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16. Abstract

This document is the culmination of the eleventh offering of a Mentors Program at Texas A&M University on Advanced Surface Transportation Systems that was presented in 2001 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 2001, 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

ADVANCED SURFACE TRANSPORTATION SYSTEMS

AUGUST 2001

Class Instructor and Mentors (front row, from left) Conrad Dudek, Joseph McDermott, Jack Kay, Patrick Irwin; (back row) David Roper, Wayne Kittelson. (Not in Photo: William Spreitzer)

PREFACE

This document is the culmination of the eleventh offering of a Mentors Program at Texas A&M University on Advanced Surface Transportation Systems that was presented in 2001 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 2001, 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 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.

Patrick Irwin, Jack Kay, Wayne Kittelson, Joseph McDermott, David Roper and William Spreitzer devoted considerable time and energy to this Program. We are extremely grateful for their valuable contributions to making the 2001 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, B, and C. A listing of all the papers prepared since 1991 is shown in Appendix D.

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2001 MENTORS

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, which 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), which 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.

JACK L. KAY

Mr. Jack L. Kay is a retired transportation consultant with a specialty interest in the application of technology to aid in solving complex transportation problems. Prior to his retirement, Mr. Kay served as Executive Transportation Advisor to the transportation sector of Science Applications International Corporation (SAIC). Prior to that, he was CEO and Chairman of JHK & Associates (which became a wholly owned subsidiary of SAIC). In that position he managed the firm's nationwide transportation practice, which included a major interest in ITS activities. The firm is now a part of TransCore, a national transportation and toll consulting and integration firm.

The firm's projects included computerization of traffic signals throughout New York City, Los Angeles, San Jose, Anaheim, Portland, Charlotte, Raleigh, Baltimore, and numerous other cities throughout the United States. The firm also provided consulting and operations services in corridor and freeway management, including the Los Angeles Smart Corridor, the New York INFORM system, enhancements to the Atlanta regional system, and portions of the I-95 corridor project. The firm also conducted comprehensive regional ITS studies under Mr. Kay's administration and developed training courses for the Federal Highway Administration. He also provided direct technical consulting to the World Bank, working on transportation issues in Moscow, Manila, Bangkok, Jakarta, and several smaller cities in the Philippines.

Although retired, Mr. Kay continues to be active in the professional community where he serves on the TRB FHWA Research and Technology Coordinating Committee and chairs a committee for FHWA looking at innovative technologies and processes to mitigate the impacts of construction work zones. He previously served on the Board of Directors for ITS America and chaired the board of that organization for a one-year term. Mr. Kay is the recipient of one of ITE's highest awards, the Theodore M. Matson Memorial Award.

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.

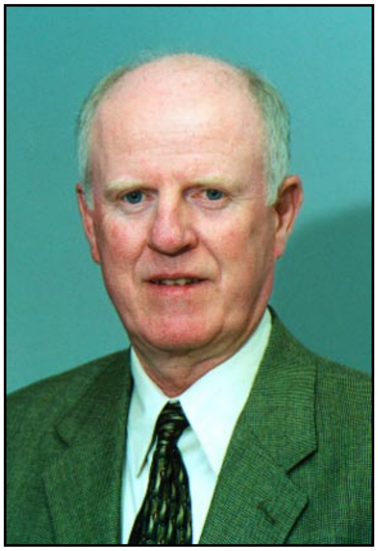
For over twenty-five years, Mr. Kittelson has been directly involved in a wide variety of applied research activities. Whether as a project participant, Project Manager, Panel Member, or Principal Investigator, he has assisted in the development and application of state-of-the-art techniques for accurate 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 M. McDERMOTT

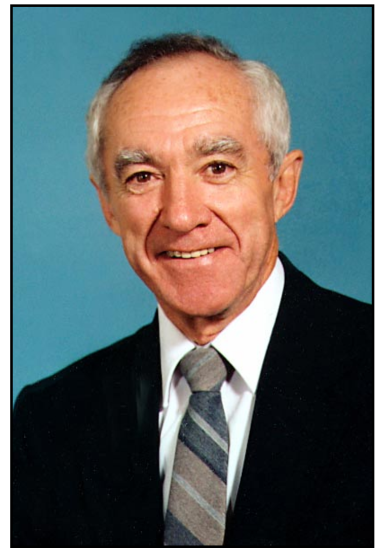


Mr. McDermott is a self-employed consultant, having completed 36 years of state government public service in 1997. His most recent public position was the Bureau Chief of Traffic in District 1 (Chicago Area) for the Illinois Department of Transportation. He had the responsibility for the traffic engineering functions of the District including programs, studies, access permits, signs, signals, markings, and systems operations, along with four sign shops, the Emergency Traffic Patrol and the Traffic Systems Center. Prior to this 1992 appointment, Mr. McDermott was Manager of the Traffic Systems Center where he worked since 1963. A native of Cleveland, Ohio, Mr. McDermott received his B.S. from the University of Detroit-Mercy and M.S. from Northwestern University, both in Civil Engineering.

As manager of the Chicago Area Traffic Systems Center, he was directly responsible for one of the first and largest freeway surveillance and control programs in the U.S. A registered professional engineer in Illinois and Ohio, Mr. McDermott's affiliations include: member and former chairman for the Committee on Freeway Operations of the Transportation Research Board, where he also served on the Group 3 Council; member and former chairman of the Committee on Traffic Operations for the American Society of Civil Engineers, from which he received the 1980 Frank M. Masters Transportation Engineering Award and the 1981 Arthur M. Wellington Prize; former chairman of the ASCE Urban Transportation Division Executive Committee; occasional Guest Lecturer at the Northwestern University Traffic Institute; and vice chairman of the American Association of State Highway and Transportation Officials Highway Subcommittee on Advanced Transportation Systems.

The freeway surveillance and control system developed by IDOT was recognized by the National Society of Professional Engineers as one of the ten outstanding engineering achievements in the U.S. in 1971. In 1976, the Traffic Systems Center was one of twenty transportation sites selected for HORIZONS ON DISPLAY, an U.S. Bicentennial tribute to community achievement recognizing 200 examples across the nation that illustrate the "continuing capacity of Americans to find creative approaches to contemporary needs." In 1987, the Institute of Transportation Engineers named the IDOT "Chicago Area Freeway Traffic Management Program" as the recipient of its annual Transportation Achievement Award. The Public Employees Roundtable selected the IDOT Freeway Traffic and Incident Management Program as its State Government winner of the 1995 Public Service Excellence Award.

DAVID H. ROPER



David H. Roper is an internationally recognized authority in the operation of metropolitan freeway networks and HOV systems, and in the development and operation of automated traffic management systems.

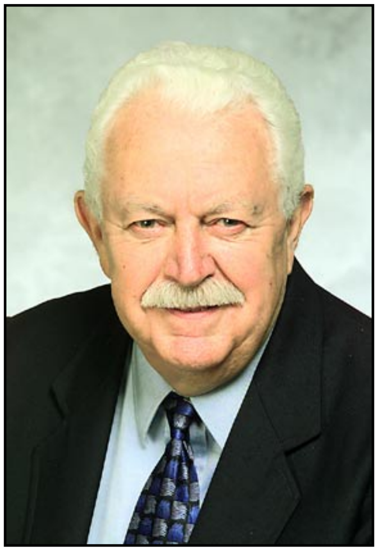
During the latter half of his 41-year career with the California Department of Transportation (Caltrans) in Los Angeles, he served as Deputy District Director responsible for the operation of the Los Angeles freeway system. He was at the forefront in the then-emerging area of freeway operations and traffic management. He carried out pioneering work in the conceptualization, development, and operation of automated systems and techniques which comprise today's state-of-the-art in traffic management and corridor optimization, surveillance and incident detection systems, ramp metering, high occupancy vehicle lanes, traffic operations centers, incident management programs, closed circuit television cameras, communications systems, HOV lanes, and motorist information systems. He has directed and/or conducted a variety of applied research and demonstration projects in this, and related, fields.

As Director of Caltrans' 1984 Olympics Transportation Program, Roper managed the planning, implementation, and operation of the highly successful plan to manage traffic during the 1984 Summer Olympic Games in Los Angeles.

Since his retirement from Caltrans, he has continued his work in the traffic management and ITS areas, both in the U.S. and abroad, as an independent consultant.

Roper is licensed as a Professional Engineer and as a Traffic Engineer in the State of California. He is a long-time member of the Committee on Freeway Operations of the Transportation Research Board, and, in recognition of his years of dedicated service, was named as a Member Emeritus of the Committee. He is the recipient of a variety of awards and commendations in recognition of his contributions and achievments, including the Professional Achievement Award of the Professional Engineers in California Government, and the President's Modal Award of the American Association of State Highway and Transportation Officials.

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 world-wide.

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

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GUIDELINES FOR THE APPLICATION OF PORTABLE TRAFFIC MANAGEMENT SYSTEMS AT WORK ZONES

by

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Prepared for
CVEN 677
Advanced Surface Transportation Systems

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SUMMARY

As the nation's transportation infrastructure continues to age, construction and maintenance zones have become increasingly common. Lane closures or changes in geometry can reduce the capacity of roads that are already congested, creating the potential for long queues on work zone approaches. On freeways, vehicles may approach the end of a slow moving queue at high speeds. If a location has limited sight distance, drivers may not have adequate advance warning of the end of the queue. This could create an unsafe condition where high-speed vehicles must decelerate rapidly as they approach the end of the queue.

Portable traffic management systems (PTMSs) have been promoted as a way to improve safety and reduce congestion at locations where traditional traffic management centers do not exist. PTMSs integrate portable changeable message signs, speed sensors, and highway advisory radio through a central control system that automatically determines appropriate messages for current traffic conditions. These systems are designed to provide real-time traffic management and traveler information with minimal human intervention. Manufacturers of these systems claim that they can warn drivers of downstream congestion, alert drivers of slower speeds ahead, and suggest alternate routes based on prevailing conditions.

Transportation agencies are often asked to make a decision on the installation of a PTMS without the benefit of objective information on the performance of these systems. A relatively small number of operational tests of these systems have been performed around the country, and their results are not always well documented. Agencies need guidance to help them determine whether a PTMS may improve safety and operations at their work zone. If they determine that a PTMS would be appropriate, guidance for the proper location and use of the system is needed.

Guidelines were developed for the use and placement of PTMSs in work zones. These guidelines were generated based on a review of past applications of PTMSs around the country. Research reports and interviews with personnel involved with PTMS evaluations were used to examine the performance of PTMSs during past field tests. This information was used to generate a list of desirable system attributes and produce general guidelines for determining whether PTMSs are appropriate for a site. Some guidelines were also developed to help agencies determine the proper placement of system components within the work zone. These guidelines were applied to an existing Texas work zone to illustrate their completeness and applicability. Recommendations for future research and improvements to PTMSs were also provided.

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INTRODUCTION

As the nation's transportation infrastructure continues to age, construction and maintenance zones have become increasingly common. Lane closures or changes in geometry can reduce the capacity of roads that are already congested, creating the potential for long queues on the work zone approaches. On freeways, vehicles may approach the end of the queue at high speeds. If a location has limited sight distance, drivers may not have adequate advance warning of the end of the queue. This could create an unsafe condition where high-speed vehicles must decelerate rapidly as they approach the end of the queue.

Some urban areas have infrastructure in place that can be used to mitigate some of the problems associated with work zone capacity restrictions. Traffic management centers (TMCs) can use incoming data to determine when congestion is present at a work zone. Upstream changeable message signs can then be utilized to alert drivers to conditions in the work zone. Information on alternative routes may also be displayed, allowing drivers to potentially avoid downstream congestion.

TMCs are not present on most roadways, and traditional work zone signing does not provide drivers with real-time, dynamic information on downstream conditions. Requiring workers to manually activate portable changeable message signs (PCMSs) when congestion occurs is labor-intensive and may not be feasible. Static signing may be used to warn drivers that they may be approaching congestion, but the signing may or may not accurately reflect conditions at the work zone at any given time.

Portable traffic management systems (PTMSs) have been developed to provide advance traveler information in areas where permanent traffic management systems do not exist. These systems integrate PCMSs, speed sensors, and highway advisory radio (HAR) through a portable computerized control system that determines appropriate responses to current traffic conditions. PTMSs are designed to provide real-time traffic management and traveler information with minimal human intervention. Manufacturers of these systems claim that they can warn drivers of congestion downstream of their position, alert drivers of slower speeds ahead, and suggest alternate routes based on prevailing conditions.

Current PTMSs all operate in the same basic manner. Speed sensors are placed at several sites within the work zone in order to determine the traffic conditions at that specific location. This speed data is transmitted to a portable, central control system located at the work site that processes the incoming data. The speed data is examined by the central control system in order to determine if a speed advisory, delay advisory, or route diversion message should be displayed. If the data indicates that some type of message should be displayed, the central control system transmits a signal to PCMSs, HAR, or other information dissemination device (such as an Internet web site) in order to alert drivers to conditions in the work zone.

As congestion continues to increase across the nation, many transportation agencies are considering the use of PTMSs as a means of reducing congestion at some long-term work zones. Transportation agencies usually have limited information on the performance of PTMSs beyond what is provided by the manufacturer. Vendor-provided information may provide a biased indication of system performance. Several objective field tests have been performed, but not all of these evaluations have been well documented. There is a need to summarize the limitations of PTMSs because agencies often do not have access to objective information about system performance.

PROBLEM STATEMENT

Many manufacturers are promoting portable traffic management systems as a tool to reduce congestion and improve safety at work zones. Transportation agencies are often asked to make a decision regarding the use of PTMSs when they do not have any experience with the systems and have little objective information on their performance. Agencies need a set of guidelines that would allow them to determine whether PTMSs should be applied at a particular location. This evaluation developed a set of guidelines that will help transportation agencies determine whether a PTMS is appropriate for a given site. Guidelines on the installation of the system are also provided.

RESEARCH OBJECTIVES

A set of guidelines for the application of PTMSs to freeway work zones was generated during this study. The following objectives were established in order to achieve this goal:

- determine the capabilities and features of portable traffic management systems that are currently available;
- examine the results of past field tests and research projects that utilized portable traffic management systems;
- identify characteristics of situations where portable traffic management systems improved traffic operations and safety;
- document the usability of the system by examining issues relating to equipment installation, hardware and software reliability, and ongoing maintenance;
- identify desirable characteristics of PTMSs and develop guidelines for the application of portable traffic management systems at freeway work zones;
- apply the guidelines to an existing work zone in Texas to validate the guidelines and assess their applicability to an actual freeway work zone; and
- develop recommendations for future research and potential system improvements.

SCOPE

Guidelines were developed for the use of PTMSs at freeway work zones. Non-freeway work zones were not considered. It was also not the purpose of this paper to compare the features of various systems, so this evaluation will describe the systems in a vendor-independent manner. Systems will be identified based on their functions and equipment, rather than by any trade name.

STUDY DESIGN

A work plan was developed to aid in the formulation of guidelines. Five separate tasks were performed in this project. This section discusses each task in detail.

Review Literature

The literature was reviewed to gather information related to the use of portable traffic management systems. Vendor product information was examined in order to define the capabilities of existing systems. Vendor web sites and product literature obtained at the *2001 International Conference on Roadway Work Zone Safety* were also consulted in this task. Past field tests and research studies of the effectiveness of portable traffic management systems were examined.

Develop and Conduct Telephone Interviews

States that had evaluated PTMSs were identified through the literature review. A distinct questionnaire was developed for each state that had experiences with PTMSs in order to clarify any issues related to the specific application of PTMSs in that state. Telephone interviews were conducted with personnel involved with these evaluations in order to gather more information about their experiences with these systems. In some cases, unpublished reports on the PTMS evaluation were obtained through these interviews. Examples of representative questions from these interviews are included in Appendix A. The purpose of these surveys was to:

- gather objective information of the effectiveness of the PTMS;
- clarify any questions about any published research findings;
- identify site characteristics for any field tests;
- gather additional information on the impact of the PTMS on traffic operations and safety;
- learn if any additional evaluations of PTMSs have been performed;
- assess the degree to which the system could be operated without human intervention;
- identify if any guidelines for PTMS use have been established;
- determine any issues related to the installation or ongoing operation of the system; and
- identify any system design issues that may have impacted the performance of the PTMS.

Develop Guidelines for the Use of PTMSs at Freeway Work Zones

A series of guidelines were developed based on the results of the interviews and literature review. First, a series of desirable characteristics for PTMSs were developed. Next, guidelines for determining the applicability of a PTMS to a given site were developed. Guidelines for locating PTMS components within a work zone were also generated. Existing agency guidelines were used as the basis for these guidelines. Guidelines were then added or modified based on past agency experiences with these devices.

Application of Guidelines to a Texas Work Zone

The guidelines were applied to an existing work zone on US 59 in Montgomery County, Texas. This was done to illustrate the procedure that an agency would use to locate PTMS components. This case study also served to validate the guidelines and assess their applicability to an actual freeway work zone.

Develop Recommendations for Further Research

The review of past field studies and the development of guidelines revealed some areas when PTMS performance was lacking. Recommendations for further improvements to these systems were developed.

BACKGROUND

Work zones can present a number of challenges to drivers. Changes in geometry, congestion, and heavy information loads can complicate the driving task in work zones, and studies have shown that work zones tend to have higher crash rates than roads that are not under construction. PTMSs have been proposed as a way to improve safety in work zones, but these systems must be well designed in order to be understood and respected by drivers. Past research on work zone crash characteristics is briefly summarized in this section. Information on PTMS abilities is also presented.

Work Zone Crashes

Despite the efforts of traffic engineers, work zones are still a potentially dangerous place. A series of studies has shown that crashes occur more frequently in work zones than they do on roads that are not undergoing reconstruction, rehabilitation, or repair. A synthesis of past studies of work zone crash experience showed that the crash rate at a site increased anywhere from 7 to 119 percent after a work zone was installed (*1*). While there is some variation in the magnitude of the increase in the crash rate, the crash rate consistently increased when a work zone was installed in all of these studies.

Results of past studies have also shown that fixed object and rear-end crashes were the most common types of crashes in work zones. The results of these past studies are shown in Table 1. Rear end collisions comprised between 22 and 57 percent of work zone crashes, while fixed object crashes accounted for between 6 and 53 percent of crashes in work zones. Some of the rear end crashes may be caused by vehicles approaching slow moving queues at high speeds. In these cases, drivers may not have been aware of the upcoming queue, and may not have had sufficient time or space to decelerate.

Table 1. Types of Crashes in Work Zones

Author	State(s)	Date	Percent of Crashes				
			Rear End	Fixed Object	Sideswipe	Angle	Other
Nemeth and Migletz (*2*)	Ohio	1977	40.4	37.1	9.9	No Data	12.6
Graham, Paulson, and Glennon (*3*)	Colorado, Georgia, Michigan, Minnesota, Ohio, New York, Washington	1977	38.8	16.2	9.9	10.6	24.5
Richards and Faulkner (*4*)	Texas	1981	40.0	19.0	10.0	15.0	16.0
Nemeth and Rathi (*5*)	Ohio	1983	22.7	52.4	9.7	No Data	15.2
Pigman and Agent (*6*)	Kentucky	1990	29.3	6.0	15.1	14.3	35.3
Thomanna (*7*)	Virginia	1997	57.0	25.0	15.0	No Data	3.0

PTMS Description

PTMSs were developed by manufacturers in order to improve safety and reduce delays at work zones by providing real-time information on traffic conditions to the driving public. Before discussing the characteristics of actual PTMSs that are on the market, it is necessary to define the functions that the PTMSs can perform.

PTMS Functions

A PTMS should provide drivers with real-time information about work zone conditions. While static signs could be used to alert drivers to the potential for delays and congestion, the messages on static signs may or may not accurately reflect actual conditions in the work zone at any given time. It is possible that static signs may lose credibility with drivers if they do not reflect current conditions. Message credibility could be improved by providing real-time information, potentially causing drivers to alter their behavior while driving through the work zone. PTMSs can perform four basic functions to give drivers or agency personnel real-time information about work zone conditions (*7*). The goals and potential applications of each function are summarized in Table 2.

Table 2. PTMS Functions

Function	Goal	Applications
Surveillance	Detect abnormal conditions in the work zone, such as slow speeds or long queues	• Incident detection • Queue detection • Congestion monitoring • Measurement of traffic flow
Advance warning	Alert drivers to potentially hazardous conditions that may be present in the work zone	• Congestion advisory messages • Queue advisory messages • Speed advisory information
Advisory	Alert drivers to potentially hazardous conditions that are actually present in the work zone	• Delay advisory messages • Slow speed advisory messages • Alternative route advisory messages
Control	Provide regulatory information to drivers	• Speed limit information, including variable speed limits • Lane closure information

Characteristics of Current PTMSs

Vendor literature on existing systems was examined to determine common features and capabilities of these systems. The systems that were examined are summarized in Table 3.

Table 3. Manufacturer Information Examined

Manufacturer	System
Scientex Corporation (*8*,*9*)	Adaptir
Asti Transportation Systems (*10*)	Computerized Highway Information Processing System (CHIPS)
ADDCO, Inc. (*11*,*12*)	Smart Work Zone
PDP Associates, Inc. (*13*,*14*)	Travel Time Prediction System (TIPS)

A similar architecture was used by all commercially available systems. A schematic of the information flow in these systems is shown in Figure 1. PTMSs are composed of four principal components:

- Speed detectors and surveillance equipment (such as video cameras),
- Central control system,
- Information dissemination devices, and
- Communications systems.

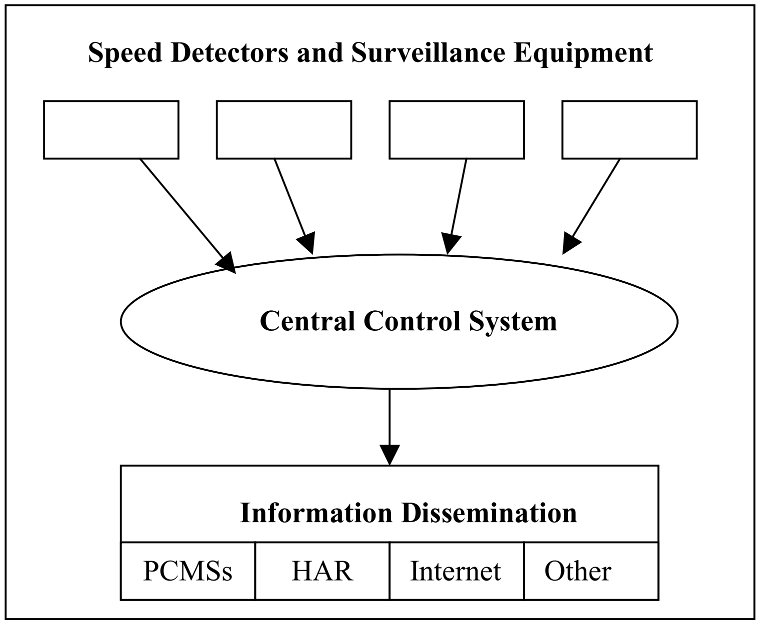

Figure 1. System Architecture

A series of speed detection and surveillance units are used to collect information on traffic flow characteristics on work zone approaches and within the work zone. The number and type of speed sensors will depend on the characteristics of the site and the type of information to be provided to drivers. The information processed from the detectors may include data on travel speeds and traffic volumes. In some cases, real-time video surveillance may also be provided.

The data from the speed sensors are regularly transmitted to a central control system located at the work site. The central control system is a portable personal computer that can be easily moved from location to location. Proprietary software is used to automatically process the incoming data. A series of criteria are applied to the incoming data to determine if the PTMS should display PCMS messages, change HAR messages, update Internet sites, or alert agency personnel to work zone conditions. The types of analyses performed depend on the functions established for the system. If a criterion is met, the information that is displayed on the appropriate information dissemination devices is altered. No human intervention is required to change messages.

The performance of a PTMS is dependent on the provision of a good communications system. The communications system connects the various components of the PTMS, typically through some form of wireless communications. The speed detection devices, central control system, and information dissemination devices must have reliable communications in order for the entire system to function properly.

An example deployment of a PTMS at a work zone is shown in Figure 2. A series of speed detectors are attached to PCMSs throughout the work zone. Portable traffic cameras are also provided at these locations. The communications system transmits data to the central control system from the sensors. Appropriate messages are generated based on current conditions at the site, and the messages are transmitted back to the PCMSs in order to provide information to drivers.

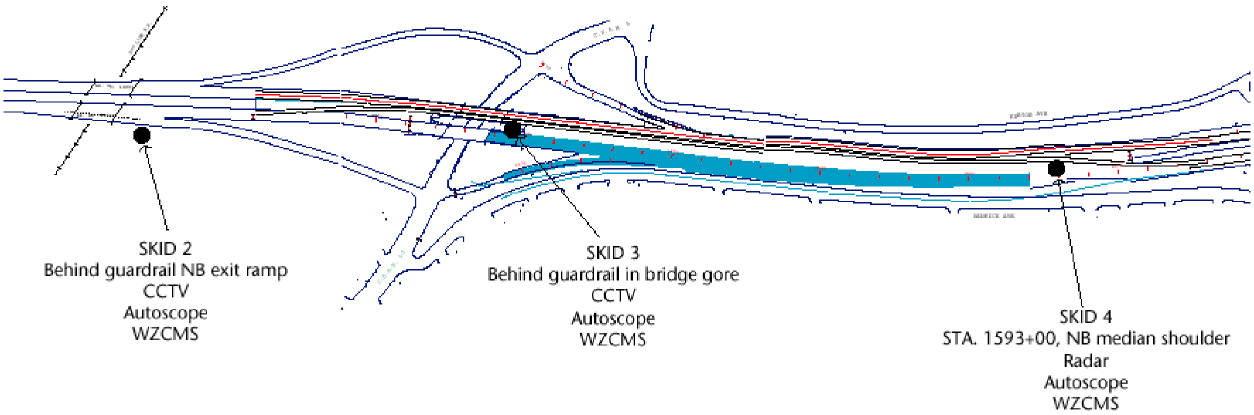

Figure 2. Sample PTMS Layout

PTMS Components

A variety of options are available for speed detection and surveillance, central control system functions, information dissemination, and communications. Some of the characteristics of these components are described in this section.

Central Control System. The central control system is used to manage the operations of the PTMS by processing incoming data from the speed sensors and generating responses to be displayed on the information dissemination equipment. The central control system is a desktop computer that runs proprietary traffic management software. An example of software that might be used to manage the operation of the PTMS is shown in Figure 3. The central control system computer must have a reliable source of electrical power in order to ensure that the PTMS system operates continuously. If a telephone connection is available, the system can be monitored by off-site personnel, or can be used to alert personnel when abnormal conditions occur in the work zone.

