freeway congestion (*8*).

An ATMS can provide information gathering and dissemination, condition monitoring, communications, and intervention strategies that will be part of an effective management plan. Although the above discussion has covered transportation management on freeways, the concepts can be beneficial on other roadways as well.

SURVEY RESULTS

22/Renew Project - Allentown, Pennsylvania

The Route 22 improvement project, known as 22/renew, began in 1997 and lasted approximately two years. Pennsylvania Department of Transportation administrators saw a need to manage the heavy volume of traffic through the work zone to lessen the impacts of the work zone. The eight-mile long work zone was located in the Allentown, Bethlehem, Easton area which is in Pennsylvania's Lehigh Valley.

.An Advanced Traffic Management System (ATMS) was developed specifically for the work zone area. The system consisted of several variable message signs (both portable and permanently mounted), Highway Advisory Radio (HAR), ramp metering, and automatic queue detection. The system was controlled from a single desktop computer located in a field office on the project. Traffic queues were automatically detected and pre-determined traffic management scenarios were programmed into the system. The coverage area was 20 miles in length, which included the eight-mile work zone and additional mileage on the approaches. Now that construction is complete, the Pennsylvania Department of Transportation is working to convert the ATMS for permanent use on the highway. More information concerning the project may be found on the Pennsylvania Department of Transportation 22/renew project Internet site at http://www.22renew.com.

Queues were detected using infrared queue detection. This information was received at the central computer through FM radio. Once a backup occurred, the system automatically displayed messages on the variable message signs using a pre-determined scenario specific to the particular location and problem. No technician was required to display the messages, which meant that the messages were displayed almost immediately. This provided the fastest warning to the motorist traveling through the work zone and approaches, which improved traffic flow through the area. Some difficulties were encountered with the infrared detectors. Due to their placement in close proximity to traffic, they were hit and damaged often and occasionally gave false information as a result of vibrations from truck traffic and construction equipment. They were beneficial during construction because they were non-intrusive and could be easily moved. The conversion of the ATMS to a permanent system includes installing inductive loops for queue detection.

Ramp meters were used to manage the flow of traffic, from entrance ramps, into the work zone. This may have helped reduce some of the common problems with entering and merging traffic. This capability was well received by the public.

Highway Advisory Radio channel 1630 AM was used to provide detailed information on the work zone traffic and operations. The Pennsylvania Department of Transportation personnel often found it challenging to effectively maintain the HAR messages. This was true because of the time and personnel necessary to constantly update the information. Another difficulty encountered with the HAR was the radio station choice. Many in-vehicle AM radios do not go as high as channel 1630.

Incidents occurring in the work zone were often noticed first by project personnel. The appropriate responders were notified and the system was monitored closely. The Pennsylvania State Police also operated a remote station ATMS for the same area. Their system was linked to the same system that was running the Pennsylvania Department of Transportation station. This link allowed the state police to enter predetermined scenarios for the variable message signs, HAR stations, and ramp meters.

Limited personnel made the automatic functions of the ATMS even more beneficial. The system provided indications on the computer screen when traffic was slowed or stopped. In addition, an audible alarm would have been beneficial due to there not being someone at the computer at all times. Another capability that would have been beneficial is closed circuit television (CCTV). CCTV would have benefited the operation by providing verification of queues detected by the system, reducing problems with false detection (*9*,*10*).

Northern Virginia Smart Traffic Center (STC) - Arlington, Virginia

The Northern Virginia Smart Traffic Center ATMS began operation in 1985 covering a total of 85 miles of Interstates 66, 95, 395, and 495 and Route 267 (Dulles Toll Road). The center serves freeways maintained by the Virginia Department of Transportation in Fairfax, Arlington, and Prince William Counties in the Washington, D. C. metropolitan area. As a courtesy, the STC covers the bridge approach to the Woodrow Wilson Bridge and the American Legion Bridge (I-495) located in Maryland. The 14th

Street bridges in and out of Washington, D. C. are also covered. Traffic volumes often run as high as 250,000 vehicles per day. With expansion over the next several years, the center will cover an additional 40 miles of freeway.

The ATMS has the capabilities of video surveillance through CCTV, automatic incident detection, permanent mount variable message signs, ramp metering, and call boxes. Reversible and single direction HOV lanes are also managed from the STC. Inductive loops and GIS mapping are used extensively. The center also manages several Safety Service Patrol units. A maintenance department is located on site that maintains and repairs all equipment associated with the center and Interstate roadway lighting. Expansion to include HAR is scheduled for completion in the fall of 2000. Automated Vehicle Location (AVL) for monitoring traffic flows is planned with an implementation date to be determined. Traveler information is provided on the Virginia Department of Transportation Smart Travel Internet site at http://www.vdot.state.va.us/smart/smart.html.

Inductive loop detectors provide data for automatic incident detection software. Incident detection is also accomplished through various means such as CCTV, Safety Service Patrols, call boxes, and cellular telephone calls. Incidents are detected by monitoring police and emergency service frequencies using scanners and through traffic reports form local media who monitor traffic conditions. Movable, color capable video cameras provide color video to the CCTV system that is monitored by traffic controllers at the center. The CCTV is used to both detect and verify incidents that are detected by other means. Once an incident is detected and verified, efforts are focused on response and clearance of the incident. During incident clearance, lane closure and restriction information is provided to the effected motorists using the appropriate variable message signs. During major incidents, alternate route signal timings are adjusted to lessen the impacts of the increased traffic along those routes. Direct radio links with the National Weather Service, all public safety agencies, and all emergency service operators in the Washington, D. C. region provides additional support and helps reduce incident response and clearance time.

Traffic flow through both maintenance and construction work zones is also managed by the STC. Variable message signs are used to provide lane closure information and specific details of the operation. Motorists are notified of planned work which may impact traffic several days in advance using the variable message signs. Drivers may alter their travel schedules or routes when provided with this advance warning. By reducing the number of vehicles traveling through the work zone, traffic flow will improve.

The ATMS is operated by the Virginia Department of Transportation with minimal involvement from other agencies. At this time, radio communication and coordination are the extent of other agency participation. Communication and cooperation between agencies have been challenging in some situations. Due to the many jurisdictions in the Washington, D. C. metropolitan area, timely notification of the appropriate jurisdictions has presented additional difficulties.

Benefits realized from ATMS coverage of work zones have been fewer complaints and reduced congestion. Specifically, motorists are promptly advised of traffic conditions through variable message sign displays, so that they can make informed decisions that help reduce congestion. Ramp metering assists with easing merging situations. Congestion is also greatly reduced by quicker response and clearance of incidents. HOV lanes are open to all traffic during major incidents.

Additional functional capabilities that may be beneficial in improving operations of the ATMS include improved communications between agencies and efficient ways to get information to the traveling public before they become part of the congestion (*11*,*12*).

Coordinated Highways Action Response Team (CHART) - Hanover, Maryland

The Coordinated Highways Action Response Team (CHART) Statewide Operations Center is an ATMS that serves the entire state of Maryland. Coverage is provided on approximately 400 miles of freeways and 400 miles of major arterial highways. This statewide center coordinates traffic management activities with four regional centers located near College Park, Baltimore, Rockville, and Annapolis. The traffic operations center near Annapolis at the Bay Bridge on Route 50/301 is operated seasonally to handle increased tourist traffic headed to the Ocean City area. The CHART system also partners with the Maryland Transportation Authority in operating a center for the Fort McHenry Tunnel on I-95 in Baltimore. ATMS operations in Maryland began as early as 1989 at the College Park center. The CHART Statewide Operations Center began operation in 1994.

Functional capabilities of the CHART ATMS include both portable and stationary variable message signs, portable and stationary HAR, Road Weather Information System (RWIS), and video surveillance through CCTV. Inductive loops, overhead radar units, and side fire radar units are used to obtain traffic flow volumes, which may average 210,000 vpd on a portion of the Capital Beltway. The center also manages several safety patrol units known as Emergency Traffic Patrols and Emergency Response Units. New software upgrades currently underway will include automatic incident detection and Automatic Number Identification (ANI) using cellular telephones to monitor traffic speeds. Current traffic conditions, travel times, and ITS information are available on the Maryland Department of Transportation, State Highway Administration CHART Internet site at http://www.chart.state.md.us/chartweb/default.htm.

Incidents are often detected through communications with the freeway safety patrols, Maryland State Police, county 911 centers, the media, and through cellular telephone calls. Several Washington D.C. area radio and television broadcasters and Montgomery County (MD) use aircraft to monitor flows and provide live traffic reports. They are often first to see incidents and traffic backups. Video from the CCTV, primarily used for verification, is also used for detection. However, most incidents are first reported by some other means. Benefits of video are verification of the incident and related visual details. Some video coming to the center is available to the public through the Internet, with future plans for all video to be available. This information is often used by the media for live traffic reports. Once an incident is detected and verified, the appropriate agencies are notified. CHART personnel have distributed alpha-numeric pagers to employees, selected other agencies, and news media for notification of incidents. Software allows multiple individuals to be quickly notified with a brief description of the event. This helps to disburse the information quickly so that the incident can be cleared and alternate routes may be chosen. The proposed automatic incident detection system will use pre-programmed traffic management scenarios to recommend a solution to the system operators. The operator will give final approval before any traffic management solution is put into action.

The CHART ATMS assists with traffic management through both maintenance and construction work zones. HAR and variable message signs are used to provide advance notice of operations effecting traffic on major projects. The ATMS is also involved with daily work zone operations such as lane closures.

The ATMS is operated by the Maryland State Highway Administration in cooperation with the Maryland State Police, the Maryland Transportation Authority, and local jurisdiction's transportation agencies within the state. A state police trooper is assigned to the statewide operations center and work stations are being installed in Maryland State Police facilities. This provides a direct link to the state police and allows the state police use of the ATMS resources. A direct link to Montgomery County video and signals provides control of signals on local roadways, which provides additional capacity on the local roadways. This tends to lessen the impacts of traffic on the freeways through work zones and during incidents. Area cities and counties and the Maryland State Police have connected work stations at their facilities.

Communications between the CHART ATMS and other agencies presented challenges in early operations of the center. Since that time, measures have been taken to overcome the communications difficulties through the use of cellular telephones, agency radios, and scanners to monitor various frequencies. Plans in the near future are to join the Capital Wireless Integrated Network (CapWIN), a communications network of federal, state, and local agencies in the Washington, D.C. metropolitan area focused on transportation, incident management, and public safety. An additional challenge that is being addressed is maintenance of the overhead radar units which requires lane closures. This is being addressed by replacing the overhead units with side fire units.

A manager recalled two major incidents where the ATMS was particularly beneficial in reducing back-ups and improving traffic flow. A gasoline tanker accident on I-270 in Montgomery County blocked all travel lanes in both directions. Very little backup was experienced due to advance warnings and rapid response. Traffic flow was restored in approximately 18 hours. In the second incident, a pedestrian bridge over the Baltimore Beltway/I-695 collapsed without warning. The bridge blocked all lanes in one direction and emergency response vehicles blocked all lanes in the other direction as a precaution in case the remainder of the bridge collapsed. The maximum traffic backup experienced over the 11-hour closure was approximately three miles. The ATMS traffic management and coordination kept traffic delays at a minimum given the severity of the incidents. The overall number of accidents, on roadways covered by the system, has been reduced since the ATMS began operation.

The capability of automatic incident detection may improve operations of the ATMS. The involvement of all responding agencies, including the medical examiner, also prove beneficial in operations. A medical examiner is called to the scene of all fatal accidents and must complete their review prior to clearance. Coordination with the ATMS can improve response time by providing routing information and coordinating police escorts (*13*,*14*,*15*).

Transportation Systems Management Center (TSMC) - Seattle, Washington

The Transportation Systems Management Center (TSMC) began ATMS operations in 1966 with a single camera monitoring traffic on a reversible express lane on I-5. The center currently manages a 110-mile fiber optic network in the central Puget Sound area with additional coverage of critical locations in outlying regions.

The TSMC has the functional capabilities of CCTV, HAR, variable message signs, weather stations, call boxes, HOV lanes, and ramp meters. The center also uses cameras and variable message signs to coordinate manual switches of reversible lanes. Inductive loops are used to monitor traffic volumes and speeds. Traffic control for tunnels is also managed by the TSMC. Several different motorist assistance teams known as Incident Response Teams, Service Patrols, and Highway Helpers are operated from the ATMS. Traveler information and traffic operations details may be found on the Washington State Department of Transportation Internet pages at http://www.wsdot.wa.gov/traveler.htm and http://www.wsdot.wa.gov/fossc/trafficoperations/.

Incidents throughout the system are detected by monitoring inductive loop data and CCTV with full pan, tilt, zoom, and color capabilities. Motorists using mobile telephones report many incidents. The various motorist assistance teams, in air State Patrols, and media traffic monitors all provide traffic information to the center. Incident Response Teams respond once it has been determined that an incident will block any portion of the roadway for one hour or more. All traffic operations during incidents are coordinated with the Washington State Patrol. To assist with overflow traffic from freeways, the cities often change signal timings on the arterial routes.

Traffic flow through both maintenance and construction work zones is managed by the TSMC. Inductive loop data are analyzed to determine best times for lane closures based on traffic volumes. Advance warning of lane closures due to maintenance and construction work zones is provided on variable message signs. Ramp metering is also adjusted to improve traffic flow through work zones.

The TSMC is operated by the Washington State Department of Transportation in close coordination with local jurisdictions, transit agencies, and the Washington State Patrol. Video is available to anyone with the capability to receive it and is provided directly to localities, the University of Washington, the Washington State Patrol radio dispatch, and transit agencies. The center receives video from some local cities and plans to use video from the counties when their systems become operational. The fiber optic network helps the localities get video back to their transportation management centers. The public can access video from the localities' cameras through the Washington State Department of Transportation internet site. Washington State Patrol access to video allows a dispatcher to have more information than a telephone call alone, which often provides a more appropriate response. Localities and transit agencies can better predict delays and plan accordingly by using the video feeds.

Cities with populations over 22,500 are, by law, responsible for maintenance and operations on state highways within their jurisdictions with the exception of limited access facilities. Limited access facilities are maintained by the Washington State Department of Transportation. This has presented coordination challenges as well as incompatibilities with equipment and system software.

In March of 2000, the Seattle Kingdome implosion project provided a high impact test of the capabilities of the ATMS. Due to the location of the Kingdome, its close proximity to several freeways and ramps presented tremendous potential impacts on traffic. These factors and safety concerns due to the use of explosives for the demolition made planning and the capabilities of the system particularly important. Advance warning was provided several days in advance using variable message signs. The project involved ramp closures and complete freeway closures in close coordination with the Washington State Patrol. Motorist delay was minimal due to the advance planning and traffic control capabilities of the TSMC.

Integration of arterial roadways into the system would be beneficial to the operators of the system. During the summer of 2000, the personnel at the center were working toward that goal (*16*,*17*,*18*).

TransGuide - San Antonio, Texas

The TransGuide ATMS opened on July 26, 1995 covering 26 miles of freeway primarily in the downtown San Antonio area. The center now covers a total of 63 miles of freeway and other routes with traffic counts reaching as high as 215,000 vehicles per day. With expansion currently underway, the coverage area is expected to reach 100 miles by fall of 2001.

TransGuide utilizes the functional capabilities of CCTV, variable message signs, and lane control signals. The center also receives speed, volume, and lane occupancy data from inductive loop detectors and acoustic detectors. The detectors provide data for the automatic incident detection software. Automatic Vehicle Identification (AVI) is used on some of the main arterial city streets and beyond the standard incident management coverage area. Current traffic conditions, travel times, and ITS information are available on the Texas Department of Transportation TransGuide Internet site at http://www.transguide.dot.state.tx.us/.

Automatic incident detection is primarily used as the first notification of incidents or slowing traffic conditions. Data from the inductive loop detectors and acoustic detectors are gathered every 20 seconds. From the 20-second loop data, the system software algorithm generates an alarm if the lane speed drops to 25 mph or less. Once an alarm is received, the traffic problem is verified through CCTV with cameras that have full pan, tilt, zoom, and color capabilities. Once verified, an operator can execute a pre-determined scenario specific to the particular location and problem. The scenario uses variable message sign displays and lane control signals to inform motorists of existing roadway conditions. Lane control signals are located at one-half mile intervals throughout the system. A red X is displayed when necessary due to any obstruction that impedes traffic. An amber directional arrow is displayed to advise motorists to merge either left or right in preparation for a lane closure downstream. A green arrow, pointing down, is shown to indicate that the lane is not obstructed. The green display allows system operators to confirm the displays are in working order. Each variable message sign and lane control signal can me modified individually to constantly update real-time conditions. After the condition has been cleared, the variable message signs are cleared and the lane control signals show green arrows indicating the lane is open.

The AVI system consists of a central computer with AVI software, field AVI readers, and AVI tags. Vehicles equipped with AVI tags pass by the AVI readers which transmit tag information to the central computer. The AVI software determines if any other tag readers in the system have read the tag. If a vehicle equipped with an AVI tag passes two or more tag readers, then the average speed can be calculated. Approximately 56,000 tags out of a proposed 78,000 have been distributed to motorists throughout the area. Average speed data from the tags provide real-time traffic data to the TransGuide Advanced Traveler Information System (ATIS).

Traffic flow through work zones is also managed by the TransGuide ATMS. Variable message signs provide motorists with advance notice of construction and maintenance operations which may affect them. The variable message signs and lane control signals are used to advise motorists of current operations affecting traffic. This information is also placed on the internet site along with other traveler information such as real-time messages, incident information, and travel times.

The ATMS is operated by the Texas Department of Transportation in cooperation with several other agencies. Other partners located at the TransGuide facility are the City of San Antonio Public Works Department – Traffic Management, Police Department – Traffic Section, Fire Department, Emergency Medical Services, and VIA Metropolitan Transit. Courtesy Patrols operate independently of the ATMS, but maintain close radio contact with the center and the San Antonio Police Department. Both the San Antonio Police Department Traffic Dispatcher and the VIA Bus Dispatcher operate workstations alongside the Texas Department of Transportation operators in the center. The police dispatcher relays information concerning accidents to the appropriate police personnel and coordinates with operators at the center for scenario execution. The transit dispatcher is provided with all lane closure information so that route modifications can be made to account for delays due to construction, maintenance, incidents, or any other events that may cause delays. The police, fire, and emergency medical services have a complete communications back up system located on the third floor of the TransGuide building.

In order to address the public perception of being watched through the CCTV system, numerous media releases were prepared. Through daily tours, television and radio station visits, and speaking to groups throughout the community, the ATMS personnel were able to educate the public and spread the word that the cameras on the freeways help in dispatching emergency assistance and clearing incidents more efficiently. One manager indicated that the public information process was money well spent and that the process should continue with any expansion or enhancement of the system.

The ATMS has been an asset to improving traffic flow through work zones by providing accurate current information to motorists. By having this information available, motorists can often alter their travel plans or take an alternate route to their destination. The center personnel can often place and update messages faster than workers within the work zone. An example of improving work zone traffic flow is on the I-10/I-410 total reconstruction project which is expected to take five years to complete. Construction involves widening from three to five lanes in each direction, fly over ramps, and is approximately 14 miles in length. The project has required closure of several exit/entrance ramps leading to a heavy business district. Approximately two weeks prior to ramp closures, messages were displayed on the system variable message signs and on portable variable message signs operated by the contractor. Information about the closure along with alternate route information was displayed. As a result, the ramps have been closed with minimal traffic congestion.

A TransGuide manager recommended identifying the needs of the system (incident detection alone vs. incident detection with automated response, etc.) when planning an ATMS. Resource sharing, long range plans, and potential growth and expansion should also be considered. It is also recommended to involve other agencies and surrounding localities where appropriate in the planning and operation of an ATMS (*19*,*20*).

Hampton Roads Smart Traffic Center (STC) - Virginia Beach, Virginia

The Hampton Roads Smart Traffic Center ATMS opened in June of 1993 serving freeways in the cities of Norfolk, Chesapeake, Portsmouth, and Virginia Beach. The center covers a total of 19 miles of Interstates 64, 264, and 564 and as many as 189,000 vehicles per day may pass a given point. With expansion currently under way, the coverage area is expected to reach 120 miles within the next four years.

The ATMS has the functional capabilities of HAR, permanent mount variable message signs, and video surveillance through CCTV. The center also manages High Occupancy Vehicle (HOV) lanes, a reversible roadway with gate control, and several Freeway Incident Response Teams. Inductive loops are used to monitor traffic flow volumes. Call boxes are monitored for the James River Bridge on Route 17 which is four miles in length and has no shoulders. Traveler information is provided on the Virginia Department of Transportation Smart Travel Internet site at http://www.vdot.state.va.us/smart/smart.html.

Incidents, whether in work zones or not, are detected through communications with Freeway Incident Response Teams, Virginia State Police, and through cellular telephone calls from the general public. In addition, personnel at the center have direct radio contact with state police, fire, rescue, and the incident response teams. Another beneficial method of detection is through CCTV. Technicians at the center monitor video from strategically placed cameras that have full pan, tilt, and zoom capabilities. Once traffic flow is interrupted, the center operators concentrate on the appropriate response to minimize clearance time. A reported problem location and direction are verified by the operators using CCTV. This is particularly important due to the loop nature of some roadways. For example, I-64 eastbound continues east then turns south and finally terminates in a westerly direction. Motorists often confuse the interstate directional designation with compass or map directions. This is particularly true of the high volume of tourist traffic and transient military population. Direct radio communication with the appropriate responders helps reduce response time. Re-routing assistance is also provided when necessary due to blockages, hazardous materials, or other factors.

The Smart Traffic Center also manages traffic flow through both maintenance and construction work zones. During any operation, the center may use variable message signs and/or HAR to provide lane closure information or specific details of the operation, such as tunnel washing, road work, etc. Motorists are notified of planned work which impacts traffic several days ahead using the variable message signs. This advance warning allows drivers to alter their travel schedules or routes if they choose to do so. CCTV is also used to monitor traffic flow through the work zone. Alternate route diversion information is often provided where practical. Reducing the number of vehicles will improve traffic flow through the work zone.

The center is operated by the Virginia Department of Transportation with limited involvement from other agencies. The state police do work from the center during major incidents which last for an extended period of time.

Some of the challenges in operating the center involve formulating messages appropriately and coordinating with neighboring traffic management systems. The Hampton Roads area has several tunnels that have individual ATMS capabilities. The tunnels, which are adjacent to the STC coverage area, also come under the Virginia Department of Transportation's jurisdiction. The traffic management systems do not interface with each other which makes it difficult for the STC to provide up to date information on operations and traffic flow at the tunnel facilities. An additional challenge is the formulation of both variable message sign and HAR messages. It is sometimes difficult formulating messages that are up to date and credible so that they are effective for the motorist. Operators are continually working to make messages more descriptive to better serve motorists.

The ATMS was successful in improving work zone traffic flow on a recently completed freeway widening project in the city of Norfolk. The project lasted approximately two years and involved closing sections of the shoulders and acceleration lanes during construction. The center operators used variable message signs to advise motorists of traffic pattern changes and to advise of lane restriction information. They worked closely with the local office in charge of construction to provide advance information on planned traffic changes, usually two to three days in advance. Providing this advance information allowed travelers to be better prepared in order to make good decisions concerning their travel plans. Although no specific data were available, it is reasonable to expect that a number of motorists chose alternate routes or changed travel times, which would have improved traffic flow through the work zone. A manager who witnessed an accident in the work zone recalled an example of the efficiency of the system. The incident had been detected by the operators through CCTV and the appropriate agencies had been called faster than the manager could report the incident to his co-workers at the center.

Functional capabilities that may improve operations of the ATMS include automatic incident detection, shared data and device control, and a regional approach to traffic management involving the surrounding localities. The center personnel are currently working on each of these items. Automatic incident detection is being included in a new software upgrade currently underway. The ATMS managers are working closely with the surrounding localities to achieve a regional approach to traffic management. The Virginia Department of Transportation and the City of Norfolk are working toward shared data and shared device control. This will allow each to control the others variable message signs and HAR when needed and to obtain traffic data. The owner of the equipment would have the first priority of use (*11*,*21*).

SUMMARY OF SURVEY RESULTS

Contact was made with six ATMS facilities to gather information on their operations and capabilities. A list of the contacts and their facilities can be found in Table 1 of the appendix. A summary listing of functional characteristics at each facility can also be found in the appendix, in Table 2. The intent of contacting the facilities was to gain an understanding of their operations and the current state of practice with ATMS. Several facilities in the eastern United States were contacted along with one in Texas and one in Washington State. Limited information was available concerning how the individual ATMS helped improve traffic flow through work zones. However, more information was available on traffic management in general and during incidents. These same principles may be applied to work zones, in which similar traffic flow problems are often encountered.

From the surveys and from discussions with the contact persons, several ATMS characteristics are recommended as essential in operating an ATMS. These characteristics include CCTV, variable message signs, good communications, and involvement with other agencies. Also beneficial, is informing the public of operations and roadway conditions through the Internet.

RECOMMENDATIONS

This section of the paper presents several recommendations for use in developing ATMS to improve work zone traffic flow. The formulation of these recommendations was accomplished by adopting current successful strategies used by ATMS operations and applying those strategies specifically to work zone areas. The recommendations rely on agency support and funding availability. The nine recommendations are listed below in Table 2, followed by a detailed description of each recommendation.

Table 2. Recommendations for Developing ATMS to Improve Work Zone Traffic Flow

Recommendations
1. Determine coverage area for the ATMS
2. Identify existing traffic management resources
3. Establish central point of coordination
4. Select information dissemination methods
5. Choose incident/queue detection method
6. Specify system functional characteristics
7. Develop and test ATMS software
8. Implement the ATMS
9. Evaluate the ATMS

Determine coverage area for the ATMS

A first step in developing an ATMS is to identify the area to be covered by the system. Factors to consider include funding and resource availability, locations where accidents or congestion frequently occur, and locations where alternate routes may be used as diversion points. Long-term work zones, where traffic backups are expected, should also be considered for coverage. Resources such as office space and personnel to operate the system as well as funding may limit the desired coverage area. Coverage locations should be prioritized by the agency to determine the most important locations to be covered. It is likely that an ATMS will start small, with limited capabilities and coverage area, and be expanded over time.

Identify existing traffic management resources

Existing traffic management resources already owned by the agency, such as variable message signs, inductive loops, HAR, safety patrols, etc. should be identified for possible integration into the ATMS. The availability of these resources may also help define the ATMS coverage area. By using these existing traffic management tools, the ATMS can be developed faster with less cost. Care should be taken in the use of existing devices for cost savings unless there is an added benefit to the system. (Only use the right equipment for the needed task.)

Establish central point of coordination

To effectively manage traffic, a great deal of coordination and cooperation is required. Other agencies and localities should be involved in the planning and operation of the facility where appropriate. An operations center will function as the central point of coordination. The operations center may range from a simple desk top computer in an office, similar to the 22/renew ATMS, or it may be a complete stand alone facility comparable to the other ones identified in this paper. By having all ATMS functions operated from a central location, traffic can be managed most efficiently through work zones and during incidents. Police agencies and other emergency services at the same location can enhance incident response, which will improve traffic flow.