When the PTMS is operational, the speed sensors continuously collect speed data. Measurements are regularly reported to the central control system computer. The data are then analyzed to determine if any action needs to be taken. Depending on the configuration of the PTMS, the central control system may either automatically change messages or alert personnel at a TMC that a message should be changed. Most commercially available systems are being marketed with an automated control system, and do not require a TMC.

Several automated algorithms are available to analyze incoming sensor data. In general, commercial PTMSs are used to display three types of messages. Some typical procedures used to determine if a message should be displayed are summarized below.

- **Speed Advisory.** The communications system transmits average speeds from the sensors to the central control system at regular time intervals. The average speeds from each sensor are compared with the average speeds at adjacent sensors for each time interval. If the average speeds differ by more than a preset threshold value, the upstream PCMS displays a message that alerts drivers to the slower downstream travel speed.

- **Travel Time or Delay Advisory.** An ideal value for travel time through the work zone is calculated based on free flow speeds or the posted speed limit. The central control system uses the incoming speed data to determine the approximate travel time between data collection points. PTMSs can calculate this in two ways. First, they can assume that the speed collected by a sensor represents the travel speed to the next sensor. A travel time through the work zone can be calculated using these speeds. Second, an average of the travel speeds collected at two adjacent sensors can be used as that travel speed on the link. These calculations are then compared to the ideal travel time to generate a delay. Based on these calculations, a message will be displayed that either provides an estimate of travel time or delay through the work zone. Using spot speeds from radar units to generate travel times may not always be accurate, since speeds may vary between speed collection points.

- **Diversion Guidance.** Messages on possible alternate routes can also be displayed. Typically, the user specifies a delay threshold above which alternate route information will be displayed. Delays are calculated in the same manner as the delay advisory.

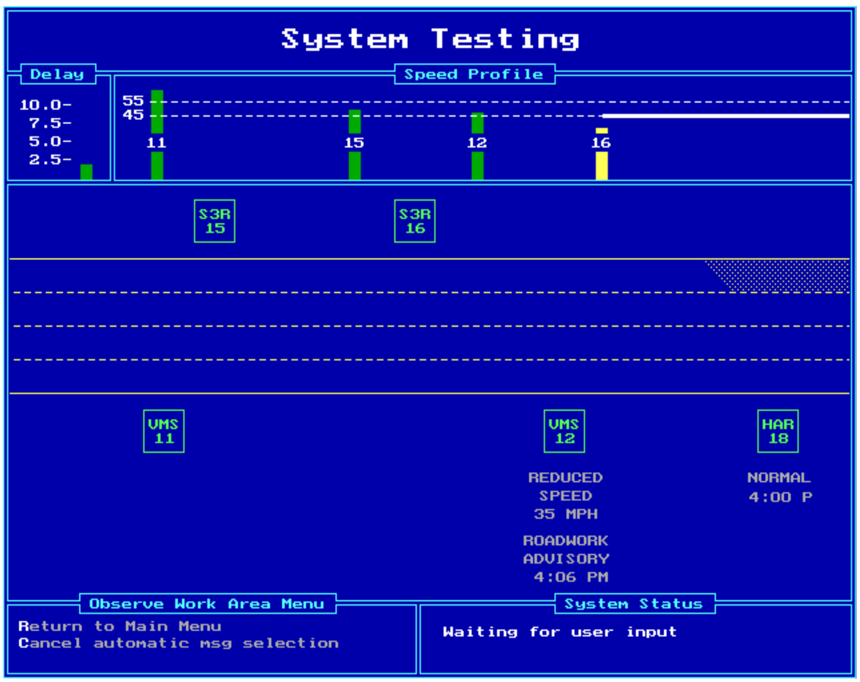

Figure 3. Example of Central Control System Software (9)

Speed Detection and Surveillance. A variety of speed detection and surveillance options are available. Most PTMSs use radar for speed detection, although video detection and infrared sensors can also used. The sensors are either mounted independently with communications equipment on a trailer, or attached to PCMSs in order to reduce the number of communications stations. The number and location of the sensors depends on work zone characteristics and the type of message that the PTMS will display. An example of a radar sensor mounted to a PCMS is shown in Figure 4.

Some vendors offer portable cameras for traffic surveillance and incident verification. These systems are not used to collect data on traffic volumes or travel speeds, and only provide a video image back to a TMC or the central control system. The quality of the video image depends on the bandwidth of the communications system used. Pan-tilt-zoom units are typically provided so operators can remotely change the field of view of the camera to verify site conditions. These systems are typically placed near locations where congestion is expected to occur.

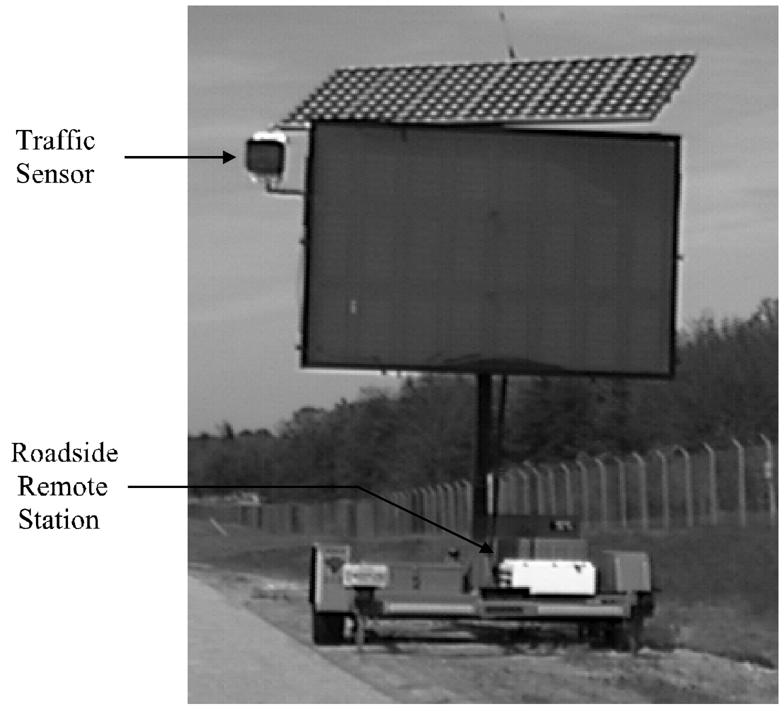

Figure 4. Example of Speed Sensor on a PCMS (<u>9</u>)

<u>Information Dissemination.</u> Information can be transmitted to drivers and other users in a variety of ways. PCMSs are used by every existing PTMS. PCMSs are familiar to drivers and offer a means of providing information on current conditions that is accessible to everyone in the traffic stream.

Many systems can also dynamically change messages on HAR units. The PTMS can select from a series of prerecorded messages to choose one that is appropriate for current conditions. In order for HAR systems to be effective, signing notifying drivers of the HAR frequency must be placed upstream of the site. Beacons on the sign can be activated to indicate when a message is providing information on unusual conditions within the work zone.

Several other options are also available. The central control system can automatically update traveler information web sites and kiosks. It can also automatically contact agency personnel or a TMC when abnormal conditions are found in the work zone. While most commercially available systems have focused on providing information only to drivers and agency personnel, these systems could be potentially used to provide information to a variety of users. Data on traffic conditions in the work zone could also be transmitted to law enforcement agencies, emergency services providers, media outlets, and transit providers.

<u>Communications.</u> The PTMS cannot function properly without reliable communications between the various components. The type of roadside communications used by a system can vary depending on characteristics of a particular site. Some of the options include:

- Ethernet TCP/IP
- Spread spectrum radio,
- Telephone line,
- UHF radio, and
- Cellular communications.

Most PTMS systems use spread spectrum radio, but each of these forms of communications has specific areas of application. Cellular communications cannot be used in some rural areas where infrastructure does not exist. The availability of cellular service may not be reliable during peak hours in urban areas, where the capacity of the cellular system could be exceeded. Many other wireless applications can be adversely impacted by weather conditions and site topography. When wireless communications are used, the locations of speed sensors and PCMSs need to be considered carefully to ensure that a strong signal can be obtained. In cases where strong signals cannot be maintained between components, it may be necessary to install repeater stations to boost signal strength. Telephone or other wireline communications are typically only used when the communications infrastructure is already in place.

Design of Messages

Messages displayed on PCMSs represent a critical link between the PTMS and the driver. Drivers must understand and believe the messages displayed by the PCMSs in order for the system to have any impact on traffic conditions. Given the importance of these messages, it is essential that messages be well designed.

Messages must be designed so drivers can understand messages in the limited amount of time available. A driver's travel speed and the legibility distance of the PCMS determine the amount of time available for a driver to read a message. Approximately 85 percent of drivers can read 18-inch characters at a distance of 650 feet from the sign (*15*). When a driver is traveling at 55 mph, approximately 8 seconds are available for a driver to read and comprehend the message on a PCMS. In general, it can be assumed that drivers take 1 second to read each short word (excluding prepositions), or 2 seconds per unit of information (*15,16*). Several factors can increase reading time, including, heavy driving task demands and potential visual obstructions. Current PTMSs utilize full-matrix PCMSs that can produce letter heights suitable for freeway applications. Many manufacturers offer PCMSs that can produce character heights in excess of 18 inches.

Appropriate guidelines should be consulted when determining PTMS message content. Messages that advise the driver to leave a freeway must be designed with particular care. Before an alternative route is recommended, the message designer should be sure that the travel time on the alternate route is significantly shorter than if the driver stayed on the freeway (*16*). If the recommended route does not have a shorter travel time, the driver may be less likely to believe future messages. While it is not the purpose of this document to develop typical messages for use on a PTMS, a number of resources are available for message design. Any message used on a PTMS should also be tested to ensure that drivers understand the message and can read it in the time available.

Credibility of messages is also very important. Since the PTMS is supposed to provide real-time information, all messages must be timely and accurate in order to ensure credibility of the PTMS. Failure to provide accurate real-time information will cause driver confidence in the system to degrade. Messages may be time stamped in order to indicate to drivers that the message represent current conditions.

System Requirements

Based on the basic functions and architecture of PTMSs, researchers at Virginia Tech proposed a series of system requirements for PTMSs in work zones (*7*). These requirements were based on the results of a survey of traffic engineers. The proposed requirements were:

- **Real Time Operation.** The PTMS system must operate in real-time and provide information that represents current conditions within the work zone.

- **Credibility.** Drivers must believe that a system is reliable in order for it to have a significant impact on operations or safety. If a system does not present relevant, accurate information, drivers will not pay attention to these systems.
- **Portability.** PTMSs must be easily moved between work zones and within individual work zones in response to changing conditions.
- **Ease of Installation.** If the PTMS is to be used for short-term applications, it must be relatively quick and easy to install. This is less of an issue for long-term projects.
- **NTCIP Compliance.** Systems should be compliant with applicable National Transportation Communications for Intelligent Transportation Systems Protocols (NTCIP) in order to ensure the interchangeability of system components and to guarantee that the system will be interoperable with other intelligent transportation systems. This is particularly important if a TMC will interface with the system.
- **Information Dissemination Tools.** Information from the PTMS must be easily transmitted to the driving public. The PTMS may use PCMSs, HAR, the Internet, and kiosks to distribute information.
- **Cost Effectiveness.** The system's benefits should justify the cost to install, operate, and maintain the system.
- **Reliability.** The system must be able to be operated with minimal failures and false alarms.
- **Operation Under All Environmental Conditions.** The system must be effective under all weather conditions and during both the day and at night.

FIELD OPERATIONAL TESTS

Agencies that had evaluated portable traffic management systems were contacted in order to determine past experiences with these systems. Published evaluations, unpublished reports, and interviews with personnel involved with the evaluations were used to document the experiences of these states with PTMSs. The information used to assess PTMS performance for each state is summarized in Table 4.

Table 4 . Information Sources

State	Source		
	Published Reports	Unpublished Reports	Interviews and Correspondence
Minnesota	✔	✔	
Maryland		✔	✔
Iowa	✔		
Kentucky	✔		✔
Nebraska	✔		✔
Illinois			✔
Ohio		✔	

The focus of the field testing varied from state to state. In some cases, only the technical feasibility of using the PTMS was evaluated, and no attempt was made to quantify any impacts on traffic operations. Only Minnesota, Kentucky, and Nebraska attempted to determine the impact of a PTMS on traffic operations, but these evaluations all had some limitations. Given the small number of tests that evaluated operational impacts, it is difficult to determine the impact of a PTMS on the traffic stream.

The evaluations also had a number of other limitations. Messages were not tested in any of the evaluations prior to installing the PTMS in the field. In some cases, message testing was performed at the same time as the testing, but the researchers did not attempt to correct any deficiencies in the messages during the study. All evaluations used PCMSs with 18-inch characters, so words should have be legible from at least 650 feet. Several early tests encountered significant technical problems that were not present in later evaluations. 7

The results of past field deployments are summarized in this section. The results of these field tests are presented in chronological order in order to illustrate how the abilities and performance of PTMSs changed over time.

Minnesota

The Minnesota Department of Transportation (MnDOT) also had a major role in the early development of PTMSs. Minnesota first tested PTMSs for the management of special event traffic in 1994. A PTMS system was developed with help from a private company, and a series of field tests were conducted during four events (*17*). The system consisted of a series of portable video cameras that transmitted information back to the MnDOT TMC. TMC personnel would then remotely change messages on PCMSs based on the incoming video data received at the TMC. Traffic signal timings and HAR messages could also be changed from the TMC based on the video data.

MnDOT performed a qualitative assessment of these field tests, and were generally satisfied with the performance of the system. Some problems with communications were experienced during the first field test, but these were due to poor configuration of the spread spectrum radios (*17*). The evaluation relied upon comments from TMC personnel, on-site traffic controllers, and the public. Comments were usually favorable towards the system. No quantitative data was collected to determine the operational impacts of the system.

Based on the successful field tests of PTMS for special event traffic, MnDOT decided to apply the concept at work zones. In 1997, MnDOT conducted an assessment of the use of PTMSs in work zones at two sites in the Minneapolis area.

Site Characteristics

The PTMS was tested at two work zones in the Minneapolis/St. Paul area in 1996 (*18*). The first location was on Interstate 94 in downtown Minneapolis. Work activities included reconstruction of an interchange, reconstruction of four bridges, and rehabilitation of a mile of Interstate. The average daily traffic (ADT) at this site was approximately 141,000 vpd at the time of the study.

The second work zone was located on Interstate 35 in Lakeville, Minnesota. Over two miles of rural Interstate were being reconstructed at this site, and a new interchange was being built. The ADT at this site was 58,000 vpd at the time of the study.

System Configuration

Different equipment was used at the two sites. At the I-94 site, three video detection cameras, five radar speed sensors, and ten PCMSs were used. A portion of this site's layout is shown in Figure 5. At the I-35 site, three video detection cameras, one radar speed sensor, and four PCMSs were installed. The layout of this site is shown in Figure 2. Several additional cameras were also used at both sites to provide real-time video back to the MnDOT TMC.

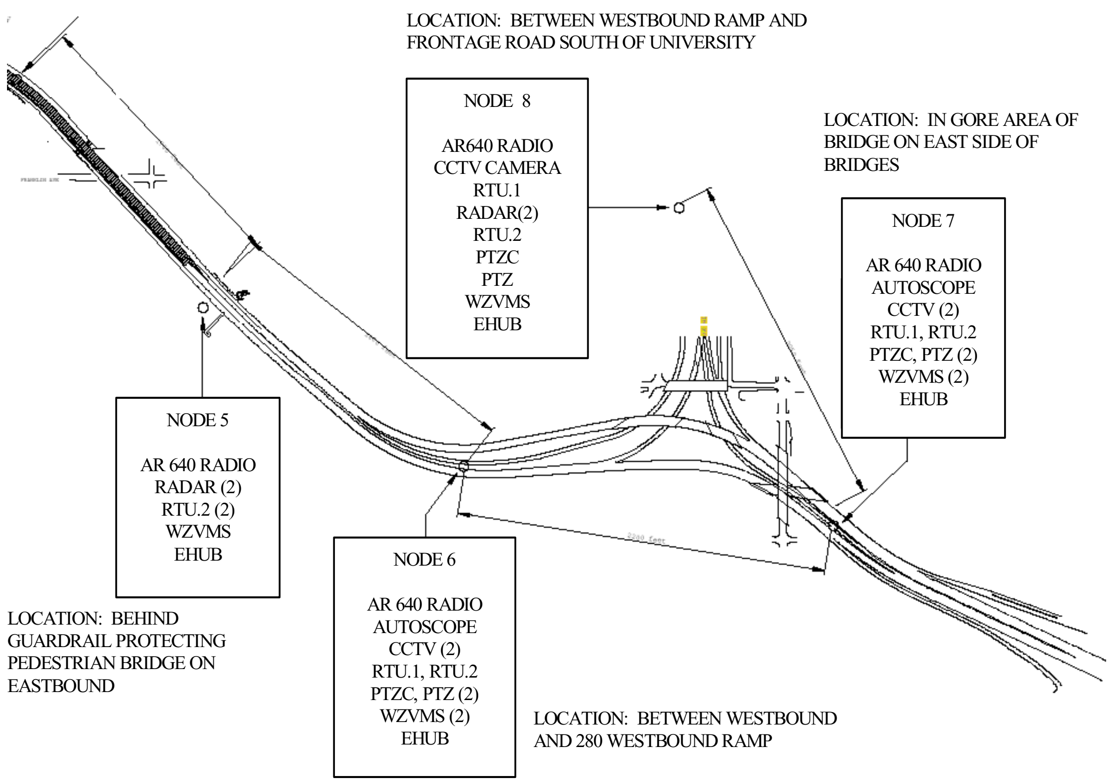

Figure 5. Minnesota I-94 Partial PTMS Layout (<u>*18*</u>)

Video cameras were used to provide speed detection at these sites (*18*). Cameras provided information on the volume and speed of the traffic stream. Radar speed detectors were used at locations where cameras could not be feasibly installed. This data was transmitted to the MnDOT TMC where operators examined the data to determine if messages needed to be changed.

Information was distributed to drivers using a variety of methods, including PCMSs, HAR, and an Internet web site. The messages used by the PTMS were determined by personnel stationed at the MnDOT TMC, and were not generated automatically (<u>*18*</u>). These personnel were responsible for monitoring conditions at the site and determining the appropriate response. The PTMS was not functioning in a purely automated manner at either site, so a central control system was not used. Messages that were displayed on the PCMSs were not logged during the study, although the report shows that speed advisory messages were used.

The PTMS system primarily used spread spectrum radio for communications. Cellular and regular telephone links were used to supplement the spread spectrum radio communications when necessary.

Evaluation Results

Traffic data were collected for approximately one month at the I-94 site. Data collection was limited to 8 days at the I-35 site.

Capacity. The impact of the PTMS on work zone capacity was examined at I-94. After the PTMS was put into operation at I-94, throughput during the morning peak was found to increase an average of 3.6 percent, which was significant at the 90 percent confidence level (*18*). Throughput during the afternoon peak was found to increase 6.6 percent, which was significant at the 99 percent confidence level (*18*). There were no changes in the work zone configuration or types of construction activity during this period. MnDOT concluded that traffic flowed more smoothly through the work zone when advance information on work zone conditions was provided, thus improving capacity at the work zone. These findings may be questionable, given that the data were collected using inductive loop detectors. It is possible that the perceived increase in capacity could be due to sensor problems.

Speeds. The impact of the PTMS messages on travel speed was examined at the I-35 site. The average speed approaching the work zone was found to be 9 mph lower when the PTMS was active, which was a statistically significant reduction (*18*). However, average speeds were reduced from 32 mph to 23 mph, so it is questionable how much of this reduction could be attributed to any speed advisory messages used by the PTMS. Congestion may have played a role in these reductions, or may have made drivers more likely to reduce speeds since traffic was already moving slowly. Average speeds within the work zone were not significantly different following the installation of the PTMS.

System Operation. The PTMS was evaluated from a usability perspective to determine the labor and time requirements for the installation of the system (*18*). Trained personnel were required in order to properly set up the PTMS components, especially for the video detection systems. Two people were required for the assembly and deployment of the PTMS. MnDOT estimated that trained personnel could deploy each PCMS/speed collection station in about 40 minutes. An additional 20 to 30 minutes was required to install each video detection camera. An experienced TMC employee was used to monitor the work zone during the peak periods.

Several potential operational issues were discovered during the PTMS testing (*18*). At one site, a video detection camera was placed near construction activity. Work crews moved the camera trailer slightly, changing the field of view of the video detection system. This caused the video detection camera to produce inaccurate results. At the I-35 work zone, a video detection system was placed near a location where a jackhammer was used to break up pavement. The vibrations generated by the jackhammer caused extensive vibrations, which cause differential settlement of the soil under the camera trailer. This altered the camera's field of view, and resulted in erroneous data being transmitted to the TMC.

Several problems were encountered with the spread spectrum radios at the I-94 site (*18*). Multipath interference was encountered at this site, degrading the signal strength at one location. When countermeasures were implemented to eliminate this interference, the radios would sometimes skip intermediate receivers. The researchers recommended a change in the communications architecture to facilitate point to point links.

User Reactions. Driver surveys were conducted to determine user opinions on the PTMS. License plates were recorded at the site in order to identify drivers that had been exposed to the PTMS. Surveys were then sent to these drivers. This survey found that 66 percent of drivers remembered seeing a PTMS message (*18*). Of these drivers, 51 percent said they took some action in response to the message, and 61 percent felt that they felt more informed about work zone conditions.

TMC operators were also interviewed to determine their opinions on the system operation. Operators felt that they could master the system within three hours. No major technical problems were reported, although operators did request that an audible alarm be sounded when speeds fell below a user-specified threshold.

Proposed Guidelines. As a result of the testing, MnDOT developed a series of preliminary guidelines for the location of the PTMS components (*18*). These guidelines included:

- Ensure that communications infrastructure is available, if needed;
- Locate equipment to minimize the need to move it during construction activities;
- Minimize the potential for PTMS equipment to interfere with work activities;
- If wireless communications are to be used, try to ensure a clear line of sight between radios;
- Locate any speed sensors on stable ground in order to minimize the potential for aiming problems related to the detectors;
- Avoid locating equipment near construction activities that may create vibrations.

Maryland

The Maryland State Highway Administration and Federal Highway Administration provided funding for a private company to develop an early prototype PTMS. This evaluation was the first application of a PTMS that utilized an automated control system that did not require continual monitoring by personnel. Two generations of the PTMS were tested in Maryland with limited degrees of success. Technical difficulties prevented the completion of a detailed, documented study of the operational performance of the system at either site (*19*).

Prototype System

Site Characteristics. A first-generation PTMS was tested at a work zone on Maryland Route 214 in Prince George's County in 1996 (*20*). This work zone was experiencing recurring congestion, primarily due to its close proximity to an amusement park.

System Configuration. The prototype system consisted of three PCMSs placed along Route 214. This system used optical sensors that were mounted on span wire at fixed locations above the roadway to detect vehicle speeds. This type of installation took a long time to install and could not be easily changed based on work zone conditions. The sensors were powered using diesel generators. The central control system was housed in a job site trailer, and spread spectrum radio was used to communicate between all of the components of the system.

Evaluation Results. The prototype system experienced recurrent technical problems throughout the testing period. The developers of the prototype system attempted to make the PTMS operational from March 1996 to September 1996 (*20*). During this time, almost every component of the system suffered a hardware, software, or communications problem that caused a fatal error in the PTMS. The system was not continuously operational for more than 6 hours during this 7-month time period. By September 1996, the work activities were complete and congestion due to the amusement park had abated. The system was removed without ever functioning as intended, and no evaluation of this system was performed.

Modified System

The vendor performed extensive modifications to the prototype PTMS following the initial testing. Improvements were made to the communications system hardware and software, and new speed sensors were selected. The modified system was deployed at a new work zone to test its operation.

Site Characteristics. The modified PTMS was tested in a work zone on Maryland Route 90 (*19*). This road is a major route to Ocean City, a popular beach destination. The PTMS was installed to manage congestion along the route during the summer. The system was installed for approximately 1 month during the summer of 1997.

System Configuration. The system consisted of two PCMSs, one in each direction of travel (*19*). The PCMSs were placed at each end of the work zone, and a supplemental speed station was located within the work zone. Microwave radar sensors were used for speed detection. Speed sensors were mounted to PCMSs and were powered from the PCMS solar panels. An advisory speed message was displayed when there was a difference of at least 10-mph between the speed at the start of the work zone and the speeds within the work zone. Two different speed messages were tested at this site. The messages are shown in Table 5.

Table 5. Messages Displayed on Maryland Route 90

Message 1	Message 2
SLOW TO XX MPH **NOW**	WORKZONE SPEED XX MPH

The central processing system was housed in a construction trailer on the job site, and operated the system in a purely automated manner. Spread spectrum radio was used to provide communications. The layout of this site is shown in Figure 6. The asterisks represent locations where a PCMS was placed with a radar speed sensor. The asterisk closest to "CSC" represents the location of the central processing system.

Figure 6. Maryland Route 90 PTMS Layout (*8*).

Evaluation Results. Changes to the speed detectors and communications software generally improved the performance of the system, but communications problems were still observed. During the testing, it was noticed that there was a significant time lag between when slower speeds were detected within the work zone, and when the upstream PCMS would display the speed advisory message (*19*). During this time lag, conditions within the work zone often changed, reducing the credibility of the system. The range of the wireless communications was also severely limited, with a maximum communications range at the site of only 0.75 miles (*20*). The PTMS did not give accurate, real-time information about work zone conditions, so Maryland State Highway Administration personnel elected to discontinue the test until these communications issues could be resolved.

The vendor concluded that nearby cellular phone towers were interfering with the spread spectrum radio, and requested more funding to improve the system. Contracting difficulties prevented these modifications from being performed, and no follow-up studies have been conducted by the Maryland State Highway Administration. No operational studies were performed at this site.

Iowa

The Iowa Department of Transportation evaluated a PTMS in 1997 at an Interstate work zone (*21*). This was a prototype device that was purchased for a total cost of just over $100,000. An automated system was used to control the messages displayed on PCMSs.

Site Characteristics

The PTMS was tested on Interstate 80. The interstate was a four lane divided highway. One side of the Interstate was closed for reconstruction, and the other side was handling two-way traffic on two-lanes. Because only one lane was available for traffic in each direction, there was the potential for long queues at the site.

System Configuration

Figure 7 shows the general configuration of the PTMS tested. The PTMS used two PCMSs, one HAR, and two trailer-mounted video cameras on one approach to the work zone. All components were solar powered. The incident detection unit in Figure 7 is the central control system for the PTMS and a microwave speed sensor. This was the only location where a speed sensor was located. The trailer mounted video cameras were used by Iowa DOT personnel to verify incidents.

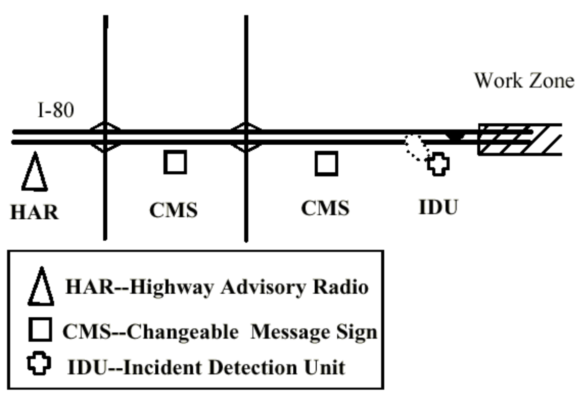

Figure 7. Iowa I-80 PTMS Layout. (*21*)

The central control system and microwave speed sensor were placed approximately 500 feet in advance of the taper. A cellular modem was used to communicate between the central control system and the upstream PCMSs and the HAR. The microwave sensor collected speed data at the taper in 1-minute increments. When the mean speed for the last eight minutes of traffic fell below a speed threshold, the message on the PCMSs was changed.

Two portable video cameras were placed alongside the microwave speed sensor. These cameras were aimed both upstream and downstream in order to visually verify conditions at the site. Cellular communications were provided to allow the cameras to be operated remotely. The cameras transmitted compressed video images to off-site personnel.

A solar-powered HAR unit was placed 2 miles before the work zone. The HAR had a range of 3 to 12 miles, and signing was provided to alert drivers to the HAR station. A flashing beacon on these signs was activated when unusual conditions were present at the site. The HAR had four pre-programmed messages. The first message informed drivers that they were approaching a work zone, and traffic was flowing smoothly. This message was transmitted under normal traffic flow conditions. During congested conditions, the message was changed to inform drivers that delays were present, and drivers should be prepared to stop. The last two messages were used when I-80 was closed, and drivers were instructed to divert to alternate routes.

Two PCMSs were used at the site. The first one was placed 3 miles upstream of the work zone, and the second was placed further upstream prior to an interchange. These PCMSs remained blank under normal conditions. When speeds fell below the speed threshold, the delay advisory message was automatically displayed. When the surveillance cameras verified a severe incident, the diversion message was displayed on the PCMS that was located prior to the interchange. The delay advisory and diversion messages used are shown in Table 6.

Table 6. Messages Used in Iowa Field Test

Message Purpose	First Frame	Second Frame
Delay Advisory	TRAFFIC DELAY AHEAD	PREPARE TO STOP
Diversion to Alternate Route	I-80 CLOSED AHEAD	USE EXIT 133

Evaluation Results

Several problems were noted with the communications and control system on this device (*21*). If congestion occurred at the taper, and dissipated within the next minute, the system would not change the messages to indicate that there was no delay at the site. This was perceived as a major problem with the system by Iowa DOT personnel. The cellular communications also did not have sufficient bandwidth to obtain real-time video from the cameras. A still-frame was updated approximately every 4 seconds, but this was felt to be sufficient for surveillance of the work zone. The impact of the PTMS on traffic operations was not evaluated.

Kentucky

The Kentucky Transportation Center performed an evaluation of two PTMSs in 1999 (*22*). One system was commercially available. The second system was developed by the construction contractor and was designed to mimic the operation of the commercially available system.

Site Characteristics

The systems were tested on Interstate 64 in Franklin County, Kentucky (*22*). I-64 was a four-lane divided highway with an ADT of approximately 34,000 vehicles per day. The regulatory speed limit was reduced from 65 to 55 mph through the work zone, and the right lane was closed in each direction. The work zone was five-miles long, and was bounded by two interchanges. Pavement rehabilitation and bridge reconstruction activities were taking place at the site.

System Configuration

The commercially available PTMS was used in the westbound direction, while the contractor provided system was used in the eastbound direction. Both systems used four PCMSs to display information to drivers. Radar units collected speed data at each PCMS, as well as at the arrow panel at the work zone lane closure. The first PCMS was located approximately 2.5 miles upstream of the lane closure, with additional PCMSs being placed every 0.5 miles after the first one. Figure 8 shows the layout for the commercial system. The asterisks represent locations where PCMSs were placed with radar sensors. CSC represents the location of the central processing system.

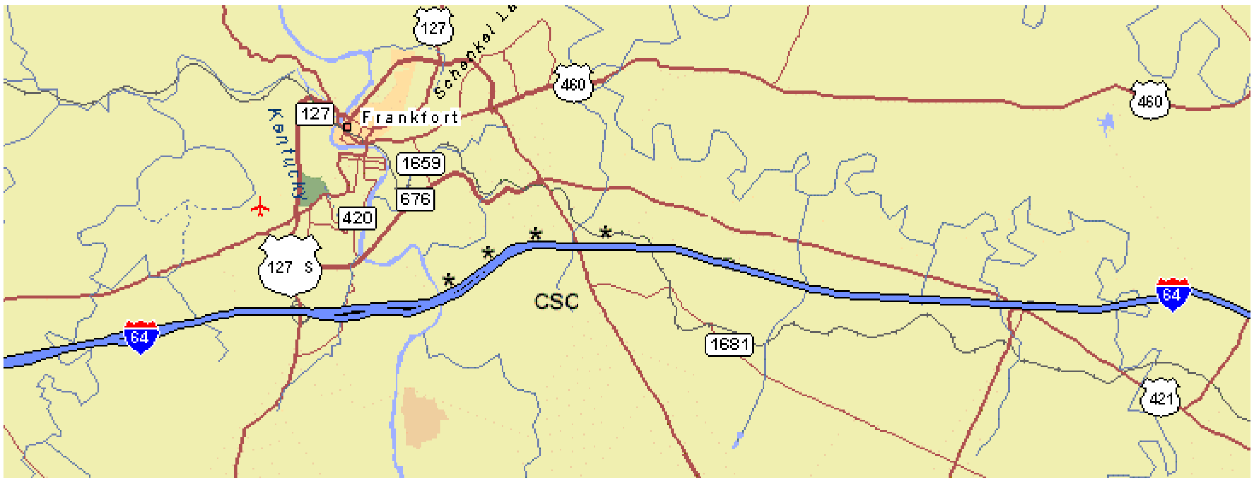

Figure 8. Kentucky I-64 PTMS Layout (*8*)

Messages were chosen based on a series of criteria that were input into the central control system. Three types of messages were displayed during this study: speed advisory messages, delay advisory messages, and diversion messages. The speed advisory and delay advisory messages used a time stamp frame. The time stamp was expected to improve message credibility by indicating that the information was current. The specific messages used are shown in Table 7.

Table 7. Messages Used in Kentucky Study

Message Purpose	First Frame	Second Frame
Speed Advisory	ROADWAY ADVISORY XX AM OR PM	REDUCE SPEED TO XX MPH
Delay Advisory	ROADWAY ADVISORY XX AM OR PM	XX MIN DELAY AHEAD
Diversion Message	LONG DELAYS AHEAD	FOLLOW ALT RTE

The two systems used similar methods to determine when to show the speed advisory message. The systems computed average speeds at each data collection station at preset time intervals. The average speed was calculated every 2 minutes with the commercially available PTMS and every 3 minutes with the contractor-provided system. When the difference in average speeds was greater than 10 mph between adjacent stations, the upstream PCMS displayed the speed advisory message shown in Table 7. Messages were updated every 2 minutes for the commercially available PTMS, and every 3 minutes for the contractor system. Speeds displayed on the PCMS were rounded to the nearest 5-mph increment. A minimum speed of 5 mph was established so that the PCMS would not provide an advisory speed of 0 mph when traffic was not moving.

Delay messages were also evaluated. The systems first computed the time it would take for a vehicle to travel through the work zone at the posted speed limit. Next, a projected actual travel time was determined based on current speed information. This was done in two different ways by the two systems tested. The contractor system assumed that the measured speeds at a station would represent the travel speeds to the next downstream speed measurement station. The commercial system averaged the measured speeds at two adjacent locations, and used the average of these two values as the travel speed between measurement stations. In both cases, it was assumed that the speed measured at the arrow panel would be the travel speed throughout the work zone activity area. Delay messages were displayed when the total delay exceeded five minutes.

Finally, alternate route information was displayed to drivers. An alternate route was suggested when the delay exceeded 15 minutes and this level of delay was maintained for at least 10 minutes. PCMSs were also present on the alternate route to provide guidance information to drivers.

The central control system placed these three types of messages in a hierarchy to determine which one would be displayed. The speed warning messages took precedence over the delay and alternate route messages. It was possible for some PCMSs in the work zone to be displaying speed messages, while others displayed the delay or alternate route information, depending on the speeds at different points in the work zone. The software ensured that the alternate route messages were not displayed after the potential diversion point. Signs remained blank unless a speed or delay criteria was met.

Evaluation Results

<u>Performance and Reliability.</u> Installation and initial calibration of the system was performed over a period of several weeks (*23*). The system was physically installed in only two days, but fine-tuning the message logic and proper aiming of the speed sensors lasted for several weeks. During this period, a significant amount of user intervention was required.

In general, the systems remained operational much of the time (<u>*22*</u>). Poor communications, lightning strikes, and low battery power caused some interruptions in system performance, but no long-term problems were observed. Repeaters were sometimes required when speed sensors were placed at low elevations relative to the central control systems.

Several problems were observed with the speed sensors used on the contractor provided system. The units used on this system initially could not record speeds below 20 mph. When low speeds occurred, the corresponding delays could not be calculated with any degree of accuracy, and were not displayed. The radar units were replaced, and this problem was corrected.

Several issues related to the aiming of the radar speed sensors were identified. First, if the radar was not properly aligned, speeds in the opposite travel direction would be detected, causing the system to show erroneous information. High winds also altered the aim of the radar units occasionally. This created large angles between the radar and the traffic, resulting in low speed measurements. Regular monitoring of the radar units was required to maintain proper operation of the system.

Speed Measurements. The speeds measured using the radar speed sensors were validated using field data. The original speed sensors used by the contractor system were found to have problems at low speeds, but this was corrected. Researchers determined that the PTMS displayed appropriate speed advisory messages based on current conditions.

Delay Estimates. Actual travel times through the work zones were determined to evaluate the accuracy of the delay estimates produced by the system (22). While both systems could usually determine when large delays were occurring, there were sometimes substantial differences between actual travel times and those displayed by the PTMS.

The major difference in the delay measurements appeared to be due to the lack of speed measurements within the work zone activity area. The last speed measurement occurred at the arrow panel, and this speed was used as the travel speed throughout the 2.5-mile work zone activity area. The activity area represented approximately ½ of the length of the entire site. In most cases, vehicles were delayed significantly at the lane closure itself, but traffic flowed reasonably well within the activity area. Thus, the speeds measured at the taper were often not representative of travel speeds within the lane closure, and delays were often overestimated. These differences caused the alternate route message to be displayed frequently when the actual delay was far below the 15-minute threshold. The actual delay through the work zone was greater than 15 minutes in only 20 percent of the observed cases where the diversion message was displayed.

Diversion. Drivers did not tend to respond to the diversion message unless there was a visible queue or there were obviously significant delays. Drivers may not have reacted to the diversion message for several reasons. First, the diversion message was often displayed when delays did not exceed 15 minutes. Regular drivers of the route may not have felt that the diversion message was credible based on their experiences. The travel time along the alternate route was also significantly longer than 15 minutes. Since the criteria for displaying the diversion message was set unrealistically low, drivers familiar with the area may have been unlikely to divert.

The lack of effectiveness of the diversion messages may also be partially attributable to a poor system design (*22*). The delay in the work zone was calculated at individual locations. Thus, the speed measurement sites located the farthest from the arrow panel had the largest potential to have a delay that exceeded the 15 minute threshold, because they included delay from that measurement station through the end of the work zone. In some cases, an alternate route message would be displayed upstream of the exit point, but a delay message would be displayed at the actual exit point. This may have caused drivers to conclude to that they did not need to exit the freeway.

Driver Opinions. Researchers interviewed 66 drivers at a rest stop immediately east of the work zone. Approximately 89 percent of drivers indicated that they had seen the PCMSs, and 74 percent stated that they had seen a message on the PCMS. The drivers surveyed indicated that the felt the messages were very understandable and very useful.

Nebraska

The University of Nebraska evaluated a PTMS at an Interstate work zone over a 49-day period in the summer of 1999. This evaluation examined speed advisory, delay advisory, and diversion messages.

Site Characteristics

The PTMS was tested on Interstate 80 between Lincoln and Omaha, Nebraska (*24*). The site was a four lane divided highway. One side of the freeway was closed for resurfacing, and there was two-lane, two-way operation on the other side of the freeway. This section of I-80 carried 40,000 vehicles per day, with trucks composing 21 percent of the traffic stream. The regulatory speed was reduced from 75 mph to 55 mph within the work zone.

System Configuration

This evaluation used a commercially available PTMS. Three PCMSs were used, and radar speed sensors were mounted on each PCMS. An additional speed sensor was located at the arrow panel at the work zone. PCMSs were placed approximately 1, 3, and 8 miles in advance of the work zone taper. The PCMS was placed 8 miles upstream of the work zone in order to facilitate diversion, if needed. A fourth PCMS was placed on a cross street to alert drivers of potential delays on the Interstate. The layout of the system components is shown in Figure 9.

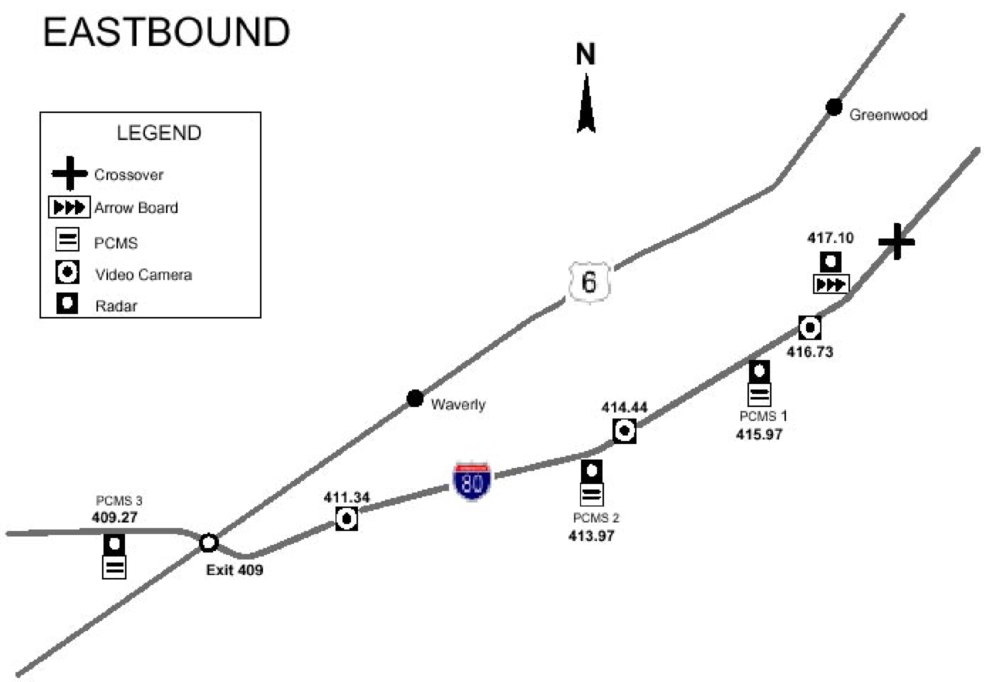

Figure 9. Nebraska I-80 PTMS Layout (*24*)

A delay message, a diversion message, and a speed advisory message were evaluated at this site. The PTMS used a hierarchy in order to determine which message should be chosen for the given conditions. The speed advisory message was chosen to have priority over other messages because there was some concern over the safety consequences of high speed differentials between vehicles. Table 8 shows the specific messages used in this study. The speed and delay advisory messages used time stamps in order to indicate that the information was current.

The radar speed sensors produced average speeds at each station every 4 minutes during the peak period, an every 8 minutes during the off-peak periods (*24*). These average speeds were then compared between adjacent data collection stations. If the speeds were found to differ by more than 10 mph, the advisory speed message would be displayed at the upstream PCMS. These speed advisory messages would display the downstream speed rounded down to the nearest 5-mph increment. Advisory speeds were limited to between 5 and 55 mph (*24*). The PCMSs that were placed 3 and 8 miles upstream of the work zone were blank when a speed advisory message was not needed. The PCMS located 1 mile upstream of the work zone displayed a lane closure message when no advisory was needed.

Table 8. Messages Used in Nebraska Study

Message Purpose	First Frame	Second Frame
Speed Advisory	I-80 (E) ADVISORY XX:XX AM OR PM	REDUCED SPD AHD XX MPH
Delay Advisory	I-80 (E) ADVISORY XX:XX AM OR PM	XX MIN DELAY AHEAD
Diversion Message	30 MIN DELAY AHEAD	CONSIDER ALT ROUTE

A delay message was displayed when the estimated delay exceeded 5 minutes (*25*). Delays were calculated by comparing the theoretical travel time through the work zone to the projected travel time determined by the central control system. Travel times were determined by averaging the measured speed at adjacent data collection stations and determining total travel time through the work zone.

A diversion message was displayed when the estimated delay exceeded 30 minutes. No alternative route guidance information was provided on the PCMS.

Evaluation Results

Diversion. The amount of traffic diverting from Interstate 80 in response to the alternate route message was evaluated. When the PCMSs were blank, approximately 8 percent of all traffic exited the Interstate onto Nebraska Highway 6, the only realistic alternate route (*26*). When the diversion message was active, this percentage increased to 11 percent. The 3 percent change in the volume of traffic exiting the freeway was found to be statistically significant, although an increase of 3 percent may not produce large actual benefits. It is also possible that some of this variation may be due to natural changes in travel patterns during the study period. The researchers hypothesized that greater diversion percentages could have been obtained if specific directional guidance, such as exit numbers or route information, had been provided.

The researchers also examined the changes in travel patterns on Highway 6 to determine if the PTMS messages shown by the PCMS on Highway 6 prevented drivers from entering the highway during periods of large delays (*28*). The percentage of vehicles exiting Highway 6 declined 1 percent, which was not found to be statistically significant.

Speed Advisory. Researchers originally intended to conduct a before and after study of the effectiveness of the speed advisory message. During the before period, congestion was never observed at the site so before data could not be collected.

The analysis showed that the speed advisory messages had a limited impact during uncongested conditions. Researchers found that mean speed, standard deviation, 85^{th} percentile speed, and the percent of vehicles exceeding the speed limit did not change significantly following the application of the PTMS when all traffic densities were aggregated (*25*). However under uncongested conditions, the speed advisory messages were rarely displayed, so the uncongested time periods may have masked an impact that occurred only during congestion. In order to help identify the impact of the messages during congested conditions, the researchers developed a series of regression equations to help identify the impact of density and the speed advisory message on mean speed, 85th percentile speed, and the mean speed of vehicles traveling faster than the 85th percentile speed (*24*).

This analysis showed that the speed advisory messages produced mixed results. Drivers tended to ignore the suggested advisory speeds during uncongested conditions, while they tended to have more effect during congested conditions (*28*). Researchers defined congestion as occurring when traffic density exceeded 40 vpm (*24*). Speed messages were not observed to create significant reductions in 85th percentile speed when densities were below 40 vpm. Better compliance with the speed advisory messages was observed at higher densities and when drivers were closer to the work zone and could visually confirm congestion. Previous research has shown that drivers will not reduce their speed by more than 15 mph on rural freeways and 10 mph on urban freeways, regardless of the type of speed control used (*27*). Since the speed advisory message was only displayed when the speed differential was greater than 10 mph, it is probably not surprising that the drivers only responded when congested conditions were present.

The researchers felt that the 5-mile spacing between the first and second PCMSs was too large for drivers to perceive the need to slow down (*28*). Speed advisory messages displayed on the PCMS located 8 miles upstream of the work zone did not have any noticeable impact on travel speeds. The researchers recommended that PCMSs be spaced no more than 2 miles apart in order to maintain speed reductions.

Driver Survey. Drivers were surveyed at a downstream rest stop in order to determine driver perceptions about the messages displayed. Table 9 summarizes these results (*28*). In general, the researchers found that the drivers that noticed the PTMS thought that it provided useful information. The lack of specific alternate route information limited the effectiveness of the diversion message. Drivers were also unsure of the meaning of the blank PCMSs. Drivers did not frequently notice the time stamp message, either.

Table 9. Nebraska Driver Survey Results (*28*)

Message	% of Time Displayed	% of Drivers That:		
		Noticed Message	Understood Message	Thought Message Was Useful
I-80 (E) ADVISORY X:XX XM	22	3	75	83
REDUCED SPD AHD XX MPH	17	11	98	98
XX MIN DELAY AHEAD	5	8	87	83
CONSIDER ALT ROUTE	1	6	88	48
Blank	55	29	24	N/A

Safety and Crash Experience. The researchers attempted to assess the impact of the PTMS on work zone crashes. The researchers compared crash data from two years prior to the study to data from the year that I-80 was under construction. The researchers found statistically significant increases in the total number of crashes, the number of rear-end crashes, and the number of property damage crashes after the work zone was implemented (*28*). This analysis only shows that crashes increased when the work zone was implemented, and the PTMS did not manage to reduce the number of crashes to a level comparable to non-construction conditions. The PTMS was not in place for a long enough period to generate any noticeable impact on crashes. The researchers also examined the number of forced merges that occurred at the site (*25*). The number of forced merges at the taper did not change significantly after the PTMS was installed.

Benefit/Cost Analysis. The potential benefits and costs of PTMSs were quantified in an attempt to determine when the system should be used (*28*). The analysis was performed for directional traffic volumes between 15,000 and 28,000 vpd, with trucks composing between 0 and 50 percent of the traffic stream. The potential savings in delay and crashes were weighed against the initial purchase cost of the PTMS. The analysis assumed that the PTMS would improve capacity by 250 vph, 15 percent of traffic would be diverted to alternate routes, and that crashes would be reduced due to fewer hours of congestion at the work zone.

Based on these assumptions, PTMS was only found to be appropriate for situations where the directional ADT was high. With 0 percent trucks, the directional ADT needed to be greater than 27,000 vpd to economically justify the use of a PTMS. With 50 percent trucks, this volume dropped to approximately 22,000 vpd. Below these volumes, the initial costs of the system were too large to justify use of the system. It should be noted however, that the assumption of 15 percent diversion is not consistent with the results of the field testing, however.

Illinois

Illinois Depart of Transportation (IDOT) recently completed a field test of a PTMS on a bridge reconstruction project in Peoria, Illinois.

Site Characteristics

From March to October of 2000, the McClugage Bridge was undergoing bridge deck rehabilitation. The bridge actually consisted of two structures, one of which was closed for rehabilitation. The remaining bridge had two regular travel lanes and a wide shoulder that was used as a travel lane. These three lanes were used to carry traffic in both directions throughout the construction project. The bridge carried 40,000 vehicles per day, and the speed limit was reduced from the normal regulatory speed of 55 mph to 45 mph during the project (*29*).

System Configuration

Agency personnel were concerned that the bridge closure would create significant congestion and queuing during construction (*29*). In order to address these concerns, IDOT decided to implement a PTMS in conjunction with a movable barrier system. The movable barrier system used at the site is shown in Figure 10. The agency determined traffic volumes traveling into Peoria were about twice as large as outbound volumes during the AM peak. The opposite trend was observed during the afternoon peak. The moveable barrier system was used to place concrete barriers so that there were two lanes inbound and one outbound from 9 PM to 11 AM, and two lanes outbound and one inbound from 11 AM to 9 PM (*30*).

Figure 10. Movable Barrier in Use on McClugage Bridge (*30*)

The PTMS used 10 PCMSs with radar speed detectors (*29*). These PCMSs were placed on McClugage Bridge, as well as on the approaches to the bridge. An interchange was located on either side of the structure, so PCMS were placed on all approaches to the interchanges so drivers could be alerted to potential congestion on the bridge and have an opportunity to select alternate routes. Wreckers were stationed on either side of the bridge to clear any incidents that occurred on the bridge. The PTMS was used to provide delay advisory messages to drivers. If the calculated delays on the bridge were less than 10 minutes, a default message was displayed. The default message is shown in Figure 11. Figure 12 shows the layout of the PTMS components at this site.

Figure 11. PTMS Default Message (*30*)

Evaluation Results

There was some difficulty in initially installing the system (*29*). The site was located in a river valley with bluffs on either side. This made initial set up of the spread spectrum radio communications system rather difficult. Antenna location and placement of the PCMSs had to be modified several times before the communications system worked as intended.

IDOT never performed an evaluation of the PTMS, in part because the expected levels of queuing and delay never developed (*29*). IDOT personnel indicated that the movable barrier system allowed the bridge to have sufficient capacity during construction. Personnel could only recall a single time during the 8-month construction project that the PCMSs displayed anything other than the default message (*29*). In this case, a vehicle had stalled in the non-peak direction, blocking the only open lane. The wreckers on duty quickly cleared the vehicle, and the queue quickly dissipated.

The PTMS was struck by lighting when about 1 month remained in the project (29). IDOT elected not to repair the system because it did not appear to have any significant impact on traffic flow through the site. No changes in congestion were observed after the PTMS was removed.

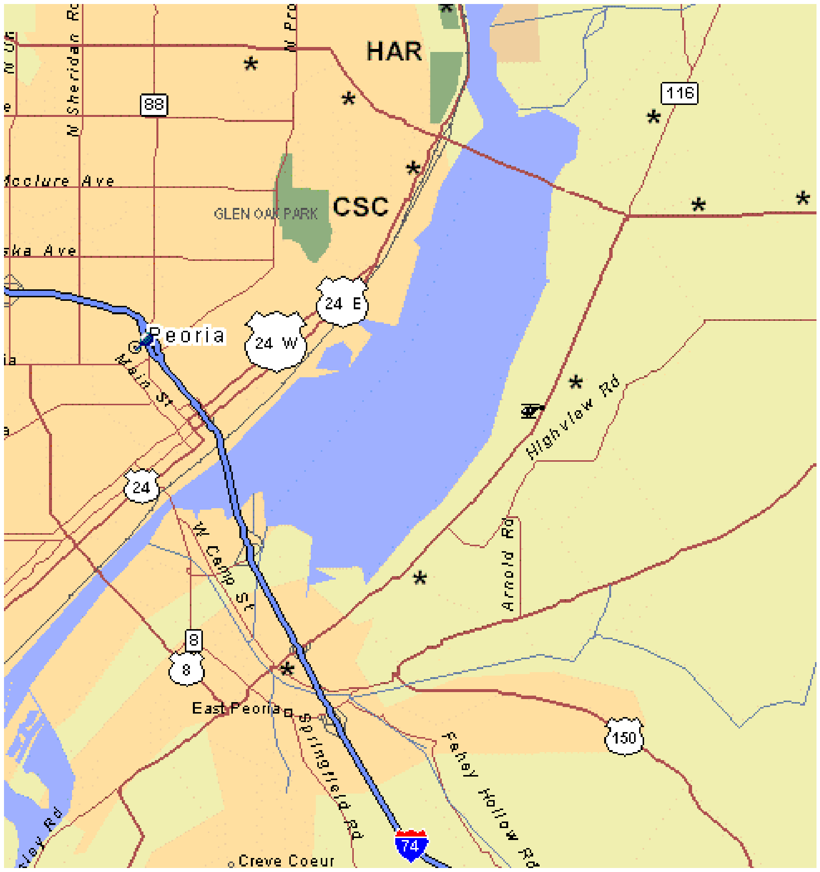

Figure 12. Illinois McClugage Bridge PTMS Layout (8)

Ohio

Ohio University conducted an evaluation of a PTMS for the Ohio Department of Transportation (*31*). This study was primarily concerned with determining whether the system could provide accurate travel time estimates and whether the driving public felt that the system was beneficial.