Select the information dissemination method

Information must be passed along to the public in two ways. First, the public should be informed in advance of any plans for developing an ATMS. Educating the public and spreading the word about the benefits of an ATMS are essential in gaining public support. It is also important that motorists have a basic understanding of the equipment they see, or may not see, and the information available to them as a result of that equipment. Second, the methods(s) of notifying motorists of roadway information (variable message signs, HAR, Internet, etc.) once the system is in place, should be selected. This may depend on factors such as equipment already in place, reliability, cost, portability, and other factors.

Choose incident/queue detection method

The incident/queue detection method should be chosen based on factors such as equipment already in place, reliability, cost, portability, and other factors. Information from other ATMS operators concerning particular components may be beneficial for planning purposes.

Specify system functional characteristics

Functional characteristics such as those discussed throughout this paper, and found in Table 3 of the appendix, should be reviewed to determine applicability to the particular coverage area. Once the overall plan for the ATMS has been developed, many functional characteristics may be phased in over a specified time period. Portability and location of devices should be considered if the area has been identified for construction.

Develop and test ATMS software

By incorporating the above recommendations, software would be developed to run the system. Where practical, the software should incorporate use of existing traffic management resources as part of the system. The software will use data acquired from the chosen incident/queue detection method to notify system operators of possible backups. This may be through CCTV detection or through automatic incident/queue detection. The system should be tested and field verified prior to providing any real-time information to motorists. The software should include provisions for providing information to an Internet site accessible by the public.

Implement the ATMS

Once the ATMS coverage area and characteristics have been specified, all system equipment should be installed and tested. After these steps have been completed, the system should be activated for transportation management.

Evaluate the ATMS

To evaluate the success of the ATMS, several measures of effectiveness need to be identified. By monitoring accident rates and incident clearance times, the effectiveness of the ATMS can be measured. Varying incident severity will make it difficult to compare individual occurrences. However, general trends in the data may indicate effectiveness. Effectiveness of the ATMS can be measured by monitoring travel times through the coverage area. Although difficult to measure the effects of work zones, travel times before and after ATMS implementation can be compared.

Even though the above measures may indicate increased accident rates, incident clearance times, or travel times, it is difficult to conclude that the ATMS is not successful due to constantly changing and unique conditions. It is likely that accident rates, incident clearance times, and travel times would increase even more without benefit of the ATMS.

Public perception is probably the most important measure of effectiveness. No matter how much traffic an ATMS manages, the public perception of benefit to the motorist must be realized. The public must understand, even though there are delays in an ATMS coverage area, that, in most cases, conditions could be much worse without the ATMS.

APPLICATION OF RECOMMENDATIONS: A CASE STUDY

The information in this section presents an application of the recommendations to improve work zone traffic flow for a specific work zone. The recommendations are applied to a 16-mile segment of I-81 in Virginia that has been identified for redesign and improvement, located between milepost 136.4 and milepost 152.4. The following is intended to present one possible scenario that will depend on many factors such as funding, equipment, personnel, and agency support. Each portion of the case study described in this section corresponds to one of the recommendations presented in the previous section.

Coverage Area

The 16-mile segment of I-81 in Virginia, between milepost 136.4 and milepost 152.4, has been chosen for coverage by an ATMS. This segment was chosen because of the proposed construction over the next several years. Other factors considered in choosing the coverage area include traffic volumes and possible traffic diversion points. The 16-mile segment is located within the Roanoke Valley, the most populated area within the Virginia Department of Transportation's Salem District. Traffic counts and heavy truck volumes tend to be higher through this segment. There are six interchanges within the coverage area that may be used as diversion points. Each of the interchanges provides short connecting route to U.S. Route 11, which follows the I-81 corridor throughout Virginia. Although, the urban character of U.S. Route 11 and the connecting arterial roadways often exceed capacity in a very short time when traffic is diverted from I-81. However, each of the interchanges has fuel, food, and lodging available so travelers may benefit from exiting the freeway and waiting for the condition to clear.

Existing Traffic Management Resources

Several traffic management resources are available or are planned in the near future, including safety patrols, variable message signs, and HAR. It is likely that each of these resources can be incorporated into the ATMS with minimal difficulty.

Two overhead variable message signs undergoing installation and testing are expected to be operational beginning in 2001. The signs are located at milepost 136.2 northbound and milepost 152.5 southbound and would cover traffic entering the work area from the mainline in most cases, except when work activities are very close to the signs. Although, the placement of these signs may not provide motorists an opportunity to divert before entering the work zone, depending where work activities are taking place at a given time. Additional permanent mount variable message signs are proposed for connecting arterial roadways to provide motorists information prior to entering the freeway. They are expected to be operational late 2002. Several portable variable message signs can also be readily available. The signs would be used by the ATMS to provide incident and lane closure information.

Safety Service Patrols operated by the Virginia Department of Transportation and Motorist Assistance Patrols operated by the Virginia State Police, patrol the entire coverage area. The two patrols offer assistance to motorists with disabled vehicles and respond to incidents. They are often the first contact an individual has when they are stranded or have been involved in an incident. This first contact can provide valuable information to the ATMS.

Also available for ATMS operation are two portable HAR stations. These are often used to provide traffic information for work zones or sports events. These may be used to provide supporting detailed information for variable message sign messages.

Central Coordination

Coordination and cooperation with other agencies and localities will be essential to successful ATMS operations. The Virginia State Police and local emergency services respond to incidents on the freeways.

These agencies can utilize the information provided by the ATMS to more efficiently respond to incidents, thereby reducing response time and interruption of traffic flow. Ideally, a dispatcher would have direct access to ATMS resources such as video, speed data, variable message sign messages, and any other traffic information that may be needed.

The surrounding localities of Botetourt County, Roanoke County, and the City of Salem would also benefit from ATMS information. In addition to emergency services, the police departments and sheriff's offices can utilize the traffic information to avoid congestion on the freeways and anticipate increased traffic on roads under their respective jurisdictions due to motorists choosing alternate routes.

Operation of the existing variable message signs is to be performed from a desk top computer located in an office of the Traffic Engineering section at the Salem District Office Complex, which is located just off the freeway near the proposed I-81 project area. This close location to the project will serve as an ideal location for beginning ATMS operations. It is anticipated that any additional ATMS control software could be installed on the same computer or an additional computer at the same location. The Salem District Traffic Engineering office would serve as the central point of coordination, or Traffic Management Center, for the ATMS.

Information Dissemination

The public should be kept informed of milestones in the development of the ATMS and anticipated benefits once the system is in place. This can be accomplished through media releases and interviews, and well-publicized citizen information meetings.

Variable message signs will be used to advise motorists of lane closures and traffic conditions. The existing overhead variable message signs, located just beyond the project limits, can be utilized to provide this information. The additional planned variable message signs, to be located on arterial routes, will provide traffic information to motorists prior to entering the freeway. In addition, it is proposed that 10 additional variable message signs be installed between interchanges throughout the project area. These will be divided such that there will be one variable message sign, in each direction, in advance of each interchange, providing motorists opportunities to exit the freeway. The variable message signs should be either portable or permanently mounted so that they do not interfere with construction activities. In many cases, installation out of the construction limits may not be possible until additional right of way has been purchased.

HAR stations will be used to provide additional project information about construction and scheduled lane closures. The HAR may also be updated with any current incident information. It is anticipated that two HAR stations will be located prior to the last interchanges to be reconstructed. One HAR station will be installed in advance of Exit 132, northbound, with the other in advance of Exit 156, southbound. Continuous coverage of the entire work zone will require approximately four HAR stations in addition to the two on the approaches.

An Internet site will be developed to provide project construction information and real-time traffic information. The Internet site will show a graphical representation of the project area with information concerning lane closures, incidents, and traffic-backups similar to those found on ATMS Internet sites noted in this paper.

Incident/Queue Detection

In determining the incident/queue detection method, the nature of the coverage area must be considered. Terrain, right of way, and future construction plans may influence the chosen method. The 16-mile segment of I-81 has rolling terrain and is scheduled for improvements. The terrain may cause some concern with wireless communications between certain devices. Existing right of way is sufficient for installation of most any type of detection equipment.

Due to future plans for improvements, detection equipment should be portable in nature. This will provide flexibility for construction phasing and allow for equipment re-use at other locations. For permanent installations, inductive loops and software are commonly used to determine speeds. However, with construction planned in the near future, an alternate approach should be chosen.

Concerns with reliability of infrared detectors, especially in areas with heavy truck traffic, should be addressed. Other methods of detection, such as acoustic detectors and radar-type detectors should be further evaluated for reliability.

Portable CCTV cameras are recommended for the system regardless of the type of detection method selected. The video may be used as the primary detection method or to verify incidents and traffic queues. Automatic incident detection is recommended as the primary detection method with CCTV used for verification and for providing additional details. Pre-programmed scenarios for displaying messages on variable message signs would be used only after verification and approval by a system operator. This would serve as a check for any messages displayed automatically by the system software and lessen the chances of any incorrect displays. The CCTV video should be closely monitored for incidents and queues during known times of congestion.

Functional Characteristics

Through incorporating existing traffic management resources and selecting the coverage area, central coordination location, and information dissemination methods, many of the ATMS functional characteristics have been identified. Specifically, the ATMS will be operated from the Salem District Traffic Engineering office, covering a 16-mile segment of I-81. Coordination of incident response and work zone activities will be handled by the ATMS. Variable message signs, HAR, and the Internet are proposed for providing information to motorists. To ensure accuracy, automatic incident/queue detection should be used with CCTV for verification. ATMS personnel will approve all messages prior to display. It is proposed that all ATMS field devices be portable or located such that they do not interfere with the proposed construction. Once the construction projects are complete, the ATMS equipment may be relocated for use in other work zones or converted to permanent installations in the reconstructed area.

ATMS Software

ATMS software will be developed to incorporate the operation of existing variable message signs and additional ones identified to be part of the system. The software will also use data from the acoustic or radar-type detectors to determine if queues are forming and provide notification to system technicians. The software will also provide traffic data for the Internet site.

Implementation

It is recommended that the ATMS and all associated components be installed and fully operational well in advance of any roadway construction activities. Ideally, the entire 16-mile system would be installed in one phase and be completed three to six months prior to construction. This will allow time for system testing and time for system operators to become familiar with the system without added difficulties caused by the work zone.

Evaluation

Accident rates, clearance times, and travel times before and after ATMS implementation may be compared as measures of effectiveness of the ATMS. In this particular case, the work zone may contribute to increases in each of the comparisons. Although generally empirical in nature, relating the experiences of those who work to clear incidents and work in the work zones can provide good indications of the effectiveness of ATMS. Another method to monitor the effectiveness and improve the system is to gather public input. This can be accomplished through mail surveys and input from the Internet site. Through constant evaluation of the system, changes may be made to improve operations.

CONCLUSIONS

The rise in traffic and congestion on our nation's highways has led to increased accident rates. On practically any given day, it is common for motorists to travel through work zones, which often contribute to congestion. Traveling through work zones requires extra attention from the driver to avoid slowing traffic and properly navigate through equipment personnel, and work zone safety devices such as cones, barrels, signs, and barriers. An ATMS can improve work zone traffic flow by monitoring conditions, providing proper warnings to motorists, and improving incident management.

Common accident causes and types were reviewed for a 16-mile segment of I-81 in Virginia for a period of over five years. An ATMS may better prepare motorists to avoid the top two causes of work zone accidents; driver inattention and exceeding the safe speed limit. It is expected that statistics are similar for other locations along I-81 and other freeways throughout the country.

A relatively small sample of six ATMS facilities were contacted to gather information on their operations and capabilities. Although only the 22/renew project ATMS was specifically designed for work zone traffic flow, the other facilities offered valuable traffic management information that can be used in developing an ATMS and may be applied to work zones.

When developing an ATMS, no two areas are identical. The needs of each area must be carefully considered and functional characteristics chosen accordingly. Such decisions depend on funding, personnel, and other resources. The recommendations presented in this paper are intended to outline a possible scenario for developing an ATMS, for one location in Virginia, that can be used by others who intend to improve work zone traffic flow.

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15. Telephone interview with Alvin Marquess. July 2000.

16. Washington State Department of Transportation Traveler Information Internet site. http://www.wsdot.wa.gov/traveler.htm

17. Washington State Department of Transportation Traffic Operations Internet site. http://www.wsdot.wa.gov/fossc/trafficoperations/.

18. Telephone interview with Morgan Balogh and Roger Steinert. July 2000.

19. Texas Department of Transportation TransGuide Internet site. http://www.transguide.dot.state.tx.us/.

20. E-mail from David Rodriguez. July 2000.

21. Telephone interview with Stephany Hanshaw, Virginia Department of Transportation. July 2000.

APPENDIX

Telephone Interview Questions

- What are the functional capabilities of your ATMS? (What are you able to do with the ATMS? (Detection and response?)
- What equipment is used to detect traffic problems, such as slowing, stopping, and incidents? Video surveillance, inductive loops, automatic detection, cellular telephones, freeway incident response teams, etc.?
- What are procedures for restoring traffic flow once problems are identified?
- How is the ATMS involved with daily operations in work zones?
- What other agencies are involved with the ATMS? (Police, fire, rescue, transit, etc.) What is their involvement?
- How do you feel ATMS are helpful in work zones?
- What unanticipated barriers did you encounter, if any, in the development or operation of the ATMS?
- What are some examples of successes in improving work zone traffic flow due to the ATMS?
- Are there other functional capabilities that may be beneficial in operating the ATMS?

Table 1. ATMS Contacts

Contact	Facility	Telephone Number
Morgan Balogh	Transportation Systems Management System (TSMC)	206-440-4485
Stephany Hanshaw	Hampton Roads Smart Traffic Center (STC)	757-424-9907
Alvin Marquess	Coordinated Highways Action Response Team (CHART)	410-582-5677
Carlene McWhirt	Northern Virginia Smart Traffic Center (STC)	703-383-2600
David Rodrigues	TransGuide	210-731-5242
Michael Pack	22/renew Project ATMS	610-798-4257
Roger Steinert	Transportation Systems Management System (TSMC)	206-440-4471

Table 2. Summary of Functional Characteristics at Each Facility

Functional Characteristic	Facility					
	22/renew	NOVA STC	CHART	TSMC	TransGuide	HR STC
CCTV		✓	✓	✓	✓	✓
HAR	✓		✓	✓		✓
Variable Message Signs	✓	✓	✓	✓	✓	✓
Ramp Meters	✓	✓		✓		
Automatic Incident/Queue Detection	✓	✓			✓	
Call Boxes		✓		✓		✓
HOV Lanes		✓		✓		✓
Reversible Lanes		✓		✓		✓
Inductive Loop Detectors		✓	✓	✓	✓	✓
Acoustic Detectors					✓	
Infrared Detectors	✓					
Radar Detectors			✓			
GIS Mapping		✓				
Safety Patrols		✓	✓	✓		✓
RWIS			✓	✓		
Lane Control Signals					✓	
ANI		✓				
AVI					✓	
Other Agency Partnerships		✓	✓	✓	✓	✓
Web Page	✓	✓	✓	✓	✓	✓

CHRISTOPHER D. MCDONALD

Chris McDonald is currently Assistant District Traffic Engineer for the Virginia Department of Transportation (VDOT), Salem District. In this role, he is responsible for traffic signals, traffic studies, and installation and maintenance of signs and pavement markings for a twelve county area. Chris is also responsible for planning and coordinating ITS technology for the same area.

Chris received a Bachelor of Science degree in Civil Engineering from Virginia Polytechnic Institute & State University (Virginia Tech) in December 1993. While at Virginia Tech, he was employed with the Virginia Department of Transportation as a Construction Inspector. Upon graduation, he entered the Transportation Engineer Training Program with VDOT. Chris completed the training program in 1995 and was promoted to Transportation Engineer. In 1996, Mr. McDonald accepted the position of Assistant Resident Engineer, a position he held until he was recently promoted to Assistant District Traffic Engineer in the fall of 1999.

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ARTERIAL DYNAMIC MESSAGE SIGNS: A SYNTHESIS OF EXISTING PRACTICE AND GUIDELINES FOR FUTURE USE

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SUMMARY

Applying dynamic message sign (DMS) technology onto an arterial street poses special problems compared to a similar installation on a freeway. There is often less space available for the placement of the DMS device, due to a typically narrower right-of-way, the close proximity of structures, driveways, and other control devices such as traffic signals. Other potential obstacles to effective arterial DMS deployments may include background clutter reducing the conspicuity of the DMS, improperly sized characters that are too small to read, and ineffective sign placement. These potential obstacles could limit the number of motorists that can read or comprehend the sign or limit the ability of a motorist to make a decision based on the information provided.

One potential location for the application of arterial DMS technology is along the corridor of an arterial street and a freeway. While many urban freeway users are provided travel information from DMS technology, it is much less common that motorists attempting to move from an arterial to a freeway are provided this information *before* moving onto the freeway. Incident congestion that blocks a portion of the freeway would almost certainly delay motorists. Warning arterial motorists of poor operating conditions on a nearby freeway could keep motorists on the arterial network, and result in an overall travel time savings. With few previous arterial DMS system deployments across the nation, a need exists to determine the proper steps in designing such a system to maximize benefits and avoid potential pitfalls.

Using the information gathered from a the literature review and from information gathered from telephone interviews with engineers responsible for the operation of existing arterial DMS systems, guidelines for designing an arterial DMS system to provide arterial motorists real-time condition information of a nearby freeway, or alternate route information were developed. The guidelines include the following steps:

- Clearly establish the objectives of the arterial DMS system
- Identify what information is necessary to be conveyed to motorists to accomplish the objectives
- Prepare messages
- Identify existing technologies available for deployment
- Evaluate effectiveness of competing technology alternatives in meeting objectives
- Identify the existing physical constraints of the arterial-freeway corridor
- Determine the appropriate locations for installation of the DMS technology
- Identify environmental conditions
- Specify system characteristics

A review panel consisting of transportation professionals from across the United States with experience in implementing and/or operating arterial DMS systems critiqued the guidelines. This review process and subsequent revision were intended to improve the applicability of these guidelines to be more useful to practitioners. The guidelines were applied to a hypothetical case study in order to illustrate the design process, which can be used by a city that requires an arterial DMS system to divert traffic in an arterial-freeway corridor.

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INTRODUCTION

Cities across the country are experiencing continuing growth in the number of vehicle-miles traveled. It is expected that urban motorist commute times will double by 2010 if traffic continues to increase at its present rate (*1*). With limited transportation funding, cities can no longer hope to build their way out of congestion, and must focus on better management of existing facilities. One method of reducing congestion is to reroute arterial motorists around areas of incident congestion to reduce their travel times. While much of the focus of past research and construction has been to improve the quality of flow on freeways, improvements on arterial streets will also help to reduce congestion. Arterial streets, being second only to freeways in the roadway hierarchy (*2*), have potential for incident-based congestion reduction. As yet, however, relatively few arterial corridors have been equipped with information dissemination systems to help motorists avoid incident congestion. One method that can accomplish this is to use advanced traveler information systems (ATIS) to aid motorists in real-time. City traffic management centers across the nation are being compelled to develop innovative methods of managing the increasing demand on their urban street network to curb congestion. ATIS, in the form of real-time dynamic messages may be one method of accomplishing this.

Dynamic message signs (DMS) have been found to be effective and useful tools in managing freeway traffic, and DMS technology is also proving to be an effective traffic management tool on arterial streets where it has been implemented (*1*). Implementing DMS technology on an arterial street offers many benefits to motorists, such as information on incidents, travel time, route diversion, and special event traffic routes. This information has the potential to reduce congestion, reduce travel times, and ease motorist frustration.

Applying DMS technology onto an arterial street poses special problems compared to a similar installation on a freeway, however. There is often less space available for the placement of the DMS device, due to typically narrower rights-of-way, the close proximity of structures, driveways, and other control devices such as traffic signals. Other potential obstacles to effective arterial DMS deployments may include background clutter reducing the conspicuity of the DMS and ineffective sign placement. Another is the potential of selecting a DMS character size that is too small to be seen in time to react to the message. These obstacles could limit the number of motorists that can read or comprehend the sign or limit the ability of a motorist to make a decision based on the information provided (*3*).

One potential location for the application of DMS technology is along a corridor of an arterial street with a freeway. While many urban freeway users are provided travel information from DMS technology, it is much less common that motorists attempting to move from an arterial to a freeway are provided this information *before* moving onto the freeway. Incidents that block a portion of the freeway would almost certainly delay motorists. Warning arterial motorists of poor operating conditions on a nearby freeway could keep motorists on the arterial network, and result in an overall travel time savings. With few previous arterial DMS system deployments across the nation, a need exists to determine the proper steps in designing such a system to maximize benefits and avoid potential pitfalls.

Research Objectives

The overall goal of this research was to develop a set of design and implementation guidelines useful to an urban traffic management center of city traffic engineering office with an interest in placing DMS technology on an arterial street. The specific objectives of this research included:

- Determine what information motorists need from arterial DMS systems;
- Establish how DMS technology is currently used both on freeway and arterial environments;
- Determine the obstacles to DMS implementation specific to an arterial street environment;
- Determine the positive and negative attributes experienced in previous arterial DMS system deployments;

- Develop guidelines useful to an urban traffic management center to maximize the effectiveness in the design and implementation of an arterial DMS system;
- Facilitate a panel discussion of transportation professionals with arterial DMS experience to determine methods of improving the developed guidelines, and make the recommended changes; and
- Apply the developed guidelines in a hypothetical case study using an arterial street for traffic route diversion along a freeway corridor.

Scope

This research was limited to developing guidelines for the design of an arterial DMS system along a network of arterial streets near a freeway corridor. Also included in this research was a review of literature pertaining to DMS use. In order to meet the objectives of this research, telephone interviews were conducted with transportation professionals from cities and state departments of transportation who have experience in deploying and/or operating DMS technologies used in providing arterial traveler information.

STUDY DESIGN

The procedures followed in carrying out this research to develop arterial DMS design guidelines along a freeway-arterial corridor consisted for four main tasks: literature review, data collection, guideline preparation, and panel review facilitation. These tasks are discussed in greater detail in the following sections.

Literature Review

A review of current and classic literature was performed in order to examine previous research and present issues related to arterial DMS systems and arterial traveler information systems. Specifically, the history of DMS technology, its application on urban street networks, as well as previous case studies of the design and installation of arterial DMS systems were examined.

Data Collection

To fill gaps in the literature regarding applications of arterial DMS systems, officials from cities and state departments of transportation with existing arterial DMS systems were contacted and interviewed on the telephone. The following questions were asked to these officials regarding their organization's use of DMS technology in an arterial environment:

- Is DMS technology currently in use on any of the arterial corridors in your city?
- Could you provide a description of your DMS system, such as type of DMS device(s), quantity, and placement?
- For what specific purpose was this DMS technology implemented?
- Is this DMS technology integrated into a larger area-wide traffic management plan?
- What types of problems were observed in the planning and installation phase of this system that had to be overcome?
- What types of problems have been identified during the operation of your arterial DMS system?

Additionally, many of the interviewees were asked to provide written documentation or other information regarding the specifics of the arterial DMS systems in their jurisdictions. A copy of the complete telephone survey is provided as Appendix A to this report.

Guideline Development

Using the information gathered from the literature review and interviews with knowledgeable transportation professionals, guidelines were developed for designing an arterial DMS system along an arterial-freeway corridor. The guidelines were formulated using two methods. Systems reviewed in this research were used as a beginning basis, with modifications made based on the comments from transportation professionals with intimate knowledge of the installation and operation of such systems. An expert review panel consisting of transportation professionals from across the United States willing to volunteer their time to assist this research effort then reviewed these preliminary guidelines. These modified guidelines were then applied to a hypothetical case study to illustrate the design process.

BACKGROUND

This section describes the history and development of DMS technologies, and how these technologies are used. Additionally, previous guidelines for the development of DMS systems were reviewed and summarized.

History of DMS Technology

DMS technology previously referred to as variable message signs (VMS) and changeable message signs (CMS), have been used as motorist information devices for about 40 years. The earliest signs were rudimentary mechanical devices with little flexibility in use. These early signs were typically fixed static signs that could only operate in an "on" or "off" mode, that is, displaying a specific message or off. These signs were typically were used for only a specific purpose, such as fog warning or weigh station control, and were often manually operated (*4*). Over time a proliferation in types of more advanced DMS devices occurred, and now fiber optic and light-emitting diode (LED) signs which can be remotely operated and with greater flexibility in sign messages are common today (*5*).

Today, these types of technology can be defined into three different basic categories (*6*):

1. Light- emitting;
2. Light- reflecting; and
3. Hybrid

Light-reflecting devices require an external light source to convey their message by reflecting this light toward the motorist with reflective disks. External light sources typically include headlights, specially mounted external lights, and sunlight. Light-emitting devices generate their own light on or behind the viewing surface, and convey the light to the sign surface, typically through fiber-optic connections. Some manufacturers have combined these two basic DMS technologies into a hybrid design that capture the characteristics of both designs (*6*). Table 1 provides a summary of various types of DMS technologies that have been used throughout the history of dynamic technology (*4*). Many of these devices, including the manual systems, are no longer in widespread use.

Several of the DMS types listed in Table 1 require manual labor to change signs, such as cloth signs and removable panel signs. As a result, these types of signs are not widely used today. Other sign types that limit the type of message that can be displayed, such as neon, blank-out, fold-out, scroll, and rotating drum signs limit the number of signs that may be displayed. This limitation has reduced the effectiveness of these signs compared to more modern sign types that are able to provide more versatility. In 1997, Dudek reported the most recent DMS technology purchased by state departments of transportation was more likely to be fiber optic, reflective disk, LED, or bulb matrix devices (*5*).

Table 1. DMS Display Types, and Related Technologies (4)

Display Types	Technology Used
Light-emitting	• Blank-out • Lamp matrix • Fiber optics • Neon
Light-reflecting	• Fold-out (both manual and motor-driven) • Scroll (Belt) • Rotating drum • Electromagnetic disk matrix • Electromechanical flap matrix • Electrostatic vane matrix • Cloth • Removable panels
Hybrid	• Static sign with flashing beacon • DMS units of limed shape

Lodge Freeway Corridor, Detroit, Michigan

Pretty and Cleveland reported a study of several the early DMS technologies in 1970 (7). The study area was a section of the Lodge Freeway in Detroit covering eight interchanges, and an adjacent arterial used as the diversion route. The intent was to reduce delays be helping motorist's avoid congestion due to ramp metering at a series of eight on-ramps to the Lodge Freeway in this corridor. This corridor made use of eight "ramp information" lighted blank-out signs, one neon DMS unit, one large blank-out DMS unit, 19 single-message blank-out DMSs, and 16 neon arrow trailblazer signs, all for benefit of arterial motorists. The purpose of the study was to measure the effectiveness of the system in diverting traffic to alleviate recurring ramp congestion and to evaluate the effectiveness of the signs.

A series of experiments were conducted using volunteer motorists. These motorists drove the corridor and attempted to follow the instructions provided by the DMS system. This study revealed that motorists were less likely to see and comply with route guidance signs placed on the shoulder of the roadway. These motorists were more likely to see signs placed over the roadway. Additionally, the graphic-type ramp information signs were found difficult for motorists to comprehend. This indicates an early realization that motorists do not easily understand nonstandard symbols.

Additionally, this study found that neon was generally not suited for Detroit's climate. In cold temperatures, the neon trailblazer signs were only visible from 0 to 90 feet in the daytime, which was substantially less than the recorded warm-weather distances of 174 to 309 feet.

DMS Use and Application

As Table 1 indicates, a wide range of DMS technologies is available to highway agencies. As the available technology proliferated, the need quickly arose for a set of guidelines to help determine which technology was best suited to a specific project. Dudek (6) developed a procedure to be followed for determining the appropriate DMS technology to fulfill the needs of a highway agency. This set of guidelines encompassed concerns about display capability, cost, operating parameters and maintenance of the system. The procedure developed is as follows:

- Clearly establish the objectives of the DMS;
- Prepare the messages necessary to accomplish the objectives;
- Determine the required legibility distance;
- Determine the location of the DMS;
- Identify the type and extent of localized constraints;
- Identify environmental conditions;
- Determine target value and legibility of candidate DMS units;
- Determine costs of candidate DMS units; and
- Select DMS type based on the above considerations.

Human Factors Issues

Three important human factors issues in determining DMS system characteristics are legibility, credibility, and message wording (*6*). Each of these factors must be satisfactorily addressed to achieve a successful DMS system.

Legibility

Legibility refers to the distance at which motorist can begin reading a message (*4*). This distance may be effected by the features of the sign, including the size and font of the lettering, the light intensity emitted by the sign and the spacing of adjacent letters. Research by Messer, Stockton, and Mounce conducted in 1978 indicated that the 85th percentile legibility distance of an 18-inch letter height of a lamp matrix sign was about 650 ft (*8*). Clearly, size of the message is critical to the proper legibility of the system, and should be considered early in any DMS system design.

Credibility

Credibility of the DMS system has nothing to do with the type of technology used to convey the message. Rather, it deals with how well the driving public believes that the information conveyed is accurate and timely. If incorrect or untimely messages are routinely displayed, the motorists who act on these incorrect messages will be less likely to believe the information in the future. "The system will work only if the motorists believe in the system (*6*)," is perhaps the most straightforward way of making this point.

Message wording

Sign wording is an important part of motorist understanding of a DMS message. Even if the message is easy to read, if the wording is confusing, motorists may easily misunderstand it. Simple messages with redundancy are important in getting motorists to understand the intended message. In 1977, Weaver, et al. studied the impact of including redundancy in the wording of a freeway DMS system in use for special event traffic route guidance in Dallas, Texas (*9*). Two messages were studied, with the total message divided between two trailer-mounted bulb-matrix DMS units. The competing messages are shown in Table 2. The study found that Message 1, with a redundant message, was able to divert 56.2 percent of motorists, where the second message set was only able to divert 43.8 percent.

Motorist information preference

Studies have been conducted to determine what types of information motorists would prefer to receive from DMS systems. Much of the early research in this area has been in freeway applications. Hall and Dickinson surveyed freeway motorists in the Baltimore-Washington D.C. area to determine what types of information the motorists would most value (*10*). From this research a basic hierarchy of information importance was developed.

Table 2. DMS Message Sets Evaluated (*9*)

Sign	Message 1	Message 2
Location 1, first panel	BEST ROUTE TO FIREWORKS	ROUTE TO FIREWORKS
Location 1, second panel	USE FITZHUGH AVE	INFORMATION AHEAD
Location 2, first panel	FIREWORKS BEST ROUTE	FIREWORKS BEST ROUTE
Location 2, second panel	FITZHUGH AVE 1 MILE	FITZHUGH AVE 1 MILE

A DMS message should have the following attributes (shown in decreasing order of importance):

- Be brief and concise;
- Indicate the nature of the situation;
- Suggest appropriate driver response; and
- Provide supplementary information.

Dudek, Messer, and Jones studied where Houston and Dallas motorists preferred to receive additional traffic information about a usual condition on a freeway (*11*). Of the respondents to their survey, 92 percent indicated that they would divert to an alternate route if provided information prior to reaching the freeway. This dropped to 75 percent once the motorists were on the freeway. This indicates that motorists are more amenable to route diversion while still on the surface street network. Additional preferences gathered in the study included motorists' preference to receive information on the location, length, and degree of congestion.

Heathington, Worrall, and Hoff studied the reasons why Chicago motorists would choose to divert from their preferred route by surveying motorists (*12*). The responses to the survey were examined to reveal perceived attitudes toward diversion. In general, motorists were more likely to divert to avoid congestion or reduce travel time if they were on their way home. However, in this study, respondents tended to be more willing to divert simply to avoid congestion rather than to reduce travel time alone.

CURRENT APPLICATIONS OF ARTERIAL DMS SYSTEMS

Several cities throughout the United States have implemented permanent DMS systems on arterial streets. Reasons for these deployments vary, but typically include providing traveler information for special event traffic, route guidance for traffic diverted from an freeway due to an incident, and providing information about the status of nearby freeways to arterial traffic. A discussion of six existing permanent arterial DMS deployments in United States cities is included in this section. Speeds for all of the arterials reviewed were in the range of 30-40 mph.

Anaheim, California (*13*, *14*)

Anaheim, California has installed a network on DMS technology to guide motorists to and around many of the special event forums in the city, including Disneyland, the Anaheim Convention Center, and the Anaheim Stadium Complex. The intended function of this arterial DMS system, which became fully operational in 1992, was to provide guidance for special event traffic through the arterial and collector system to the special event venues. Information provided typically includes the status of the local road network and parking facilities in the vicinity of the special event venues.

The DMS technology consists of five full matrix type LED signs, allowing both a nominal 14-inch sign on arterial streets, with two freeway signs with 18-inch lettering height depending on how it is used. These signs have a message area measuring 5 feet by 20 feet. Additionally, two 6.5-feet by 25-feet full matrix type LED signs with nominal 18-inch letter height were installed on nearby Interstate 5 to provide information to freeway motorists. These larger signs can provide either two lines of 18-inch text or three lines of 14-inch text. All of these signs also have the capabilities of displaying up to 20 different symbols, such as arrows, and special symbols intended to represent Disneyland, the Convention Center, and the Anaheim Stadium.

Conversations with staff from the city engineering department indicate that these signs are utilized in some fashion almost every day, and have met with much public approval. The large proportion of non-local, special event traffic using the city streets forced Anaheim to be an early innovator in arterial DMS development.

Baltimore, Maryland (*15*)

In 1992, Baltimore, Maryland sought to improve special event traffic flow to a new downtown activity center, as well as to the city's baseball stadium. Additionally, there was a need to improve route diversion from the nearby freeway in case of incidents. At that time, the city purchased ten portable DMS units to provide special event traffic information. The ten flip matrix DMS units have a message area of 48 inches by 96 inches long with the capability of providing three 12-inch lines of text or one line of larger text. Currently, however, eight of the ten devices have been mounted at permanent locations on mast arms.

Communications with these signs was reported to have been problematic in the past. Originally, this system was designed to have cellular communications capability, but because of cellular communications failures due to heavy cellular phone use by the public during nearby special events, the permanently mounted units currently use twisted pair wire communication, and the two portable units are operated locally with laptop computers.

Greensboro, North Carolina (*16*, *17*)

The City of Greensboro, North Carolina installed an arterial DMS system to provide traveler information to guide special event traffic to and from the Greensboro Coliseum from nearby Interstate 40. The system was installed in 1994 to help special event traffic find parking areas. Additionally, the system was designed to provide lane control for a center reversible lane.

The DMS system consists of 14 dynamic signs mounted on six overhead sign bridges along the one-mile route leading to and from the coliseum, in conjunction with static trailblazing signs. Each DMS unit is 36 inches by 96 inches long, and is able to display two lines of 12-inch text or three lines of 9-inch text. These units are of a flip matrix design, which is similar to a lamp matrix, except that plastic disks are used to form characters. This sign type uses electromagnets to flip disks from a dark side to a light side to create messages. As a result, messages change more slowly than light-based DMS technologies, such as LED or fiber optic types. Conversations with engineers at the Greensboro Engineering Department indicated that these signs take up to 30 seconds to transition to a new message (*16*). During the transition between panels of a multi-panel message, portions of the old and new message are displayed simultaneously. Motorists viewing this type of sign during transition could be easily confused by the garbled message (*4*). As a result, the city staff tends to display messages that do not often need to be changed, such as directions to parking areas.

City engineers also expressed concern that maintenance has become an issue with the aging signs. The flip matrix design has moving parts that require increasing maintenance over time. Additionally, early efforts at using radio communication with these signs were found to be problematic, and as a result, the city switched to modem-based communication.

Figure 1. Disk Matrix Signs in Greensboro, North Carolina (*17*)

Integrated Corridor Traffic Management Project, Minnesota (*18*, *19*, *20*)

In 1994, Minnesota Department of Transportation (Mn/DOT) partnered with Federal Highway Administration (FHWA), Hennepin County, and the Cities of Bloomington, Richfield, and Edina to develop the Integrated Corridor Traffic Management System. The purpose of this system was to improve travel along an 8-mile stretch of Interstate 494 (I-494) in the southern portion of the Twin Cities area, by diverting traffic during incidents from I-494 onto the adjacent local network. The total project included real-time traffic systems to adjust and coordinate 27 ramp meters and 75 traffic signals on streets adjacent to I-494. Additionally, nine variable message signs and 81 electronic arrow signs were used to provide traveler information to motorists in this area on the recommended alternate routes to take to avoid congestion. Examples of this equipment is shown in Figures 2 and 3.

The DMS units, located on the major local streets in this area, consisted of nine fiber optic DMS units with 2 lines of 12-inch text displayed. The 81 electronic arrow signs consisted of an LED arrow placed above a static sign with the words "ALTERNATE ROUTE WHEN ARROW ON." This relatively simple device allowed route diversion information to be spread over a larger area than would be financially possible if only text-based DMS units were used. This ability to economically provide information dissemination over greater area was relayed by Mn/DOT officials as a major benefit of this system.

Salt Lake City, Utah (*21*, *22*)

The Utah Department of Transportation (UDOT), as part of its effort to improve transportation facilities in preparation for the 2002 Summer Olympics, installed a series of arterial DMS units in the vicinity of Interstate 15 (I-15) through Salt Lake City. This system was installed to provide advance construction

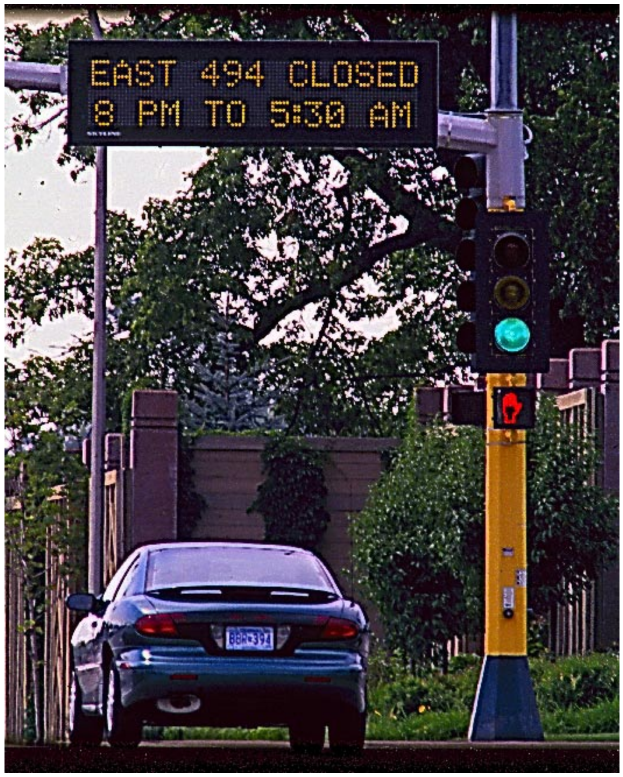

Figure 2. Arterial Variable Message Signs used by Mn/DOT (19)

Figure 3. Electronic Arrow Signs Used by Mn/DOT (19)

information regarding the $1.5 billion I-15 reconstruction effort. Seventeen fiber optic arterial DMS units became operational in 1999, and provide two lines of 12-inch text. UDOT engineers explained that the typical mode of operation of these signs provides three "bits" of information to motorists: what is happening, where it is happening, and the recommended action. The first "bit" of information is typically provided on the top line of the DMS, with the remaining "bits" alternating on the second text line. This method seems to have met with positive public reaction. If the situation is not clear to the staff of the traffic management center at the time a message is displayed, no recommended action will be displayed.

At the time of this report, UDOT officials had been using this system for approximately six months, and had more experience relaying construction information then incident information.

Further conversations with UDOT staff indicated that they were concerned with the cost of providing text-based DMS devices on all street-level approaches to a freeway. This would typically result in three to four times as many signs as would be needed on the freeway itself, and while the arterial DMSs are smaller, the total installation cost on a per sign basis experienced in Salt Lake City has been similar to the larger freeway DMS devices. UDOT engineers generally feel that freeway DMS signs are activated more frequently by the traffic management center, and get more exposure to a larger number of motorists. As a result, it is believed that the freeway signs are more effective than the arterial units, further compounding the belief that the benefits of the arterial DMS system may not be worth the cost.

In future arterial DMS deployments, UDOT is considering less expensive technology, such as a static sign with an LED arrow and two short lines of text indicating the direction of I-15 that is being diverted. This approach, while limiting the DMS system to simple messages, would allow UDOT to cost-effectively provide a small amount of traveler information to a larger number of local streets. An example of this proposed system is shown in Figure 4.

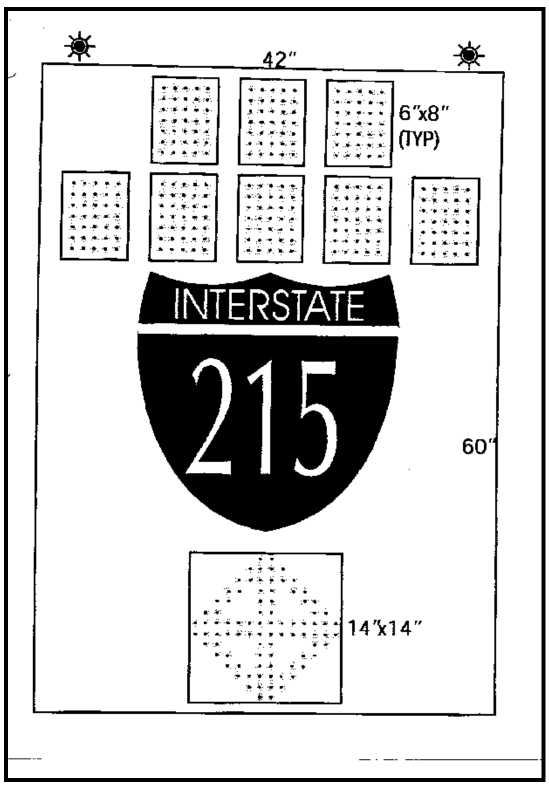

Figure 4. Future Arterial DMS/Static Sign for UDOT (Proposed) (*22*)

San Antonio, Texas (*23*, *24*)

The DMS system project in San Antonio was deployed in 1997 as part of a larger Model Deployment Initiative, which included other city-wide improvements such as traveler information kiosks, railroad advance warning deployment, and advanced assistance to emergency medical services. This arterial DMS deployment was meant to offer the opportunity for Interstate 10 (I-10) motorists to divert to a parallel arterial street (Fredericksburg Road) in response to an on-freeway incident. The DMS system was also designed to provide motorists on Fredericksburg Road with information on the traffic conditions on I-10. When an incident is detected on I-10 in this area, the traffic management center will recommend an alternate route using freeway and arterial DMS systems. Additionally, this will change the signal timings on Fredericksburg Road to accommodate the additional demand as motorists are funneled off of I-10.

The Fredericksburg/I-10 corridor benefits from nine DMS units on three interchanges that connect the two parallel roads. Each DMS sign utilizes a fiber optic display with overall housing dimensions of 40 inches by 54 inches. An example of these signs is shown in Figure 5. These signs were specified to provide three lines of 7-inch text. Additionally, these signs were designed to automatically change their luminous intensity based on ambient light conditions.

This system, although deployed in 1997, had not been used for its designed purpose at the time of this report. Officials at the City of San Antonio Traffic Engineering Department stated in telephone conversations that the reason for this was that the required communication between the DMS system and the freeway detection devices was only recently completed. The effectiveness of the signs will be assessed in the coming years.

Figure 5. Arterial DMS Unit in San Antonio, Texas (24)

Summary

This section has provided examples of existing arterial DMS applications in the United States. While other arterial DMS systems undoubtedly exist, it is believed that the systems reviewed provide a representative overview of arterial DMS applications in general. Table 3 provides a summary of the reviewed arterial DMS systems. Table 4 lists the types of design and operational problems experienced by these systems, as explained by the engineering department of these cities. The variety of design types, as well as the range of problems experienced, indicates a need that design guidelines are needed. A set of guidelines is developed in the following sections that could help alleviate the occurrence of these problems in future arterial DMS systems.

Table 3. Summary of Reviewed Arterial DMS Systems

Location	Installation Date	Purpose of System	Number of Devices	Letter Height of DMS Text
Anaheim, CA	1992	• Special event traffic management • Freeway route diversion	• 7 LED DMS	14 inch
Baltimore, MD	1992	• Special event traffic management • Freeway route diversion	• 8 Permanent flip matrix • 2 portable flip matrix	12 inch
Greensboro, NC	1994	• Special event traffic management	• 14 flip matrix	3 lines 9 inch, or 2 lines 12 inch
ICTM Project, MN	1994	• Freeway route diversion	• 9 [Don't know at the moment] • 81 LED arrows	12 inch
Salt Lake City, UT	1999	Freeway route diversion	• 17 Fiber optic	12 inch
San Antonio, TX	1999	Freeway route diversion	• 9 Fiber optic	7 inch

PANEL REVIEW PROCESS

As a part of this research, a set of guidelines was developed to assist in determining the types of DMS technology that would be acceptable for a given arterial location. In order to improve the applicability of the research to practitioners, a panel of engineering professionals with experience in arterial DMS installation and operation was established to review a set of preliminary guidelines. The process of selecting the panel, the panel review process, and the recommendations of the panel are discussed in this section. The information provided to panel members, including the preliminary guidelines, is provided in Appendix B.

Panel Selection Process

During the review of current arterial DMS systems, several engineering professionals were recognized as having extensive knowledge in the area of arterial DMS systems. Professionals that participated in this study tended to be city or state traffic engineers that were responsible for operating an existing system, or had been responsible for the installation of a system in the past. Each of the panel review participants volunteered their services to critique the guidelines developed as a part of this report. The group critique process occurred as a conference telephone call on the morning of July 13, 2000, and lasted approximately one hour.

Table 4. Perceived deficiencies of reviewed arterial DMS systems

Location	Perceived deficiencies of existing arterial DMS system
Anaheim, California	• No deficiencies reported
Baltimore, Maryland	• Original portable DMS concept manpower intensive • Cellular communications problematic, abandoned
Greensboro, North Carolina	• Slow message change rate limits sign operation • Radio communications problematic, abandoned
ICTM Project, Minnesota	• DMS units positioned at intersection locations
Salt Lake City, Utah	• High initial cost
San Antonio, Texas	• Small sign size • Budgetary constraints on staffing

The panel members were:

- Mr. Joe David, City of Baltimore, Maryland;
- Mr. Adam Fischer, City of Greensboro, North Carolina;
- Mr. John Friebel, City of San Antonio, Texas; and
- Mr. Dave Kinnecom, Utah Department of Transportation.

Results of Conference Call

The conference call participants focused on three areas that they believed were important enough to warrant further discussion in the guideline process. Specifically, these areas of importance included: cost-effectiveness of specific technologies, stressing the recognition that the urban street environment is fundamentally different from a freeway environment, and the need to evaluate vendors to determine what technology each has available.

Determination of the Cost-effectiveness

Each of the panel members expressed the need to incorporate the financial aspect of the design into the guidelines. It was stated by several of the panel members that financial trade-offs will always exist, limiting the engineering design from the ideal to that which can be accomplished for the resources available. For example, even though in the design process it becomes apparent that a large amount of information is desired to be provided to the motorist, it may not be possible to provide all of this information and remain within the project budget. Due to these trade-offs, a prioritization of the importance of the information provided was also stated as a necessary part of the process. Budgetary constraints may also require the use of other less expensive types of information dissemination equipment, such as static trailblazing signs.

Street environment

The physical environment where the DMS system would operate and how this limits a motorist's ability to see the sign was considered critical. One of the panel members even questioned whether the human factors assumptions developed for DMS systems on freeways were even applicable on city streets. The additional visual clutter, presence of cross streets and driveways, and the fact that city streets are built to a lower geometric standard than freeways all contribute to making arterial DMSs less noticeable than freeway versions.

It was the belief of the review panel, however, that a basic engineering study could overcome many of these deficiencies. For example, recognizing the presence of brightly-lit buildings could lead a designer to specify brighter nighttime visibility of the DMS system. In another example, some approaches with more activity might require larger lettering or brighter signs than less developed interchanges, as fewer distractions would exist.

Vendor evaluation

All of the panel participants agreed that because there is currently no nationally accepted practice in the development of arterial DMS technology, each product vendor tends to provide different equipment. It was the thought of the review panel that any engineer designing an arterial DMS system must have extensive knowledge of the types of equipment available, and the advantages and limitations of each. Specifically mentioned examples of required information included maintainability and interchangeability of equipment, as well as expected life span of the equipment. The review panel recommended including a review and evaluation of each vendor's products as a step in the guideline process.

Summary

The critique by the expert review panel was essential to the creation of the guidelines developed from this research. The input provided increased the applicability of the guidelines, making them much more useful to anyone desiring to develop an arterial DMS system. Each of the ideas put forth by the panel review committee were adopted in the final guidelines.

DESIGN GUIDELINES FOR ARTERIAL DMS SYSTEM

The guidelines presented in this section are designed to provide guidance in designing a traveler information system that would provide freeway condition information to motorists on a local street network as they approach an arterial-freeway corridor. Using these guidelines, a city engineering department, traffic management center, or state department of transportation should be able to create an effective information dissemination system for use under incident conditions. It should be emphasized that the steps, although listed and discussed individually, are interrelated. A summary of the guidelines is shown in Table 5.

Prior to the use of these guidelines, several issues must have already been addressed. Specifically, the need for an information dissemination system in the vicinity of an arterial-freeway corridor must have already been determined. Does this location even need such a system? A basic engineering study may provide a solution without requiring the cost of a DMS system at the location in question. If no other method appears satisfactory to improving arterial traffic flow, then the following guidelines will be useful. Additionally, the capital funds, as well as the availability of operations and maintenance funds must already be available. It may be likely, however, that the establishment of the DMS system objectives (Step 1) must be determined as part of a funding proposal. In such a case, Step 1 would already be completed prior to using these guidelines. In general, however, these guidelines presume that these issues of need and funding have been satisfactorily resolved. If these issues have not been addressed, then the use of these guidelines would be premature.

Table 5. Guidelines for Designing an Arterial DMS System

Guidelines
Step 1: Clearly establish the objectives of the DMS system
Step 2: Identify what information is necessary to be conveyed to motorists to accomplish the objectives
Step 3: Prepare messages
Step 4: Identify existing technologies available for deployment
Step 5: Evaluate effectiveness of competing technology alternatives in meeting objectives
Step 6: Identify the existing physical constraints of the arterial-freeway corridor
Step 7: Determine the appropriate locations for installation of the DMS technology
Step 8: Identify environmental conditions
Step 9: Specify system characteristics

Step 1: Clearly establish the objectives of the DMS system

A necessary first step in this process is developing the objectives that are sought through the installation and use of this system. This step is very important because the objectives directly influence message content, format, length, and as a result, the type, size, and placement of the DMS technology. Examples of legitimate objectives could be to reduce incident-based delay for arterial motorists, alert arterial motorists of an upcoming or current freeway work zone lane closure, or to provide special event information. Short-term as well as long-term objectives should be examined, as the needs of the public may change as long-term network conditions change. Additionally, it must be determined which approaches to the arterial-freeway corridor are to be included in the system.

Step 2: Identify what information is necessary to be conveyed to motorists

With the objectives established, the type of information to be disseminated to motorists must be identified. If the information is simple, such as only a direction recommended for travel, the need for a full-text DMS may not exist; a series of LED directional arrow on a trailblazing sign may be all that is required.

If more complex messages are necessary to accomplish the objectives, text-based DMS technology should be considered. The length of the text messages will assist in the determination of character size, message line length, and the number of message signs required by the DMS technology. This will be important for the system specifications developed in Step 9.

Step 3: Prepare messages

Before an arterial DMS system can be selected, the wording of the messages it will display must be established. Certain message components should be included in any message to meet the stated objectives of the project. These messages might include such components as the problem statement, location, and an action statement. These messages might also include an effect statement such as “MAJOR DELAY,” and/or an attention statement, which might be used to specify the target audience.

Motorist understanding of the wording must be evaluated to determine that the target audience understands what the signs are trying to convey. This preliminary step will assure that the selected technology will be able to provide the required messages.

The needs of a DMS system may also vary by location, meaning that the information needs of motorists in one city may vary from those needed in another. For example, if an arterial DMS system is the first DMS technology in a region, the messages may have to be more basic to accommodate motorists than if the system were designed for a city whose motorists were more likely to have seen previous installations.

Step 4: Identify existing technologies available for deployment

A designer needs to recognize that there are no national standards or common practices regarding the design of an arterial DMS system. This, coupled with the wide variety of DMS technology available from vendors, results in a vast number of potential designs for consideration. In order to make knowledgeable evaluations of the most appropriate technology for use, the designer must have adequate knowledge of products available for use. This step will also allow a designer to determine which devices are not up to the technical specifications required of the project, as well as the costs of the competing technologies.

Step 5: Evaluate effectiveness of competing technology alternatives in meeting objectives

Based on the prioritized information requirements established in Steps 2 and 3, each of the viable technology alternatives determined in Step 3 are analyzed to determine how well each technology could accomplish the information dissemination required for the project. The more able a technology can meet the higher priority information requirements, the better it should rate compared to other technologies. Technologies that cannot accomplish the most important information needs should be discarded as ill suited to the task of this project. Each of the remaining viable alternatives should then be analyzed for cost-effectiveness, to determine how well each alternative can meet the information requirements for the cost. Placing a dollar value on information provided can be problematic, so another approach, such as a categorical ranking process, could be created as an alternative.