Site Characteristics

The PTMS was tested on a 13-mile segment of Interstate 75 during the summer and fall of 2000. A construction project in downtown Dayton, Ohio was creating significant peak hour congestion along the route.

System Configuration

The PTMS was deployed in the northbound direction of I-75. Five radar speed sensors were used to determine travel time information. Travel time information was displayed on three PCMSs along the route based on these travel time calculations. Travel time information presented on the PCMSs was updated every four minutes, and travel times could only be presented in four-minute increments. Travel speeds at adjacent data collection stations were averaged together to determine the travel speed between these points. These speeds were then used to calculate travel times through the work zone. The layout of the PTMS is shown in Figure 13.

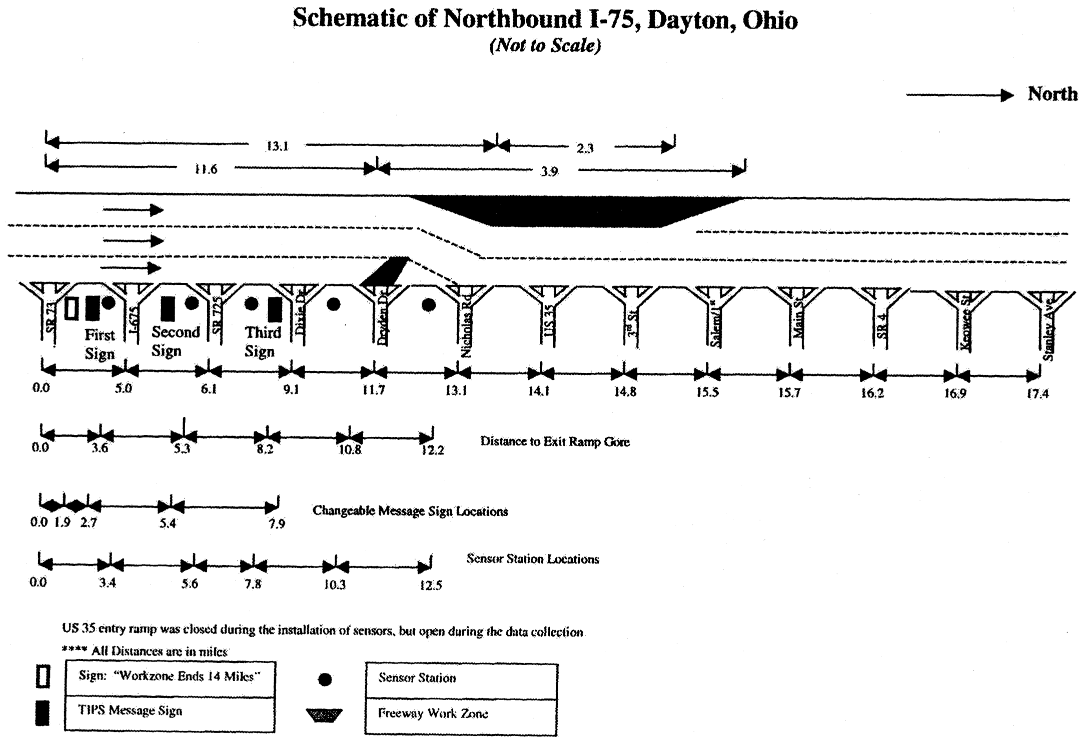

Figure 13. Ohio I-75 PTMS Layout (31)

Two panels were used to display the travel time messages. The first frame showed the travel time to the end of the work zone, and the second frame showed the distance to the end of the work zone. Table 10 shows the message used in this evaluation. Travel times were reported from the PCMS displaying the message to the end of the work zone.

Table 10. Messages Used in Ohio Evaluation

Frame 1	Frame 2
XXMIN TO END OF WORKZONE	WORKZONE ENDS XX MILES

Evaluation Results

The evaluation was concerned with determining if the system could present accurate delay information. It also examined whether drivers saw a benefit in the system.

Accuracy of Delay Information. Predicted travel times were compared to a series of 117 actual travel time runs through the work zone. The evaluation showed that 88 percent of the delays generated by the PTMS were within 4 minutes of the actual travel time. Given that the maximum travel time predicted was 36 minutes, an error of +/- 4 minutes could be a significant percentage of the total travel time. Differences between predicted and actual travel times were sometimes as large as 18 minutes. The PTMS tended to underestimate long delays. Large errors tended to occur when the road was most congested, with the PTMS reporting a 15 to 26 minute travel time when travel times in excess of 32 minutes were present.

Driver Acceptance. Researchers recorded over 3000 license plates of private vehicles traveling through the work zone, and sent the registered owner of each vehicle a survey to determine opinions of the system. Approximately 20 percent of the surveys were returned. The survey produced the following findings:

- The travel time information caused 60 percent of drivers to leave the freeway earlier than they planned;
- Drivers did not believe that the PTMS consistently provided accurate travel time information. Approximately 42 percent said the system was only sometimes accurate, 5 percent said it was not accurate, and 25 percent did not know.
- Drivers generally had a favorable impression of the system, with 90 percent stating that system either sometimes or always provided useful information, and 86 percent saying that real-time information on the work was helpful.

Future and Ongoing Testing

PTMSs testing is either underway or planned in the near future in at least two more states. California will be performing a total of 6 field tests of PTMSs (*32*). The first field test is scheduled for late summer of 2001 on the American River Bridge near Sacramento.

A PTMS is currently being tested in Albuquerque, New Mexico at a major reconstruction of the interchange between Intestates 25 and 40 (*33*). The system consists of two PTMSs which both have surveillance video cameras and PCMSs. These systems are being operated in conjunction with a series of PCMSs and closed circuit television cameras from a temporary traffic operations center located at the job site.

Summary of Field Tests

The review of the field operational tests revealed some important operating characteristics of PTMSs. Improvements have been made in the technology that is used with these systems, but some problems with communications were observed even in the more recent studies. Some of the key characteristics and findings from the review of past tests are summarized in Tables 11-13.

The characteristics of messages used in each field study are summarized in Table 11. In all cases, the researchers did not perform message testing prior to the start of the test. Kentucky, Nebraska, and Ohio performed some message testing as part of the PTMS study, but messages were not corrected if potential problems were observed. In all cases, the characters on the PCMSs were at least 18 inches tall.

The operational and safety impacts of the PTMSs are summarized in Table 12. Only Minnesota, Kentucky, and Nebraska attempted to determine the impact of the PTMS on traffic operations and safety. The existing results indicate that PTMSs may produce small increases in capacity, have a limited ability to cause vehicles to divert from the freeway, and only create speed reductions under congested conditions. Given the small number of evaluations performed, it is not possible to verify whether these results are accurate. Because of the problems with sensor location, message design, and overall system operation that were present in these studies, the results of these evaluations may be questionable. Determination of the operational and safety impacts of PTMSs will require further study.

Table 11. Summary of Message Characteristics from Field Tests

State	Minnesota	Maryland	Iowa	Kentucky	Nebraska	Illinois	Ohio
Type of Advisory Message	Speed, possibly others	Speed	Delay	Speed, delay, and alternate route	Speed, delay, and alternate route	Travel time	Travel time
Size of PCMS Letters	21 inches	18 inches	18 inches	18 inches	18 inches	Unknown, 18 inches probable	18 inches
Message Testing	Unknown	No	No	Yes, as part of test	Yes, as part of test	Vendor specified message	Yes, as part of test

Table 12. Summary of Traffic Operations and Safety Impacts from Field Tests

State	Minnesota	Maryland	Iowa	Kentucky	Nebraska	Illinois	Ohio
Safety	No data	No data	No data	No data	No detectable change	No data	No data
Capacity	3 to 6 percent increase	No data	No data	No data	No data	No data	No data
Speed	Up to 9 mph lower on approach	No data	No data	No data	Messages effective when density > 40 vpm	No data	No data
Diversion	No data	No data	No data	Not effective	3% increase	No data	No data

The results of the technology evaluations are summarized in Table 13. Technical problems were present in four of the seven evaluations performed, although they are not seen in the most recent evaluations. Early tests in Maryland and Iowa suffered from poor communications systems, which resulted in old information being transmitted to PCMSs upstream of the work zone. In these cases, problems with the technology were so acute that the evaluations of these systems were discontinued prematurely. Problems with sensor alignment and accuracy were also observed in Minnesota and Kentucky. Evaluations of the delay and travel time messages showed that they did not always accurately reflect the conditions at the site. This may be partially attributable to the placement of the sensors in the work zone, however.

Although the field tests offer some initial information about the performance of PTMSs, more research still needs to be done. The impact of the PTMS on traffic operations needs to be determined and several technology issues need to be addressed. Future studies must avoid some of the problems that were encountered in earlier studies in order to produce data that could be generalized to other sites. Before further evaluations of these systems are performed, guidelines for the application of PTMSs and location of PTMS components need to be developed. These guidelines will allow researchers to better install PTMSs and avoid some of the flaws of past studies.

Table 13. Summary of Technology Evaluation from Field Tests

State	Minnesota	Maryland	Iowa	Kentucky	Nebraska	Illinois	Ohio
Sensor Type	Video detection, radar	Optical sensors, radar	Radar, video cameras	Radar	Radar	Radar	Radar
Information Dissemination Devices	PCMSs, HAR, Internet	PCMSs	PCMSs, HAR	PCMSs	PCMSs	PCMSs	PCMSs
Accuracy of Information	Messages were determined by TMC personnel	Messages not in real-time	Messages not in real-time	Poor delay estimates	Good	Good	Delay estimates worsened during congested conditions
Technology Problems?	Minor	Major	Major	Minor	None reported	None reported	None reported

SYSTEM REQUIREMENTS AND APPLICATION GUIDELINES

The results of past studies have not been able to conclusively demonstrate that PTMSs have a significant impact on safety or traffic operations in freeway work zones. In some cases, PTMSs were installed in situations where they were not appropriate, or PTMS components were not optimally located. Researchers and departments of transportation that will be evaluating PTMSs need to be aware of the problems encountered in earlier evaluations. Basic requirements for PTMSs are needed so that agencies can ensure that the systems they utilize have the potential to be effective in work zones. Guidelines are also needed so that users can determine situations where a PTMS may be beneficial. If a PTMS is found to be appropriate for a location, agencies need guidance to properly locate system components in a work zone. Information on basic functional requirements for PTMSs are provided in this section. Guidelines for PTMS usage and placement are also provided.

Characteristics of Well-Designed PTMSs

The review of past field tests revealed several design issues that may influence the overall effectiveness of a PTMS. These issues relate to the technology used, system usability, system cost, and message design. Since a transportation agency may have a limited ability to change these design features, it is important that any PTMS considered for use at a work zone be well-designed initially. The characteristics presented in this section should provide agencies with a list of features that can be used to select a PTMS.

Credibility

The effectiveness of a PTMS is directly tied to the credibility of the system. If drivers do not believe that the information being presented to them is both timely and accurate, they will not alter their behavior in response to the messages. For example, the system tested in Kentucky did not produce accurate estimates of delay. Thus, when drivers were directed to use an alternative route, they did not divert from the freeway since they had no faith in the accuracy of the system.

Information must reflect current conditions in order to maintain the credibility of the system. If drivers see a message that says they are approaching congestion, congestion should actually be present at the work zone when they drive through it. The requirement for current information can influence system design in two ways. First, the system must be able to quickly detect the presence of congestion and transmit commands to PCMSs or other information dissemination devices. Second, enough data should be collected by the system to ensure that the congestion exists and is not caused by a short-term problem. These two requirements must be balanced to ensure that the information that is given to drivers is current and represents a real problem.

The PTMS should also provide accurate information. Travel time estimates should closely represent actual conditions, alternative routes should improve travel times, and speed advisories should reflect the real traffic speeds. While some error may be permissible, this information should provide useful information that drivers can use to make decisions. The algorithms and thresholds used by the central control system need to be set in a realistic manner in order to maintain system credibility. Failure to use realistic thresholds will undermine the credibility of the system.

Clear, Effective Messages

Well-designed, effective messages are needed in order to convey information to drivers. Previous evaluations did not perform any message testing prior to the start of the evaluation, and most used default messages provided by the vendor. Before implementing a message on a PCMS or HAR, the message should be tested to determine if drivers understand the message content and think that it provides useful information. It is not the purpose of this document to propose actual messages that should be used by PTMSs. Messages should be carefully designed using appropriate guidelines and testing procedures.

PCMS messages should also be legible to drivers traveling at freeway speeds. As noted earlier in this paper, 18-inch characters are legible to most drivers from a distance of at least 650 feet (16). Most commercially available PCMSs have characters that are at least 18 inches tall. When a driver is traveling at 55 mph, a 650 feet legibility distance translates into approximately 8 seconds where the message is legible to the driver. Messages should be designed so that drivers can read the message during the time available. PCMSs should be placed in locations where there is good sight distance to ensure that drivers have as much time as possible to read the message.

Accurate and Reliable Sensors

The ability of a PTMS to provide relevant information to drivers is based on the provision of accurate and reliable sensors. Sensors should be able to collect data under all traffic, weather, and environmental conditions. The sensors should be able to collect data during both congested and uncongested periods, and be able to determine data regardless of the composition of the vehicle fleet. The performance of the sensors should not be impacted by the level of ambient light, temperature, or by precipitation.

The sensors should also be reliable. Once the sensors have been installed at a location, personnel should need to perform very little maintenance. Sensors should remain properly aligned and functional under a wide range of weather conditions. Dust generated by the work zone activities should not impact the performance or reliability of the sensors.

Reliable Communications

A PTMS would not be able to function without a reliable communications system. In order to ensure that a reliable communications system exists, potential users should examine the characteristics of both the communications technology and the work zone site. The impact of site characteristics on communications reliability will be discussed later in this report.

Several issues related to the communications system should be considered. First, the user should determine the bandwidth demand that will be generated by the system. The amount of transmission capacity required depends on the types of information that will be transmitted. If a system is going to provide real-time video, the communications system will need to have a large bandwidth. If insufficient bandwidth is provided, the reliability of the system may suffer.

Next, the agency should examine different communications technologies to find one that satisfies the bandwidth requirements. While wireline communications are much more reliable and usually have a larger bandwidth than wireless systems, the infrastructure costs associated with these installations can be very large. When wireline systems are used, PTMS components must be placed at fixed locations, reducing the portability of the system. In many cases, reliability and bandwidth may need to be weighed against flexibility and cost in order to determine the type of communications to be used at a site. Given the rapid changes that are occurring in communications, agencies should carefully examine the most recent data on the performance of various systems.

Quick Installation and Easy Operation

PTMSs should be installed in a relatively short amount of time. Ideally, it should take no more than one week to completely install and configure the system. Protracted installation times are contrary to the purpose of a PTMS, since these systems should be portable and adaptable to changing work zone conditions. Manufacturer personnel can be used to train agency personnel on how to install the system, but the PTMSs should be configured so that the installation of the system can be performed by agency personnel after initial training is completed.

The PTMS should be able to be operated with little human intervention. The software used by the central control system should be easy to use and effective. The agency should not need to monitor the operation of the system except in rare cases.

Cost Effectiveness

A complete PTMS for a short work zone will easily cost in excess of $250,000, so the benefits of the PTMS must justify its cost. The agency should examine the projected impacts of the PTMS at a specific site. The anticipated reductions in delay and improvements in safety should justify the use of a PTMS at a particular location. The PTMS must be able to provide quantifiable results in a cost-effective manner.

Guidelines for Use of PTMSs

Before an agency chooses to install a PTMS at a work zone, they should be confident that the characteristics of the work zone lend themselves to the application of a PTMS. Past field tests have revealed several conditions where PTMSs could potentially provide a benefit. While more research needs to be done in order to provide specific warrants for the application of a PTMS, general guidelines could be developed to help agencies determine whether a PTMS may be beneficial at a work zone.

Presence of Congestion

The most basic prerequisite for installing a PTMS at a work zone is that congestion must be present. If no congestion occurs at the site, the PTMS will not display any messages and will not produce any benefits. The test on the McClugage Bridge reconstruction in Peoria illustrated that these systems should not be used when congestion does not occur.

The agency should perform a capacity analysis of the work zone using reasonable estimates of traffic demand volumes. Several models are available to predict travel speeds and maximum queue lengths as a function of work zone geometry and traffic demand. As long as the model assumptions are accurate, these models should provide a reasonable indication of traffic flow characteristics at the site. The agency should be sure to examine the queuing and travel speeds throughout the day, and not just during the peak hour. The duration of queues and slow travel speeds should be noted.

If congestion occurs at a work zone, the agency should carefully examine the data to determine if a PTMS is appropriate. Static signing or normal PCMSs may be sufficient to provide information when congestion consistently occurs at the same time of day and there is a large percentage of commuter drivers. In these cases, drivers develop expectancies about conditions at the site, and the PTMS may not provide additional useful information to drivers. A PTMS will probably be most effective when congestion is maintained for a protracted period of time, and the length of queue, differences in travel speed, and travel time through the work zone are somewhat variable from day to day.

Duration of Work Activities

PTMSs should only be used on long-term construction or maintenance projects. Existing systems are costly and can take up to one week to install and configure. Often, the work zone has to actually be installed before the proper speed sensor locations and message thresholds can be determined.

If a work zone is only going to be in place for a short duration, it is probably difficult to justify the use of a PTMS. The time required to properly locate system components, install equipment, and configure the central control system algorithms to existing conditions at the site may be too large to warrant installing PTMSs at short-term work zones. If it takes one week to properly install a PTMS, it is likely that use of these systems would not be justified unless a work zone was going to be present for at least several months. Individual agencies will need to determine the minimum project duration that warrants the installation of a PTMS based on the expected safety and efficiency benefits of the PTMS at a site.

Speed Advisory Messages

Speed advisory messages appear to only be effective under congested conditions. If speed advisory messages are to be used, the PCMSs should be placed in the areas where vehicles may be transitioning between congested and uncongested flow. Researchers found that speed advisory messages were only effective when density exceeded 40 vpm. PCMSs should be placed in advance of locations where the density increases above this value. In these cases, the speed advisory message may produce a safety benefit by causing drivers to reduce their speed and alerting them to slow moving traffic downstream of their current location.

Delay, Travel Time, and Alternative Route Advisories

Delay, travel time, and alternative route advisories all provide the driver with information that allows them to choose a new route in order to avoid delays through the work zone. Delay and travel time information allows drivers to determine whether to divert to an alternative route. In this case, each individual driver determines whether to divert based on their own tolerances for delay and willingness to leave the freeway. An alternative route message recommends a specific diversion route, and carries the implicit message that the alternate route will significantly improve the driver's travel time to their destination.

Before using one of these messages, the agency should determine whether there are potential alternative routes in the area. If the agency is only considering providing travel time or delay information, they should still ensure that there are alternative routes. Otherwise, drivers will be aware of how long it will take to travel through the work zone, but they will not have any options for reducing their trip time. The presence of alternative routes allows drivers to select a path if they feel it will minimize their travel time. Agencies may desire to provide information at the closest freeway-to-freeway interchange in addition to major interchanges near the work zone since some drivers may be reluctant to divert to regular surface streets.

When a PTMS provides specific information about an alternative route, the agency must be confident that the alternative route will significantly improve travel time around the work zone. Conditions on the route must be analyzed to determine how traffic diverting from the freeway will impact the roadway. In cases where the PTMS is diverting traffic to city streets, conditions on the alternative route could be changed to accommodate the increase in traffic. For example, signal timings could be changed or parking could be removed.

Guidelines for Component Location

Once the agency has determined that a PTMS may be effective at a particular site, they must determine where to place individual system components. General guidelines that impact the placement of all components were generated. Specific guidelines were also generated for the following components:

- PCMSs;
- speed sensors;
- central processing system; and
- wireless communications systems.

General Guidance for Component Placement

If possible, speed sensors, PCMSs, and other components should not be placed near locations where work activities will be performed. PTMS components could interfere with the ability of work crews to perform their duties, and workers could inadvertently change the orientation or position of a component. This could significantly impact the performance of a PTMS, particularly if a speed sensor becomes misaligned or a device is damaged due to work zone activities. If possible, all components should be located in areas away from actual work zone activities.

Components should also be placed away from locations where they may be prone to vandalism. PTMSs should not be placed near freeway rest areas, or near areas where vandals could easily access the system.

PCMS Placement

Next, the location for PCMSs should be determined. The location will be based on the desired function of the system, minimum spacing requirements between signs, and requirements for message legibility. The *Manual on Uniform Traffic Control Devices* (MUTCD) states that PCMSs be visible from at least 0.5 miles away, and that the message should be legible for 650 feet (*34*). The MUTCD also suggests that drivers be able to be read the entire message at least twice at the posted speed, the off-peak 85th percentile speed prior to the start of work activities, or at the anticipated operating speed. The PCMSs should be located so that these minimum criteria are met. PCMSs should also be located a sufficient distance from static signs so that they do not interfere with any work zone or guide signing.

The PCMSs should be placed so that drivers will see any messages prior to encountering the end of the queue. This will allow drivers to either reduce their speed or seek alternate routes based on conditions in the work zone before encountering severe congestion. The results of the capacity analysis of the work zone should be used to determine the maximum queue length, and PCMSs should be placed accordingly.

If travel time, delay, or diversion messages are to be displayed, PCMSs must be placed in advance of any interchanges where drivers can access alternative routes. It is important that PCMSs be placed in such a way that drivers have information to make route decisions prior to reaching interchanges where they may divert to alternative routes. As a minimum, PCMSs should be placed in advance of interchanges for the alternative routes closest to the work zone. The agency may also wish to consider placing a PCMS at the nearest freeway to freeway interchange since some drivers prefer not to divert from a freeway to a surface street. Drivers should receive this information before they see guide signs for interchange exits in order to provide enough time for drivers to decide to exit the freeway. PCMSs may also be placed on minor roads that intersect the freeway in order to alert drivers to potential delays on the freeway. Drivers on the minor road may choose not to enter the freeway if they feel that delays are excessive.

If a speed advisory message is to be used, the PCMSs need to be placed upstream of any locations where traffic is traveling at slow speeds. The PCMSs should be placed far enough upstream that vehicles can easily decelerate to the appropriate advisory speed. However, past research has shown that PCMSs should be spaced no more than 2 miles from the location of slow moving traffic in order to maintain the effectiveness of the message. This represents a maximum spacing, and PCMSs may be placed more frequently of speeds are highly variable in the work zone.

Speed Sensors

The location of speed sensors will vary depending on the characteristics of a site and the primary function of the PTMS. When providing speed advisory messages, speed sensors should first be placed at locations where traffic speeds are expected to be lower than normal. For example, speed sensors may be placed at the work zone taper, near the projected end of a queue, or near freeway entrance or exit ramps. This will provide an indication of the traffic conditions at the locations where speeds are most likely to be much lower than the approach speeds. Once these locations have been identified, additional sensors should be placed upstream of slower speed locations, where traffic has not yet slowed significantly. This will allow the PTMS to determine speed differentials between approaching traffic and traffic that is already traveling at slow speeds. The speed sensors upstream of slow moving traffic should be located with a PCMS to provide information on speed conditions at the downstream location. The 2-mile maximum spacing between the PCMSs should be maintained, and a sufficient number of sensors should be provided so that the PCMSs have accurate data.

The placement of sensors can have a large impact on the accuracy of travel time estimates. In general, large numbers of sensors at short spacings will produce the most accurate travel time results. Agencies usually have a fixed number of available speed sensors, and do not have the luxury of using large numbers of sensors to produce accurate travel time estimates. In these cases, agencies should first install the work zone and then determine typical travel speeds through the work zone. The work zone should then be split into segments where travel speeds are similar based on typical travel speeds. This will identify locations where congestion occurs, and if speeds begin to increase after traveling through a bottleneck. Sensors should be placed so that speeds can be accurately captured for each representative segment. For example, speed sensors should be placed at a work zone taper, and also within the work zone in order to determine whether vehicle speeds increase after the taper. Under no circumstances should a single speed sensor be used to predict travel times for long stretches of road, particularly if travel speeds are variable in that segment. By determining representative travel speeds, the agency should be able to determine locations where traffic speeds change, and set up speed sensors accordingly.

Central Processing System

The central processing system needs to be placed in a climate-controlled location where a steady power supply is available. If the central processing system is located at the work site, it is typically located in a work site trailer. This allows personnel at the site to determine whether the system is functioning properly.

Wireless Communications System

Virtually all commercially available PTMSs use spread spectrum radio in order to communicate between PTMS components. Spread spectrum radio has several inherent limitations that must be considered when determining the location of PTMS components. First, spread spectrum radio requires a clear line of sight between devices that are trying to communicate with one another. If there are elevation changes or structures between a transmitter and a receiver, the quality of the communications link will suffer. Second, the maximum range of a spread spectrum radio signal is only 2 to 3 miles. These two limitations limit the ability of PTMSs to be installed over long distances. Repeaters can be used to extend the effective range of the system, but they represent an additional cost to the agency. These devices receive a signal, regenerate it, and rebroadcast it. By using a series of repeaters, it is possible to overcome elevation changes and transmit information to distant devices.

EXAMPLE OF GUIDELINE APPLICATION

The guidelines were applied to a work zone on US 59 in Montgomery County, Texas. The geometric and traffic characteristics of the site represent real-world conditions, but the remainder of this case study is purely hypothetical. Information on this work zone was obtained from Texas Department of Transportation (TxDOT) construction plans (*35*). This case study is intended to illustrate how these guidelines would be used to determine whether a PTMS should be deployed, and where the components of the PTMS should be located

Site Description

US 59 is a access-controlled freeway with a posted speed limit of 55 mph. The road is a four-lane, divided highway with continuous one-way, two-lane frontage roads on each side of the freeway. All interchanges with cross streets are grade-separated diamond interchanges. The total length of the work zone is 4.2 miles, and the right lane is closed in both directions at the project limits. The freeway is being widened and drainage improvements are being constructed from 0.5 miles south of the interchange with Roman Forest Boulevard to 0.8 miles north of the interchange with Creekwood Drive. According to TxDOT traffic counts collected in 1999, the ADT is approximately 36,475 vpd. Trucks compose 17 percent of the traffic stream. The project is expected to take three years to complete, but the lane closures will only be present for the first year of the project. Figure 14 shows the area around the work zone.

Agency personnel were concerned that work zone lane closures would create significant delays on this route. Because of this concern, the agency wanted to provide drivers with an indication of the travel time through the work zone using a PTMS. US 59 has a significant number of commuter drivers that travel to Houston, and it was felt that travel time information would provide useful information to these drivers. An alternative route was not specified, primarily because the department of transportation did not have any direct control over some of the local roads adjacent to the work zone. It was felt that travel time information would allow drivers to make their own decisions about whether they wanted to divert from the freeway.

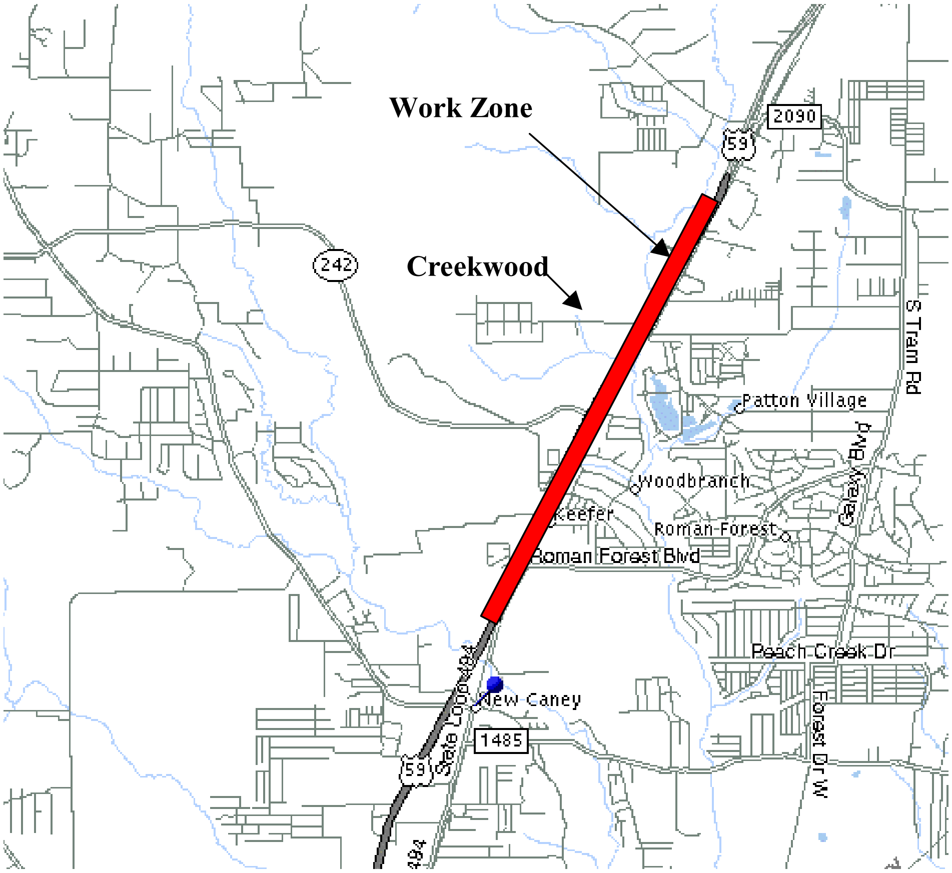

Figure 14. US 59 Work Zone Location

PTMS Applicability

First, the agency assessed whether it was appropriate to use a PTMS to provide travel time information at this site. The level of congestion, duration of work activities, and applicability of the travel time information were assessed.

Presence of Congestion

First, the department of transportation examined the level of congestion on the highway. A hourly flow profile was developed for US 59 based on the ADT of the road. This flow profile was created assuming that there were large peak hour volumes traveling into and out of Houston, and that the northbound and southbound flows were mirror images of one another. The QUEWZ-92 model was used to analyze this hypothetical flow profile. Recurrent congestion on normal weekdays results in a maximum of a 1.2-mile long queue at the site. A modified flow profile was created to represent heavy traffic experienced around holidays and weekends. This modified flow profile was input into the QUEWZ-92 model to determine the potential queuing that may occur at the work zone. The results of this analysis are included in Appendix B. The queues during these high demand periods extended up to 2.1 miles from the work zone taper, and queues were present for at least 5 hours. Travel speeds within the work zone were projected to be up to 20 mph lower than the approach speeds. Figure 15 shows the maximum queue length in relation to the surrounding streets.

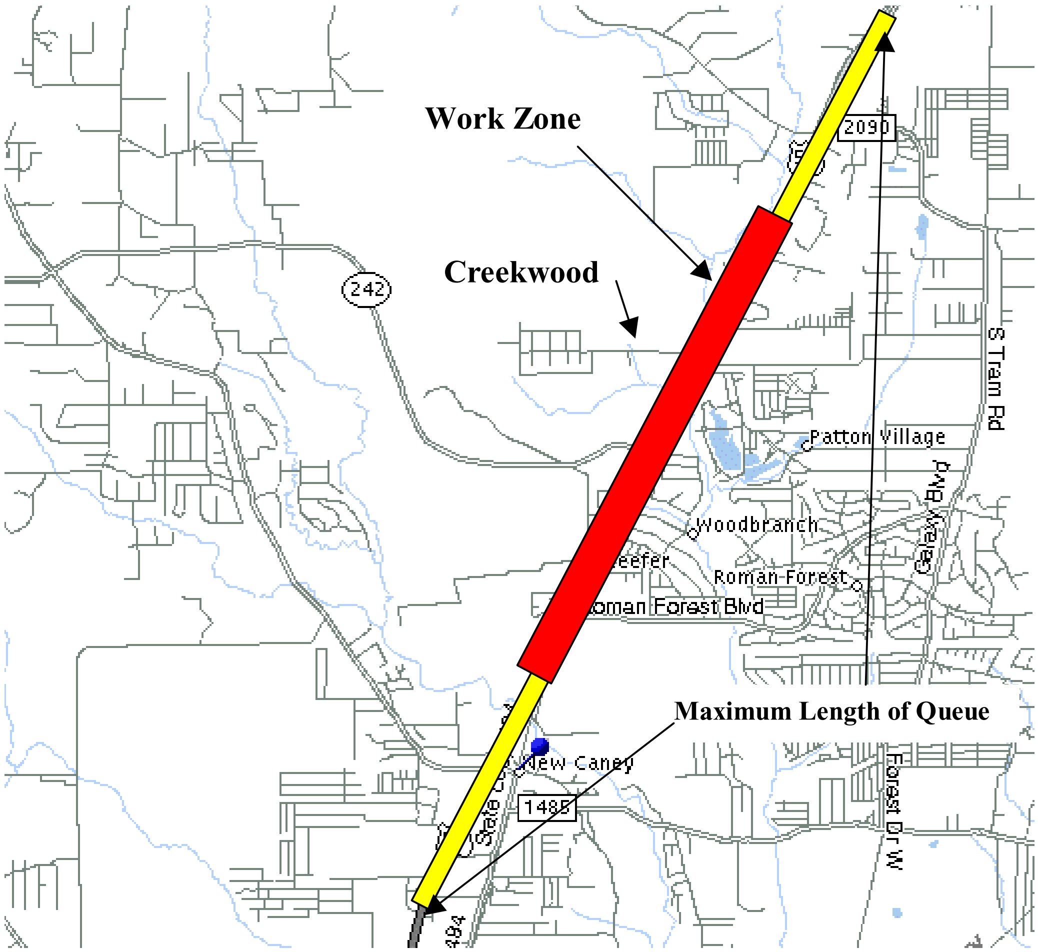

Figure 15. Maximum Length of Queue

A PTMS may be appropriate at this work zone based on the congestion experienced at the site. Congestion was present for up to five hours of the day, and the length of the queue varied by up to one mile depending on the demand characteristics tested. Static signing would not be able to adequately capture this variability in the queue length and travel time.

Duration of Work Activities

The total duration of the project is three years, and the lane closures will be present for one year. Given that the project will be in place for a long period of time, it appears that the installation of a PTMS may be justifiable. The calibration and installation of the system was expected to take one week, which is reasonable given that the system will be in place for at least one year.

Applicability of Travel Time Information

Two potential alternative routes exist at this site. The continuous frontage roads will not be impacted by construction while the lane closure is in effect on US 59. It will be possible for vehicles to travel on the frontage roads, and re-enter the freeway after bypassing the work zone. The frontage roads will provide the shortest, most direct path for drivers seeking to avoid congestion. A longer route involves traveling the route between FM 1485 and FM 2090. This route is longer and goes through residential areas, so it will probably not be used by a significant number of drivers. Since there are several alternative routes available, the travel time information could be useful to drivers.

PTMS Applicability and System Considerations

Based on these guidelines, the agency believed that a PTMS is applicable at the site. Congestion is present at the work zone, the work zone will be in place for an extended period of time, and alternative routes are available. The agency expects people to divert onto the frontage roads at the interchanges with FM 1485 and FM 2090 if they feel that the queue is traveling too slowly. Given this expectation, the signal timings at all interchanges between these two locations are being altered to provide more green times to the ramp phases during the projected periods of congestion.

Component Location

Since a PTMS was to be used at the site, the location of individual components had to be determined. The location of PCMSs, speed sensors, the central processing system, and wireless communications components was determined.

General Considerations

Work activities will occur within the closed lane during the next calendar year. Any equipment placed in the right lane of the work zone will probably need to be relocated at some point during the year in order to accommodate work activities. No locations that would be prone to vandalism were identified.

PCMSs

PCMSs were placed in the northbound and southbound direction approximately 0.5 miles before the projected maximum length of the queue. A second PCMS was placed 0.5 miles before the first advance guide sign for FM 1485 and FM 2090. By providing estimated travel times at these four locations, drivers should have sufficient information to determine whether they wanted to leave the freeway and take an alternative route. There was good sight distance at all of these locations.

Speed Sensors

The agency only had 10 speed sensors available for placement in the work zone. Some preliminary speed data were collected after the work zone traffic control was installed in order to determine typical speeds throughout the work zone. The speed data showed that speeds were generally uniform within the work zone, except in the vicinity of the interchange with Texas Route 242. The on ramp at this location caused traffic speeds to be somewhat slower in this area. Speeds were also slower on the work zone approaches in the area where queuing occurred. Based on this data, the agency elected to place speed sensors at the following locations:

- at the first PCMS in each direction (located 0.5 miles before the maximum length of queue);
- at the second PCMS in each direction (located approximately 0.5 miles before the first advance guide for FM 1485 and FM 2090);
- at the work zone arrow panel in each direction; and
- 0.5 miles before and after the entrance ramp from Texas 242 in each direction.

The speeds collected at each sensor station would be averaged together to determine a travel speed on the link between adjacent sensors. The sensors located at the PCMSs and the arrow panel would provide travel time information on the work zone approaches. The arrow panel sensor and the sensors located within the work zone would provide data on travel speeds within the work zone. The sensor spacing should capture the relatively smooth flow after the Texas 242 entrance ramp, but also include the slower traffic near the entrance ramp. Table 14 summarizes the sensor spacing used.

Table 14. Sensor Spacings Relative to First Sensor

Location	Cumulative Distance From First Sensor (Miles)	
	Northbound	Southbound
PCMS 0.5 miles from end of queue	0	0
PCMS 0.5 before first advance guide sign	1.0	0.9
Arrow panel	2.6	2.6
Sensor 0.5 miles before Texas 242	4.1	4.6
Sensor 0.5 miles after Texas 242	5.1	5.6

Central Processing System

A work site trailer is located just west of US 59 on Texas 242. This trailer is climate controlled, and has a steady electrical power supply. The agency wanted to have the central control system located at the job site so that personnel could monitor the system and change parameters as needed. Based on these requirements, the central control system was located in the work site trailer.

Wireless Communications System

Spread spectrum radio was used to communicate between the various system components. All of the components were within 2 miles of the next component, so no repeaters were necessary. The only potential obstructions were the interchange bridge structures at FM 1485, Texas 242, and FM 2090. At these sites, the bridge structures were approximately 30 to 40 feet taller than the locations where the PCMSs and speed sensors were placed. In these cases, high-gain antennas were used in order to increase the signal strength so that the sensor and PCMS could communicate with the next component.

Final System Configuration

Figure 16 shows the final system configuration at the work site based on the application of these guidelines. The location of the speed sensors with the work zone will have to change as work activities progress, but they will remain as close to their current positions as possible without interfering with work activities.

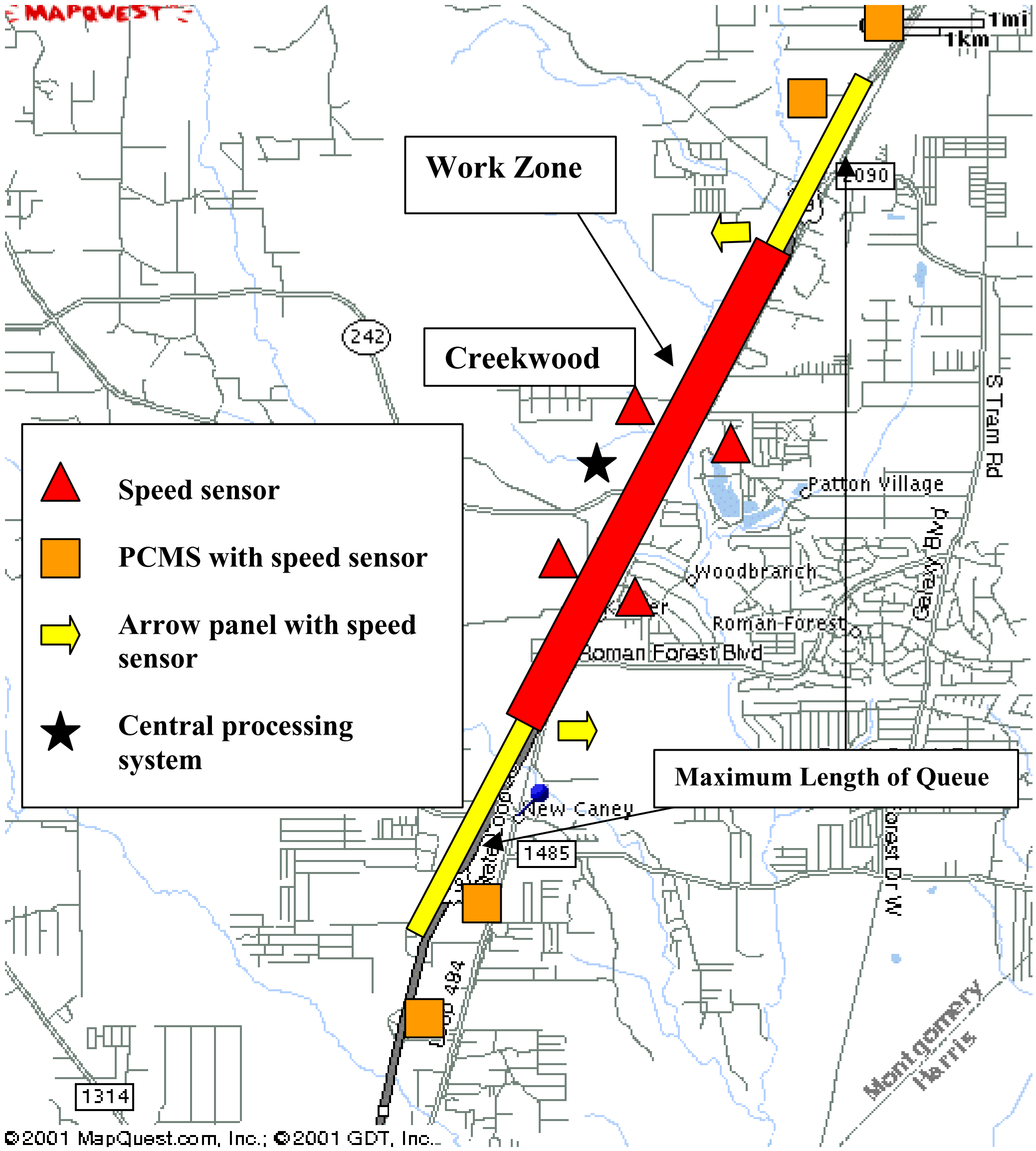

Figure 16. Final PTMS Component Layout.

RECOMMENDATIONS FOR FURTHER RESEARCH

The examination of current system capabilities and the review of past field tests showed several areas where information on the performance of these systems is lacking. Possible areas for further research or development could include:

- **Improved Communications.** Many of the states that evaluated PTMSs noted communications problems when wireless communications systems were used. Vendors need to devote some time to improving the reliability and speed of the wireless communications systems that are offered.
- **Diversion Impacts.** More information on the ability of PTMSs to divert traffic to an alternate route is needed. The existing studies of the impact of the diversion messages either did not specify the alternate route, or used unrealistically low delay thresholds for displaying the diversion message. Further studies are needed with improved message design.

- **Safety Impacts.** More information on the safety impacts of PTMSs is needed. To date, the only analysis available compared crash data from when the PTMS was in place to a time period when no work zone was present. Comparisons need to be made to show the impact, if any, of the PTMS on work zone safety.
- **Non-Freeway Applications.** PTMS have been evaluated on freeways, but these systems could also be applied to arterial streets. Traffic signals, intermediate access points, and other characteristics of arterials could require significant modification to some of the delay and travel time algorithms used by these systems. Deployment of these systems to arterial roads needs further examination.
- **Driver Information Preferences.** Research needs to be performed to determine what types of information drivers want from PTMSs. Specifically, these surveys should be used to determine the minimum speed differential that should be displayed on speed advisory messages.
- **Message Choice.** More research needs to be performed to determine if normal freeway message sets are appropriate for use on these dynamic systems. Future research could examine the merits of time-stamping messages, and compare driver preferences for delay versus travel time information.

CONCLUSIONS

As the nation's road system continues to age, drivers are coming into more frequent contact with work zones. Portable traffic management systems have been proposed as a way to help improve safety at these work zones and to alert drivers to alternate routes. These systems can provide drivers with real-time information that can allow drivers to alter their route or change their behavior approaching the work zone.

Manufacturers of these systems are promoting them as a solution to many of the safety and capacity problems in work zones, but field testing shows that the capabilities of these systems are limited. Drivers tend not to alter their behavior in response to speed advisory messages unless the road is already very congested and they are already driving at a speed much lower than the posted limit. The ability of these systems to divert traffic has also been shown to be limited, but this may be in part due to limitations in the evaluations. Although it is probably reasonable to expect that these systems will produce safety benefits by preventing rear-end crashes, no studies have been able to adequately document any safety impacts of these systems.

The results of past field testing suggest that PTMSs may only have an application at long-term work zones where congestion is recurrent and sometimes severe. A set of guidelines was developed to aid agencies in determining whether a PTMS would be appropriate at a given site. If a PTMS addresses the problems present at a site, then several guidelines are offered for locating system components within the work zone. These guidelines were hypothetically applied to an actual work zone in order to illustrate the feasibility of the guidelines.

Although past studies provide sufficient information to generate some guidelines for the use of PTMSs, more research is still needed. The ability of PTMSs to improve safety and divert traffic needs further examination. Even though PTMSs have shown a steady improvement in the reliability of the wireless communications that they use, more development is needed to ensure that the central control system is constantly in contact with all of the field devices. PTMSs have made large strides in technology since their inception, but further research on their ability to impact operations is still needed.

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APPENDIX A

Representative Telephone Survey Questions

1. Has your agency tested any portable traffic management systems (PTMSs), such as the ADAPTIR, ADDCO Smart Work Zone, etc.? If so, was the evaluation documented?
2. Do you know of any guidelines to help transportation agencies decide whether a PTMS may be appropriate for a given site?

The following questions apply if PTMSs were tested and there were no documented results:

3. What are the characteristics of the site(s) where the PTMS was tested (location, urban/rural, type of work, ADT, speed limit, cross section, geometry, etc.)
4. What was the setup of the PTMS system (number of CMSs, type of speed detection, placement of signs, use of HAR, etc.)?
5. How long was the device tested?
6. What types of messages were displayed? What criteria were used to determine when a message should be changed? How often were these messages displayed?
7. Was any data collected to determine the amount of traffic diversion, reduction in speed, or change in capacity? If so, what did these data show?
8. Did the system display messages correctly based on prevailing conditions?
9. Was any data on motorist perceptions of the system collected, such as a downstream driver survey?
10. Was there any evaluation of potential safety impacts of the system?
11. What technical problems, if any, were encountered during the test?
12. How much day-to-day user intervention was required to keep the system operational?
13. Approximately how much time was required to install the system?

APPENDIX B

QUEWZ-92 Output

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INPUT DATA SUMMARY: ROAD USER COST OUTPUT                 PAGE 1 OF 3
Ai US 59 Queue                                              QUEWZ-92
--------------------------------------------------------------------
LANE CLOSURE CONFIGURATION:

  TOTAL NUMBER OF LANES
    INBOUND                        2
    OUTBOUND                       2

  NUMBER OF OPEN LANES
    INBOUND                        1
    OUTBOUND                       2

  LENGTH OF WORK ZONE              4.00 MILES

  INBOUND  CAPACITY
    NORMAL                      4600. (VPH)
    RESTRICTED                  2070. (VPH)
    WORKING HOURS               1429. (VPH)

TRAFFIC PARAMETERS:

  PERCENTAGE TRUCK               17.

SCHEDULE OF WORK ACTIVITY:

  HOURS OF RESTRICTED CAPACITY
    BEGINNING                      0
    ENDING                        24

  HOURS OF WORK ZONE ACTIVITY
    BEGINNING                      0
    ENDING                        24
--------------------------------------------------------------------
```

SUMMARY OF ADDITIONAL ROAD USER COSTS PAGE 2 OF 3
Ai US 59 Queue QUEWZ-92

HOUR	ADDITIONAL ROAD USER COSTS ($) INBOUND	OUTBOUND	TOTAL
0- 1	1.	0.	1.
1- 2	0.	0.	0.
2- 3	0.	0.	0.
3- 4	0.	0.	0.
4- 5	0.	0.	0.
5- 6	5.	0.	5.
6- 7	236.	0.	236.
7- 8	6876.	0.	6876.
8- 9	9157.	0.	9157.
9-10	1645.	0.	1645.
10-11	17.	0.	17.
11-12	27.	0.	27.
12-13	27.	0.	27.
13-14	27.	0.	27.
14-15	63.	0.	63.
15-16	236.	0.	236.
16-17	709.	0.	709.
17-18	11935.	0.	11935.
18-19	7793.	0.	7793.
19-20	128.	0.	128.
20-21	27.	0.	27.
21-22	27.	0.	27.
22-23	10.	0.	10.
23-24	2.	0.	2.
TOTAL	38949.	0.	38949.

NOTE: LANE CLOSURE ONLY IN INBOUND DIRECTION

SUMMARY OF TRAFFIC CONDITIONS -- INBOUND DIRECTION PAGE 3 OF 3
Ai US 59 Queue QUEWZ-92

HOUR	APPROACH VOLUME (VPH)	CAPACITY (VPH)	APPROACH SPEED (MPH)	WORK ZONE SPEED (MPH)	QUEUE LENGTH (MILES)
0- 1	91.	1429.	60.	59.	0.0
1- 2	46.	1429.	60.	59.	0.0
2- 3	46.	1429.	60.	59.	0.0
3- 4	46.	1429.	60.	59.	0.0
4- 5	46.	1429.	60.	59.	0.0
5- 6	274.	1429.	59.	57.	0.0
6- 7	1094.	1429.	56.	47.	0.0
7- 8	2006.	1429.	52.	30.	1.1
8- 9	1277.	1429.	55.	30.	1.9
9-10	547.	1429.	58.	42.	0.8
10-11	456.	1429.	58.	54.	0.0
11-12	547.	1429.	58.	53.	0.0
12-13	547.	1429.	58.	53.	0.0
13-14	547.	1429.	58.	53.	0.0
14-15	730.	1429.	57.	51.	0.0
15-16	1094.	1429.	56.	47.	0.0
16-17	1368.	1429.	55.	40.	0.0
17-18	2553.	1429.	50.	30.	2.1
18-19	237.	1429.	59.	32.	2.1
19-20	912.	1429.	57.	49.	0.0
20-21	547.	1429.	58.	53.	0.0
21-22	547.	1429.	58.	53.	0.0
22-23	365.	1429.	59.	56.	0.0
23-24	182.	1429.	59.	58.	0.0

MICHAEL D. FONTAINE

Mike Fontaine received his BSCE degree from the University of Virginia in May 1996, and his MSCE degree from the University of Virginia in May 1998. He is currently pursuing his Ph.D. in Civil Engineering at Texas A&M University. Mike has also been working as an Associate Transportation Researcher at the Texas Transportation Institute (TTI) since May 1999. Since arriving at TTI, Mike has been involved in research on sign and pavement marking retroreflectivity, work zone traffic control, automated speed enforcement, freeway guide signing, and capacity analysis and simulation.

Prior to joining TTI, Mike served as the Transportation Engineer for the city of Charlottesville, Virginia. While at the city, Mike performed a broad base of traffic engineering activities. Some of his duties included administering the city's traffic calming plan, traffic signal design, site plan review, oversight of the city's signing program, and development of bicycle facilities. Mike was a member of Charlottesville's bicycling and walking committee and the metropolitan planning organization's technical advisory committee.

While at the University of Virginia, Mike was both an Undergraduate Research Assistant and Graduate Research Assistant at the Virginia Transportation Research Council. While an undergraduate, Mike helped perform an evaluation of changeable message signs with radar for work zone speed control. The paper he wrote based on this research won the 1997 Institute of Transportation Engineers student paper award. As a graduate student, Mike developed guidelines for the selection of an interchange type for new construction or major reconstruction. These guidelines are currently being utilized by the Location and Design Division of the Virginia Department of Transportation.

Mike is a member of the Institute of Transportation Engineers, Chi Epsilon, and Tau Beta Pi. His areas of interest include work zone traffic control, traffic operations, and traffic control devices.

INTEGRATION OF ITS TECHNOLOGIES AND APPLICATIONS TO TxDOT'S LUBBOCK DISTRICT

by

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SUMMARY

An intelligent transportation system (ITS) is comprised of an infrastructure within the transportation network involving information processing, communications, and electronics technologies designed to improve overall safety and operational characteristics. The emerging technologies represent the way transportation agencies are addressing the increasing demands placed on the existing transportation network in order to provide for the safe and efficient movement of people, goods, and services in rural and small urban areas as well as large urban areas.

Presently there is limited use of available ITS technologies in rural and small urban TxDOT Districts. While these Districts account for a vast majority of the landmass within Texas, they make up a small percentage of the actual deployment of ITS technology. By contrast, TxDOT's urban Districts have began to develop ITS on the transportation network encompassing their boundaries. In these more urbanized Districts there is the realization that ITS technologies provide operational and safety benefits.

This report contains a current state-of-the-practice regarding rural and small urban ITS applications in Texas and other states. This determination was made through information collected during a literature review, interview of state transportation operations professionals in several other states as well as a survey of Directors of Transportation Operations and District Traffic Engineers in seventeen TxDOT Districts. The literature review, discussion during the interviews, and survey provided information about the different ITS technologies currently in place and plans for proposed future deployments.

Using information collected through the means described above, an analysis of all information gathered was performed and a deployment plan entailing proven and supportable ITS technology was developed for TxDOT's Lubbock District and surrounding area.

The literature review and interviews with the operations professionals associated with state transportation agencies presently applying ITS technologies served as a basis of comparison for the ITS applications within the Texas Department of Transportation (TxDOT). Information gained from the survey of TxDOT transportation operations professionals not only provided insight to the degree of ITS application of technologies within rural and small urban areas of Texas but to the overall understanding of ITS capabilities within the organization as well.

The author's recommendations regarding the application of ITS technology are meant to serve as an example of the commitment that could be made by TxDOT in the deployment of ITS technology in rural and small urban areas within Texas. Moreover, these recommendations and ideas could serve as a model for TxDOT Districts with similar characteristics and transportation needs.

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INTRODUCTION

The application of ITS technology in rural and small urban areas has recently been the focus of the U.S. Department of Transportation (USDOT) and various state transportation agencies. This development of the National ITS Architecture has provided a basis for many transportation organizations to begin building a communications infrastructure to operate ITS capable of meeting their individual transportation needs. In fact, the National ITS Architecture defines a tiered structure that promotes interoperability among systems within various transportation agencies. Learning from the deployment of ITS in highly urbanized areas it is clearly seen that the development of an advanced communications infrastructure is the basic foundation of an effective ITS program.

Advancements in electronics and telecommunications technology have enabled intelligent transportation systems (ITS) to become progressively more useful in providing real-time information to the traveling public. The result of real-time information regarding traffic conditions being relayed to the driver ultimately provides for improved operational safety and efficiency characteristics of the transportation network (*1*). While ITS has seen increasing use in America's urban centers, it is now being recognized that many ITS applications have potential and are becoming especially important to transportation officials in rural and small urban locations.

However, ITS needs and their purposes in these rural and small urban areas are unique compared to those seen in highly developed urban centers (*2*). With this difference in need, decisions must be made pertaining to the correct application of ITS ideas and technologies.

Just as in the highly urbanized areas, commuters in rural and smaller urban locations are faced with increased traffic and travel times when compared to the past. This is a result of a number of factors, some of which include:

- Increased development of business and industry in areas away from where they have been traditionally located in central business districts;
- Increased residential development associated with the desire of people to live in areas near but removed from urban centers;
- Overall increase in the number of vehicles using existing transportation facilities; and
- Population that is increasingly mobile compared to the past.

In Texas, the North American Free Trade Agreement (NAFTA) has brought increased traffic to the transportation network in many rural areas. Some of these highways with increased traffic have come as a surprise to many local and regional transportation officials. For example, traffic on US 83 extending from Brownsville to Perryton has experienced a substantial increase in the percentage of trucks since the passage of NAFTA (*3*). Similar circumstances can be expected in many states bordering Mexico and Canada.

A major focus associated with ITS in the rural transportation network is improved highway safety as a direct result of implementation. Improvement in the safety aspects associated with the transportation network is a goal that all transportation agencies and professionals desire to attain. Along with increased safety comes improved efficiency from an operational standpoint. Concerns for both safety and efficiency are principal in responsibly managing the transportation network through the use of cost effective available technologies related to ITS.

Problem Statement

Presently, many TxDOT Districts consist of a largely rural landmass with a moderately urbanized area that activity centers around. Of the 79,185-centerline miles maintained by TxDOT, 40,963 are classified as Farm-to-Market roads. There are also 3,233 centerline miles of Interstate highways and a combined total of 28,239 centerline miles of US and State highways (*4*).

The vast majority of these centerline miles encompass largely rural areas of Texas. With the large majority of centerline miles of TxDOT maintained facilities in rural areas, the potential for using ITS technology to facilitate transportation efficiency in these areas is immense. The ability to identify and describe cost-effective solutions addressing transportation related needs in rural to moderately developed urban areas is necessary to efficiently move people and goods in and across these areas.

Rural transportation problems can often be a result of topography, weather events, and a dispersed telecommunications infrastructure. Currently, crashes on the nation's rural highways account for a significantly higher percentage of fatalities opposed to crashes occurring in urban areas. Emergency response time to these crashes is also greater than in urban areas. Additionally, 5 percent of crashes in rural areas go unreported for more than 30 minutes (*5*).

Research Objectives

The goal of this research was to examine the potential for the development and implementation of a viable ITS rural highway infrastructure designed to improve the safety and operational performance in rural to moderately developed urban areas of Texas. The specific objectives to accomplish this goal were as follows:

- Identify successful rural applications of ITS in other states;
- Identify successful applications of ITS within TxDOT's urban Districts
- Identify applications of ITS in TxDOT Districts where rural and moderately urban conditions exist;
- Synthesize successful ITS applications in rural areas
- Determine the need for ITS applications in TxDOT's Lubbock District;
- Identify feasible ITS technologies for use in TxDOT's Lubbock District; and
- Demonstrate the benefit of using these ITS technologies through application to the Lubbock District.

STUDY DESIGN

The procedures followed in conducting the research in order to develop the implementation plan consisted of six principal tasks:

- review of current literature
- interview of operations professionals in Texas and other states;
- survey of TxDOT operations personnel;
- Synthesis of data gathered;
- Analysis of transportation needs within the Lubbock District based on synthesized data;
- Development of deployment plan for the Lubbock District and surrounding areas.

Literature Review

A review of current literature pertaining to the subject of ITS applications in rural and small urban areas was conducted in order to examine the uses of this ITS technologies in states other than Texas that could be potentially viable in Texas. Since much of the information within the literature is from states currently developing ITS applications in rural settings, points of contact were made in various states in order to obtain pertinent literature.

Interviews with Operations Professionals / TxDOT Survey

Information gathering was accomplished through interviews with transportation researchers and engineers in Arizona, Montana, Nebraska, and Washington State and a survey of District Traffic Operations Directors and Traffic Engineers in eighteen TxDOT Districts. These TxDOT Districts are shown below.

Abilene	Austin	Corpus Christi	El Paso	Odessa	San Antonio
Amarillo	Bryan	Fort Worth	Lubbock	Pharr	Tyler
Atlanta	Childress	Houston	Lufkin	San Angelo	Wichita Falls

Two different surveys were developed for this portion of the research. The distinction was made between rural and urban Districts. A copy of the complete survey is provided respectively as Appendix A and Appendix B to this report.

Synthesis of Data

After completing the above tasks, all data collected was integrated to form a collective basis for analysis and the recommendation of ITS strategies in the remaining tasks. The research from other states and the survey also supplied information regarding the transportation needs within rural and small urban areas. This research also provided a basis to measure the effectiveness of ITS technologies best suited to these locations. In order to broaden the understanding of ITS, within rural and small urban areas, a hypothetical application of appropriate technology was made to TxDOT's Lubbock District. This District is well suited to this application due to its geographic location and proximity to medical and emergency response services.

Analysis of Transportation Needs for Lubbock District

The analysis of transportation needs is developed from information gained through the literature, interviews, and survey.

Deployment Plan

After completing the above tasks, an ITS deployment plan was developed for the Lubbock District and surrounding areas to address the needs previously identified.

BACKGROUND

The US Department of Transportation (USDOT) has developed a Strategic Plan for the Advanced Rural Transportation Systems (ARTS) (6,7). This plan describes the infrastructure required to support transportation providers and system users. The ARTS Strategic Plan is the basis for the National ITS Architecture and addresses rural needs in the following seven critical program areas (CPA) (7, 8):

- Traveler safety and security;
- Emergency services;
- Tourism and travel information services;
- Public traveler/mobility services;
- Infrastructure operations and maintenance;
- Fleet operations and maintenance; and
- Commercial vehicle operations.

Each of the seven CPA's illustrates specific user needs defined by ARTS. These program areas illustrate how the country's diverse transportation needs will be addressed through the implementation of the National ITS Architecture.

The Strategic Plan for the ARTS is not intended to create a separate rural ITS, it is described by the USDOT as a means to "ensure rural needs and conditions are represented in an interoperable, international system" (*7*). The plan further illustrates the ~~F~~ federal role in the development of rural ITS (*8*). This role is organized into three categories as seen below (*7*).

Federal Roles in ARTS

These categories are designed to provide a method of developing and implementing ITS in a cost effective and time efficient manner and consist of:

- Research & development
- Deployment incentives
- Delivery

Research & Development

The Research and Development component of the USDOT plan identifies technologies and procedures designed to improve ARTS. This aspect of the plan is intended to aid the private sector inhibited by risks or inability to recapture costs through pricing.

Deployment Incentives

Deployment incentives include grants to states and local governments specifically for planning ARTS projects.

Delivery

Delivery includes training, procedure development and support systems to promote ARTS planning, deployment, and operation within various transportation agencies. This attribute is designed to mainstream ITS into the various transportation agencies' planning and programming processes.

Communications

A well planned and constructed communications infrastructure is essential to the success of ITS in rural areas. The National ITS Architecture also provides the framework that ties the transportation and telecommunication worlds together to enable the development and effective implementation of the broad range of ITS user services (*8*, *9*). Presently, there are many communications options available to the system designer. This large number of options offers greater flexibility in choosing the specific technology that meets the identified ITS need.

The National ITS Architecture defines four communication media types to support the communications requirements between the nineteen subsystems in the physical architecture. These media types are (*7*):

- Wireline communications (fixed-point to fixed-point),
- Wide-area wireless communications (fixed-point to mobile),
- Dedicated short-range communications (fixed-point to mobile), and
- Vehicle-to-vehicle (mobile to mobile)

Wireline Communication

Wireline communication is typically accomplished in today's market through fiber optic lines. This method of delivery is cost effective in many instances and should not be overlooked when developing an ITS system.

Wide-Area Wireless Communication

Wide-area wireless communication and dedicated short-range communications differentiated by range and coverage area. Wide-area wireless communications are appropriate for instances where information is passed on to system users who are not located in the vicinity of the transmission. This is in contrast to an example of dedicated short-range communication such as Highway Advisory Radio (HAR).

Dedicated Short Range

Dedicated short-range communications from a fixed point to a mobile source can be equipped for use on emergency response vehicles many highly urbanized areas and are well suited to applications in smaller urban areas. For example, a fire truck equipped with a short-range communication technology having the capability of communicating with signalized intersections along the route to the destination of a call. This type of technology not only provides for increased safety to other vehicles along the route but decreases the response time of the emergency vehicle.

Vehicle-to-Vehicle Communication

Vehicle-to-vehicle communication is the transfer of information between two mobile sources. The National ITS Architecture ultimately sees this method of communication between vehicles being required to support automated highway system applications. More specifically, ITS applications pertaining to collision avoidance.

Figure 1 illustrates the applications of the different communications methods and their potential use as stipulated by the National ITS Architecture (*8*). There are many applications of the technology illustrated in Figure 1 presently in use as illustrated in the examples above.

Section 5206(e) of the Transportation Equity Act for the 21st Century (TEA-21) requires that ITS projects using funds from the Highway Trust Fund conform to the National ITS Architecture (*7*).

ITS IN RURAL AREAS

The application of ITS in rural areas was examined in a number of states through a comprehensive literature review and interviews with transportation operations personnel. While many of these states are in the initial phases of ITS deployment, plans are in place and projects are being developed and implemented into an existing transportation infrastructure.

Alaska

In Alaska the transportation network is unique where the system consists of multiple transportation modes, principally roadway, marine, and air. The weather poses more difficulty and disruption to transportation than anywhere else in the country (*10*). This being the case, the Alaska Department of Transportation and Public Facilities (ADOT&PF) has pushed to develop a Roadway Weather Information

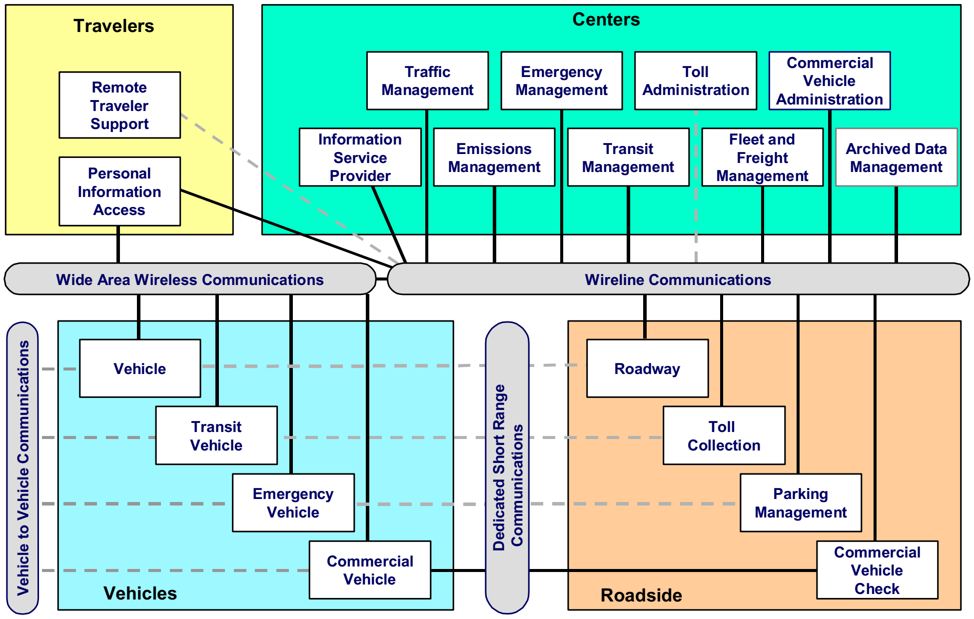

Figure 1. Communications Using the National ITS Infrastructure

System (RWIS) centered around its deployment of ITS technology. Even though the reference is made to "roadway" weather information, a broader approach will be employed specifically designed to meet the needs of marine and aviation transportation. Figure 2 illustrates an RWIS tower used in this type of technology (*11*).

Figure 2. RWIS

One of Alaska's unique weather conditions is associated with the formation of fog in many areas of the state. The ADOT&PF uses a system to warn drivers of a reduction in visibility due to fog. Figure 3 illustrates an example of the warning device that in many cases is linked to a variable speed limit (VSL) sign (*11*).

Figure 3. Fog Advisory Area

Presently, the ADOT&PF is in the process of deploying and building an architecture centered around ITS applications that are designed to address specific local and regional needs (10). Currently, efforts have been initiated to develop a statewide deployment system (SDS) that will integrate existing and future ITS projects to function as compatibly as possible. The SDS will require the completion of the following five major tasks (11):

- Articulation of a long-range, statewide ITS vision;
- Development of a statewide ITS architecture;
- Project identification and prioritization;
- Development of a prioritized funding plan; and
- Development of a deployment schedule.

Articulation of a Long-Range, Statewide ITS Vision

This vision is to be achieved from the needs indicated by a variety of system users. The long-range vision outlines a plan that will address transportation needs from a variety of system stakeholders including roadway, marine, and aviation. Initial efforts will be to determine local, regional, and statewide transportation needs that can be addressed through ITS. A tangible outcome of this outreach and consensus-building task will be a long-range ITS Vision. This step is important because ITS architecture and implementation plans will emerge from this vision.

Development of a Statewide ITS Architecture

ADOT&PF's ITS architectural design will ultimately identify the boundaries the state's system will function under. The framework for the statewide ITS communications infrastructure will conform the National ITS Architecture. As with other state transportation agency plans for ITS implementation, conformance with the National ITS Architecture will promote an interoperability among the state's ITS systems. As previously seen in other states, this type of commonality also promotes competition among vendors of ITS technologies.

Project Identification and Prioritization

The SDS will employ a means for prioritizing and programming ITS related projects. A team that is specifically responsible for identifying potential projects relating to the long-range vision for ITS in Alaska will be formed. The project team will identify both individual projects needed to deploy the ITS systems and components within ongoing or planned transportation projects that would benefit from the inclusion of ITS technologies. The project team will also develop a set of criteria to prioritize projects.

Development of a Prioritized Funding Plan

The deployment of additional networked ITS infrastructure within the state will require the identification of available funding sources including FHWA, public-private partnerships, and coordination of state and local resources. ADOT&PF views the funding of ITS technologies within their long-range vision as providing a cost efficient means of enhancing the differing modes of transportation within Alaska. This notion is required to ultimately develop the ITS infrastructure capable of supporting the proposed systems.

Development of a Deployment Schedule

Presently, the deployment as part of the SDS is associated with the implementation of ITS projects in the 2001-2006 timeframe. This timeframe for the deployment of ITS technologies in the field is necessitated by the need for stakeholder meetings to identify the ITS technologies best suited for an area's transportation needs. The proper identification of traveler needs in Alaska is extremely important due to the diverse modes of transportation and weather conditions.

Arizona

The Arizona Department of Transportation (ADOT) has recently developed their *Strategic Plan for Statewide Deployment of Intelligent Transportation Systems in Arizona* (*12*). This plan was developed around an initiative previously begun to lay the groundwork for the implementation of ITS technologies, *Strategic Plan for ITS Communications* (*13*). Transportation leadership within ADOT felt that in order for the development of ITS to succeed on a statewide level, the communications plan would initially be required (*14*).

Needs of users were identified at rural ITS workshops, focus group meetings, and regional coalition meetings around the state (*12*). These needs were matched to one or more FHWA user services defined in the ARTS program. The conceptual ITS architecture developed for the state is modeled from the National ITS Architecture and includes three timeframes for deployment, 1999-2001, 2002-2007, 2008-beyond (*13*).

High priority needs identified during the study included traveler information, enhanced emergency services in rural areas, increased agency information sharing capabilities, commercial vehicle operations, and improved methods for handling traffic at port-of-entry locations. Additional interest in long-term needs was associated with in-vehicle navigation systems, collision avoidance, and increased roadway emergency systems (*12*, *14*).

A critical need identified by ADOT is to deliver critical real-time information on highway conditions and construction areas statewide to the traveling public. Location, range, and cost limit the current systems for real-time traveler information. ADOT insists that even though web based applications are unique, currently they cannot be accessed easily from moving vehicles. ADOT is moving towards advanced traveler information systems (ATIS) that may provide more timely and reliable traveler information. Currently, the desire is to field-test ATIS technology in the more rural areas of Arizona (*12*).

California/Oregon

California and Oregon have teamed to form California/Oregon Advanced Transportation System (COATS) to address rural ITS. The primary goal of the COATS project is to make rural travel safe, dependable, and convenient (*8*). The boundary for the COATS study area encompasses northern California and southern Oregon. This area is illustrated in Figure 4.

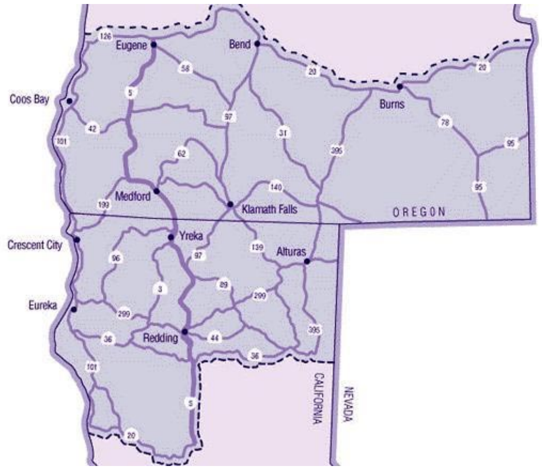

Figure 4. RURAL COATS Study Area Boundaries

Within the COATS area, the reduction of emergency and incident response times, dissemination of weather-related information, and warning systems concerned with roadway incidents or flooding have been identified as ITS technologies best suited to address traveler needs. One unique need that is addressed within COATS is an animal detection and warning system. This system detects animals along migratory routes and triggers a dynamic message sign (DMS) upstream to warn motorists of animal activity ahead (15).

Oregon has also developed a video surveillance system not only within the confines of the COATS area but statewide. The rural installation of video surveillance is unique compared to urban areas in that in most instances there are no buildings or highway structures on which cameras can be easily mounted. An example of the type of video surveillance camera installation used by ODOT and other agencies in rural areas is illustrated in Figure 5.

Figure 5. Rural Surveillance Camera Installation

Views along interstate and major highways in both rural and urban areas over the entire state of Oregon are available to the user via the Internet. Images from these cameras are available in real-time directly from the ODOT's internet website (16). This site is somewhat unique in that the users have the ability to customize their own web page with images from different camera locations. This feature is especially helpful to users traveling along the same route on a regular basis. Camera locations along Oregon's transportation network are found on a state map of Oregon and the user is prompted to click on cameras at different locations to view roadway conditions in real-time.

Idaho/Montana/Wyoming

ITS technology and applications in Montana, Idaho, and Wyoming primarily consist~~s~~ of RWIS and video surveillance cameras at mountain passes and other locations where weather related incidents are a factor. Wyoming and Montana possess a greater number of video surveillance applications than Idaho at the present time. Montana also has a limited number of WIM locations primarily situated along the Canadian border.

Since the ITS needs within these areas are so similar, these three states have joined together to form the Greater Yellowstone ITS Corridor. The study for this area was initially centered about the needs of travelers in the rural areas of Wyoming, Idaho, and Montana. The study focused specifically in the areas of safety, driver information, communication mediums, and demographics (17).

Safety

Through the research conducted it was apparent that safety within the Greater Yellowstone Corridor is of particular importance. There are safety issues particularly related to weather resulting in poor driving conditions in the majority of the year. Primary weather concerns are associated with ice and snow. In this area temperatures can drop to a point where the pavement itself freezes. This condition is known to cause a hazardous driving surface referred to as "black ice." The ice-detection warning system is designed to warn motorists when this condition exists.

In this area there is also a need for advance warning of potential impacts with large animals as well as geometric roadway conditions resulting from rolling and mountainous terrain. Locations of regular deer crossings are typically places where these types of collisions occur. Even though many portions of these states are open expanse, geometric conditions within much of the Greater Yellowstone Corridor dictate the potential benefits of using ITS technologies to promote roadway safety. MAYDAY systems are also beneficial in these types of rural areas.

Driver Information

As a means to address the needs illustrated above, research has been performed to evaluate driver needs in the areas of ice-detection warning systems, animal-vehicle collision warning, vertical and horizontal curves, travel/tourist information, and encountering heavy and recreational vehicles (17).

Communications Mediums

There are a number of communications options available when deploying ITS technologies specifically designed to address driver needs. In this area, there was interest in the dissemination of information through television and radio, Internet

Demographics

It is important to note that the goal of research pertaining traveler needs focused on local residents as well as tourists. Research was then conducted to obtain a sample population that was representative of this fact. In the research conducted to assess the rural traveler's needs within the Greater Yellowstone Corridor, approximately 70 percent of the respondents were tourists and 30 percent local.

Minnesota

Minnesota Guidestar is the Minnesota Department of Transportation's (Mn/DOT) ITS program (*18*). The state has recognized from early on, the difference in traveler needs from a metropolitan, suburban, or rural area (*19*). With this idea in mind, Mn/DOT is in the process of constructing nine transportation operation and communication centers (*18*). The goal of these centers is to establish an integrated statewide communication network serving the rural and smaller urban areas of Minnesota.

At the forefront of Mn/DOT's current ITS research is their Intelligent Vehicle Initiative (IVI) (*19*,20). This project is associated with improving safety by assisting drivers, especially in poor visibility conditions. 3M's Magnetic Lateral Warning and Guidance System is one component of Mn/DOT's IVI. In this system, magnetic pavement marking tape secured with adhesive is applied to the roadway. Magnetic sensors on the driver's vehicle detect the tape when the vehicle is within a one meter distance and the information on the vehicle's lane position is then relayed to the driver. As a result, the driver is provided information that is invaluable assisting navigation along the roadway in poor visibility conditions.

Another unique element of Mn/DOT's IVI is a collision warning system. Radar emitted around the perimeter of the vehicle is used to detect and inform the driver of approaching obstacles. These detectors, mounted on the front, sides, and rear of the vehicle are being implemented on Mn/DOT's snowplows. When other vehicles become too close, high intensity strobe lights are turned on automatically. An example of this technology is illustrated in Figure 6. Warning lights are shown mounted on the fenders of the truck.

Figure 6. Collision Warning System

It is important to note that initially Mn/DOT's ITS Architecture, known as Polaris, pre-dates the National ITS Architecture by approximately 5 years. Minnesota is currently developing newer ITS systems with procedures according to the National ITS Architecture. The ultimate goal of Mn/DOT in this area is to create a system that deals with interface issues and enables ITS projects to be developed more efficiently.