Step 6: Identify the existing physical constraints of the arterial-freeway corridor

Field inspections of the site are important to determine the existing conditions of the arterial-freeway corridor. This process can ensure that there are no physical obstructions due to existing structures such as bridges, traffic signals, or sign structures that would adversely impact the DMS system. Conversely, if these structures are in advantageous locations, they could provide opportunities for the placement of the DMS technology (Step 7), reducing the additional infrastructure needed.

It is essential at this stage to determine any human factors or physical issues that could effect the usefulness of the DMS system. These could include the presence of a large amount of visual clutter in the vicinity of the DMS, narrower lanes or other less than ideal geometry which might distract motorists, or other factors which may prevent motorists from seeing and recognizing the DMS messages.

Step 7: Determine the appropriate locations for installation of the DMS technology

Potential locations for the placement of the DMS system need to be determined. These locations must allow motorists to comprehend the message with ample time to react to the message. Additionally, the components of the system must be placed so that existing traffic control and static message signs form an integrated and compatible information system. The approaches that will benefit from this system should already have been determined in Step 1. Typical installations for DMS technology include placement on existing traffic signal mast arms, existing bridges, existing sign structures, and on newly installed mast arms or on overhead sign structures.

Step 8: Identify environmental conditions

The environmental conditions in which the information dissemination system will operate must be identified. Weather conditions such as rain, snow, wind, etc. will have an effect on the operation of the system components. Other environmental factors, such as dust, extreme heat, and extreme cold may have an impact on the design and maintenance of the system. Glare, occurring when the sun shines from behind the signs, is an important condition, one that is often overlooked. An examination of where the sun will be positioned relative to a motorist's line of sight throughout the year will indicate when a glare problem exists. A sign with this problem can be designed with either glare protection, a brighter display, or both. These conditions should be made known to the manufacturers of the system components so that the best characteristics of the system can be achieved.

Step 9: Specify system characteristics

Based on the results from steps 1 through 7, technologies to be used to disseminate travel information should be specified. Possible technologies include, but are not limited to, full-text DMS systems, LED arrow displays, and static trailblazing signs. It is possible, even likely, that different technology would be used in different parts of the same project. For example, DMS technologies may be used on high-volume approaches, where more information could be provided to a higher volume of motorists. These issues should be answered based on the results of the previous steps.

The method of communication with this system must also be determined. Possible options include fiber-optic, copper wire, land-based telephone, and cellular telephone communication. The positive and negative attributes of each of these systems are beyond the scope of this research. An existing communications network, if any, would provide guidance as to which type of communications would be selected. Consideration to the total communication network is critical to allow for future expansion with minimal additional cost.

Implementation and Operation

These guidelines were only intended to cover the proper *design* of a DMS system at a typical arterial-freeway corridor. The installation, operation, public education, and evaluation of an arterial DMS fall beyond the scope of this research. These steps should not be discounted as unimportant, however. Even an optimally designed system will not perform to expectations unless some thought is given as to proper training of the personnel that will operate such a system. Likewise, it should not be assumed that the public would naturally accept and understand what the system is telling them without training. An effective public education program must accompany any new traveler information system, or the system will bring confusion instead of assistance.

HYPOTHETICAL APPLICATION

The following is a discussion of the guidelines developed above applied to a hypothetical situation. The hypothetical situation is presented as follows.

In the past, motorists have experienced long delays when incidents occur on Interstate 99, the major east-west freeway through one particular portion of Large City, Texas. The traffic engineering department in Large City has been given a directive to alleviate delays experienced by motorists on the street network desiring entrance to the freeway when a freeway incident has reduced the carrying capacity of a portion of the freeway. Funding is available in the city's budget to support a pilot program to provide route diversion in the corridor containing four freeway interchanges. It is expected that if the project is successful, expansion could occur in future years. The city engineer has requested a design for an arterial DMS system for this corridor.

The corridor contains 24th Street, a major arterial street just to the south of the freeway. Any diversion of arterial traffic to alternate interchanges must take place on the arterial. Arterial traffic in this area consists primarily of daily commuters. The basic layout of the arterial-freeway corridor is shown in Figure 6. Major arterial traffic flows are illustrated with arrows. At this location, there are ten arterial approaches to the corridor that must be accommodated in any route diversion design.

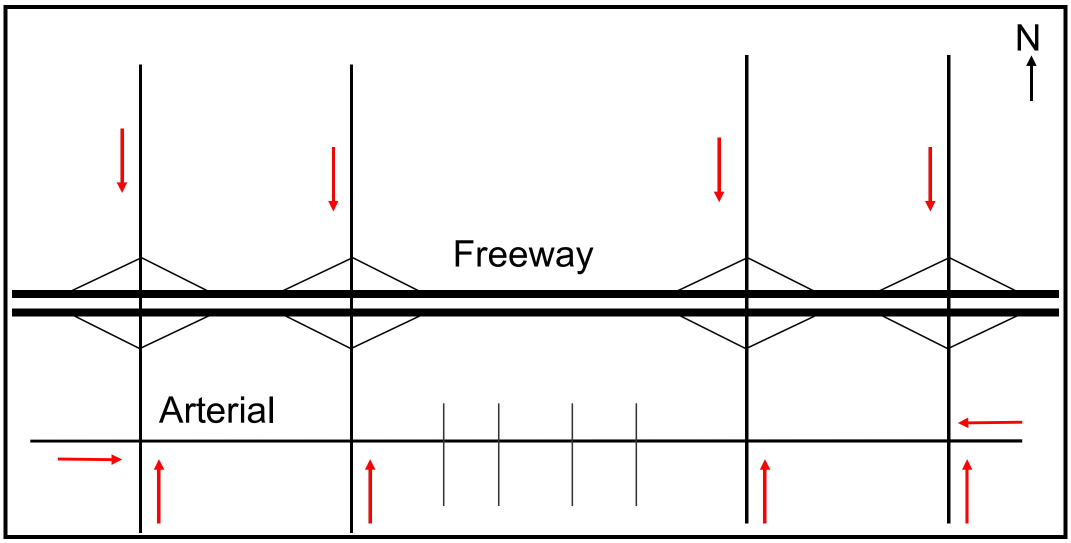

Figure 6. Freeway Corridor for Hypothetical Case Study

Step 1: Clearly establish the objectives of the DMS system

The goal of Large City is to divert arterial motorists prior to reaching the freeway during freeway incidents, in order to reduce motorist travel times. If properly designed, this system could also have the effect of reducing demand on the freeway at the point of the incident, reducing the severity of congestion on the freeway. This could also result in reduced travel times for freeway through traffic. In order to be effective, any route diversion strategy would need to be able to divert approaching arterial traffic from any one interchange in the corridor to any of the other three.

Step 2: Identify information dissemination needs

The DMS system must be able to convey three units of information to approaching arterial motorists. First, the system must make motorists aware of the presence of the incident, the direction of the freeway affected, and the recommended action. The target audience of motorists on the arterial will be mixed in with others will not need this information, such as those heading in the opposite direction of the freeway, and those who are not planning to take the freeway at all. Therefore, it is important to quickly provide the above information to alert the affected motorist in time to divert.

Once a motorist decides to take the alternate route, that motorist must be provided with guidance along the length of the diversion route to reassure the motorist that he/she is still on the diversion route. The form these messages will take at different portions of the corridor is established in the following step.

Step 3: Prepare messages

In order to provide three units of information to motorists as they approach the corridor, it is believed that a small DMS system would be needed. Before such a system can be selected, however, the wording of the messages it will carry must be established. This preliminary step will assure that the selected technology will be able to provide the required messages.

The first line of any message should provide motorists with information as to what is happening. This could be simply “ACCIDENT,” or “CRASH.” It could also be more generic, such as “DELAY”, or “DETOUR.” The second line, which should provide information as to where the incident is located, could say something such as “I-99 EAST.” The third unit of information to be conveyed to motorists is the recommended action. Wording for this might include “USE 24TH.” Determining the required wording will help in the determination of the size of any DMS units selected in Step 9.

Wording for the route guidance throughout the diversion route must be established in a similar way. Such wording might simply be a trailblazing-type static sign that simply says “ALTERNATE ROUTE” or DETOUR ROUTE.” In order to provide real-time route guidance, some type of DMS-type arrow or direction indicator would also be required. At locations where a DMS-type arrow is used, the accompanying static message could be “ALTERNATE ROUTE WHEN ARROW ON.”

In order to determine the optimal wording for these messages, studies should be conducted in Large City to determine what local motorists perceive to be the meaning of these phrases. This study would assure the proper wording for these messages in order to communicate effectively with the intended audience.

Step 4: Determine existing technology alternatives

Next, the engineering department would need to gain a better understanding of the current technology that could meet their needs. All products that appear capable of meeting the information needs that were established in Steps 2 and 3 would be researched to determine factors such as cost, weight, and environmental operating ranges. This could be as simple as requesting product catalogs from a number of vendors with DMS products and conversations with vendor sales personnel.

Based on the speed limits of the arterials where potential DMS units might be placed, signs that provide 12-inch font are determined to be the minimum effective letter height. Applications of DMS technology in other areas of Large City show that this letter size will allow enough time to read and comprehend displayed message.

Step 5: Determine competing technology alternatives

Once information has been gathered for Step 4, the preferred DMS technologies should be determined so these characteristics can be written into the design specifications. Factors such as warranties, durability, and reliability are important characteristics that must be determined for each of the competing DMS alternatives. Additionally, the ability of city maintenance personnel to maintain these technologies must be evaluated. If the city already uses one type of DMS unit, that technology might be a more favorable choice, as maintenance personnel should already be familiar with it.

Several existing sign types are in use in other portions of Large City. Providing these technologies can successfully meet the needs of the project, the city decided to limit the design to match the existing DMS units.

Step 6: Identify existing constraints

Several factors in this corridor will affect the final design of the DMS system. First, there is only one parallel route to which diverted motorists could be rerouted. This arterial street must also be able to handle traffic from motorists approaching the freeway from the north as well as the south. The design of this system must clearly lead motorists approaching from the north to pass the freeway without entering. Second, the arterial street used for the diversion route intersects several streets that do not lead to the freeway. These intersections should be examined to see if trailblazing or additional DMS technology is needed in the design to guide diverted motorists through these intersections. Finally, as stated above, this corridor is primarily urban at the western end, and primarily suburban residential at the eastern end. This must be considered in the selection of appropriate DMS technology that will aesthetically fit the surrounding area. It is likely that different technologies would be needed at these two locations.

No specific constraints, such as poor sight distance, overhead structures, vertical or horizontal curves, or other geometric features are present along this corridor that would reduce the effectiveness of DMS technology.

Step 7: Determine locations for technology placement

To avoid potential safety issues with placement of DMS technology on existing mast arms at intersections, all DMS devices would be placed at a mid-block location, on existing sign bridges or on new mast arms erected for this project. Any trailblazing signs or changeable LED arrows would be placed on existing curbside poles when possible, to reduce installation costs. (The large potential number of trailblazing signs and changeable arrows on any project would likely prohibit the placement of new overhead mast arms for each of these.) For this project, financial limitations require that all technology other than text-based DMS units would be placed to the side of the street.

Where text-based DMS technology is selected at a location, placing the sign units over traffic should be strongly considered. Placing these units on existing sign structures or overhead bridges would reduce the need for mast arms. However, in this study, it will be assumed that no mid-block overhead structures currently exist, requiring the need for a mast arm for each of these types of signs selected.

Step 8: Identify environmental conditions

Environmental conditions such as snow, rain, extreme heat, and extreme cold should be noted in the engineering study to be able to provide a manufacturer with a realistic reference of the environment in which the DMS technology will be operating. It is assumed for this case study that no adverse environmental conditions exist that would inhibit the proper functioning of the DMS system.

Step 9: Specify system characteristics

Based on the results from steps 1 through 8, the design for the arterial DMS system was completed. A summary of the hypothetical design for use in Large City can be found in Figure 7. The following design was selected for the corridor:

DMS units

At each of the ten arterial approaches to this corridor, a three line DMS unit that is capable of 15 12-inch characters per line is to be mounted on new mast arms. These will be located at mid-block locations to avoid potential safety problems at intersections. An additional advantage of locating DMS units at these locations is extra versatility for use with other purposes, such as notification of work zone lane closures, should the need arise.

Trailblazing Signs

Just upstream from each intersection along the diversion route, an LED changeable arrow, attached to a static trailblazing sign, will be installed to guide motorists to the alternate freeway interchange. The sign and wording are similar to that shown in Figure 3, and will be able to change direction to indicate whether motorists need to travel straight through an intersection or turn left or right. These signs will be placed on

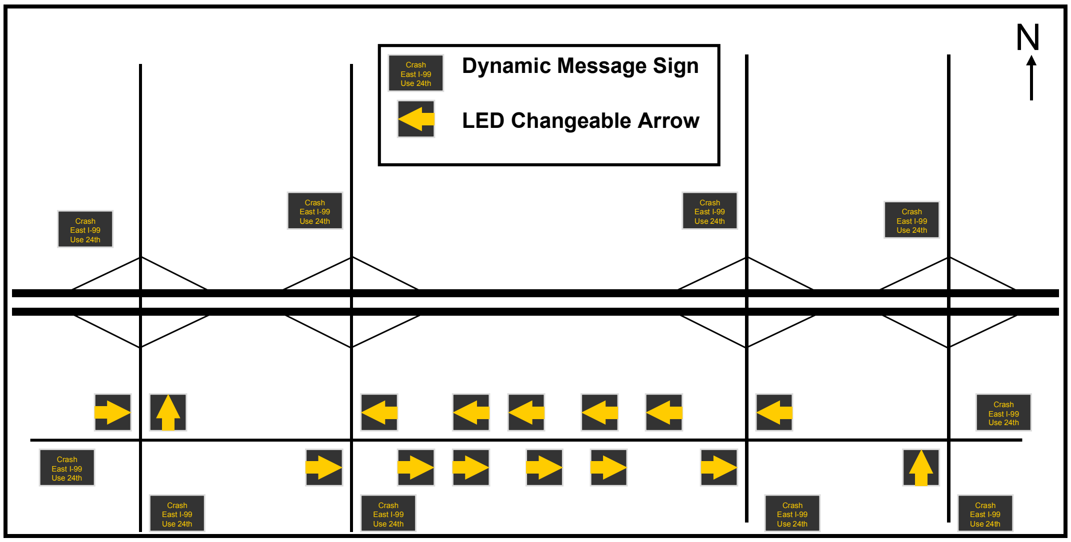

Figure 7. Arterial DMS Design for Large City, Texas

existing luminaire poles at mid-block locations when possible. These signs will be used even at locations where the arrow will never be changed, to provide a consistent format for motorists.

System Coordination

Large City has an existing traffic management center that will operate this system. Interconnection of the devices in this system to the traffic management center will be achieved through modem-based telephone communication, which is consistent with the communication used by the TMC for other technology.

CONCLUSIONS

As vehicle-miles traveled in urban areas continue to grow, cities will not be financially able to build enough capacity to alleviate this demand. Motorists traveling in urban areas are also coming to expect more and more real-time traveler information. In several cities reviewed in this research, arterial DMS systems have been shown to be innovative and effective methods of providing real-time traveler information as well as improving traffic flow. Arterial DMS systems will only become more widespread in the future as a useful traffic management tool.

When designing an arterial DMS system to provide nearby freeway condition information, it is important to consider the needs of the motorists using the information, since voluntary compliance effects the success of the system. Arterial DMS systems must operate in a very different environment than a DMS system on a freeway. An arterial system must compete with a motorist's attention with many other visual stimuli, such as traffic signals, business signs, and turning traffic from cross streets and driveways. The increased visual competition for arterial DMSs, and the potentially large number of signs required compared to freeway DMS systems, show a need for clear, concise design guidelines to prevent an inferior or ineffective system.

The guidelines developed for designing an arterial DMS system near a freeway provide a means for traffic engineers to design a system that conveys freeway condition information to motorists in an effective and efficient manner. An expert review panel was formed to critique and improve the content of the guidelines. This review process lead to improvements in the final guidelines, ensuring that the guidelines would be more useful to practitioners. The guidelines were applied to a hypothetical case study in order to illustrate the design process, which can be used by any city that requires an arterial DMS system to divert traffic in an arterial-freeway corridor.

A need exists for future research in the area of arterial DMS technology. Proper sizing of DMS characters needs to be fully developed. This researched uncovered the possibility that DMS character sizing requirements used for freeway applications may not apply on arterials. Additionally, the proper location of an arterial DMS unit should be determined. Current systems contain DMS units on mast arms, on curb-side poles, at mid-block locations, and at intersections. The operational and safety implications of these locations must be determined. Finally, the proper wording to be used on the DMS and trailblazing signs should be determined. Again, it should not be assumed that designs developed for freeway applications would apply to an arterial environment.

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- Mr. John Friebel, City of San Antonio, Texas
- Mr. Dave Kinnecom, Utah Department of Transportation
- Mr. John Thai, City of Anaheim, California

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APPENDIX A: SAMPLE TELEPHONE INTERVIEW FORMS

Interview of City Transportation Official
Date of Call:
Telephone Number:
Name:
Position:
Organization:
Direct Number:
Email:

Hello, my name is Steve Schrock, and I am a graduate student at Texas A&M University. I am conducting some independent research on the state-of-the-practice in the use of Dynamic Message Sign (also known as variable or changeable message signs) technology applied to arterial street systems.

I have been told that your city may use this type of technology on at least some of your streets, and I was hoping that there was someone there who could answer a few questions about why and how this system was installed in your city, and how it operates.

1. Is dynamic message sign technology currently in use on any of the arterial corridors in your city?

2. For what specific purpose was this DMS technology implemented on the arterial streets in your city?

3. Could you provide a description of your DMS system, such as type of DMS device(s), quantity, and placement?

4. Is this system integrated into a larger area-wide traffic management plan? If so, please describe the area-wide plan, and the part this system plays in that plan.

QUESTIONS 1-4 ARE TO BE USED IN AN INITIAL QUICK INTERVIEW. THE REMIANING QUESTIONS WILL BE USED IN MORE IN DEPTH INTERVIEWS OF SPECIFIC DMS SYSTEMS THAT SEEM TO BE RELAVENT TO THIS RESERCH.

5. What types of problems were observed in the planning and installation phase of this system that had to be overcome?

6. What types of problems have been identified during the operation of your arterial DMS system?

7. From your experience, what aspect(s) of your system do you find work especially well, and might lead you to recommend this aspect for future arterial DMS applications?

8. If were faced with the installation of an arterial DMS system in the vicinity of an urban freeway, what might you do differently today compared to the installation of your existing system? (Note that this question might focus on both new technology, and different uses of the same technology.)

9. Are there diagrams and/or pictures available of the arterial DMS system in your city, and if so, is it possible for me to obtain a copy?

10. Were implementation guidelines developed for the implementation of your system? If so, would it be possible for me to obtain a copy?

11. Were there any other documents that you found useful in developing your arterial DMS system?

12. Are you aware of any other cities that use DMS technology on their arterial streets? If so, please list these cities.

13. As part of this research, I am attempting to put together a panel of professionals with experience in implementing or operating DMS technology on arterial streets. There are really only 2 duties that I envision a panel member undertaking. First, each panel member would critique a draft of my proposed arterial DMS guidelines. Second, I am hoping to get all panel members to participate in a conference call on Thursday, July 13th, at 10:00 a.m. CDT, to share ideas on how to improve the proposed guidelines. Could I count on you to aid me in this research by participating as a panel member?

APPENDIX B: PANEL REVIEW GUIDELINE SAMPLE

These guidelines are designed to provide guidance in creating a traveler information system that would provide freeway condition information to motorists on a local street network as they approach an arterial-freeway corridor. Using these guidelines, a city engineering department, traffic management center, or state department of transportation should be able to create an effective information dissemination system. It should be emphasized that the steps, although listed and discussed individually, are interrelated.

Prior to the use of these guidelines, several issues must have already been addressed. Specifically, the need for an information dissemination system in the vicinity of an arterial-freeway corridor must have already been determined. Does this location even need such a system? If the answer is yes, then the following guidelines will be useful. Additionally, the capital funds, as well as the availability of operations and maintenance funds must already be available. These guidelines do not address how project funding is to be achieved. These guidelines presume that these issues have been satisfactorily resolved. If these issues have not been addressed, then the use of these guidelines would be premature.

Guidelines
Step 1: Clearly establish the objectives of the DMS system.
Step 2: Identify what information is necessary to be conveyed to motorists to accomplish the objectives.
Step 3: Identify the existing constraints of the arterial-freeway corridor.
Step 4: Determine the locations for the DMS technology
Step 5: Identify environmental conditions.
Step 6: Specify system characteristics.

Step 1: Clearly establish the objectives of the DMS system.

A necessary first step in this process is developing the objectives that are sought through the installation and use of this system. This step is very important because the objectives directly influence message content, format, length, and as a result, the type, size, and placement of the DMS technology. Short-term as well as long-term objectives should be examined, as the needs of the public may change as long-term network conditions change. Additionally, it must be determined which approaches to the arterial-freeway corridor are to be included in the system.

Step 2: Identify what information is necessary to be conveyed to motorists to accomplish the objectives.

With the objectives established, the type of information to be disseminated to motorists must be identified. If the information is simple, such as only a direction recommended for travel, the need for a full-text DMS may not exist; a series of LED directional arrow on a trailblazing sign may be all that is required.

If more complex messages are necessary to accomplish the objectives, text-based DMS technology should be considered. The length of the text messages will assist in the determination of character size, message line length, and the number of message signs required by the DMS technology. This will be important for the system specifications developed in Step 6.

Step 3: Identify the existing constraints of the arterial-freeway corridor.

Field inspections of the site are important to determine the existing conditions of the arterial-freeway corridor. This process can ensure that there are no physical obstructions due to existing structures such as bridges, traffic signals, or sign structures that would adversely impact the DMS system. Conversely, if these structures are in advantageous locations, they could provide opportunities for the placement of the DMS technology (Step 4), reducing the additional infrastructure needed.

Step 4: Determine the locations for the DMS technology

Potential locations for the placement of the DMS system need to be determined. These locations must allow motorists to comprehend the message with ample time to react to the message. Additionally, the components of the system must be placed so that existing traffic control and static message signs form an integrated and compatible information system. The approaches that will benefit from this system should have already been determined in Step 1. Typical installations for DMS technology include placement on existing traffic signal mast arms, existing bridges, existing sign structures, and also on newly installed mast arms or on overhead sign structures.

Step 5: Identify environmental conditions

The environmental conditions in which the information dissemination system will operate must be identified. Weather conditions such as rain, snow, wind, etc. will have an effect on the operation of the system components. Other environmental factors, such as dust, extreme heat and/or cold may have an impact on the design and maintenance of the system. These conditions should be made known to the manufacturers of the system components so that the best characteristics of the system can be achieved.

Step 6: Specify system characteristics

Based on the results from steps 1 through 5, technologies to be used to disseminate travel information should be specified. Possible technologies include, but are not limited to, full-text DMS systems, LED arrow displays, and static trailblazing signs. It is possible – even likely – that different technology would be used in different parts of the same project. For example, DMS technologies may be used on high-volume approaches, where more information could be provided to a higher volume of motorists. However, on comparatively minor approaches, simple LED arrows as guide signs may be installed to minimize cost. Additionally, the method of communication with this system must be determined. Possible options include fiber-optic, copper wire, land-based telephone, and cellular telephone communication.

Concluding Thoughts

These guidelines were only intended to cover the proper *design* of a DMS system at a typical arterial-freeway corridor. While not addressed in these guidelines, the installation, operation, public education, and evaluation stages that follow the system design are also important. Even an optimally designed system will not perform to expectations unless some thought is given as to proper training of the personnel that will operate such a system. Likewise, it should not be assumed that the public would naturally accept and understand what the system is telling them without training. An effective public education program must accompany any new traveler information system, or the system will bring confusion instead of assistance.

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A TRAFFIC DETECTION TOOL KIT FOR TRAVELER INFORMATION SYSTEMS

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SUMMARY

Congestion, particularly along urban freeways, is expected to only increase in the coming years. It is becoming more and more difficult for transportation agencies, such as Departments of Transportation, to pave their way out of congestion with additional lane-miles. More innovative solutions must be developed to delay or prevent future gridlock in urban areas.

This report identified one such innovative solution, traveler information systems (TISs). In order for TIS to be effective, the controlling agency must collect real-time, accurate traffic data that can be processed quickly and disseminated to the motorist before and during an urban freeway trip.

The modern transportation engineer has many types of vehicle detection devices available to choose from in collecting traffic data. It is important that the engineer is aware of the capabilities, the speed, the accuracy, advantages and disadvantages of each type of device in order to make an informed selection for a particular purpose.

This paper presents the currently used methods of vehicle detection and a sampling of what various state Departments of Transportation (DOTs) are using. The paper includes such valuable information as the type of data that can be collected, the accuracy of the detection devices and effective locations for placing the devices. In addition, this paper includes a case study of the research finding as applied to a section of urban freeway located in Baltimore, Maryland.

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INTRODUCTION

Today, Americans are on the road more than ever before, for business and for pleasure. Increasingly, these travelers are in need of timely and accurate information about the path ahead. Particularly on freeways near metropolitan areas, congestion is an ever-increasing problem. Studies show that 33 percent of the nation's urban interstate highways are rated poor or mediocre for congestion and the number of miles traveled is expected to grow by 30 percent over the next decade (*1*). Travelers are in need of information to help them plan the best path to reach their destination with a minimum of delay. Traveler Information Systems (TIS) service this need (*2*).

Public agencies such as state Departments of Transportation have typically taken the lead in collecting the real-time data needed for information dissemination. The public agencies are interested in collecting the most useful data at the least cost to taxpayers. Intelligent Transportation Systems (ITS) can assist in this goal. The United States Department of Transportation and ITS America have found that on average, ITS systems have an eight to one benefit/cost ratio in the nation's 75 largest metropolitan areas (*1*). One area where ITS is developing rapidly is in TIS and the traffic data collection to support TIS.

A TIS requires current and accurate field data to support the information communication with the motorist. Information disseminated by TIS must adhere to the same traffic control device principles as more traditional traffic control devices. The information must fulfill a need, be easily understood and be consistent in application and usage (*3*). The communication with the motorist can be either pre-trip or along the roadway. Examples of pre-trip information sources include commercial radio and television reports, Internet web sites, information kiosks, pagers and personal data assistants (PDA). Examples of along-the-roadway information sources include dynamic message signs (DMS) which may be either portable or fixed, highway advisory radio (HAR), cellular phone hotlines, commercial radio, citizens band (CB) radio, in vehicle video display terminals (VDT) and heads-up displays (HUD). Most of the driver information sources are passive-visual systems. Most visual systems require short messages that can only be transmitted to an individual motorist for a few seconds. Audio messages have the advantage that they can be transmitted over a range of area and for longer periods of time, allowing longer messages and more perception and reaction time (*3*).