Mn/DOT recently had entered into a partnership with private industry to install a fiber optic communications network along their entire network on 2,200 miles of Interstate and State Highways (*18*). The plan has recently been terminated pending a review of newer technology and recent market downturns in the business communications sector.

Nebraska

The Nebraska Department of Roads (NDOR) is presently in the process of deploying their own ITS technologies. The focus areas of their deployment are associated with needs tied to weather, rural Lifelink, DMSs and 511 (*21*). Through an enhanced communications infrastructure, the statewide Joint

Operations Center (JOC) will possess center-to-center contact with a mini-version of the JOC in each of the state's transportation Districts. Each of these District JOCs will house personnel from the Nebraska State Patrol, NDOR, and the Nebraska Emergency Management Agency. A preliminary estimate for the cost of developing the needed communications infrastructure statewide is $20 million per year for over the next ten years (*21*). This cost is to be paid for through federal, state, and local funding sources.

RWIS stations will be employed and monitored in each of the Districts as weather is a major factor in poor driving conditions in the winter months. Weather and incident related information will be passed on to the driver through a series of DMS along IH-80 and posting of information will be communicated with information sharing with Wyoming and Colorado (*21*). Along the same lines as providing information to the traveler, 511 service will be implemented on a state-wide basis in October 2001 and will be interconnected with systems currently in place in Minnesota, North, and South Dakota.

Washington

The Washington State Department of Transportation (WSDOT) has been involved with ITS applications over recent years. DMS are used typically for road, weather, and mountain pass information (*22*). HAR is used for traveler information as well as tourism with approximately 50 transmitters across the state. At this time, funding is being sought for a project to tie all HARs into a statewide server in order to access all from a single point.

There is also a variable speed limit (VSL) system in place on I-90 to react to rapidly changing weather conditions. Two automated bridge de-icing systems have recently been installed. Along the same lines as ODOT, WSDOT operates a number of cameras that offer real-time information through their website. Currently, WSDOT operates three TMC's with 2 more in the planning stage (*22*). Table 1 provides an overall summary of ITS systems used by the states mentioned above.

Table 1. Overall Comparison of State ITS Technology Applications

ITS Technology	AK	AZ	CA/OR	ID/MT/WY	MN	NE	WA
Roadway Weather Info. System	✔	✔	✔	✔	✔	✔	✔
Emergency Response	✔	✔	✔	✔	✔	✔	✔
Real-Time Video via Internet			✔	✔	✔		✔
Closed Circuit Television	✔		✔	✔	✔		✔
Dynamic Message Signs	✔	✔			✔	✔	✔
CVO / Veh. ID & Clearance	✔	✔	✔	✔	✔		✔
Advance Traveler Info. System		✔			✔		
Animal/Veh. Collision Avoidance			✔	✔			
Intelligent Vehicle Initiative		✔			✔		
511 Service		✔			✔	✔	
Bridge De-Icing				✔			✔
Flood Warning							✔
Traffic Management Centers			✔		✔	✔	✔
Weigh in Motion	✔			✔	✔		✔
Highway Advisory Radio		✔	✔	✔			✔

CURRENT PRACTICE OF ITS WITHIN TxDOT'S URBAN DISTRICTS

ITS applications have seen increasingly more use within the urbanized TxDOT Districts. Transportation operations engineers recognize that ITS technologies assist in providing improved operational characteristics to the transportation network. Operations professionals at TMCs within the Houston, Fort Worth, San Antonio, and Dallas Districts are in the process of continually finding ITS solutions to address transportation needs in these urbanized areas. As illustrated in the case of other state transportation agencies, the identification, assessment, and solution to these needs is of primary importance.

TMCs

TxDOT's partnership with other state and local government agencies in their TMCs has enabled increased operational capabilities to be realized within the transportation network encompassed by the respective TMC. The ability of transportation and governmental entities to be housed under the same roof ultimately leads to increased information sharing among agencies that can only enhance the transportation network. Operations professionals are able to provide real-time information to the highway user through video and DMSs and become involved with emergency and incident management at advanced level compared to emergency and incident responders lacking this type of communications infrastructure.

Real-Time Information

Figure 7 illustrates the images available from the DalTrans/TransVISION internet website. The real-time images offered to the user at this website are comparable to those found on other state's websites as mentioned above, with the exception being that these ITS technologies are principally being used in urban settings. The user is not only able to view camera images from around the major highways but is also able to view the actual messages being displayed on DMSs as well (<u>*23*</u>).

Figure 7. DMS and Camera Information Available via the Internet

San Antonio's TransGuide website also provides real-time information in a format that is somewhat unique. On one page within the TransGuide website, the user is prompted to choose views from particular cameras or has the option of viewing all camera images from in and around the city. This page allows the user to view road conditions at key points within San Antonio's transportation network in real-time. Information regarding construction zones and incidents is also made available to the user at these sites.

Another unique aspect of TransGuide's information providing capability is the operation of a Low Power Television (LPTV). The signal from the LPTV can travel up to 20 miles and anyone with a UHF antenna in range can pick up the signal (*24*). The video is also available via a local television station that rebroadcasts the original images.

Houston TranStar provides it's own distinctive method of providing information to the user regarding travel speeds along major routes. Figure 8 illustrates a speed chart available through their website (*25*). This information is helpful to the traveler in allowing vehicle speed to be shown in graphical form.

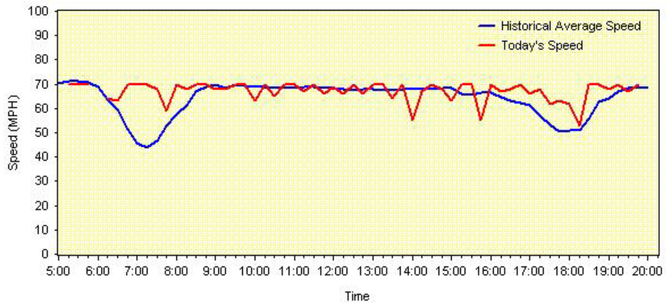

Figure 8. Example of Speed Chart

While this aspect of real-time information may be best suited for urban situations it illustrates innovative thinking that is required to address traveler needs in a given situation. There are many traveler needs in rural and smaller urban areas where applications of ITS to address these needs have not been designed.

Emergency Response

TransGuide, DalTrans/TransVISION, and TranStar have experienced increased capability to deal not only with emergency response but emergency and incident management overall. In fact, TranStar is referred to as the Greater Houston Transportation and Emergency Management Center. Each of these facilities realizes benefits of interagency cooperation with local fire, police, and emergency medical personnel through the operation of these centers. This cooperation yields results not only on a day-to-day basis, but when during severe weather events as well. For example, an ice storm that struck San Antonio in 1998 and floods recently experienced in Houston in the spring of 2001.

These centers also possess capabilities to communicate and disseminate information associated with MAYDAY and Rural Lifelink systems. As advances in ITS technology continue to develop and the operation of systems become more common, it is of utmost importance that these centers be equipped to handle communications in these types of emergency situations. These TMCs not only serve as a single point of contact to people with the responsibility of responding to emergencies and incidents but possess a larger role as well by providing support when necessary to the Federal Emergency Management Agency (FEMA) and the Governor's Office of Emergency Management.

Incident Management

The ability to manage with incident management is a unique aspect of daily occurrence on the transportation network where a well designed plan can aid in improving transportation operations that would otherwise not be possible. Plans for incident management often become second nature and these types of enhanced communications between agencies make quick responses to properly handle incidents possible.

Table 2 illustrates some of the ITS technologies that are currently in place within the Urban TxDOT Districts studied.

Table 2. ITS Technologies in Urban TxDOT Districts

TxDOT District	Roadway Weather Information Systems	Dynamic Message Signs	Closed Circuit TV	Traffic Management Center	Courtesy Patrol	Lane Control	Emergency Response	Video Images via the Internet
Austin	✔	✔	✔	✔	✔	✔	✔	
Fort Worth	✔	✔	✔	✔	✔	✔	✔	✔
Houston	✔	✔	✔	✔	✔	✔	✔	✔
San Antonio	✔	✔	✔	✔	✔	✔	✔	✔

Statewide Integrator Program

The acknowledgment that ITS is important to improving operations has also been recognized at the Division level with the development of the Statewide Integrator Program (SIP). While not on a scale as comparable to many other states plans for ITS deployment, the SIP has recently seen moderate increases in funding levels (<u>*26*</u>).

Presently, TxDOT is implementing ITS in urban and more recently rural and small urban areas through its Statewide Integrator Program through its Traffic Operations Division (<u>*26*</u>). Initially, the program encompassed only the urbanized Districts but has recently undergone change to include a support role to the rural and small urban Districts. In this program, the decisions on what ITS applications and technology to use, if any, in order to address transportation needs are left to the individual Districts.

This approach has led to an uneven understanding of ITS technology and use among TxDOT Districts overall. Some Districts possess a broader knowledge of the benefits that could be gained from the use of ITS technology. The Amarillo District for example presently has a District Engineer with a Traffic Operations background which appears to have aided in somewhat moving ITS technology forward through the Statewide Integrator Program. By the same token, there are a few Districts that have banded together in regional efforts to implement some ITS technology (<u>*26*</u>).

The San Antonio, Yoakum, and Houston Districts are currently working on a plan to develop a series of interconnected DMS along IH-10, the Tyler and Atlanta as well as the Odessa and Abilene Districts are working on a similar approach along IH-20.

The decision to seek support for ITS applications in the Odessa and Abilene Districts was a direct result of recent weather events. Approximately 12,000 trucks were immobilized for a three-day period in December 2000 just east of the Abilene area (<u>*27*</u>). In this case, there was no advance warning of impending closures due to ice and snow

The Statewide Integrator Program has spent approximately $12 million dollars on research, software development, and implementation of ITS hardware during fiscal years 1997 through 2001 (<u>*23*</u>). This figure is in sharp contrast to the financial commitment previously made by many other state transportation agencies.

TxDOT SURVEY

As mentioned previously, there were eighteen TxDOT Districts surveyed to determine the extent of ITS technology used within TxDOT. Thirteen of these Districts were principally rural and small urban and four were urbanized. The urbanized Districts surveyed were Austin, Houston, Fort Worth and San Antonio. All Districts surveyed are illustrated in Figure 9. Questions on the survey administered were associated with determining the current ITS applications of technology within rural and small urban TxDOT Districts as well as each District's current position regarding implementation of ITS.

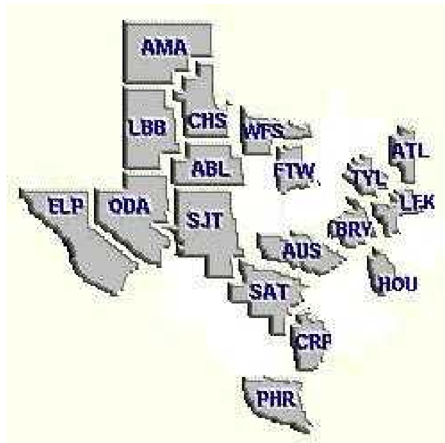

Figure 9. TxDOT District ITS Survey

SURVEY RESULTS

Table 2 illustrates the ITS technologies currently in use within the fourteen rural and small urban TxDOT Districts surveyed.

Based upon the survey results and seen in Table 3 the applications of ITS technology in the rural and small urban TxDOT Districts are less than that of other areas in the country with similar ITS needs.

One plausible reason for the noticeable difference in the use of ITS technologies is the need for a greater directional role regarding ITS applications within the organization. The common factor underlying ITS use in rural and small urban areas in various states reviewed above is commitment. Commitment by the transportation agency to recognize the available technologies in existence and apply them to the appropriate need of the traveler in the rural and small urban areas.

However, it should be recognized that ITS applications must work hand in hand with the appropriate design of a transportation facility. For example, if traffic congestion and resulting incidents are being caused by ramps in a smaller urban area that possess deficient acceleration characteristics, the decision should not be made to construct a DMS to warn drivers of the impending congestion. Instead, the decision should be made to solve the situation from a design standpoint.

Themes

Respondents from the survey of all seventeen TxDOT Districts tended to focus on six specific subject areas. These areas included: cost effectiveness, transportation needs, education, real-time information, ITS implementation within the traditional planning and design process, and the meaning of ITS. There was also discussion regarding the commitment of the agency collectively to implement ITS technologies through TxDOT's Statewide Integrator Program.

Table 3. Current TxDOT Applications of ITS Technology in Rural/Small Urban Districts

TxDOT District	Roadway Weather Information Systems	Dynamic Message Signs	Closed Circuit Television	Traffic Management Center	Ice Detection	Speed Trailers	Emergency Response	Weigh In Motion
Abilene		✔	✔					
Amarillo	✔	✔	✔	✔			✔	
Atlanta	✔					✔		
Bryan								✔
Childress	✔							
Corpus Christi		✔	✔					
El Paso		✔	✔	✔			✔	
Lubbock	✔					✔		
Lufkin								
Odessa								
Pharr		✔						
San Angelo								
Tyler		✔	✔					
Wichita Falls		✔			✔	✔		

Cost Effectiveness

Four operations personnel of the thirteen rural Districts felt that ITS applications were best suited to highly urbanized locations. The principal reason cited for these results was the cost of implementing technology versus the perceived benefits to the transportation network. All of the responses from the urbanized Districts indicated that the benefits gained outweighed the cost of implementing ITS.

Transportation Needs

Transportation needs within each rural and small urban District were similar in nature. The majority focused on providing traveler information during weather related events, such as flooding, ice, snow etc., high crash locations, construction zones in rural areas, and real-time information.

There was virtually no mention of emergency response. This result gives indication that the reduction in emergency response times in rural areas with ITS systems in place is not being realized. A recent Texas Transportation Institute study indicated that in a San Antonio, a 22 percent reduction in emergency response time within the TransGuide service area (*28*). It should be recognized that similar results can be achieved in rural and smaller urban areas as well.

Education

A number of respondents expressed interest in obtaining training regarding the use of ITS technology. There was also a desire to learn what ITS technologies and applications other state transportation agencies were deploying. When interviewed, many respondents were surprised to hear about what ITS technologies other states were researching and deploying.

One question within the survey sought information on whether operations personnel if they thought there was the need for a better understanding of ITS technology at the Area Office level. The majority of answers tended to say some education is needed at this level of the organization but not to the extent as providing in-depth training regarding the actual operation of these technologies. The survey results indicate that there is a strong need for operations personnel at the District level to take on the leadership role of supplying personnel at the Area Office level with the appropriate training and informal guidance with information on what direction the District is headed regarding ITS.

It must be remembered that within the organizational structure of TxDOT, the personnel within the Area Office are most often the first point of contact with the traveling public and are most times more aware of the transportation needs within their boundaries than those at the District level. For this reason, the personnel at the Area Office level should be as educated on the application of ITS technologies as other TxDOT operations personnel.

As a whole, the organization should utilize training regarding ITS in the most efficient manner. This could include a video for all personnel, sensible training for personnel at appropriate levels, and formalized training to individuals responsible for the statewide implementation of ITS technology.

Real-Time Information

Even though many responses to the survey indicated the need for real-time information to be disseminated, the method of delivery to the driver was centered primarily with DMS. However, with this use there was little mention of estimated travel times. Instead, more emphasis was placed on advance warning of roadway closures due to incidents and weather related events.

ITS Implementation

The vast majority of survey responses dealing with implementation were associated with the planning and programming of ITS projects. While this concern is valid, there must be the realization that funding and knowledgeable personnel interested in long-term results are required for ITS to work.

Applying ITS technology within TxDOT's traditional planning, programming, design, and construction process is the beginning of the implementation process. In order for ITS applications to be effective, the commitment must be made at the staff level to place emphasis on the use of these emerging technologies.

It should be realized that many other states presently leading the way in the field of ITS have made the commitment to designate responsible operations personnel involved solely with the implementation of ITS within their agency. With the commitment to implement ITS also comes the responsibility of operating and maintaining these systems just as any other transportation facility or technology currently in place. This concern of maintenance was of particular importance to a few survey respondents. Their primary concern was over vandalism of ITS hardware in the more rural areas. Figure 10 illustrates a speed trailer that was vandalized in a rural area. Research from other rural areas in the various states above indicates that these types of incidents do occur but not on a scale that discourages their use (*9*, *14*).

Meaning of ITS

In order to gain insight to the understanding of each District regarding ITS, the question was asked to explain in fifteen words or less what ITS is and its meaning. Responses to this question were primarily associated with ways that technology can improve safety and efficiency of the transportation network.

Figure 10. Vandalized Speed Trailer

There were a few responses that indicated specific ideas regarding the dissemination of real-time information warning devices, and the efficiency of collective resources. Upon personally speaking with many individuals responding to the survey it is apparent that there has previously been primarily only an informal sharing of information of ITS technology. The information shown in Table 4 provides an abbreviated summary of the rural and small urban survey responses.

APPLICATION OF ITS TECHNOLOGIES WITHIN TXDOT'S LUBBOCK DISTRICT

The application of ITS technology within the Lubbock District should ultimately progress outward across District and state boundaries. This notion has worked well for the various states researched above. Studies performed with regard to ITS application in these areas indicated that similar transportation needs were faced within geographic locations opposed to those confined within state boundaries. This concept is important to this District because it is centered geographically in the Texas Panhandle. Lubbock itself is referred to as the "hub city" due to this very fact.

Top of West Texas ITS Region

Figure 11 illustrates the proposed area to be covered by a regional TMC in Lubbock. This TMC would be ultimately responsible for coordinating ITS through District Transportation Operations Centers within the neighboring Amarillo, Abilene, and Odessa Districts and will be classified as the Top of West Texas (TWT) ITS Region. The regional partnerships made between the various supporting agencies involved with providing the safe and efficient movement of goods and services will provide a basis for the proper identification of traveler needs and long-range planning of ITS deployments in the area.

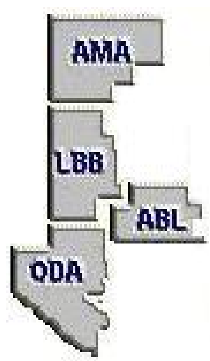

Figure 11. TWT ITS Region

Table 4. Abbreviated TxDOT Rural/Small Urban District Survey Responses

	Is ITS best suited to urban areas?	**What ITS needs do you have?**	**What new technology would you like to see implemented?**	**Is ITS effective in moving traffic more efficiently?**	**Is better understanding of ITS needed at the Area Office level?**	**Is formalized ITS training necessary?**
Abilene	no	real-time information	high-load detection	Tradeoff, safety vs efficiency	in the future	omitted
Amarillo	no	Flow rates, incidents	N/A	N/A	no	not presently
Atlanta	no	Construction, incidents, weather	DMS	if used properly	yes	yes
Bryan	yes	DMS	high water warning	at capacity constrained locations	no	no
Childress	no	weather, volume counts	DMS	very effective	large District yes, small, less	yes
Corpus Christi	yes	real time traffic map	self optimizing traffic signal system	somewhat	no	omitted
El Paso	no	faster info. processing	automated transit time reporting	yes	yes, over time	possibly
Lubbock	yes	CMSs in urban area	CCTV	limited	omitted	possibly
Lufkin	no	incidents, volumes	illumination monitoring	yes	yes	not necessarily
Odessa	no	weather	Omitted	omitted	possibly	for those directly involved
Pharr	no	speed, occupancy	traffic signal corridor mgmt.	once pieces all work together	yes	yes
San Angelo	yes	none at this time	N/A	N/A	no	no
Tyler	no	congestion, flooding	spread spectrum radio	yes	yes	yes
Wichita Falls	no	weather	additional DMSs	yes	yes	yes

The proposed ITS applications will be based on rural and small urban traveler needs within this region of Texas. Previous research from communication with transportation operations personnel within these Districts indicates that traveler's needs over the region are similar in nature. Each District within the region has local and Interstate travelers. It should be noted that the transportation needs of local traffic versus cross-country travelers are different and as such these needs should be addressed to provide the optimal solutions for providing real-time information, emergency response, and network management.

The initial goal in developing an ITS strategy to address transportation needs throughout the region would be a result of a number of factors. This would best be accomplished by the creation of two levels of contact responsible for identifying ITS needs.

The upper level of contact for the four Districts, or Team 1, would be a team comprised of each District's Director of Transportation Operations and District Engineer or appointed designee. This eight member team would ultimately be responsible for collectively forming an ITS deployment plan to address the needs identified by the first team level. The lower level of ITS teams, or Team 2, would be formed from a group of individuals within each District.

These ITS teams would be led by TxDOT's Director of Transportation Operations in each of the four Districts. The members within each team would consist of TxDOT Area Office representatives, local professionals associated with transportation, emergency services, city/county officials, and a member of the public who would serve on a rotating basis. The team from each District would consist of approximately 7-9 members and would also be responsible for developing regional Incident and Emergency Management Plans. The organizational chart for Team 1 and Team 2 is shown in Figure 12 and Figure 13 respectively.

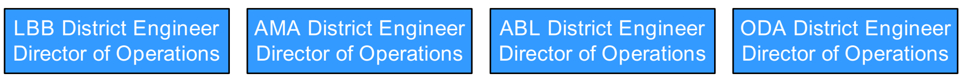

Figure 12. TWT ITS Team 1

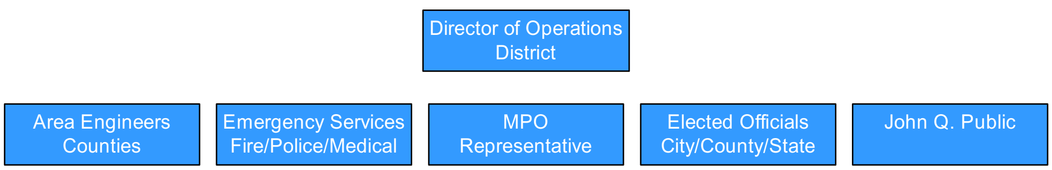

Figure 13. TWT ITS Team 2

The initial plan for deploying ITS technologies begins with the creation of a TMC to serve the region. This TMC will be constructed after meeting with TxDOT and architectural personnel responsible for the creation of other TMC's in Texas. Once this task has been accomplished, it must be imperative to make the commitment to construct the regional TMC in a timely manner. If all things worked well, and the commitment for the regional center was made at TxDOT's executive level, this task could reasonably be accomplished within a two-year time frame. It must be important for officials at this level to realize that this TMC could serve as a pilot for other regional centers to be developed throughout the state.

Before the TMC is constructed, there should be the initial development of plans and deployment of many technologies such as communications infrastructure conforming to the National ITS Architecture, DMS, cameras, RWIS, WIM, incident management plans, and improvements in emergency response.

After the TMC is constructed, it will be responsible for the TWT ITS Region and will be essentially responsible for providing real-time information through a number of ITS technologies. Table 5 summarizes the ITS applications to be implemented within the TWT ITS Region.

Table 5. TWT ITS Region Systems

• Emergency Response • Incident Management Plan • IVI (High Crash Intersections) • Speed trailers used in construction zones • WIM • ATIS – 511; MAYDAY • Expanded communications infrastructure	• RWIS • DMS • Video Surveillance available to the user via the Internet • CCTV • HAR

RWIS

Weather in this area of the state, especially from Lubbock northward has been known to typically produce poor driving conditions during the winter months. This area of the Lubbock ITS Region would therefore receive a greater proportion of RWIS to monitor changing weather conditions. As illustrated in Figure 13, RWIS are located along IH-20, IH-27, IH-40, US 60, US 287, and US 385. HAR will be used in conjunction with the RWIS.

DMS

DMS will play an integral role in the rural areas by providing information regarding driving conditions due to incidents and bad weather. Information received from RWIS will be used to provide advance warning of road conditions in a timely manner. A logical place to construct DMS to receive the greatest benefit is on Interstate Highways within the region. Portions of I-40, I-20, and I-27 are encompassed within the region. DMS will be placed at strategic locations in the region.

Video Surveillance

Video depicting traffic movements along the transportation network are valuable to operations and emergency management personnel. As seen in other states as well as urban TxDOT Districts, an overall reduction in emergency response times can be realized. Video imagery is not only possible through fixed locations, but mobile video trailers can provide real-time information with the benefit of being able to be deployed at different locations.

Video images via the Internet are an application that research shows users in other states have seen as beneficial in providing real-time information. A principle benefit in using this technology is the ease in which real-time information is available to users of the transportation network. This technology is relatively cost effective to implement and maintain and as such should be at the forefront of ITS technology deployment.

Emergency Response

As previously mentioned, research indicates that ITS technology is beneficial in reducing emergency response times. In the more rural areas, this reduction in overall emergency response time is critical. Within the TMC itself, space for representatives from fire and police in the Lubbock area will be provided. These emergency response personnel will be responsible for the Lubbock area and support to the surrounding area. It should be noted that the medical infrastructure in Lubbock presently serves as the region's principal facilitator of medical services.

The introduction of a MADAY and Rural Lifelink systems has proven beneficial in many other areas of the country in providing information to emergency dispatchers in critical situations (29). These types of systems are associated with providing real-time information in critical emergency situations dispatch centers. These systems provide information on the actual location of the crash and information regarding the severity of injuries at the crash scene.

Expanded Communications Infrastructure

The telecommunications infrastructure within the Lubbock ITS Region must be examined and updated with the latest proven and supportable technology in order for ITS to ultimately prove beneficial in providing real-time information to the traveler in a timely manner. There are ways to increase the capability in this area through the use of TxDOT's utility permitting process. While the telecommunications industry has suffered a recent setback, it is most surely expected to rebound and again realize the expansion the industry has seen within the past five years. Herein lies an opportunity to economically develop a necessary aspect of the ITS communications infrastructure. Through TxDOT's utility permitting process, fiber optic as well as telephone and wireless communications companies and contractors could be used by TxDOT to develop the required infrastructure. This concept has recently been used on a very limited basis within the Odessa District (23).

IVI

Current research regarding IVI technology has been promising and must be included in the Lubbock ITS Region's overall plan for implementation. Transportation officials from the TWT ITS Region must realize as Mn/DOT's does that this technology could ultimately prove beneficial in collision avoidance. The rural areas within this region have long been known for high-speed right angle crashes. This fact is primarily due to the topography of the surrounding area. This topography has very small changes in grade over long distances. In these rural areas, high speeds are common approaching intersecting roadways.

IVI technology could easily prove beneficial in these high crash locations. For example, at locations where experiencing a history of these types of crashes, this technology could be employed through vehicle-to-vehicle communication or vehicle-to-fixed-point communication. In the former, vehicles would be possess the capability to communicate with each other and alert the driver of possible conflict and in the latter, technology on either vehicle could activate warning devices to provide sufficient warning.

WIM

WIM technology has recently become more important due to the increased percentage of trucks attributable to NAFTA. ITS technology associated with WIM will ultimately prove beneficial to the trucking industry and transportation network as a whole. With more of these types of CVO technologies in place, the tracking and clearance of trucks and fleet vehicles will only improve the overall safety of this mode of transportation. This technology also assists law enforcement in providing a more efficient means of enforcing load restrictions. This method of enforcement is another illustration of the interagency cooperation that can occur with the deployment of ITS.

ATIS

ATIS technology in the region presently would best be served with 511 Traveler Information Service. Here again the appropriate telecommunications infrastructure is needed in order for this technology to be applied and maintained satisfactorily. The commitment to using 511 to provide information to the user as with all the technologies mentioned above is directly related to the satisfaction of the transportation network user.

In addition to 511, the communications infrastructure designed to incorporate MAYDAY systems could be seen as becoming necessary within a short period of time. These systems provide information regarding the exact geographical location of the vehicle when activated during an emergency. Future needs may dictate the need for a broader application of ATIS technology designed to detect and track large traffic volumes at sporting or other events placing roadways within the network over capacity.

TWT ITS Deployment Plan

The ITS deployment plan for the TWT region is shown in Figure 13. The deployment of ITS technologies is an important, significant step in the development of a safer more efficient transportation network. The application of the appropriate ITS technology designed to address traveler needs was the driving force behind the development of the plan. The work performed by the ITS teams was crucial providing the information necessary to implement the right technology to accomplish the desired goals.

Cameras designed to provide real-time information are to be deployed at strategic locations along the Interstates and major highways. These cameras are not only deployed to provide information to the user but to operations and emergency response personnel. The decision to implement these cameras is based on the success realized within TxDOT and other state transportation agencies.

WIM technology is deployed with the desire to decrease the significant number of overweight trucks operating on the road today. State law enforcement officers are understaffed to sufficiently deal with this growing problem. Overweight trucks ultimately lead to increased maintenance cost associated with pavement repairs. RWIS will be used to provide information regarding poor driving conditions related to weather. Information associated with these systems will be disseminated to the traveler through DMSs and HAR.

The implementation of these ITS technologies as illustrated in Figure 14, within the TWT region is to provide a safer more efficient traveling environment. These deployment of these technologies in this region will serve as a foundation for the development of future technological advancements in the field of ITS. These systems are deployed not only to assist motorists but transportation officials and emergency responders. The ability to implement and operate ITS will only improve transportation operations within the region while at the same time promoting public safety.

CONCLUSIONS