Problem Statement

According to the Institute of Transportation Engineers, severe traffic congestion is most frequently caused by incidents. An incident may be a collision, vehicle breakdown, roadway maintenance activity or any other irregular activity or unpredictable event (*1*). A recent California study showed that each minute of off-peak delay due to a lane blockage equates to four or five minutes of additional congestion duration (*3*). Traveler information is the key to delay the onset of congestion or to help mitigate congestion when it occurs. Vehicle detection is essential to the collection, processing and dissemination of information to the motoring public. There exist many types of vehicle detection on the market today, each with the ability to collect specific pieces of data. The number of choices for data collection for TIS information may overwhelm transportation engineers. Today's ITS savvy transportation engineer may choose from inductive loop detectors, magnetometers, microwave radar, closed circuit television (CCTV) and many others to collect the speed, density and flow data necessary to pass on real-time, accurate information to the motorist.

Research Objectives

The primary objective of this research was to assist the transportation professional in choosing the most effective method of vehicle detection for a specified purpose. The detailed objectives of this research were to:

- Identify the current methods of vehicle detection available to highway organizations;
- Determine the effectiveness of the identified detection devices for collecting specific data;
- Identify the most effective locations for detection devices to collect the necessary data;
- Develop guidelines for effective data collection using the identified devices;
- Develop guidelines for effective placement of detection equipment; and
- Apply the guidelines to effectively locate detection devices on a section of urban freeway in the Baltimore, Maryland metropolitan area.

Scope of Work

This research focused on the contemporary and developing methods of vehicle detection for application in Traveler Information Systems. The research was limited to vehicle detection on urban freeways. The paper was further limited to reviewing detection methods that transportation management centers can utilize efficiently through automatic data processing methods. The author conducted interviews with personnel from various state Departments of Transportation to determine the currently used methods of vehicle detection. The application of the guidelines was limited to a section of urban freeway, I-695, in the Baltimore, Maryland metropolitan area. This section of freeway includes the influence area of the on and off ramps at the interchanges between exits 12 and 17, inclusive.

VEHICLE DETECTION DEVICES

Background

Public agencies have been collecting data on freeway traffic since the 1930s with devices such as pneumatic tubes, "electric eye" optical detectors and magnetic detectors. As vehicle miles traveled increased and technology expanded, by the 1960s agencies were using photoelectric systems, radar, ultrasonic detectors, infrared sensors, and inductive loop detectors (ILD). By the 1970s, ILDs had become the industry standard for vehicle detection. The increasing cost of ILDs, both the direct cost of installation and indirect cost of driver delays during installation and maintenance, has caused a paradigm shift toward newer technology devices to gather the same information without the disruption of flow caused by loop maintenance operations. In recent years, video detection and geographic information systems are becoming popular methods of detection (*4*). Table 1 displays the current vehicle detection devices used by various state Departments of Transportation around the United States.

Vehicle detection devices must be able to collect the data their manufacturers claim they can collect. However, just collection of data is not enough to justify the cost of vehicle detection installations. The detection devices must also be:

- Compatible with the controllers and storage systems used by the collecting agency;
- Capable of detecting moving and stationary vehicles of various shapes, sizes and colors;
- Capable of communication with decision making apparatus;
- Operable and efficient in light and heavy traffic;
- Operable under most expected weather conditions;
- Operable under all lighting conditions including day, night and the transitional periods of dusk and dawn;
- Immune to shadows, glint, reflections and glare; and
- Immune to false detections from shoulder or unmeasured adjacent lane objects and vehicles (*5*).

Table 1. State DOT Vehicle Detection Device Usage (*6*, *7*, *8*, *9*, *10*, *11*, *12*, *13*, *14*, *15*)

State	ILDs	Magnetic	Microloop	Piezoelectric	Photoelectric	Infrared	Radar	Ultrasonic	Passive Acoustic	Video Image	AVI	GPS	Other?
Arizona DOT	U							U					
California DOT	U	U	T	U			T			T			
Connecticut DOT	U						U			U			
Georgia DOT							U			U	U		
Illinois DOT	U						U			U			*
Maryland SHA	U						U			U			
Massachusetts Highway Dept.	U						U						
Massachusetts, Central Artery Tunnel Project	U									U			
Michigan DOT	U						T			T			
Minnesota Guidestar						T	T	T		T			
New Jersey Turnpike	U						U			U			
New York DOT	U						U		U	U	U		
Oregon DOT	U									T			
Pennsylvania DOT	U			U			U			T			
Texas DOT	U					T	U	T		U	U		
Utah DOT	U						T			T			
Virginia DOT	U						U		U		U		
Washington State DOT	U						T			T			

U = Currently in use within the state
T = Currently under test within the state
* Illinois is testing cellular telephone triangulation

There is a multitude of vehicle detection devices available to the transportation engineer. The various types of vehicle detection devices can be categorized based on similar operating characteristics. The categories are in-pavement devices, roadside and overhead devices and in-vehicle devices.

In-Pavement Devices

In pavement devices are devices that are typically installed within the pavement section of the travel lane. The detectors can be located at various depths within the pavement, from lying across the top of the pavement to saw cut a few inches into the pavement to below the subgrade layer of the pavement section.

Inductive Loop Detectors (ILD)

Loop detectors are considered a mature device; highway agencies have been using loop detectors successfully for over 20 years. Much is known about their operation, capabilities, advantages and disadvantages. An inductive loop detector is composed of one or more turns of a loop wire installed within the pavement, connected to a lead-in cable, which in turn is connected to an electronic receiver. A current is passed through the loop wire, creating an electromagnetic field about the wire. A metallic body such as a vehicle passes over the detector, producing a change to the electromagnetic field of the loop. The change is registered as a vehicle passage or presence (*16*).

Individual ILDs are capable of measuring the passage of a vehicle over a particular point, the volume, and time occupancy. If one adds a second loop detector a known distance from the original (known as a speed trap), one can measure the vehicle's speed, as well as detect changes in vehicle behavior (i.e. slowing for an incident, increasing speeds), some classification of the type of vehicle and wrong way movement detection (*16*). A single loop detector is typically 95 percent accurate but can vary by as much as 20 percent with failure rates between 5 percent and 15 percent if not properly installed and maintained (*4*, *17*). Loop detectors have been and continue to be one of the least cost alternatives available with a 10-year life cycle cost of nearly $7,700 (*4*).

The disadvantages of ILDs have been well documented over the decades of use. Improper installation can cause large errors in readings or no readings at all. As ILDs are in-pavement sensors, the roadway must be blocked during installation and maintenance activities, causing motorist delay and risking the safety of the workmen. If a pavement is in poor condition, the loop detector cannot be installed without first repairing the roadway. Loop detectors cannot be effectively installed in reinforced concrete such as a bridge deck nor in pavements where the iron content of the surrounding soil is high. Buried high voltage lines can sometimes lead to mistaken signals. Trucks with a higher than average body can sometimes be misinterpreted as two consecutive small vehicles, closely spaced. Motorcycles can be missed for detection if the sensitivity of the detector is too low. Relocation of the loop detector is difficult and typically more costly than replacement. Crosstalk, the interaction of two individual loop detectors, can lead to double counting. The minimum distance recommended for pairs of loop detectors is 24 inches for low sensitivity, 36 inches for medium sensitivity, and 48 inches for high sensitivity (*18*).

Magnetic Detection Systems

There are two primary types of magnetic detection systems. They are magnetic detectors and magnetometers. Magnetic detectors are passive sensors made up of dense wire coiled around a magnetic core. Magnetic detectors operate by detecting field interruptions in the Earth's magnetic field. The movement of large metal objects causes the interruption, typically caused by a vehicle passing over top of the detector. Magnetometers are active detectors that are made up of sensor coils in a cylindrical shape. The cylinder can be embedded into the pavement or installed under a bridge deck. Magnetometers operate similar to magnetic detectors except that they create a local magnetic field and measure the interruptions created within the detection zone (*5*). Both types of magnetic detection systems can measure the same data as loop detectors but can be installed in places where loop detectors would fail such as in areas of high ferrous soil and reinforced bridge decks. The disadvantages of magnetic detection systems is that they cannot be operated too close to another similar detector, limiting their speed measurement capabilities, and they can sometimes double count trucks or discount motorcycles (*4*). One other challenge of magnetic technology devices is that the local metals at the location of installation must be known and accounted for prior to activating the system (*5*). The average cost of magnetic sensors ranges from $500 to $1700 (*15*).

Microloop Detectors

Microloop detectors are compact sensors that are embedded into the subgrade of the roadway. They are made up of compact coils of wire that conduct a charge if activated. The electrical current induced by the charge is measured and recorded as presence. Microloop detectors are capable of many of the same measurements as traditional loop detectors, but tend to require multiple detectors per lane due to the narrow focus of the detection field (*4*). The cost for microloop detectors is estimated at $5,000 per lane for a triple probe set (*15*).

Piezoelectric Sensors

Piezoelectric sensors utilize polymer molecular chains, ceramics or crystals that create a charge when deformed. A strip of piezoelectric cable transforms the mechanical energy of deformation into electric energy in the form of an electric charge. This charge can be measured for strength and duration. Piezoelectric detectors are capable of measuring presence, volume and occupancy, similar to ILDs. These sensors are best at detecting vehicle classification as well as vehicle weight (*5*). One disadvantage is a lack of durability.

Roadside and Overhead Devices

Roadside and overhead devices are vehicle detection devices that operate most efficiently when installed adjacent to the roadway or overhead of the travel lane. They are typically installed within a few lateral feet of the roadway and not more than 30 feet above the pavement (*19*).

Photoelectric Sensors

A photoelectric sensor utilizes a photocell to detect vehicles. If sufficient light continuously hits the photocell, no detection is registered. If that light source is blocked, occupancy is registered. Typically, photoelectric sensors utilize infrared light from LEDs because the light intensity is higher than light in the visible spectrum. The major disadvantage is that the source and photocell must be completely unobstructed except for vehicle passage. Weather and distance can affect the operation of photoelectric sensors. Fog and heavy precipitation can create false detections by blocking or scattering the light prior to detection at the photocell. If the light beam travels great distances, small discrepancies in the beam projection angle will produce increasingly more false detections due to the light never reaching the photocell (*5*).

Active Infrared Detection Systems

Active infrared detectors operate similar to photoelectric sensors in that the detection is measured as the interruption of a beam of light. The desired detection zone is illuminated with low power infrared energy emitted by an LED or a laser diode. Vehicles passing through the zone interrupt the signal and a detection is measured (*5*). The detector can measure vehicle height and length, presence, count, speeds and classifications. An advantage of the active infrared systems is their ability to operate under multiple lighting conditions, from day and night to dawn and dusk. Their disadvantages include beam scattering during heavy fog and dust, inconsistent beams caused by shadows, sunlight glint and precipitation, and equipment sensitive to dust, moisture and other contaminants. The approximate cost for the device is $6,500 (*15*).

Passive Infrared Detection Systems

Passive infrared detectors can collect much the same information as active infrared detectors with the exception of speed measurement. The passive detector measures the change in thermal energy within the detection zone. Vehicles' heat signatures are measured against thresholds as detections. Obvious disadvantages include hot pavements and high ambient air temperatures as compared to vehicles that have not gotten hot enough to be detected. As such, these detectors are not practical in warmer climates (*5*). The approximate device cost is $1,400 (*15*)

Microwave Radar Sensors

Microwave detection sensors utilize a microwave beam that is directed toward vehicles in the traffic stream and reflected back to the device. The device measures the rebound time of the waves and calculates the speed of the vehicles, taking into account the Doppler effect (*5, 15*). These radar detectors can measure presence, count, and speed data across multiple lanes. They can be placed either above or alongside the roadway, for easy maintenance. They are also easier to install than ILDs. The capital cost for radar detectors is higher than for loop detectors but radar units tend to be more durable over time (*15*). Estimates for the device cost average $3,500 per unit (*17*). Doppler microwave units are able to measure volume, occupancy and speed similar to microwave radar units at a significantly lower cost, averaging $400 to $600 per unit (*15*).

Ultrasonic Detector Systems

Ultrasonic detectors are similar to radar detectors in that they measure the time difference between transmitted wave and rebounded wave. The difference between the two detector types is that the energy beam is a sound wave rather than a microwave (*5*). Ultrasonic detectors are designed to be installed overhead within five to six meters of the roadway surface (*19*). Although data suggests that ultrasonic detectors are becoming more accurate in speed measurement, they are still not as accurate as loop detector speed traps. Another disadvantage of ultrasonic detectors is that ambient noise can affect the function of the detector. This fact makes ultrasonic detectors a poor choice for urban applications.

Passive Acoustic Detection Systems

Passive acoustic detectors are considered "listening" devices. An array of microphones is aimed at the traffic stream to pick up the sounds produced by passing vehicles. The controller processes each vehicle sound and determines the traffic stream characteristics of flow, volume, lane occupancy, and average speed (*5*). Future controllers may also be able to classify vehicles based on their unique sound patterns. In live tests, the acoustic detectors were accurate to plus-or-minus ten percent when compared to loop detectors. Passive acoustic system installation averages $3,500 per unit (*15*). One disadvantage of passive acoustic systems is that the highly specialized equipment involved requires highly trained technicians for maintenance.

Video Image Detection Systems

Video image detection systems are seen as the next leap in traffic detection equipment. The system utilizes a camera image and video image processors, also known as machine vision to analyze and detect vehicles (*20*). The image detection system can collect, analyze and record vehicle length and classifications, speed, lane occupancy, time headways per lane and volume (*16*). With the proper software, the video images can also produce travel times and density (*5*). Early models of video image systems utilized user-defined detection zones within the camera's field of view, known as a tripwire system. Similar to ILDs, when vehicles cross the detection zone, a presence is detected. One camera can produce multiple detection zones, allowing one camera to replace multiple lanes of ILDs. In addition, cameras may be installed with one to two mile separations, allowing fewer detectors to do the work of many ILDs (*3*). Video image systems operating through closed circuit television cameras (CCTV) can relay either full video images or simply the data extracted by the controller to a traffic management center for further processing, such as incident detection or congestion monitoring. The future of video imaging will utilize vehicle tracking to follow specific vehicles in the traffic stream and predict their future locations downstream. As software systems continue to develop, the capability of these systems will continue to grow (*3, 15*). The direct costs associated with video detection installation are far greater than the direct costs for a single ILD installation. If indirect costs such as maintenance, requirement for multiple detectors across multiple lanes and motorist delay for lane closures are factored in, video detection can be 1.2 to 18.4 times less expensive (*16*).

In-Vehicle Devices

In vehicle devices are vehicle detection devices that are physically located within the vehicle being detected. Typically these devices are some type of transceiver or transponder that can communicate with a central processing office via radio antenna. This technology utilizes each vehicle as a probe within the traffic stream. When the probe's data are compiled, an assumption is made that the probe is typical for any vehicle within the traffic stream.

Automatic Vehicle Identification Systems

Automatic Vehicle Identification (AVI) involves the use of a transponder inside target vehicles that communicate with roadside radio antenna. The transponder receives a signal demanding its identification. The transponder transmits its unique information and the system can track the vehicle from one radio tower to the next. Agencies can measure headways, volume by lane and speed of tracked vehicles. Often the transponder doubles as an electronic toll collection card, as in the E-ZPass tag system currently in use in New York and New Jersey (*21*).

When E-ZPass tags pass a roadside terminal, the tag reader at the terminal sends a signal to interrogate the E-ZPass tag. The tag then transmits its identification to the terminal. The terminal than sends the tag's identification, location, lane position and time at detection to a traffic management center. The vehicle travel times between successive roadside terminal interrogations can be measured for the probe vehicles to determine average speeds and incident detection. There are more than 1.5 million vehicles currently equipped with E-ZPass in New York, New Jersey and Connecticut. The terminals are located every 0.5 to 2.1 miles along the Garden State Parkway and the New York State Thruway (*21*). The more vehicles that have transponders, the more accurate the information becomes. Unfortunately, the disadvantage of the system is the limited number of vehicles equipped with transponders can lead to erroneous measurements.

Global Positioning System Detection

Similar to AVI systems, the Global Positioning System (GPS) system utilizes probe vehicles with transponders; in this case, GPS locators. The GPS locators track a vehicle's movement and transmits the vehicles' locations continuously. Traffic management centers can measure speeds with a three- percent margin of error using probe tracing. One disadvantage of GPS systems today is that there are not enough vehicles in the traffic stream with GPS locators. In addition, GPS may not be very reliable if the small percentage of vehicles with GPS do not reflect the diversity of driver types (i.e. aggressive drivers, slow drivers, etc.) (*22*).

Table 2. Qualitative capabilities of current vehicle detection technology

Detector Technology	Presence	Occupancy	Volume	Speed	Multilane Coverage	*Cost Comparable?	Other
Inductive Loop Detectors	D	D	D	I	No	N/A	
Magnetic	D	D	D	I	No	Yes	
Microloop	D	D	D	I	No	Yes	
Piezoelectric	D	D	D	I	Yes	No	WIM, Class.
Photoelectric	D	D	D	I	No	No	
Active Infrared	D	D	D	D & I	Yes	Yes	
Passive Infrared	D	D	D	I	No	Yes	
Radar	D	D	D	D	Yes	Yes	
Ultrasonic	D	D	D	D & I	No	No	
Passive Acoustic	D	D	D	I	No	No	Class.
Video Image	D	D	D	D	Yes	No	Class.
AVI	D	D	D	D	Yes	No	Class.
GPS	D	D	I	D	Yes	No	Class.

Key: D = Direct measurement of data
I = Indirect measurement of data via calculations based on measured data
WIM = Weigh in Motion
Class. = Vehicle Classification

*Cost comparison based on inductive loop detectors

EFFECTIVENESS OF VEHICLE DETECTION DEVICES

Transportation agencies collect data to plan, design and support the goals of the agency. The data collected is classified into three categories; tactical, strategic and historic (5). Tactical data are collected over short time periods for stimulus-response decision making. An example of tactical data is volume counts at regular intervals along a freeway upstream of an on-ramp to complete a ramp-metering algorithm. Strategic data are broader in scope than tactical data. Strategic data are a compilation of individual measurements, averaged over longer time periods to support decisions to develop more efficient, immediate operations. An example of strategic data is the use of speed and volume data to determine the appropriate message for a Dynamic Message Sign (DMS). Historic data are data collected over longer periods of time for comparison with similar time periods from previous days and weeks. Historic data are traditionally used for future planning purposes. An example of historic data is average daily traffic (ADT) counts.

The data that are typically collected are the common traffic parameters of flow, density and speed. Flow is a measure of the number of vehicles passing a single point over a fixed period of time, for example, vehicles per hour. Flow is often referred to as volume. Density is a measure of the number of vehicles within a fixed area of the roadway, for example vehicles per mile per lane. Density is often measured as lane occupancy. Speed is a measure of the distance traveled by a vehicle over a fixed time period, for example, miles per hour. There are various types of speed measurement. Speed can be measured at a specific point along the roadway to give a spot speed of each vehicle. Time mean speed is the average over time of the spot speeds at the specific point. Speed is inversely related to the travel time, which is a measure of the time a vehicle requires to travel a fixed distance, for example minutes per mile. The average of the travel times across all vehicles on the roadway is called the Space mean speed. The relationship between space mean speed and time mean speed is that time mean is the arithmetic mean of the spot speeds while space mean is the harmonic mean of the spot speeds. Future vehicle detection devices will not likely require new traffic parameters. Rather, advanced detector technologies will provide greater area coverage with better vehicle characterization increased reliability and reduced costs (5).

According to ITS transportation professionals, the most important data to collect via vehicle detectors are average travel speed or average running speed, lane occupancy, and volume (3). These strategic data are most easily manipulated into useable information (5). Many of the state Departments of Transportation representatives stated that these strategic data might be utilized in detection algorithms to produce incident detection alerts. When utilizing data to produce incident detection alerts, the accuracy of the vehicle detection device becomes a priority. Table 2 shows the desired accuracy for various types of data. The traveler information system can then communicate slow speeds, congestion, or incidents ahead. Many vehicle detection devices are able to collect other data as well, to be utilized for other purposes. Some vehicle detectors are more successful in gathering accurate and reliable data than others.

Table 3. Accuracy of Current Data Collection Methods (3)

Data Type	**Accuracy**	
	Desired	Current Capability
Speed	+/- 2%	+/- 5%
Flow	+/- 2.5%	+/- 5%
Vehicle Miles Traveled	+/- 5%	+/- 30%
Classification	+/- 2%	+/- 5%
Weight	+/- 2%	+/- 15%
Origin/Destination	+/- 5%	+/- 50%

One aspect of detection device effectiveness is not directly related to the device. In order for a device to be as effective as the manufacturer suggests, the device must be properly maintained. Transportation agencies must manage both the capital program for the installation of the detection devices and also the equipment management costs for maintenance and upgrade. As the devices become increasingly sophisticated, maintenance activities require more specialized skills than many agencies are equipped to handle. As a result, minimal maintenance is performed which can lead to the degradation of the data output. When this occurs, the additional costs associated with the added value of more sophisticated equipment is lost (23).

Another aspect of detection device effectiveness is the number of devices necessary to accurately measure a traffic parameter at a particular site. When weighing the benefits and costs of various detection devices, it is important to understand how many of the devices are needed for the freeway segment being measured. Some devices can only measure a single lane of traffic at a time. Other devices can measure all lanes in the same direction at a particular point. Others still require multiple devices for measurement within the same lane (5). This fact becomes potentially more important on urban freeways, where typically the number of lanes exceeds two in each direction.

In-Pavement Devices

Inductive Loop Detectors

Inductive loop detectors are the industry standard for data collection. Agencies have been collecting data using loop detectors for over 20 years with only minimal associated problems. ILD are very successful in inclement weather (15). One of the most challenging issues with ILDs is the direct and indirect costs for maintenance activities. Typical installations of ILDs are expected to last two to five years before first maintenance (*17*). A study of the Illinois Department of Transportation revealed that five percent of the loops in the field were inoperable at any given time. Officials attribute this success rate to a regular maintenance program that is costly (*15*).

Magnetic Detection Systems

The magnetic detection systems are similar in effectiveness to ILDs. The advantages of magnetic detectors are the compact design that allows for ease of installation and the ability to be utilized in locations where ILDs are impractical, such as in bridge decks. One disadvantage of magnetic detectors is that they cannot detect unmoving vehicles. The detection must be measured as a moving body over the device. Also, speed traps are difficult for speed measurement because the proximity of devices tends to result in interference between the two detectors. Magnetic detectors are also sensitive to weather conditions such as rain and snow. Magnetometers have similar effectiveness characteristics to magnetic detectors (*15*).

Microloop Detection Systems

Microloop detection systems are similar in effectiveness to ILDs. The advantages of microloops are their relative speed of installation, capability of being located below the pavement, and less use of wire. The disadvantages of microloops are the difficulties with installation due to highly sophisticated installation procedures and the narrow effective detection field. Often, the use of multiple devices is required for an accurate reading (*15*).

Piezoelectric Detection Systems

Piezoelectric detectors are effective for measuring presence and volume in addition to classification and weigh-in-motion. One disadvantage of piezoelectric detectors is the material deformation memory. Once the device has been in use for a period of time, the piezoelectric material will develop a deformation memory that allows it to hold the deformation rather than return to its previous state. This memory requires that the device be regularly maintained and recalibrated (*3*)

Roadside and Overhead Devices

Photoelectric Detection Systems

Photoelectric detectors have been found to be less accurate than ILDs at speed measurement, occupancy measurement and volume counting. The main problems with photoelectric systems are inaccuracy during inclement weather and miscounts during day/night transition periods (*3*).

Infrared Detection Systems

Both the active and passive infrared detection system have been found to be accurate to one mile per hour for speeds up to 70 miles per hour in a detection range of 5 to 50 feet (*15*). Infrared technology has been found to be particularly useful in daylight, at night and in the transition periods between. Newer units are unaffected by passing clouds, shadows, fog and rain, however older unit accuracy begins to break down under these weather conditions (*5*)

Microwave Radar Sensors

Microwave radar sensors have been found to be accurate to two to three miles per hour at speeds up to 85 miles per hour (*15*). Radar systems are one of the most accurate and efficient methods for collecting speed data. Volume counts have been tested to be accurate to two percent. Microwave radar is also one of the best data collection tools during inclement weather. Doppler radar detectors are accurate to one to three percent for volume measurement. Variations in measurement are often attributable to poor aiming of the device. In addtion, Doppler microwave radar has been found to be the best overall performer for collecting speed and volume data, except when the data involve stopped vehicles (5). Radar devices are often unable to detect stopped vehicles and measure occupancy (4,).

Ultrasonic Detection Systems

Speed measurement with ultrasonic detectors has been found to be accurate to ten percent with a detection range of between 5 and 26 feet (15). Pulsed ultrasonic detection has been found to be the most effective method for collecting detections and classification in rural settings (5). Ultrasonic devices require a high level of sophisticated maintenance, which makes them impractical for occasional use. Flow accuracy is similar to ILD characteristics. Ultrasonic devices are less susceptible to environmental conditions than ILDs (17)

Passive Acoustic Detection Systems

Passive acoustic detection systems are less effective than ILDs at speed detection. They can be made less effective if installed in areas with high echo potential, such as under a bridge deck (15). Typically, acoustic systems vary up to ten percent as compared to ILDs. They are, however, unaffected by inclement weather other than the densest fog (3). The device tends to undercount volume along freeways.

Video Image Detection Systems

Video image processing systems have two classifications. The first is a trip wire system. Trip wire speed measurement varies from one to five percent for speeds up to 80 miles per hour (5). Volume counts range from one to five percent accurate. Trip wire systems are able to operate in many directions and from various locations relative to the roadway. One disadvantage of the system is glare and headlight usage. As the system relies on contrast from the background, light glare floods the image to remove contrast and create false or missed detections at night.

The second classification, tracking systems, have the advantageous abilities to handle shadows effectively, handle vehicular lane changes and separate headlights for individual vehicles. The disadvantages of tracking systems include sensitivity to vibration of the camera, difficulty identifying highly aerodynamic vehicles, and the preliminary data requirements to program the detector.

In comparison, trip wire systems perform better for counting while tracking systems perform better for speed measurement. Both types of video detection have the added advantage of flexibility and multiple detection zones (4). In addition, both can directly measure all three traffic parameters of flow, density and speed directly. If video images are included in the TIS, video detection has the additional benefit to the motorist to allow each driver to see the traffic data directly through visual inspection and make more informed and personal pre-trip decisions (11).

In-Vehicle Devices

Automatic Vehicle Identification Systems

AVI systems are able to effectively record headways, volumes by lane and location, and estimated volume counts. The volumes are only estimated because the data rely on estimates of the market penetration for the transponder device, often an automatic toll collection unit. As the system becomes more mature, the future will bring origin and destination tracking as well as vehicle classification. The primary disadvantage of the system is the limited number of vehicles equipped with transponders (3).

Global Positioning System Detection

GPS systems are able to independently track each equipped vehicle for volume, lane location and speed continuously. The volume is estimated based on the estimated number of equipped vehicles. GPS velocity measurements are accurate to less than three percent of speedometer velocity measurement (22).

Similar to AVI, as GPS locators become more commonplace in vehicles, the ability of GPS tracking to collect vehicle roadway data will continue to increase.

Table 4. Summary of Vehicle Detection Device Effectiveness

Detector Technology	Average Speed	Lane Occupancy	Volume	Other?
Inductive Loop	High (in pairs)	High	High	
Magnetic	Moderate	High	Moderate	
Microloop	High (multiple)	High	High	
Piezoelectric	High (in pairs)	Moderate	High	High for WIM and classification
Photoelectric	Low	Low	Low	
Infrareds	High	High	High	
Radar	High	High (except stopped vehicles)	Moderate	Multi-lane coverage
Ultrasonic	Moderate	High	High	
Passive Acoustic	Moderate	High	High	
Video Image	High	High	High	Multi-lane coverage
AVI	High *	Moderate *	High *	
GPS	High *	High *	High *	

*If market penetration is significant

GUIDELINES FOR DETECTION DEVICE SELECTION

Traveler information systems require the collection of current traffic data to be processed into driver information. When choosing the type of vehicle detection device to be utilized for data collection, there are many questions that first need to be answered.

- What are the traffic characteristics of the site? (heavy or light traffic, urban or suburban setting, etc.)
- What type of data should be collected?
- How quickly does the data need to be processed and disseminated to the public?
- How does this site fit into the overall approach to congestion management in the locality?
- What is the budget for the vehicle detection installation?
- What is the expected maintenance budget for the life of the devices?
- What level of skill is required for maintenance of the devices?
- Can the chosen device be integrated into the local system(s)?

The answers to these questions will lead to the selection of the best vehicle detection device for the particular site application. For example, if the device is to be installed with minimal future maintenance needs and very little interruption of traffic flow, a device such as a microwave radar detector, mounted in the side-fire capability might be most appropriate. If however, the device must be integrated into the local system and the local system is only capable of using data from ILDs, then ILDs become the obvious choice.

The preceding questions can be revised into guidelines for the selection of the best detection device for a particular application. The transportation professional must analyze the needs of the collecting agency based on the purpose of the data to be collected.

1. Determine the purpose and type of data to be collected.
2. Narrow device alternatives to only those devices that can provide the data required.
3. Narrow device alternatives to only those devices that can be installed within the budget allotted.
4. Narrow device alternatives to only those devices that can be integrated into the existing system(s).
5. Determine the secondary data that each device can provide for other purposes.
6. Review the skill level of the maintenance personnel for ability to maintain each device.
7. Conduct cost/benefit analysis on each of the remaining alternatives, including the secondary data collection that each device can perform, the life cycle maintenance costs and the cost of training personnel in maintenance of the device.
8. Ensure that the device is consistent with the overall approach to vehicle detection within the area.

DETECTION LOCATION

Once the most effective method of vehicle detection is determined, the transportation engineer must decide on the most effective location for that detection device. The type of data that is being collected defines the most effective location. For accurate volume counts, the detection device should be located along the mainline freeway upstream of an on-ramp and along the on-ramp. For accurate occupancy data, the detection device should be located where lane changing is minimized. Often, this is along tangent sections away from the influence of on- and off-ramps. For speed measurement, many locations along the freeway are adequate. However, if the traveler information system reports incident information, locating the detection device where speeds can vary based on volume changes is advantageous. This would include locating the devices along the mainline roadway upstream of on-ramps, as well as along tangent sections in advance of interchanges.

Guidelines for Effective Detector Placement for Urban Freeways

Based on discussions with state Departments of Transportation representatives (*4-14*, *17*), some common detection device locations were determined (*24*). As some detection devices are able to measure the traffic stream from a distance, the location of the device is less important than the location of the detection zone, the area of the roadway that the device measures. The primary locations for detection zones along freeway sections exclusive of interchanges included:

- Downstream of major interchange locations (i.e. freeway to freeway interchanges);
- At regularly spaced intervals along freeway segments (one third to one half mile spacing was considered to be the rule of thumb for incident detection); and
- A few miles in advance of known trouble spots on the freeway.

The primary locations for detection zones along freeways within interchanges included:

- Immediately upstream of on-ramps;
- Under overpasses (for overhead device installations); and
- Along on-ramps upstream of the merge point.

SAMPLE APPLICATION OF PROPOSED GUIDELINES

Metropolitan Baltimore, Maryland experiences heavy congestion regularly during the peak periods of 7 AM to 8:30 AM and 3:30 PM to 6:30 PM. One of the most congested urban freeways in this area is I-695 (AKA Baltimore Beltway). I-695 is a four to ten lane loop freeway that encircles Baltimore City. One section of this Beltway that is notorious for AM and PM congestion is the southbound section from Exit 17 Security Boulevard south to Exit 12 Wilkens Avenue. This section is 6 lanes wide with six to twelve foot median shoulders and ten-foot right shoulders. The roadway has multiple grade changes and 55 mph curves. Within the section is a freeway to freeway interchange with I-70, a major east-west route. South of Exit 12 is another major freeway to freeway interchange for I-95, a major north-south route.

Maryland State Highway Administration is responsible for collecting all data used to support the TIS. The Coordinating Highways Action Response Team (CHART) manages the TIS program. Current information dissemination methods within the study section include a DMS and a HAR station. The pre-trip information dissemination methods include interaction with radio and television stations and an Internet web page with a color-coded congestion map and live CCTV full motion camera views.

Data to be Collected

State Highway Administration collects primarily speed data to support the traveler information system. The speed data is used to determine a measure of congestion that can be displayed on the color-coded map found on the Internet website. When the speed data reveals that vehicles are slowing, investigation is made to determine if an incident has occurred. The location of incidents is a primary message given to motorists via the DMS and the HAR within the study limits. Internally, the Administration also collects data on continuing work zone areas. The DMS and HAR display messages relating to the on-going construction activity in the area.

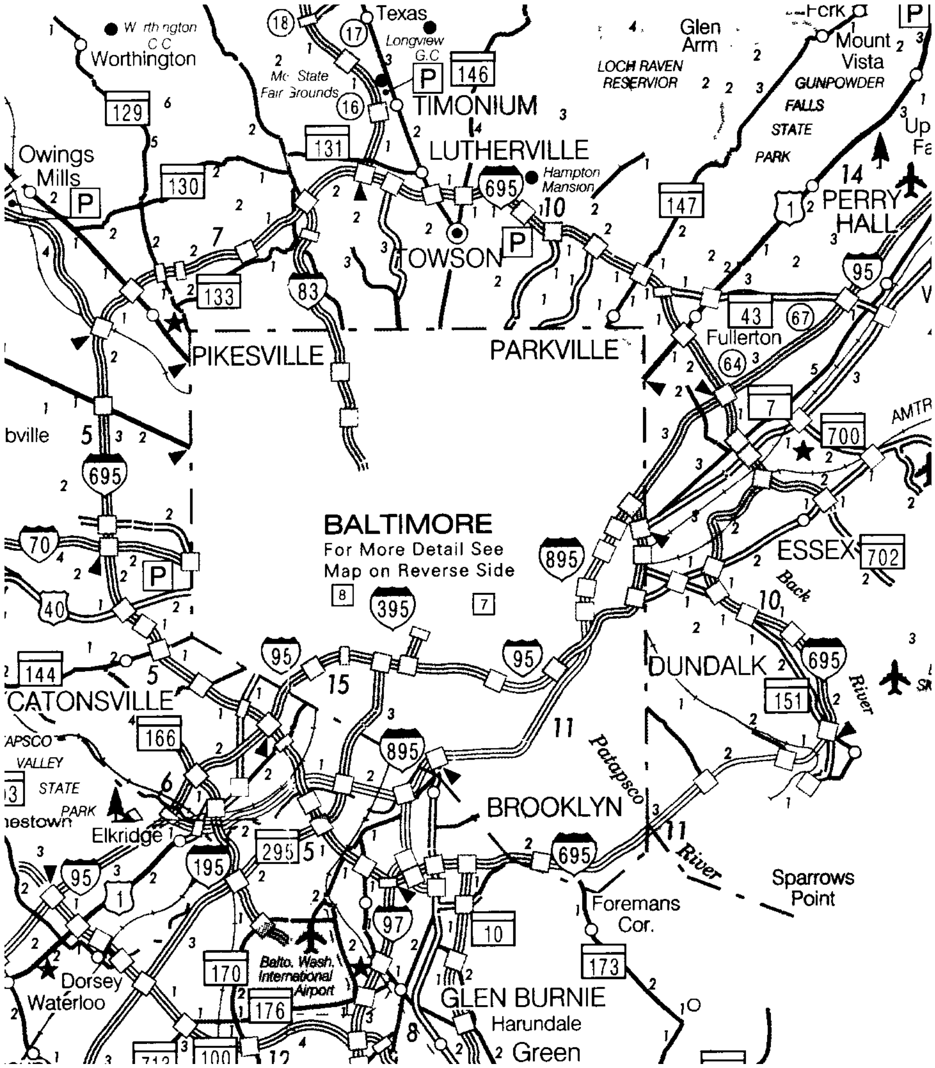

Figure 1. Map of I-695 in Relation to Baltimore City, Maryland

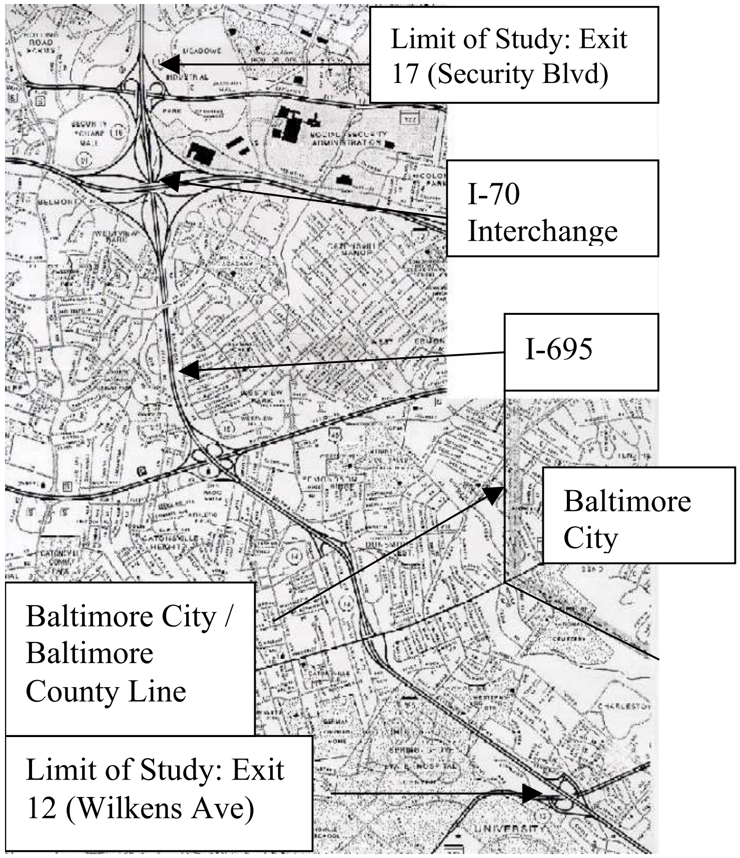

Figure 2. Map of Case Study Freeway Section

Vehicle Detection Device Selection

As speed is the primary data collected, the Administration should choose the best alternative for speed data collection. The functional requirements of the device are that the device should be able to collect speed data directly, be impervious to weather conditions, be relatively easy to maintain without having to close lanes, and be cost effective.

Following the proposed guidelines for device selection, the first step is to determine the purpose and need for data collection. In the case study, the purpose for data collection is to support the existing TIS capabilities within the study section. The second step in the guidelines is to remove alternatives that are not effective in collecting speed data. The unselected alternatives are:

- Magnetic detectors (spacing limitations);
- AVI systems (market penetration is low); and
- GPS transponders (market penetration is low).

The third step is to remove alternatives that can be installed cost effectively. The following alternatives were unselected due to their cost for materials, installation and general maintenance:

- Piezoelectric sensors;
- Microloop probe detectors;
- Ultrasonic detectors; and
- Passive acoustic detectors.

The fourth step is to remove alternatives that cannot be integrated into the system. For this case study, it is assumed that all equipment can be integrated. The next step is to determine the additional information that each remaining alternative can provide. Table 5 displays the additional capabilities of the remaining alternatives.

Table 5. Case Study, Step Five: Device Capabilities

Detection Device	Additional Capability
ILDs	presence, volume, wrong way movement detection
Photoelectric sensors	presence, volume
Active Infrared devices	presence, volume, vehicle height and length (classification)
Passive Infrared devices	presence, volume, vehicle height and length (classification)
Microwave radar devices	presence, volume
Video Image systems	presence, volume, vehicle height and length (classification), headways, incident verification

Table 5 shows that ILDs, infrared devices and video image systems provide value-added capabilities to the speed, presence and volume data that photoelectric sensors and microwave radar devices can provide.

The next step is to review the skill level required for maintaining the remaining devices. ILDs and microwave radar devices require the least skilled maintenance. Video image systems and photoelectric sensors are the next most sophisticated devices. Infrared devices require the highest level of skill for maintenance.

Once the maintenance needs are determined, the guidelines require a cost-benefit analysis. As actual costs are not available, relative costs will be used to determine device weighting. The relative costs are determined as the summation of the unit costs, the installation costs, the delay costs for lane closures, and the long-term maintenance costs. The result is, from highest cost to least cost, active infrared devices, passive infrared devices, photoelectric sensors, ILDs, video image systems and microwave radar systems.

The final step to selecting an alternative is to ensure that the selected device(s) is consistent with the agency's overall approach to data collection. The selected devices are microwave radar systems with video image detection verification for incidents. As the goal is to collect speed data quickly and efficiently while maintaining no interruptions in traffic flow, this option is acceptable. The added value of the video image cameras is to allow for incident verification.

Detection Device Location Discussion

Once the devices are selected, they need to be located effectively along the freeway. According to the guidelines, the locations for the microwave radar units (MR) and video image detectors (VID) should be as shown in Figure 3.

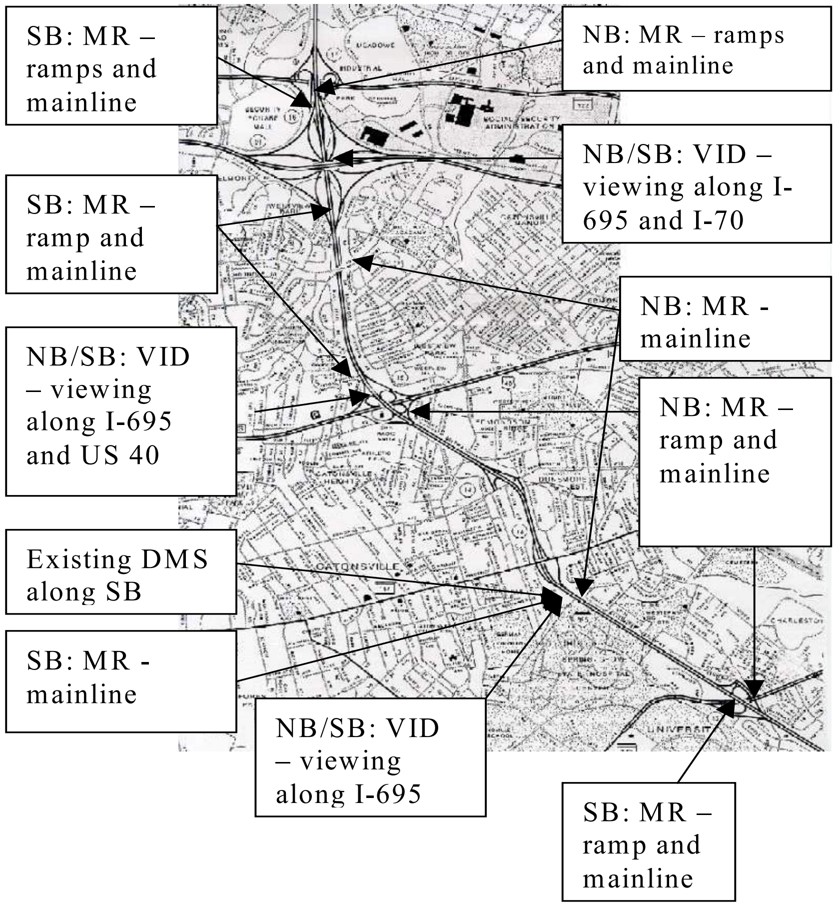

Figure 3. Location of Detectors along I-695

CONCLUSIONS

The modern transportation engineer has a multitude of vehicle detection devices available for data collection to support TIS. Each device has its unique capabilities, advantages and disadvantages. The most common device is the inductive loop detector, which has been used extensively throughout the United States for over 20 years. As technology has grown, more methods of vehicle detection have been developed including magnetic devices, infrared devices, sonar and acoustic devices, and transponder tracking systems. In the future, video systems, AVI and GPS will likely be the detection devices that become the industry standard for vehicle detection.

To select a device for a specific purpose, the engineer must first determine what the goal of data collection should be. Traveler information systems require real-time, accurate traffic data to be processed into useful and understandable information. Most systems require data of the basic parameters of traffic operations; flow, density and speed. When it has been determined what data needs to be collected, the narrowing of alternatives begins. The devices that cannot accurately, quickly and cost effectively produce results are removed from consideration. Devices that cannot be integrated into the agency's program are also removed from consideration. Some vehicle detection devices have other benefits such as ability to provide classification counts, incident detection verification and multi-lane functionality. Some devices will be removed from consideration due to their sophisticated maintenance needs. The costs and benefits of the remaining alternatives should be analyzed and prioritized to clearly indicate the best alternatives. Once a selection is made, it is important to go back to the beginning of the selection process to ensure that the device will meet the goals of the project and the supporting agency.

Once a device is selected, location becomes the key to successful implementation. The device should be located along or in the roadway in order to utilize its capabilities most efficiently. Common locations for detection zones are along tangent sections, within major interchanges, upstream of on-ramps and upstream of locations that are known congestion trouble spots.

There are many vehicle detection devices available today and technology will likely allow for many more in the future. As each new vehicle detection method is developed, it is important that the transportation engineer becomes aware of the capabilities, advantages and disadvantages of the new method. Only a fully informed transportation professional can choose the most efficient and cost effective detection device to support the traveler information system.

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DECISION PROCESS FOR DETERMINING THE USEFULNESS OF ROAD PRICING

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Advanced Surface Transportation Systems

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SUMMARY

Road pricing has generated considerable interest in the United States over the last ten years because of its potential to relieve congestion, improve the economic allocation of resources, reduce travel demand, encourage mode shifts, improve air quality, and provide an additional revenue stream for making system improvements. Economists have argued for road pricing for over 40 years, and have produced considerable amounts of literature on the subject. In recent years, implementation success stories and "how-to" papers have begun to appear as more projects are implemented. In all cases, the need for road pricing is not strongly established. For economists, in theory, every road should be tolled to achieve optimum economic efficiency. For practitioners, the need for road pricing has already been established, because the project has been implemented. However, for a particular circumstance, there are no guidelines for determining whether road pricing would be practical or not. There are a few sources that mention some items that may be important, but none of them mention all of the important factors that play a part in the success or failure of a road pricing proposal.

The goal of this study is to answer the following question: Is road pricing a possible, practical solution for a given situation? Answering this question would determine whether further investigation into road pricing may be worthwhile or if road pricing is not practical for the particular situation.

To determine what characteristics were common to successful and failed projects, several road pricing projects and proposals from the United States, Canada, Europe, and Asia were investigated. These projects had a wide range of implementation dates and strategies. Generally, the successful projects were characterized by strong political support, excellent marketing and public relations, clearly defined goals and objectives, and most importantly, urgent need for improvements and expedience in implementation. The projects that were not implemented did not possess some or all of these characteristics.

To aid a transportation decision-maker, six questions were developed that show the presence or absence of the characteristics of successful projects. These six questions, listed below, form a road pricing practicality assessment.

- Is the project urgently needed?
- Is a road pricing scheme the only (or best) practical and expedient alternative?
- Are there clearly defined, supportable goals for the project?
- Is legislation in place to support tolling?
- Is there a local political supporter for road pricing?
- Is there a way to positively market a road pricing scheme?

These questions can be used to determine if road pricing is potentially practical for a particular project or not. A potentially practical project would then be worth pursuing further, while an obviously impractical project can be quickly dismissed. A case study demonstrates the potential usefulness of the practicality assessment.

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INTRODUCTION

Toll roads have been part of United States history since the beginning of the country (*1*). The first engineered roadway in the United States was the Philadelphia-Lancaster Turnpike, completed in 1795. Toll bridges were common in many areas of the country until the creation of Federal aid programs to assist in the construction of rural bridges (*2*). The first modern toll road in the United States, the Pennsylvania Turnpike, was completed in 1940. However, these older toll facilities used a fixed toll scheme to toll traffic, and their primary purpose was to raise revenue to pay off their construction costs.

The first suggestion of using tolls to manage traffic demand appeared about 1959 as a way to solve urban congestion problems (*3*). While investigated in England, the concept did not receive much attention in the United States. A trial program by the Urban Mass Transportation Administration (forerunner of the Federal Transit Authority) in the mid-1970s did not attract very much interest (*4*), although Singapore was installing the first operable pricing scheme at about the same time. By 1992, however, the situation was beginning to change, and the Intermodal Surface Transportation Efficiency Act (ISTEA) provided for four demonstration projects in "congestion pricing." This, combined with the increasing interest in Intelligent Transportation Systems (ITS) and Electronic Toll Collection (ETC), began to spur interest in demand-based pricing schemes (*3*). Currently, demand-based road pricing has been implemented in several projects worldwide, with varying levels of success (*5*). Other projects have been proposed and are under study (*6*). With increased interest comes an increased need to determine more quickly and effectively whether some sort of road pricing might be useful in a particular situation.

PROBLEM STATEMENT

Literature about road pricing schemes generally fall into two categories: theoretical arguments for implementing demand-based road pricing and actual implementation stories, with some "how-to" papers about implementation techniques in between. Economists have long argued for road pricing schemes as a way to provide better economic utilization of roadways. (*7*) The implementers "obviously" needed a pricing scheme, or they would not have implemented one. Therefore, these two extremes do not need to ask a vital question: Is some sort of road pricing scheme applicable to a particular application?

Because of the potential for road pricing to relieve congestion and enhance the mobility of many road users in an area, the need to quickly determine if road pricing is a worthwhile alternative is becoming more important. There is no accepted format in place to readily make this assessment, however. The focus of this paper, therefore, is to provide a general aid for helping decide if and when road pricing would be worthwhile; that is, a road pricing practicality assessment.

Research Objectives

The objectives of this study were:

1. Identify the progress made toward a decision process for road pricing.
2. Identify the selection criteria used in current and proposed road pricing projects.
3. Develop a list of problematic conditions and situations for road pricing projects.
4. Develop a decision process for consideration of road pricing as an alternative.
5. Apply the decision process to a case study in San Antonio, Texas.

Study Scope

Road pricing is an extensive subject area and includes parking pricing and commercial vehicle operation. This study was limited to toll facilities intended for passenger vehicle operation. This study was also limited to the engineering, financial, and organizational considerations involved with selecting road pricing as an alternative. While social and political situations may produce barriers to the implementation of road pricing, these are not within the scope of this paper and are only mentioned where they apply to problematic conditions for implementation. Finally, a project must be both practical and feasible to be successful. This paper covers only the practical side of the assessment. A separate, parallel feasibility assessment should also be performed, and the two together will determine if a project is worthwhile.

ROAD PRICING GOALS AND DEFINITIONS

Essentially, road pricing is tolling users for using a roadway. There are a variety of different terms used to describe various types of road pricing, such as congestion pricing and value pricing, but all of them have the same basic idea behind them: charge a usage fee proportional to the use of the roadway in order to achieve some desired outcome. A quick look at the goals of road pricing, and a more rigorous definition, is now in order.

Goals of Road Pricing

Road pricing schemes have the potential to do the following:

- Efficiently allocate scarce road space (i.e., reduce congestion and enhance mobility);
- Reduce vehicle emissions by reducing the amount of unstable flow;
- Make users pay more of the actual cost of driving;
- Create a commercially sustainable mechanism for private highway investment; and
- Provide a supplementary revenue stream. (*3*)

These are true regardless of the particular application, although the subclass of variable pricing schemes discussed below are usually better equipped to handle the first four goals than fixed schemes.

Road Pricing Terms and Definitions

Because road pricing is not the most common term used when discussing tolls, a few definitions are in order. For the purposes of this study, *road pricin*g refers to any toll scheme where vehicle trips using a specified section of roadway are subjected to a well-defined toll. (*5)* This toll may vary by time of day or by usage of the roadway. Thus, road pricing encompasses all possible roadway tolling schemes. Road pricing is distinct from road taxes. *Road taxes* are items such as license and registration fees, wheel taxes, and tire taxes paid by users but that are not necessarily related to road use. (*5*) For instance, vehicle licensing is a sort of "entrance fee" for road use. Once this "entrance fee" is paid, unlimited use of roadways is permitted. While road taxes may generally influence behavior, and have been used in lieu of road pricing, they are in many ways "sunk" costs and do not necessarily alter individual trip selection. (*7,8*) Road pricing, on the other hand, is designed to try to influence user behavior, hopefully in a desirable way.

Road pricing has two general subcategories, fixed and variable. *Fixed pricing* is set for all users and does not change in response to prevailing traffic conditions. *Variable pricing*, on the other hand, may be changed due changing demand for use of a particular facility. Fixed and variable pricing usually have different objectives in transportation. Fixed pricing is usually used to retire bonded debt, and has the advantage of generating equal revenue from all users, regardless of time of day (*9*). However, fixed pricing does not necessarily discourage travel at a given time of day (*10*), and therefore is usually not an adequate congestion relief mechanism. Variable pricing, on the other hand, can be adjusted to account for these temporal variations and affect overall demand, but there are indications that variable pricing might have problems raising enough revenue to pay for itself (*11*,*12*,*13*) or for other service enhancements (*5*). Therefore, for the moment at least, the goals of revenue collection and congestion relief appear to be mutually exclusive, with rare exceptions to the contrary (*14*).

The most widely used example used to illustrate a variable pricing scheme is in the telecommunications industry, which charges by types of customer, time of use, length of use, and for other services that may enhance the use of telecommunications, such as dedicated data lines. (*15*) This example is significant for transportation issues because telecommunications is essentially transportation (in this case, transporting information instead of people and goods). The process of network design and use is very similar. The network is oriented toward the customer, is capital-intensive to produce, and is capacity-limited at peak times. Telecommunication is a real-time service (which must be used at the time of production) instead of a good (which may be stored for future use), and has a regular daily and weekly demand pattern, just like road transportation. Because of these similarities to roadway networks and roadway user behavior, telecommunications is one of the closest examples of variable pricing to road use.

The terms congestion pricing, marginal social cost, and value pricing all refer to different types of variable pricing, relating the tolls charged to congestion costs, total societal costs, and the user's value of the trip, respectively. These are the usually encountered terms when road pricing is discussed in the literature. While these terms are very important to feasibility, implementation, and marketing of a proposal, they do not serve any additional purpose when trying to determine if a road pricing scheme in general may be practical.

ROAD PRICING APPLICATIONS

Several agencies have implemented road pricing projects worldwide, and many other studies have been performed to determine if road pricing would be suitable for a particular location, both in the United States and internationally. Ten of these projects and proposals are presented here. These applications range from toll cordons surrounding downtown areas to variable pricing on existing toll facilities to HOT lanes to completely new roadways, as shown in Table 1. This is by no means an exhaustive list. Projects have also been proposed for London and Cambridge, England; Stockholm, Sweden; and the Randstad in the Netherlands, among others. The conception and implementation of these ten projects, and the later evolution of their operation provide very useful information about the decision process and important considerations in considering road pricing.

State Route 91 Express Lanes

State Route 91 (SR-91) was originally a 10-lane divided highway located in Orange County, in the Los Angeles Metropolitan Area (see Figure 1). Traffic volumes had grown substantially on the facility, and congestion had become a serious problem, with delays averaging 20-40 minutes. In response, the California Department of Transportation (Caltrans) proposed adding either a single HOV lane in the median of the roadway or some combination of HOV and general purpose lanes. However, due to a lack of public funds, the project would not be possible for about 10 years. (*12*)

There was an alternative financing method, however. The California legislature had made four public-private partnerships available under AB 680 legislation. So, instead of conventional financing, the SR-91 express lanes were to be constructed using private funds raised by the California Private Transportation Company (CPTC), a private for-profit company. The land for the lanes was leased to CPTC for 35 years, after which time it would revert to state ownership. Construction could be completed in approximately two years, and two new HOT lanes were constructed in each direction. The speed of construction was a major selling point for the project. Principal goals were to relieve congestion on the main lanes, increase carpooling and transit use, improved driver comfort, and improving air quality. (*10*) A final unstated goal of CPTC was to achieve an adequate return on investment.

Table 1. Road Pricing Projects in the United States and Internationally (5,8,16).

Location	Facility	Project Start Date	Owner/Operator	Status
Orange County, California	State Route (SR) 91	1995	California Private Transportation Company (CPTC)	Active
San Diego	Interstate 15	1995	San Diego Association of Governments (SANDAG)	Active
Toronto	Highway 407	1997	407 International Inc. (private owner)	Active
San Francisco	Oakland-San Francisco Bay Bridge	1993	None	Suspended
Sonoma County, California	US Highway 101	1996	None	Suspended
Twin Cities, Minnesota	Several freeway routes	1994	None	Suspended
Singapore	(cordon)	1975	Government	Active
Hong Kong	(cordon)	1983	None	Suspended
Norway (Bergen, Oslo, Trondheim)	(cordon)	1986	Government	Active
France	Autoroute A1	1992	SANEF (private toll operator)	Active

(cordon) = toll scheme is a cordon ring around an urban area, with multiple facilities involved.

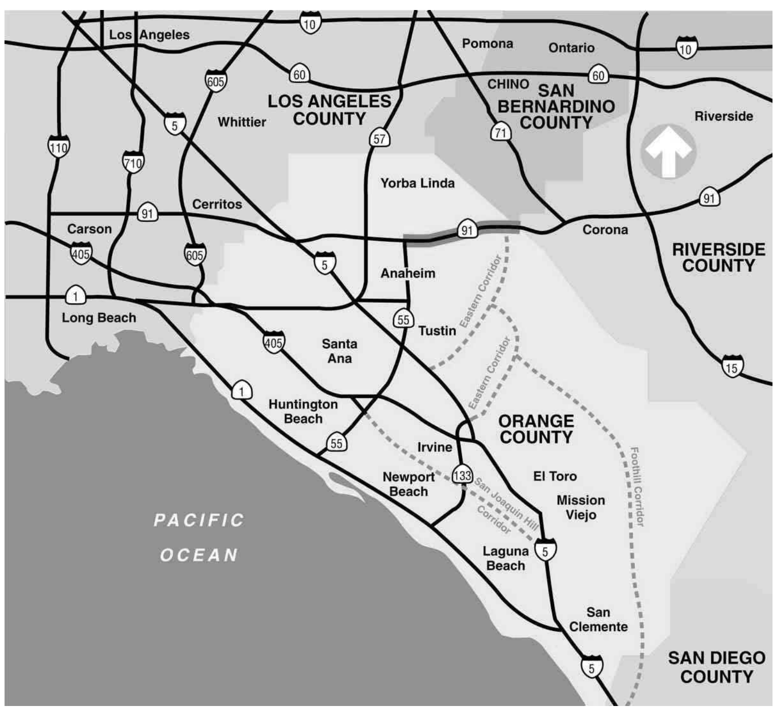

Figure 1. Location of SR-91 Express Lane Project

SR-91 features a variable toll by time of day, as shown in Figure 2. (*17*) CPTC originally considered a dynamic toll system, but opted to use a published schedule after a customer survey revealed users were not comfortable with a fluctuating toll. This published toll schedule has changed three times since the facility opened to ensure the express lanes remained congestion free as use of the HOT lanes has increased. The initial toll pattern had a single toll rate for the each peak period. Because it made no difference when a user made a trip in the peak period, users tended to choose to make trips at about the same time. This resulted in a pulse of traffic during a fairly short interval, which could threaten the ability of the express lanes to deliver congestion-free travel at all times. Also, there were pulses of demand on the “shoulders” (immediately before and after) the maximum toll periods. To even out these demands, the toll rates were gradually scaled up to a maximum amount as the peak period begins, then gradually back down again as demand decreases. Demand also varies by day of the week, so the toll schedule changes through the week (Figure 2 only shows tolls for a Monday). CPTC is free to set tolls as they see fit, provided they remain within the rate-of-return constraint in their franchise agreement. The toll is collected electronically from transponder-equipped single-occupant vehicles (SOV) in the express lanes. Discounts were also established for frequent users. Users in HOV-3+ vehicles originally were not tolled, but as of January 1998 they are tolled half the rate of SOV and HOV-2 vehicles. Commercial vehicles are not permitted on the HOT lanes (and by California law trucks are restricted to the rightmost two lanes of a freeway in any event).

Since opening, the impacts of the SR-91 toll lanes have generally been favorable. (*12*) Customers were initially skeptical of the idea of paying a toll for congestion-free travel, but this attitude has changed over time, and the fact that use of the toll lanes was optional contributed to initial acceptance of the project. HOV-3+ traffic has increased considerably to about 6,000 vehicles per day, or about 20 percent of the total traffic using the HOT lanes. However, this was prior to the implementation of half tolls for HOV-3+ vehicles, and the effect of these tolls has not yet been documented. Considerable traffic diversion and new travel has also occurred. As an indication of the level of public acceptance for the HOT lanes, about 90 percent of the vehicles in the SR-91 corridor are transponder equipped. (*10*)

So far, SR-91 has been one of the most successful variable pricing projects to date. Sullivan credits optional tolls, immediate and visible benefits, and CPTC’s consistent marketing and public relations efforts, and suggests that similar projects with similar attributes would meet with acceptance. (*12*)

Because CPTC is a business and not a government agency, return on investment is critically important. As of the summer of 1998, revenues covered operating expenses but did not cover the amortized debt load for the first year. It was expected that by the end of the second or third year, revenues would cover all expenses. (*12*) However, the financial return has apparently not been as high as the original investors had hoped. In late 1999, CPTC attempted to change its tax status from private for-profit to private non-profit to allow refinancing of the construction debt with a lower interest rate and to head off Federal taxes. (*18*) However both political officials and the general public were suspicious of the plan, its financial predictions, and its benefits. (*19*)

I-15 FasTrak

The I-15 FasTrak program in San Diego began as an extension of ongoing congestion relief efforts on Interstate 15. In the late 1980s, the I-15 corridor (see Figure 3) was considered the most congested corridor in San Diego. (*14*) As a congestion relief measure, reversible HOV-2+ lanes were constructed, but these were quickly recognized as underused. Therefore, the San Diego Association of Governments (SANDAG) began looking for ways of better utilizing the HOV lanes. In addition, poor transit service along the corridor was perceived to be a problem (and a reason why the HOV lanes were underutilized).

<table>
<tr><th rowspan="2">Time</th><th colspan="2">SR-91 Express Lanes*</th><th colspan="2">I-15 FasTrack**</th><th colspan="2">Highway 407+</th></tr>
<tr><th>Eastbound</th><th>Westbound</th><th>Northbound</th><th>Southbound</th><th>Prior to May 1, 2000</th><th>After May 1, 2000</th></tr>
<tr><td>12:00 midnight</td><td rowspan="14">$0.75</td><td rowspan="8">$0.75</td><td rowspan="24">Closed</td><td rowspan="11">Closed</td><td rowspan="11">$0.044</td><td rowspan="12">$0.054</td></tr>
<tr><td>12:30 AM</td></tr>
<tr><td>1:00 AM</td></tr>
<tr><td>1:30 AM</td></tr>
<tr><td>2:00 AM</td></tr>
<tr><td>2:30 AM</td></tr>
<tr><td>3:00 AM</td></tr>
<tr><td>3:30 AM</td></tr>
<tr><td>4:00 AM</td><td rowspan="2">$1.65</td></tr>
<tr><td>4:30 AM</td></tr>
<tr><td>5:00 AM</td><td rowspan="2">$2.90</td></tr>
<tr><td>5:30 AM</td><td>$0.75</td><td rowspan="8">$0.109</td></tr>
<tr><td>6:00 AM</td><td rowspan="2">$3.00</td><td>$1.00</td><td rowspan="34">$0.114</td></tr>
<tr><td>6:30 AM</td><td>$2.00</td></tr>
<tr><td>7:00 AM</td><td rowspan="12">$1.50</td><td rowspan="2">$3.30</td><td rowspan="2">$4.00</td></tr>
<tr><td>7:30 AM</td></tr>
<tr><td>8:00 AM</td><td rowspan="2">$3.10</td><td>$2.00</td></tr>
<tr><td>8:30 AM</td><td>$1.00</td></tr>
<tr><td>9:00 AM</td><td rowspan="2">$2.25</td><td rowspan="4">$0.75</td></tr>
<tr><td>9:30 AM</td><td rowspan="13">$0.076</td></tr>
<tr><td>10:00 AM</td><td rowspan="18">$1.50</td></tr>
<tr><td>10:30 AM</td></tr>
<tr><td>11:00 AM</td><td rowspan="27">Closed</td></tr>
<tr><td>11:30 AM</td></tr>
<tr><td>12:00 noon</td><td rowspan="2">$0.75</td></tr>
<tr><td>12:30 PM</td></tr>
<tr><td>1:00 PM</td><td rowspan="2">$2.00</td><td rowspan="5">$1.00</td></tr>
<tr><td>1:30 PM</td></tr>
<tr><td>2:00 PM</td><td rowspan="2">$2.95</td></tr>
<tr><td>2:30 PM</td></tr>
<tr><td>3:00 PM</td><td rowspan="2">$3.20</td></tr>
<tr><td>3:30 PM</td><td rowspan="2">$2.00</td></tr>
<tr><td>4:00 PM</td><td rowspan="4">$3.35</td><td rowspan="6">$0.109</td></tr>
<tr><td>4:30 PM</td><td rowspan="2">$4.00</td></tr>
<tr><td>5:00 PM</td></tr>
<tr><td>5:30 PM</td><td>$2.00</td></tr>
<tr><td>6:00 PM</td><td rowspan="2">$3.20</td><td>$1.00</td></tr>
<tr><td>6:30 PM</td><td>$0.75</td></tr>
<tr><td>7:00 PM</td><td rowspan="2">$2.25</td><td rowspan="11">$0.75</td><td rowspan="11">Closed</td><td rowspan="8">$0.076</td></tr>
<tr><td>7:30 PM</td></tr>
<tr><td>8:00 PM</td><td rowspan="4">$1.50</td></tr>
<tr><td>8:30 PM</td></tr>
<tr><td>9:00 PM</td></tr>
<tr><td>9:30 PM</td></tr>
<tr><td>10:00 PM</td><td rowspan="5">$0.75</td></tr>
<tr><td>10:30 PM</td></tr>
<tr><td>11:00 PM</td><td rowspan="3">$0.044</td><td rowspan="3">$0.054</td></tr>
<tr><td>11:30 PM</td></tr>
<tr><td>12:00 midnight</td></tr>
</table>

* Monday toll schedule shown. Tolls also vary by day of the week.
** Reversible HOT lane facility. Maximum possible toll shown (actual toll varies dynamically)
\+ Passenger vehicle schedule shown. Fares are in US dollars per mile traveled.

Figure 2. Toll Schedules for SR-91, I-15, and Highway 407

In 1992, SANDAG received funds from the Federal Transit Agency to investigate ways to better utilize existing HOV lane capacity, and in 1995 the Federal Highway Administration added a grant to study and implement SOV tolling on the HOV lanes. The goals of the project were to:

- Maximize the use of the existing I-15 HOV lanes;
- Determine if allowing solo drivers to use HOV lanes would relieve congestion;
- Improve air quality;
- Fund corridor transit improvements; and
- Develop a market-based approach to set tolls for the HOV lanes.

The program was instituted in two stages. In the first stage, permits were sold for a flat monthly fee (*14*). This limited the number of users of the HOV lanes, but created a sharp peak of vehicle use of the express lanes during peak hours. After observing that permit users did not use the express lanes all the time, the number of permits issued was expanded. The second stage involved the world's first dynamic tolling system. (*20*) Users with transponder-equipped vehicles are tolled an amount varying from \$0.50 to \$4.00 per trip, based on the time of use and the congestion level, as shown in Figure 2. The toll amount may change as quickly as every 6 minutes

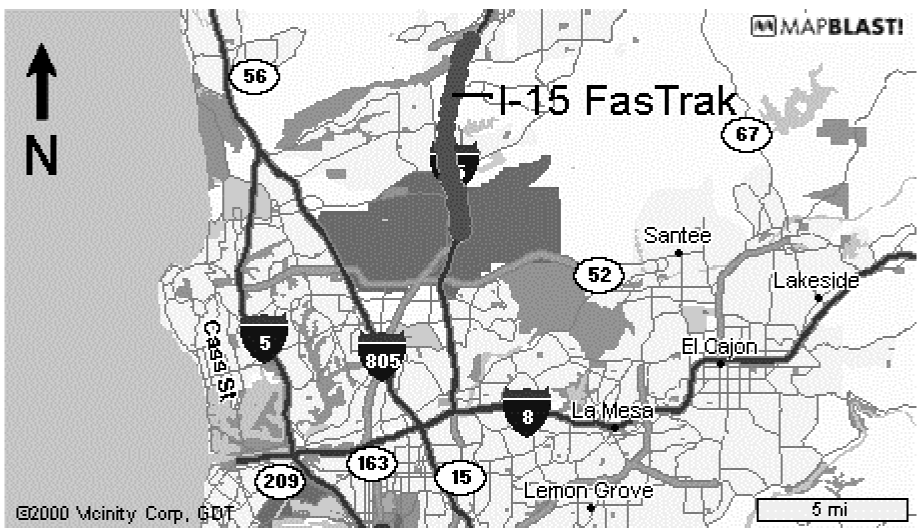

Figure 3. Location of I-15 FasTrak Project

Since its inception, FasTrak has been generally successful in meeting its goals (*20*). HOV lane excess capacity has been better utilized (at least up to the maximum flow rate set by California law). Travel times on the I-15 corridor have also improved and become more consistent. The dynamic tolling has been likewise been successful, and public opinion of the project has generally been positive. Also, HOV lane violations have been substantially reduced (*20*). The fact that the presence of the HOT lanes has become a factor in housing decisions attests to the overall success of the project. (*14*) However, transit service improvements have been mixed. While four routes currently use the corridor, two of those have experienced a drop in ridership since the program began, enough to cancel out gains made by the other two routes. Also, though most people using the corridor do not know where the revenues for FasTrak are going, most of those who do know do not support the use of toll revenues for transit improvements. (*20*) Instead, expansion of the HOT lane system is supported.

Highway 407 Electronic Toll Road

Highway 407 is a principal highway artery in the greater Toronto area, and a tolled relief valve for Highway 401 (see Figure 4). Planning began in the mid-1950s to build the highway, but the project was delayed numerous times. In the last 20 years, population and economic growth in Toronto increased dramatically, and by 1995 Highway 401 was carrying one of the highest traffic volumes in North America (approximately 400,000 vehicles per day). (*21*) Also, because of geography, most of Toronto's growth had been to the north, away from Lake Ontario. This created spillover problems on other highways. (*22*) Highway 407 had long been intended to be an alternate route for Highway 401, but delays and the high construction costs associated with urban freeways essentially kept the project from starting. To overcome time and finance problems, the Province of Ontario decided to build Highway 407 as a toll road, and operate the facility under a public-private partnership arrangement. (*11*) The highway was built in two phases, with two more extensions under construction. Unlike any other toll facility, Highway 407 uses only electronic tolling. Vehicles do not need transponders because video imaging systems detect and recognize vehicle license plates and the vehicle owners are billed accordingly. However, vehicles without transponders are subject to an additional charge, and all users are encouraged to use transponders. In 1999, Highway 407 was sold to a private consortium (407 International Inc.) for $2.11 billion (US dollars). (*23*) The new owners have pledged to continue the two extensions (due to be completed in 2001).

Figure 2 illustrates two toll schedules for passenger vehicles. The original toll scheme was somewhat similar to the one in effect prior to May 1, 2000, with different tolls for peak, off-peak, and night travel. There was also a separate schedule for weekends and holidays, which is not shown. The current toll scheme essentially only varies by day or night, with no peak charges to help spread demand. This may be because of the desire of the private operator to make a profit as opposed to operating at optimal traffic levels.

Highway 407 shares some common traits with the SR-91 and I-15 projects. First, like SR-91, building a toll road was an expedient way to place badly needed capacity into service quickly. Like I-15, however, the initial construction was paid for by a public agency. Finally, the ease of use of Highway 407 was an additional positive factor towards its implementation.

Figure 4. Map of Highway 407 Electronic Toll Road

San Francisco Bay Area Projects

Two variable pricing projects have been proposed by the Bay Area Metropolitan Transportation Commission (MTC). One involves the Bay Bridge and the other US-101 in Sonoma County. (6,24) While separate projects, these two proposals share a similar fate, so it is useful to consider them together.

Bay Bridge

The Bay Bridge is a two-deck, 10-lane structure spanning San Francisco Bay and joining Oakland and San Francisco (see Figure 5). The bridge is congested during peak hours, and MTC, along with Caltrans and FHWA, began investigating ways to reduce congestion, and funds were allocated under ISTEA to study and implement the final plan. The proposed scheme would allow HOV-3+ to travel for free but would toll all other vehicles, and it was estimated that a morning westbound (Oakland to San Francisco) commuter would save almost 40 hours per year. The additional revenues would be used to improve trans-Bay transit services and to provide discounts for low-income users. This proposal was favored by approximately 70 percent of the affected users. However, it was not favored by the California Assembly, and has been put on indefinite hold due to the lack of political support. (24) It is possible that the impeding replacement of the eastern span of the Bay Bridge (which was damaged in the 1989 Loma Prieta earthquake) played a part in reducing legislative support for congestion related tolls. (25)

US Highway 101

Several alternatives were generated for installing express (HOT) lanes in the median of US Highway 101 from the Marin County line to near Santa Rosa (see Figure 5). These would have involved a single HOT lane with multiple entrances and exits, depending on the alternative chosen. A proposal was presented in June 1998, but almost immediately afterward the project was put on indefinite hold, again in part because of the lack of political support at the state level (6).

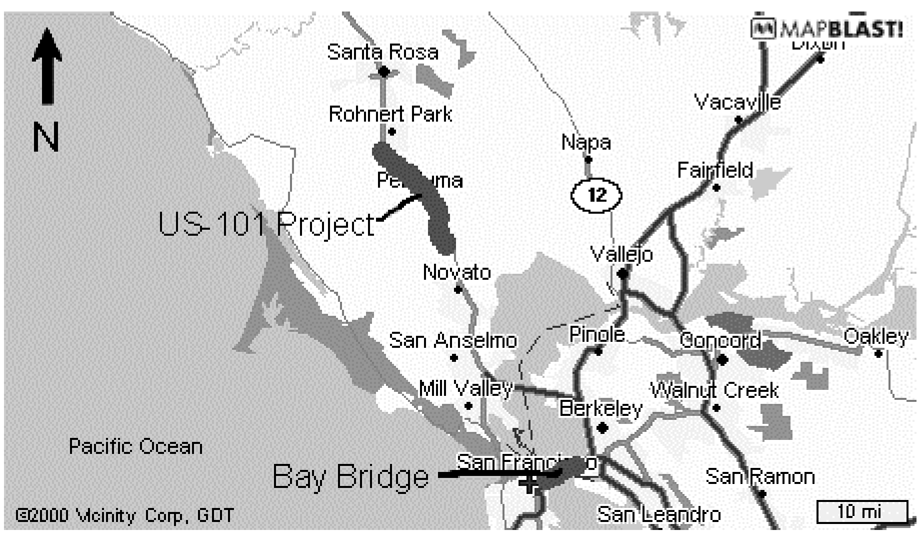

Figure 5. Locations of San Francisco Bay Area Projects

Twin Cities

In 1994, Minnesota Department of Transportation (MnDOT) began investigating the possibility of using a congestion-based pricing system on Interstate 394 in the Minneapolis-St. Paul area, as well as several private proposals. These projects are notable more for the public reaction than anything else. The public has been strongly ambivalent to any pricing scheme for roadways, even HOT lanes. (16) MnDOT has decided to use a slow, incremental approach to try to alter public opinion, and none of the projects have been implemented so far. (16)

Singapore

The city-state of Singapore installed the world's first congestion-related pricing project to deal with severe congestion in the downtown area. (5,8) Singapore's small size (226 square miles), geography, and commercial focus on the old downtown made traffic congestion there more acute, and economic development added considerable numbers of automobiles to the road network. The government felt it was essential to take some kind of action to preserve accessibility and mobility in this area. The project's structure consisted of a toll ring or cordon around the downtown, and private automobiles and taxis were required to pay a toll to enter the ring in the morning peak hour. The ring worked on a pass system, with the government strictly limiting the number of passes available. The combination of tolling and limited permits reduced auto traffic by 75 percent and total entering volume by 47 percent. (5) Since implementation, the scheme has been altered several times, with the boundaries of the ring expanded, exceptions for most vehicle types removed, adding evening restraints, all-day tolling, and finally electronic tolling.

Singapore's toll system has been an unquestioned success in terms of relieving congestion in the old downtown area, and showed that a properly employed road pricing scheme can help control travel demand. (5) Some circumstances surrounding the implementation of this project may not apply to other countries, however, because Singapore's government has very broad powers. Nonetheless, Singapore's toll system combines need and expediency, two of the most important factors in starting a road pricing project.

Hong Kong

Hong Kong has suffered from some of the same basic problems as Singapore, including limited geography and rapid economic growth, and began to look at alternatives to mitigate congestion at about the same time as Singapore (1976). (5) However, unlike Singapore, Hong Kong opted for increased vehicle taxes first, greatly increasing excise, registration, and fuel taxes in 1982 to attempt to control vehicle ownership. This measure reduced vehicle ownership by about 28 percent, but did not affect registrations for upper and middle class individuals, who were most likely to drive. Therefore, congestion was not materially affected. The following year (1983), due to an economic downturn, vehicle taxes were increased again to make up for revenue shortfalls in other areas.

Also in 1983, Hong Kong returned to the idea of road pricing, and began a two-year field test of technology for electronic toll collection using the term Electronic Road Pricing (ERP). These tests were successful, indicating that electronic toll collection was possible in the mid-1980s. The major technical problem involved the logistics of equipping every automobile in Hong Kong with the still-bulky transponders. (5,26) At the same time, a cordon-based pricing scheme was developed and approved, and in 1986, the colonial government was ready to begin implementation. Because the field tests had gone well, there was every indication that ERP was going to help relieve Hong Kong's clogged streets. (27)

The resulting implementation attempt did not proceed smoothly. Overwhelming public opposition forced an indefinite delay in using road pricing to control congestion in Hong Kong. Gómez-Ibáñez and Small outlined some of the reasons behind the public's rejection of the plan. (5) The major problems involved public perception of road pricing and electronic toll collection, the government's handling of the presentation of the proposal, and some uncontrollable outside factors. The plan's feasibility was not an issue. (26) The plan itself has been modified, and a new version was presented in 1996, (28) but to date no action has been taken.

Norwegian Toll Rings

At about the same time as Hong Kong began its road pricing implementation attempt, Bergen, Norway instituted a toll ring around its urban area. (5,8) The justification for the ring was to finance necessary roadway improvements. The small number of cross-town routes available to drivers facilitated the ring's structure. The toll was set very low to keep from discouraging traffic, because congestion was not considered to be a major problem. The Norwegian capital, Oslo, built a similar toll ring in 1990, and Trondheim followed in 1991. Again, the justification for the tolls was to finance necessary transportation improvements. None of these systems were designed specifically to manage congestion, although all of them had minor impacts on travel growth. In each of the three cities, initial public reaction was negative, although it varied by degree from city to city. Public opinion generally improved after the toll rings were in operation for a while. These three projects are not consistent with the high-demand situations seen in the United States, but they are presented as an example of relatively simple systems that serve their intended purpose.

France Autoroute A1

Due to rising Sunday afternoon and evening congestion on Autoroute A1 from Paris to Lille, the toll operator for A1 began using a variable toll to encourage peak spreading on Sunday afternoons and evenings. (5,29) Essentially, during peak times, tolls were increased as much as 56 percent, with a corresponding reduction during off peak hours. The scheme was designed to be revenue neutral (i.e., the net gain from the change would be zero).

As expected, traffic volumes during the peak travel period were reduced as drivers changed their travel times to obtain lower tolls. However, some drivers in the pre-peak period moved to the high toll peak period because of the reduction in congestion. This is an indication of more efficient allocation of resources. This particular scheme was considered to be effective enough that other toll roads in France copied it. (29)

Summary

Table 2 summarizes the key characteristics of many of the projects outlined above. Note that both immediate need for congestion relief and expedience of either using existing facilities or different financing figure prominently in the decision to use road pricing. Note that only about half of the projects described have actually been implemented, even though all of them share certain characteristics. This is due to a variety of other factors, discussed in the following section.

Table 2. Characteristics of Successful Road Pricing Projects.

- Immediate, urgent need for more capacity or infrastructure
- Road pricing is a practical and expedient (and may be the only) alternative
- Correct amount of political support at the correct time
- Clearly defined goals and benefits
- Excellent marketing and public relations
- No major public opposition

FACTORS LEADING TO ROAD PRICING PROPOSAL FAILURE

Like the successful projects, unsuccessful projects also share certain characteristics. These characteristics are the ones that prevented project implementation. The basic problems may come from any one (or several) areas: popular support, political support, communication problems, and bad timing. Some of these problems can be foreseen and avoided, while others only become apparent after implementation begins.

Popular Support

The public will generally decide whether a project will be done or not, and may determine how successful it will be, depending on the circumstances, so it is important to have at least something the public can identify with and support. (30,31) Problems relating to popular support may come from the *status quo bias*, or the unwillingness to give up a known present condition for a speculative future condition even if that future condition offers significant benefits. (32) This bias can often be overcome by a clear statement of goals, objectives, and benefits or by an incremental approach to implementation. (16) Note, however, that an initial lack of public support is not necessarily fatal. SR-91, I-15, and the Norway toll rings all initially lacked popular support, and popular opinion changed only after the projects were in service. (5,12,16) On the other hand, more widespread public opposition, as was observed in Hong Kong and the Twin Cities, will almost certainly stop a road pricing proposal completely. (5,16) This is the type of reaction that a successful proposal design is able to avoid.

Political Support

In the United States, at least, political support and public support are usually intertwined. However, political support may also be a separate entity, supporting different needs and desires than the public may express. Changing times may lead to different philosophies and priorities, thus changing the support structure for road pricing. Legislation may also have been enacted to prevent road pricing from being proposed. (33) Most of these political changes are beyond the control of the decision-maker, although a solid public relations campaign and frequent communication might help.

One particular political problem is inconsistent support throughout various levels of government. A good example of this is the Bay Bridge proposal, which had widespread support from affected users and was receiving Federal money for implementation but could not find a member of the California legislature to sponsor a bill to implement it. (24) This lack of state support came only a short time after the implementation of the SR-91 and I-15 projects, both of which also required implementing legislation. Obviously, inconsistent political support is a potential point of failure.

Communication Issues

Communication is always important in a public policy issue. When communication breaks down, there is an increased chance of misinterpretation of project goals and benefits. For instance, Hong Kong's colonial government did not release the consultant's final report to the public, so forecast accuracy could not be tracked by the public, and the summary that was released was apparently not clear about the potential benefits of the proposal. (5) A second problem in Hong Kong involved protection of privacy, and government safeguards apparently did not reassure drivers. (27) Finally, tolls collected by the colonial government were not earmarked for transportation improvements, and tolls could be increased simply to cover shortfalls in other areas, regardless of roadway conditions. This had been already done with vehicle license fees. (5) Thus, the colonial government showed some difficulty in communicating clearly what ERP was for and what the benefits would be.

Another possible problem with road pricing may lie within the terminology used (16,31,34). For instance, the term "congestion pricing" contains two terms with negative connotations: Congestion is obviously negative, and "pricing" is another word for "toll," leaving the initial impression that the user is being charged for the privilege of being in congestion. That obviously makes little sense. To help solve this problem, CPTC coined the term "value pricing," (3) and MnDOT has used the term "congestion relief tolling." (*16*) "Value pricing" has since become a commonly used term to describe road pricing concepts. However, merely changing a term will not change public perception of toll schemes. (*34*)

Bad Timing

Sometimes, circumstances surrounding a project work for it. Both SR-91 and I-15 were beneficiaries of a number of interests converging on the same solution at the same time (*15*). However, it is just as likely that a variety of external circumstances may conspire to frustrate a proposal altogether. These might include economic downturns, natural disasters, or major population shifts in a short period of time. Some more bizarre situations can also arise. As an example, the Hong Kong proposal suffered two once-only instances of unfortunate timing. First, the field trial for ERP ran from 1983 to 1985, neatly straddling 1984 and all of the additional focus about "Big Brother" stemming from George Orwell's classic novel about totalitarian society. This probably heightened concerns about privacy. (*28*) Second, Britain had recently signed an agreement to return Hong Kong to China when the lease expired in 1997. This also created some public anxiety, and there were some political issues about democratic representation that surfaced at that time. This made the public was less willing to accept the proposal (*5*).

Summary

The four key areas where a road pricing proposal can fail are summarized in Table 3. These four broad areas represent the potential external problems to project implementation. They are also interrelated, so public opinion affects political support, which affects the communication efforts, which affect popular opinion again. If problems in the above areas can be avoided or mitigated, then a road pricing proposal should have a reasonable chance at success.

Table 3. Factors Leading to Implementation Problems.

- Public Support
- Political Support
- Communication Issues
- Bad Timing

ROAD PRICING PRACTICALITY ASSESSMENT

Based on the attributes of the successful road pricing projects, and the pitfalls of the unsuccessful ones, it is possible to ask six very general questions that can demonstrate whether road pricing may be useful in a particular situation:

- Is the project urgently needed?
- Is a road pricing scheme the only (or best) practical and expedient alternative?
- Are there clearly defined, supportable goals for the project?
- Is legislation in place to support a toll road?
- Is there a local political supporter for road pricing?
- Is there a way to positively market a road pricing scheme?

Of these six questions, the first two are the most important. If the answer to these is "no," then road pricing is probably not worthwhile, and there is no need to continue. Answering "no" to any of the remaining four questions does not necessarily mean that road pricing will not work, merely that more effort will be required to get the necessary support. However, more than one "no" on the last four questions may be an indication that introducing road pricing may be fairly difficult.

Is the project urgently needed?

"Urgent need" can be characterized by recurring severe or extreme congestion on a facility, or deteriorating infrastructure, or both, combined with steadily increasing demand. Most infrastructure projects are already prioritized, so a more urgent project should be near the top of the list of projects to do. It is likely, however, that there are more "urgent" projects than funds available. However, If a particular improvement is needed immediately, and that immediate, urgent need can be demonstrated to the public (or the public complains loudly enough), the idea of road pricing may be more palatable to everyone.

For example, SR-91 was suffering from peak hour delays ranging up to 40 minutes, even with five lanes in each direction, and the regional population was steadily continuing to grow. I-15 was already heavily congested, and previous relief efforts had not been entirely successful. Drivers attempting to travel from one side of Toronto to another faced Highway 401, one of the most congested roadways in North America. Singapore and Hong Kong were both suffering from limited downtown mobility and accessibility due to congestion, and continued economic growth would only increase auto ownership and make the problem worse. The other projects mentioned in this paper also suffered from acute congestion or, in the case of Norway, infrastructure needs.

Is a road pricing scheme the only (or best) practical and expedient alternative?

There is almost always more than one practical solution to an engineering problem, either operationally or financially. However, situations may arise where an agency is backed into a corner on one or both of those issues, usually involving available funding. If a lack of alternatives can be clearly shown, or if road pricing will result in considerable savings in implementation time or cost, the use of road pricing may be more positively viewed.

Returning to the examples mentioned earlier, SR-91 had only two options: wait as much as 10 years for new capacity (and then only HOV lanes), or build toll lanes in about two years using private funds. Expedience, and favorable legislation, determined when the project would be built. Additional capacity was already available on I-15 in the form of "underutilized" HOV lanes. All that remained was to set up a way to use this capacity without jeopardizing uncongested flow on the HOV lanes. The Twin Cities proposal envisioned similar use of existing HOV facilities. Autoroute A1 also had excess capacity, but in this case the excess capacity was during non-peak times, necessitating a way to spread demand. A1 was already a toll facility, so all that was needed was to change the toll scheme. A facility that can not be expanded, such as the Bay Bridge, may have no other congestion mitigation alternatives. Highway 407 was expected to take 20 years to construct using normal financing, and that financing was not going to be available for several years at least. The alternative was to build a toll road. Hong Kong had tried other measures to mitigate congestion without much success, and ERP appeared it would be effective. US-101 was going to be reconstructed, and adding a HOT lane during reconstruction would not be too difficult. Norway needed an additional revenue stream to finance construction projects. Finally, Singapore's license scheme was quick to implement and administer. All of these projects showed that road pricing was practical and expedient for the implementing agency. In some cases, road pricing was the only available alternative.

Are there clearly defined goals for the project?

Clearly defining goals (and benefits) for a road pricing project is both a matter of conception and communication. A lack of clear goals has been one cause of project acceptance problems. (*5,16,31*) Conceiving clear goals should not be terribly difficult, particularly if road pricing is the only alternative available in a given situation. Communication may be more difficult, but this can overcome with some forethought and creative thinking.

The goals of many of the projects examined in this paper are reasonably clear (Table 4 shows goals for five examples), with congestion relief being the primary goal. One possible exception to this is Hong Kong, where the colonial government and the public may not have agreed as to the primary point of ERP.

Table 4. Examples of Goals for Various Road Pricing Projects (5,11).

Project	Goals
SR-91	Relieve Congestion Use private investment for infrastructure
I-15 FasTrak	Maximize use of existing HOV lanes Relieve congestion Improve air quality Fund corridor transit improvements
Highway 407	Relieve congestion on Highway 401 Reduce travel time variability Provide easy-to-use, transparent toll facility
Singapore	Restore mobility in congested downtown
Hong Kong	Relieve congestion

Is legislation in place to support a toll road?

Obviously, if a state has laws prohibiting toll roads, there will be no immediate way to implement road pricing. In the United States, the necessary Federal legislation has been in place since 1992, so only state legislation (and the blessing of the Federal Highway Administration) may be necessary to proceed. Since legislation can be altered, if the project marketing is handled well, necessary legislative changes may be possible, although they may take considerable time. Having a toll collection agency in place is helpful and convenient, but it can be set up later if necessary, so the lack of a toll agency is not a serious drawback. Special legislation may also be necessary. In the case of California, this was needed to initiate both SR-91 and I-15, and the same requirement has held up the Bay Bridge and US-101 projects. For special legislation, a local supporter may be necessary.

Is there a local political supporter for road pricing?

The need for a local "champion" for road pricing appears to be fairly high, since several projects have failed or been suspended without them (e.g., Bay Bridge, US-101, Twin Cities), in part because of the need for special legislation. Preferably, there should be more than one individual, and they should be influential enough to withstand lobbying by road-pricing opponents. These individuals may be very difficult to find. Nonetheless, if a champion can be located, the possibility of implementation rises considerably. (*31*)

Is there a way to positively market road pricing?

Communication (public relations and marketing) plays a large role in gaining acceptance for road pricing, and therefore there is a tremendous need to be as positive as possible about benefits to be gained from road pricing. Unfortunately, as mentioned earlier, the terminology for road pricing is not conducive to positive marketing. It may be a stretch to be able to sell "congestion pricing" as a positive feature. A change of terminology may also be necessary. For instance, one of the general goals of congestion pricing is to at least preserve the existing level of service, so the term "service protection tolling" might better illustrate what is being contemplated and provide a more positive first impression.

Summary

The goal of the six questions above is to help a transportation decision maker considering a road pricing scheme foresee some of the potential pitfalls early enough in the process to avoid them and line up the necessary support. The six questions are a practicality assessment only. A project must be both practical and feasible to be worthwhile, and a separate feasibility assessment is still necessary before a proposal can be recommended.

CASE STUDY: ROAD PRICING FOR INTERCHANGE IMPROVEMENTS

Road pricing may be used in some non-traditional applications. The following case study involves adding direct ramp connections to an existing interchange in San Antonio, Texas.

Background

The Loop 1604/US Highway 281 interchange lies about 15 miles north of downtown San Antonio, Texas, on the outer loop roadway, as shown in Figure 6. The interchange is a three-level diamond to allow uninterrupted flow on both mainlines, and both roadways have frontage roads, as shown in Figure 7. Not all of the ramps for the interchange are shown in Figure 10 due to space limitations. For instance, the ramp entering westbound Loop 1604 is located nearly 1.5 miles west of the interchange. The distance from the ramp exiting northbound US-281 to the ramp entering westbound Loop 1604 is almost 2.5 miles. This means drivers face a long trip on the frontage roads if they decide to change routes.

Traffic volumes on the approaches to the interchange reflect the development pattern in the area. As shown in Table 5, daily mainline volumes on Loop 1604 and on the south approach of US-281 are relatively high, while the north approach volume is relatively low. As can be expected, heavy directional movements are present between the west and south approaches to the interchange (US-281 northbound to Loop 1604 westbound and Loop 1604 eastbound to US-281 southbound). During the morning and afternoon peak hours, the traffic demand on these two approaches is heavy enough to cause the interchange to become congested (as shown in Table 6), with queues extending several miles. (*35*) The long distance between entrances and exit ramps and the intermingling of frontage road traffic aggravates the situation. Growth is continuing in the area, and because US-281 provides a direct route to downtown San Antonio, congestion at the interchange will likely become more serious. The highway mainlines have enough capacity to handle more traffic, so the conditions at the interchange are providing the bottleneck.

A three-level diamond interchange is useful in tight spaces where a full direction interchange can not be provided, and can operate very efficiently if traffic flows are not too high. Unfortunately, the flows present here are too high to be handled effectively. Some sort of interchange improvement is therefore necessary.

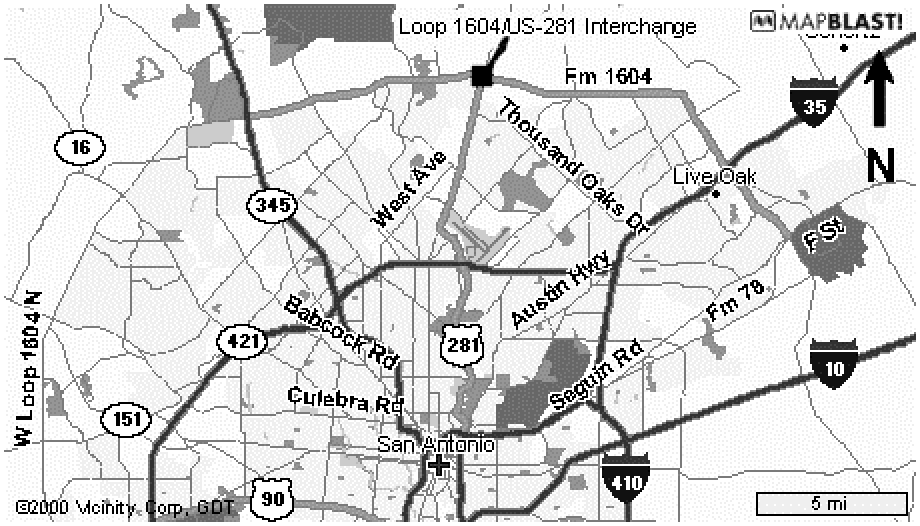

Figure 6. Location Map for Loop 1604/US-281 Interchange

Table 5. Daily Entering Volumes for Loop 1604/US-281 Interchange

Direction	Daily Traffic Volume Through Interchange
Northbound US-281	74618
Southbound US-281	38250
Eastbound Loop 1604	63070
Westbound Loop 1604	55352

Table 6. Peak Hour Entering Volumes for Loop 1604/US-281 Interchange

Direction	Volume Entering Interchange	
	AM Peak Hour	PM Peak Hour
Northbound US-281	2789	3520
Southbound US-281	1197	1284
Eastbound Loop 1604	2900	2790
Westbound Loop 1604	1831	1454

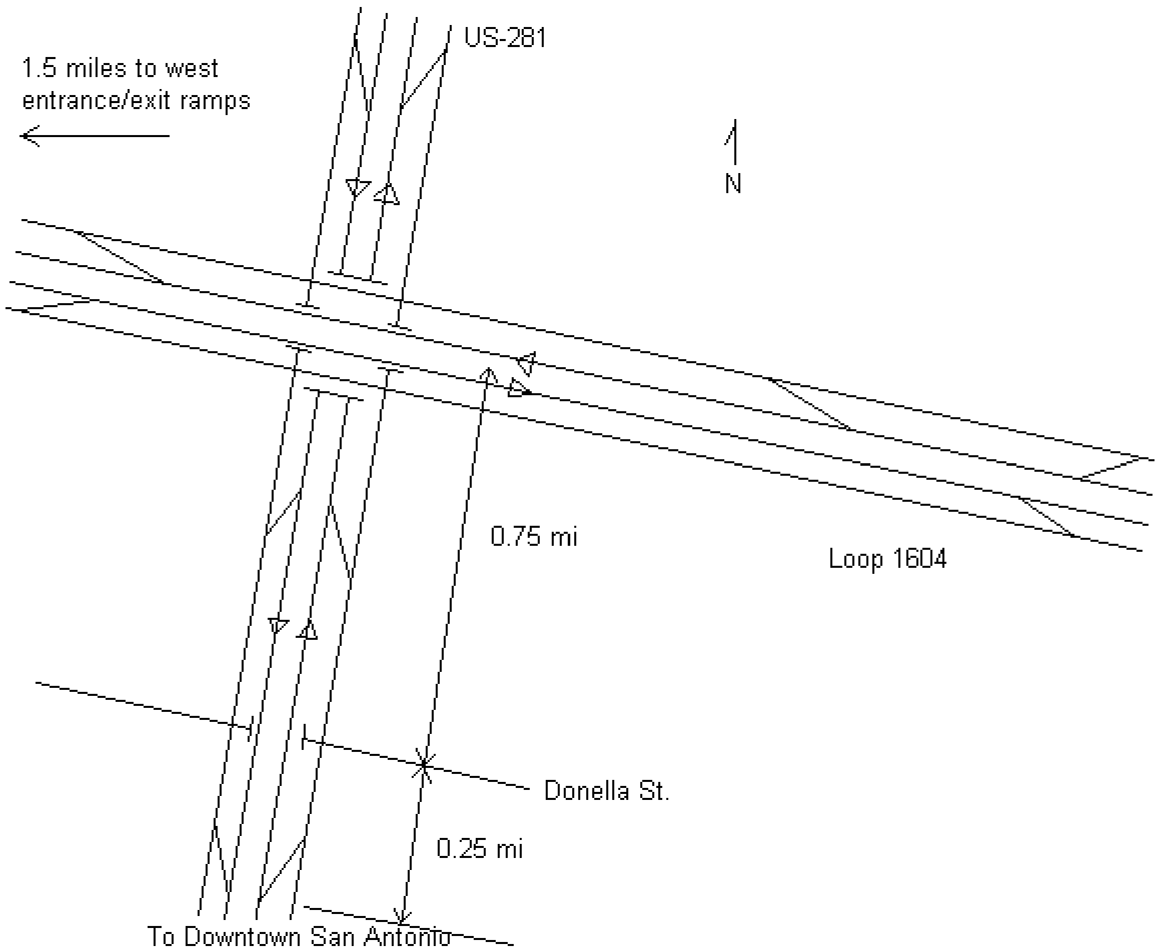

Figure 7. Existing Geometry at Loop 1604/US-281 Interchange

Proposed Solution

A possible solution to the problem of high directional movements is presented in Figure 8. Here, two one-lane direct connections have been made between US-281 and Loop 1604 for the two problem movements. This will probably relieve the congestion problems within the interchange, but may suffer capacity problems at the ramp termini. Both connections would be substantially shorter than the current routes through the interchange, and would not require vehicles to stop at the three level diamond's traffic signals. However, both connections would be need to be elevated, and therefore would be very expensive. No funds can be allocated for interchange improvements at this location for at least 15 years.

Since financing and congestion are the two most obvious problems, would it be practical to fund these two connections using a toll scheme of some kind?

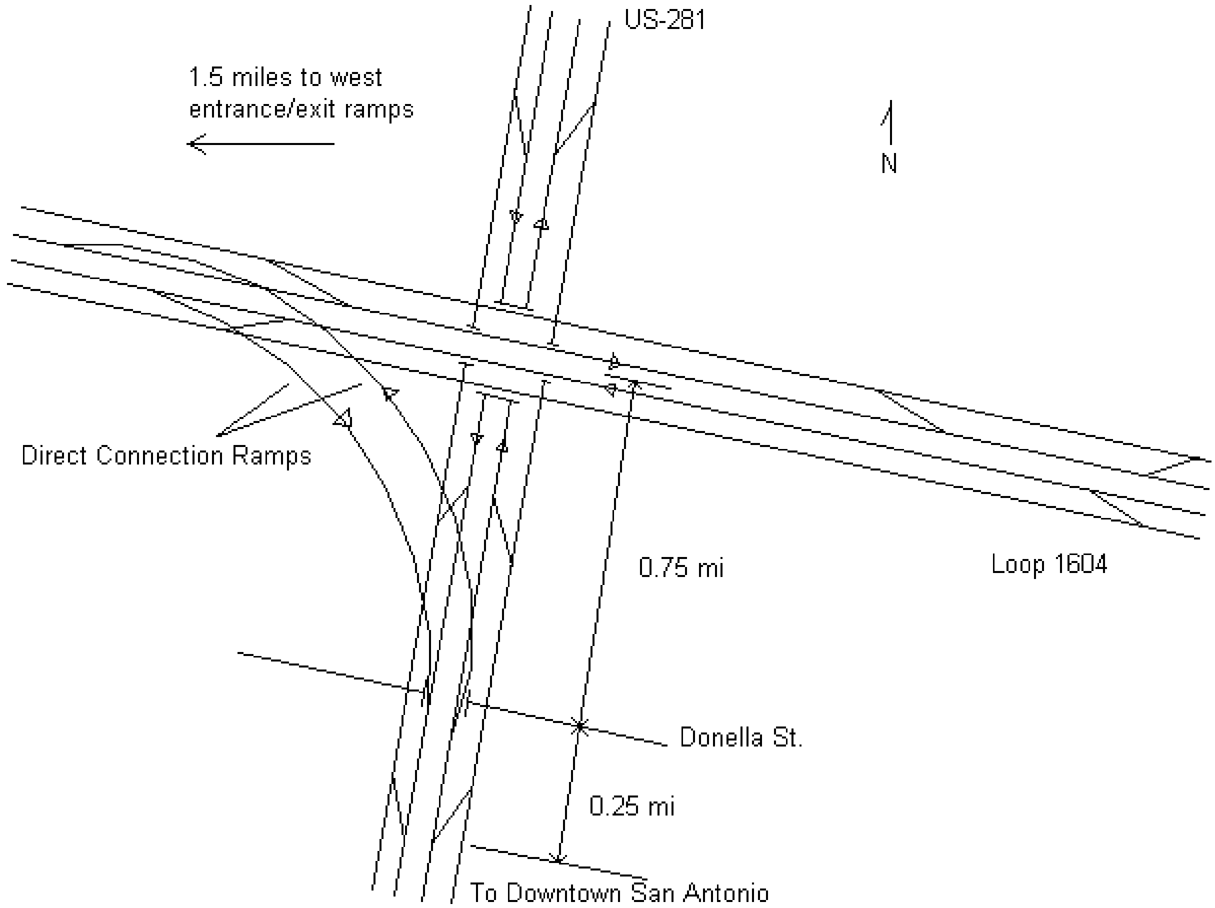

Figure 8. Direct Connection Ramps for Loop 1604/US-281 Interchange

Assessment of Road Pricing

The idea of pricing two ramps in an interchange to recover capital costs has never been done before, but the idea does not seem to be too far-fetched. A variable toll would help ensure that the ramps did not become too congested, and the original ramp system should remain in place for those unable or unwilling to pay the toll. The exact toll rates are not important at this point. These would be established in a parallel feasibility study.

Is the improvement urgently needed?

Yes. Congestion at this location is already serious, and will likely get worse as growth continues in the area. Therefore, the improvement is urgently needed.

Is a road pricing scheme the only (or best) practical and expedient alternative?

Yes. Financing is not available from another source to construct the improvement for this project, so either some sort of pricing scheme (to repay bonds) or a very long delay to wait for more conventional funding are the only two finance alternatives. Without another short-term finance option, a pricing scheme is the only alternative if the project is to be completed quickly.

Are there clearly defined goals for the project?

Yes. The obvious primary goal is congestion relief by adding capacity. This will help preserve mobility in the corridor for many years to come. Another goal would be improved driver comfort and safety, by separating frontage road and interchange traffic. Air quality could also be improved because queuing would be essentially eliminated. A tolled ramp must also be user-friendly, so ease of use would be another goal. Finally, because the project would be financed through bonds, adequate financial return would be essential.

Is legislation in place to support a toll road?

Yes. Currently, there are no toll roads in the San Antonio area. However, there are toll roads in other cities in Texas, so legislation allowing toll roads is in place. Setting up a local agency would need to be a step in the process.

Is there a local political supporter for road pricing?

Unknown, but likely no. This will probably need to be developed, probably first by discussing the problem with the representatives of the affected users. These representatives may be supportive if the situation is clearly presented.

Is there a way to positively market road pricing?

Yes. This is a unique application, but the benefits of shorter trips and more consistent travel times can be presented, probably with a slogan or catch phrase so that people will remember what the project is about. The use of funds, probably to pay for maintenance and return the construction costs, will also have to be spelled out up front. Other steps and actions will likely be necessary, and the marketing plan should develop alongside the full feasibility study. Because this would be the first road pricing project in the area, overcoming the status quo bias will be a priority.

Overall Assessment

A brief summary of the results of the road pricing practicality assessment is shown in Table 7. Overall, road pricing is practical for this project, although the lack of a known local supporter may be a problem. At this point, if political support can be found, a full scale feasibility study should begin to determine exactly how a road pricing project would function, who it would impact, and what other problems and issues remain that need to be resolved.

Table 7. Summary of Road Pricing Practicality Assessment for Loop 1604/US-281 Interchange

Question	Response
Is the project urgently needed?	Yes
Is a road pricing scheme the only (or best) practical and expedient alternative?	Yes
Are there clearly defined, supportable goals for the project?	Yes
Is legislation in place to support tolling?	Yes
Is there a local political supporter for road pricing?	Unknown
Is there a way to positively market a road pricing scheme?	Yes
Overall Assessment: Could road pricing be of practical use for this situation?	Yes

CONCLUSION

Road pricing has the potential to relieve congestion and improve travel conditions on a roadway or in an area. Several projects have successfully implemented various forms of road pricing. Each of these successful projects shared a small number of characteristics, including good political support, excellent marketing, favorable legislation, and clearly defined goals and objectives. Probably the most important characteristics, however, were the urgency of the need for improvements and the expedience of using road pricing to provide those improvements. Without those two factors, SR-91, I-15, Singapore's toll cordon, and most of the other projects would never have appeared.

For a new road project, the six questions outlined above provide an initial assessment of the practicality of road pricing. Most projects probably will not need road pricing; they will not be urgent enough, or will have alternative financing measures, or there will be legislative or political problems that will intercede. Moreover, even if the project could use road pricing, a full feasibility study may show that a pricing scheme will be undesirable, unworkable, or will not achieve the intended goals of the project. The questions will not positively identify situations where road pricing should be used, but they can identify situations where road pricing is probably not a viable alternative. Further investigation of the successes of road pricing projects, and the implementation of other projects, will yield even more insight into the opportunities and problems in assessing the practicality of road pricing.

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