The commitment to implement ITS technology into the transportation network is one that should not be taken lightly by any state transportation agency. Merely creating the initial communications infrastructure and applying the desired ITS systems to the transportation network is not enough. The transportation agency must realize the commitment of operating and maintaining these systems

One survey respondent strongly recognized the fact that TxDOT was behind other states in the deployment of ITS technology and was not concerned with the issue. Instead, concern was focused more on what direction the department would take as far as commitment to deployment. This individual recognized that without a strong commitment at the administrative level, there would be little chance of ITS technologies realizing long term success in the rural and smaller urban Districts.

While the Statewide Integrator Program currently in place within TxDOT addresses some aspects of ITS technology being applied to the state's transportation network as a whole, there remains the lack of direction into the use of ITS technologies and applications at the administrative level. The funds spent on ITS projects to date are far below those projected in many other states with resources less than TxDOT. This is not to mention the Federal funding through FHWA for projects involving ITS that TxDOT is not taking advantage of.

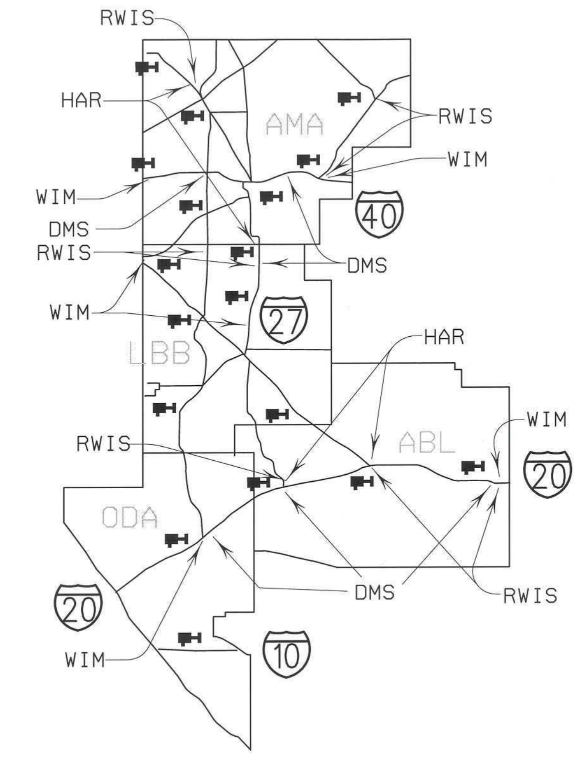

Figure 14. TWT Region ITS Deployment Plan

There are some aspects to the TxDOT's current program that have experience some success at the District level and regional level. However, it is clear that the development of a program designed to disseminate information effectively must first be devised. This plan should provide for the implementation of technology the same as those associated with safety devices and materials in other TxDOT Divisions. This means of appropriate training to personnel involved with ITS, funding made available, and including ITS as part of the TxDOT's design process in general must occur before the appropriate incorporation of ITS technology into TxDOT's planning and programming process can be realized on a scale compared to other states.

From the results of the survey and discussing ITS issues with many of TxDOT's transportation operations professionals it is apparent that in many cases there is interest in using ITS technology to address transportation needs but sharing of information is only being accomplished through informal means. This fact is reiterated by the method of dissemination of ITS information from the TxDOT's Traffic Operations Division. In these instances, the initial point of contact is left to each District to make instead of the Division contacting each District. It is agreed that each District must be willing to develop ITS based on their own needs but the support that is available must see increased resources to properly address each District's needs.

The various states researched, specifically Alaska, Arizona, and the COATS area's detailed plan for implementation of technology illustrate logical progression of the correct steps an agency should take integrating ITS technology into the state transportation network. These states developed the implementation of technology based on needs identified in series of stakeholder meetings and studies conducted by transportation research facilities. These meetings and research were conducted in a timely manner made available to decision makers within each state's respective transportation agency upon completion.

Integrating ITS solutions to problems within TxDOT is one that can be accomplished. The commitment by the agency is one that can be accomplished through research. The COATS area and Idaho/Montana/Wyoming DOT's for example used Western Transportation Institute while other states used engineering consultants to research the implementation of ITS technologies within their states. This research has proven successful in allowing the implementation of ITS technology to be placed in each state's programming, planning, design, and construction process. Texas Transportation Institute Report 1790-2 entitled *A Proposed ITS Evaluation Framework for Texas* provides groundwork to begin building arguments for the need for an ITS infrastructure in Texas (*30*).

It is this author's feeling that continuing the types of research that particularly pertain to traveler needs and methods of delivery desired by the public would provide the same result for TxDOT. However, the implementation through applied research should not be overlooked. This type of research regarding the development and ultimate deployment on a large scale is beneficial in providing proven and supportable technologies within the short term.

It should be realized that the construction of a large TMC is not necessary to begin the process of implementation ITS technologies. Center-to-center communications among Districts can be accomplished in many cases with minimal upgrades in within TxDOT's existing communications infrastructure. Many of the ITS technologies available today are considered to be cost prohibitive by many operations professionals in rural and smaller urban Districts. However, it should be recognized that there are a number of demonstrated ITS applications within TxDOT and other state transportation agencies in place that are designed to promote safety and improve efficiency relatively inexpensive to operate and maintain.

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APPENDIX A: SURVEY QUESTIONS FOR RURAL AND SMALL URBAN TxDOT DISTRICTS

1. What ITS technologies, if any, do you presently use?

2. Do you feel ITS is best suited for application in urban Districts? If so, Why?

3. What traffic information needs do you have? If not, what concepts do you feel are applicable in your District?

4. Not including the technologies currently in place within your District, what ITS technologies would you like to see in implemented?

5. How effective do you feel the ITS devices and procedures you use are in moving traffic more efficiently? (if applicable)

6. Do you feel a better understanding of ITS is needed at the Area Office level? If so, how can this be accomplished? If not, Briefly explain your answer.

7. Do you feel formalized ITS training conducted on a statewide level is necessary?

8. Do you feel the PS&E process should include the implementation and review of ITS concepts? Briefly explain your answer.

9. Explain in 15 words or less what ITS is and its meaning to you.

APPENDIX B: SURVEY QUESTIONS FOR URBANIZED TxDOT DISTRICTS

1. Do you feel ITS is best suited for application in urban Districts? If not, what technologies do you presently use would you consider applicable in a more rural District?

2. What traffic information needs do you feel would be most applicable in a rural/moderately urban District?

3. Do you feel a formalized training process conducted on a statewide level would increase the use of ITS in other Districts?

4. Do you feel formalized ITS training conducted on a statewide level is necessary?

5. Do you feel the PS&E process should include the implementation and review of ITS concepts? Briefly explain your answer.

6. Explain in 15 words or less what ITS is and its meaning to you.

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TRAVELER INFORMATION SYSTEMS FOR NATIONAL PARKS

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SUMMARY

Increased congestion, parking issues, and the frustrations they cause visitors in national parks have added to the need for the National Park Service to determine a method to enhance visitors' experience within the park. Traveler Information Systems are one way of accomplishing this task. The objectives of this research were to 1) inventory current traveler information systems in five to ten pre-selected national parks; 2) determine the similarities and differences in the traveler information systems; 3) identify tourists' information needs and preferred methods of delivery at national parks in general; 4) recommend state-of-the-art traveler information tools to address the tourists' needs; and 5) apply the recommendations to a specific national park.

Seven national parks and five organizations representing national park visitors were surveyed. The survey results were used in the development of recommendations to improve the current traveler information systems. These recommendations appear below:

1. Provide information to visitors that includes:
   a. parking availability
   b. traveler advisories
   c. animal warnings and sightings
   d. information on areas of the park with the best views
   e. special children's activities
   f. prices and services for groups
   g. peak season and off season dates and times
   h. current snow levels on hiking trails
   i. elevations where snow will be encountered on hiking trails
   j. avalanche hazard information
   k. trail conditions including erosion
   l. information on what to expect when sharing hiking trails with horses
   m. backcountry information
   n. recreational limitations or restrictions
   o. backpacking permit information

2. Maintain the distribution of information through handouts and internet while trying new distribution methods and better advertising these current methods.

3. Continue to distribute information in the park and at visitor centers within and outside the park while trying new distribution locations.

4. Improve communication and cooperation with outside organizations and hospitality providers to provide information to visitors by creating an email list serve and separate phone line for their use.

5. Create a system integrated with the national park internet sites and highway advisory radio to provide updated and current information on park conditions and activities.

6. Post bulletin boards and chat rooms on the national park internet sites for visitors to discuss their experiences and share their "secrets" such as the best viewing spots, animal sightings, and backcountry information.

7. Increase the usage of changeable message signs to provide visitors with information on road closures, traveler advisories, full parking lots, and animal warnings. Link these CMSs to the internet as well.

8. Use pneumatic tubes to count vehicles entering and leaving parking lots to determine the number of open parking spots. Link this to CMSs at the entrance stations.

9. Improve bus system.

10. Explore the possibility of creating an easier and more advertised reservation system.

To test the feasibility of these recommendations to improve current traveler information systems, the recommendations were applied to Rocky Mountain National Park in Colorado.

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INTRODUCTION

In recent years, the number of visitors to national parks has been increasing rapidly. While this increase is good for the travel and tourism industry, "continued growth in visitation may threaten significant park resources and the ability of visitors to enjoy themselves." According to Byrne and Schumm and the United States Department of Transportation, the negative aspects of visitation growth include traffic congestion in many of the parks, increased deterioration rates of park roads, rapidly expanding roadway construction needs, overcrowding, parking problems, lack of traveler information, and public safety (*1*,*2*). All of these aspects affect the visitor's experience. Instead of enjoying the natural and cultural resources of the national park, visitors sit in congestion and fight for parking spaces. This "noise and congestion create[s] frustration for park visitors, and diminish[es] their experience."

To address the issue of increased visitation affecting the visitor's experience, the Department of Interior and the Department of Transportation began a Memorandum of Understanding in 1997. This memorandum left the National Park Service to "identify opportunities to use a variety of new transportation technologies in National Parks including ITS."

Problem Description

According to the national park service, "all of our design and planning efforts are directed to ensuring that facilities lie lightly on the land and enhance the experience of our visitors." One such planning effort is a traveler information system. "...intelligent transportation systems [traveler information systems] could provide visitors with advance information regarding traffic and parking conditions, lodging/camping accommodations, weather, activity opportunities and transportation alternatives." This information would allow the visitors to make more informed decisions and would improve their experience at the park.

The problem that remains, however is that many of the national parks' current traveler information systems have not been updated with the current technologies and with the preferences of the system users. This paper will be a state of the practice and will compare what national parks are currently providing to the system users, and what the users would prefer.

Addressing these issues will provide information to the National Park Service on the comparisons of different parks along with how to update their current systems in a way that will be useful to the visitors of the parks, therefore increasing the visitors' experience at the park.

Research Position

The degradation of visitor experience in the national parks due to increased visitation was recognized by transportation engineers and in 1998 prompted the establishment of a Transportation Research Board (TRB) Task Force on transportation needs for national parks and public lands to provide a forum for transportation-related issues (*3*). One of the research topics that the Task Force identified was "exploring advanced technologies to enhance pretrip and in-route information (*3*)."

Traveler information can be distributed in two ways: pretrip and en route. Pretrip information is information that the tourist receives before they leave their home. This information is generally given in the form of radio, television, internet, and guidebooks. En route information for this research project is defined as information that is distributed anytime in the trip after the tourist has left home. Examples of methods to distribute this information include telephone, highway advisory radio, pamphlets, and changeable message signs.

The type of traveler information that can be distributed also varies widely. In a national park, the types of information needed are generally transportation and recreation related. For example, tourists should be informed if a crash has occurred ahead of them that will cause delay or they should be informed that the parking lot by the visitor's center is full, these are both pieces of transportation related information. Recreational information that could be useful to visitors includes where to get a backpackers permit and how long the wait for rental equipment such as boats, bicycles, and hiking gear is going to be.

A study, done by Pat McGowen at the Western Transportation Institute, for Yellowstone National Park addressed the park's traveler information system. The goal of McGowen's research was to identify what types of information visitors wanted, where they wanted it, and how they wanted the information delivered to them. In this study, the visitors to Yellowstone National Park were surveyed and the information they wanted, how, and where were compared by the demographics of the visitors (*4*). This research is a very good example of current traveler information needed in the national parks and was used as an example in this research. It was extended by generalizing it to fit more than a single national park.

The gap in the current research is that there is not much documentation on traveler information systems for the national parks. There is also a lack of traveler information needs surveys that have incorporated multiple national parks and there is a lack of literature comparing the current traveler information systems. These gaps are addressed in this paper.

In conclusion, the existing research has successfully shown the need for traveler information and the need to update the current systems. The author of the research discussed herein provides a new insight into what information is wanted, and how, and where visitors want to receive this information in general. The author will also give recommendations on how to improve the current traveler information systems based on the survey results. With this new knowledge, traffic engineers in the NPS, will better be able to serve their "customers" and tourists will be able to make more informed decisions leading to a better experience for visitors of the national parks.

Research Objectives

The overall goal of this research was to determine what information tourists in national parks want and need and what is the most efficient way to get it to them. The specific objectives of this research were to:

- Inventory current traveler information systems in five to ten pre-selected national parks;
- Determine the similarities and differences in the traveler information systems;
- Identify tourists' information needs and preferred methods of delivery at national parks in general;
- Recommend state-of-the-art traveler information tools to address the tourists' needs; and
- Apply the recommendations to a specific national park.

Scope

Traveler information needs in national parks were focused on in this study. The study was limited to traveler information about transportation and recreation. It was also be limited to en route information and distribution methods. The inventory of current traveler information systems was limited to five to ten national parks with characteristics that include high visitation, limited access points into the park, and availability of recreational activities to visitors. The survey of national park visitors was limited to five to ten organizations that represent a wide variety of possible national park visitors.

STUDY DESIGN

The procedures followed in carrying out this research on traveler information systems in national parks consisted of seven main tasks. These tasks are discussed in greater detail in the following sections.

Literature Review

A review of past and current literature was performed in order to identify issues related to traveler information systems and tourists' needs in national parks. Specifically, pilot programs in national parks, traveler information needs studies in national parks, and traveler information systems were examined.

Develop Contact List for Surveys

A list of contacts within national parks, selected based on high visitation rates, limited access points into the park, and availability of recreational activities to visitors, was identified along with a list of contacts for groups that represent tourists to the national parks. These contact lists were developed based on the internet, *National Parks Transportation Systems in the National Park System* Conference Proceedings (5), and the Advanced Institute Mentors. The contact lists contained twelve national parks and fifteen organizations.

Develop Surveys

A survey was used as the primary information-gathering tool for determining the state of current traveler information in the national parks. The survey questions were formulated such that information on what traveler information in transportation and recreation is given to tourists and how the information is generally distributed. Information was also sought on whether or not the traveler information system has been documented and what strengths and weaknesses are in the system.

A second survey was the primary information-gathering tool for determining what additional transportation and recreation information tourists in national parks would like available to them and how they would prefer to receive this information. This survey was filled out by organizations that represent the tourists such as hiking groups, camping groups, and automobile associations. Information about cross tabulation between demographics and what information is wanted was also identified.

The surveys consisted of check box answers for what information do they give/want, how do they give/want information, and where to they give/want information. This allowed answers to be compared through percentages. The remainder of the surveys were open-ended questions to allow the national parks and the organizations to express their opinions. A copy of each of the national park surveys is provided in Appendix A. The Organization Survey is provided in Appendix B.

Conduct Surveys

The surveys consisted of two portions. These are described below as Task 4a and Task 4b.

Conduct Introductory Telephone Call

First, a brief introductory call was placed to the contact person in each of the twelve national parks selected and each of the sixteen organizations. The purpose of this call was to:

- Ask if the contact would complete the survey and if not, ask who else might be able to complete the survey;
- Determine documents that might be available on this subject; and
- Determine whether the preferred method is fax or email.

Conduct Survey

With the information found in the introductory phone calls, surveys were distributed using the respondents preferred method.

Compile and Analyze Results

Using the results of the survey, the current traveler information systems in the selected national parks were evaluated. The information provided was catalogued in a table so that similarities and differences among various parks could be identified.

The information provided in the organizations' surveys was then catalogued in a table by the type of tourists that the organization represents. This allowed a comparison to be made of what type of tourists want which type of information, how they want it, and where they want to receive the information.

An overall comparison of what, how, and where visitors want and need information versus what, how, and where they are receiving it was done using cumulative percentages. This analysis allowed for identification of possible solutions in the current practices in National Parks.

Recommend Improvements

Using the information gathered from the previous tasks, recommendations to improve the traveler information systems in National Parks in general were made. Recommendations were a combination of common current practices and state-of-the-art practices.

The recommendations focused exclusively on methods of providing the information tourists identified as needed in the survey. Factors such as obtaining funding sources, public relations campaigns, daily operation, and system improvements will not be addressed as a part of these recommendations.

Case Study

In order to assure that the recommendations developed in Task 6 were as complete as possible and were plausible, these recommendations were tailored to a specific National Park and sent for review to the Park's contact. The National Park chosen was based on their filling out the original survey, their previously expressed willingness to review the recommendations, their perceived experience in traveler information, and the parks need for such ideas. The park was selected after the surveys were returned and was chosen by myself and three highly respected transportation engineers.

NATIONAL PARK SURVEY RESULTS

Out of the twelve national parks contacted, seven completed and sent back surveys. Those national parks were:

- Acadia National Park, ME;
- Denali National Park and Preserve, AK;
- Grand Canyon National Park, AZ;
- Grand Teton National Park, WY;
- Great Smoky Mountain National Park, TN and NC;
- Mesa Verde National Park, CO; and
- Rocky Mountain National Park, CO.

The information gathered in these surveys was divided into two parts. The open-ended questions, questions 4 through 16, in the survey were used to provide a description of the national park. The check box answers, questions 1 through 3, were used to compare and contrast the information provided by the national parks. The details of these surveys can be found below.

National Park Descriptions

Acadia National Park

Acadia National Park is located on the coast of Maine. It was first dedicated as Sieur de Monts National Monument in July 1916, it then became Lafayette National Park in February 1919, and finally became Acadia National Park in January 1929 making it the first national park established east of the Mississippi River. Acadia National Park encompasses 47, 633 acres of land that houses mountains, lakes, ponds, and ocean shoreline. This park has recreational activities that include auto touring, biking, camping, climbing, cross country skiing, fishing, hiking, and wildlife viewing. In 2000 there were 2,469,238 recreational visits made to this national park (*6*).

According to the survey respondent, Acadia National Park contains about twenty access points to visitors and has an associated fee to enter the park. Tourists move throughout the park by personal vehicle, transit, rental bikes, RV's and mopeds leading to transportation related problems in the area of inadequate parking spaces, resulting in roadside parking and congestion. The traveler information system at this park has been in place since 1916 with the addition of radio in 1982. Although, the system gets mostly annual updates with weekly updates to the radio its problem remains poor quality broadcast with the radio due to weather. A traveler information survey was completed for this park in 1999 (*7*).

Denali National Park and Preserve

Denali National Park and Preserve is located in Alaska and features Mt. McKinley, North America's highest mountain, and glaciers. It was first established as Mt. McKinley National Park in February 1917 and became Denali National Park and Preserve in 1980. Denali National Park and Preserve is home to many species of wildlife in its six million acres of land. Visitors to this national park can enjoy recreational activities that include backpacking, camping, climbing, hiking, mountaineering, nature walks, snowmobiling, skiing, dog mushing and wildlife viewing. In 2000 there were 363, 983 recreational visits to this national park (*6*).

Survey results shown that, Denali National Park and Preserve has one access point and road. After paying their fee, tourists can travel the first 15 miles into the park by personal vehicle and past this point must travel by shuttle or tour bus. The National Park has been partially closed to personal vehicles since 1972. Congestion is a problem faced by Denali. This is caused by confusion in transit reservations and large influxes of visitors twice a day when many visitors arrive by Alaska railroad. Traveler information systems have been in place since 1922 however significant changes have been made since then. An advance reservation system for shuttle buses and campgrounds became available in 1994 and internet information has become available in the past five years. Updates to the traveler information system usually occur twice a year, but depend on the information itself. Radio messages are updated seasonally, the park newspaper is updated annually, and the internet is updated as needed. Some of the problems with the current system include confusion between the different bus systems, complexities in making reservations, and wait times by phone, fax, and standing in line. Complaints by visitors include confusion about which bus to take, frustrations with the reservation system, and having to pay for the shuttle. Traveler information needs surveys were done in 1996 and 1999 (*8*).

Grand Canyon National Park

Grand Canyon National Park contains 277 miles of land along the Colorado River and its adjacent lands in Arizona. It was first established as a National Monument in January 1908 and later became a national park in February 1919. Recreational visits to this park were 4,460,228 in 2000 with recreational activities available to these visitors including backpacking, biking, camping, hiking, interpretive programs, and whitewater rafting (*6*).

Grand Canyon National Park, according to survey respondents, is a park with four access points available to tourists for a fee. Visitors travel through this park by personal vehicle, transit, walking, bicycle, and tour bus. With only 1300 parking spots and 6000 vehicles entering the park on busy summer days, the most pressing transportation related problem faced by this park is limited parking. A traveler information system has been in place in this park for more than twenty years. Updates to the system station are done on a weekly basis with the newspaper being updated four times per year. Problems with the current traveler information system include lack of shuttle buses to handle the number of tourists and confusion about bus routes during the current rerouting process. The top complaints made by visitors include confusion about the shuttle bus system and how to get around the park. Traveler information could be improved by increasing the number of shuttle buses, moving the parking to a spot outside the park and allowing visitors to come into the park by bus or train, and by providing better information at the bus stops. A traveler needs survey has not been done for this park (*9*,*10*).

Grand Teton National Park

Grand Teton National Park contains 309,994 acres of land in Jackson Hole Valley in Wyoming. This national park is home to many glaciers and the Grand Teton Mountain. The National Park was first established in February 1929, later to become Jackson Hole National Monument in March 1943, and finally Grand Teton National Park in September 1950. In 2000, this national park had 2,590,624 recreational visits. Recreational activities available in this park include auto touring, backpacking, biking, boating, fishing, hiking, hunting, interpretive programs, mountaineering, wildlife viewing, and snowmobiling (*6*).

This national park contains three entrances that are open to tourists. There is a fee to enter the park. Tourists in the park travel by personal vehicle, transit, and commercial tours. Congestion problems in this park are related to a parking area overflow at Jenny Lake during July and August. The age of the traveler information system varies with type of information distribution method. Updates to the system are constant, although some information remains the same and therefore does not need to be updated. Problems with the current system include signs that are overlooked or easily missed and complaints by visitors include frustrations with road construction and the lack of up to date information. This system could be improved through constant upgrades. Several traveler needs surveys have been conducted, most recently in 1997 (*11*).

Great Smoky Mountain National Park

Located in the southern Appalachian Mountains, the 800 square miles of Great Smoky National Park reside in both Tennessee and North Carolina. This national park, established in June 1934, is home to mountains, plants, animals and is 95 percent forested. Recreational visits to this national park totaled 10,175,812 visits in 2000 making it the third most visited National Park in 2000. Recreational activities available in this park include auto touring, biking, backpacking, camping, hiking, fishing, horseback riding, and wildlife viewing (*6*).

Results from the survey show, that this national park has no entrance fees and has three major entrances, but additional road access points and "walk-in" access points. Visitors move through the park by personal vehicle, a limited trolley service, tour buses, horseback and bicycles. Problems faced by the national park include both congestion and lack of parking. Parking problems occur at the major swimming, hiking, and picnic locations. Congestion is a severe problem resulting in a level of service E, on roadways, during the summer and in October when the travel time for the 11 mile road loop not uncommonly exceeds four hours. A highway advisory radio has been in operation for over ten years and is updated seasonally, however provides only recreational information. Problems with the current system include the lack of a system to provide traffic and parking information to visitors en route. Top complaints made by visitors include lack of advance warning about congestion on parking facilities and a degradation of visitor experience at Cades Cove due to the number of vehicles. It is felt that an improvement in this system could be made by tying the park's future system in with the state's ITS system. A limited evaluation for ITS needs was done in 2000. Plans to further explore their use at Cades Cove is planned (12).

Mesa Verde National Park

Mesa Verde National Park, Spanish for "green table," contains 52, 073 acres of land in Colorado. This National Park is known for the more than 4000 known archeological sites it contains. Among these sites are some of the most notable and preserved sites in the United States. Mesa Verde National Park was established in June 1906 and offers recreational activities such as birdwatching, camping, cross country skiing, hiking, interpretive programs, snowshoeing, and wildlife viewing to the visitors. Recreational visits to this national park were 452, 287 in 2000 (6).

This national park, according to survey results, has one access road into and out of the park and has a fee associated with it. Visitors move throughout the park by personal vehicle and tour bus with the exception of Wetherill Mesa which is closed to personal vehicle, but has a tram system to transport visitors. The transportation problems in this park are caused by congestion and crowding at specific sites within the park during the peak periods of midday in late July and early August. A visitor distribution and transportation study is currently being done to address the issues mentioned above and to allow for a traveler information system to be developed. Recently a ticketing system for the most visited sites within the park was established along with overflow parking. problems with the current system include the visitors lack of knowledge about the visitor's center being housed 15 miles from the park entrance and the need for tickets to view some of the park's sites (13).

Rocky Mountain National Park

This 416 square mile national park is located in Colorado and contains dozens of mountain peaks and a road that crosses the Continental Divide. It was established as a National park in January 1915 and has recreational activities that include auto touring, biking, backpacking, camping, climbing, interpretive programs, mountaineering, snowmobiling, snowshoeing, and wildlife viewing. In 2000, 3,185,392 recreational visits were made to this national park (6).

This national park has an entrance fee at the five primary entrance points and ten secondary points. Visitors are allowed to travel throughout the park by personal vehicle. Transportation problems in this park are in the form of parking and congestion. The traveler information system in this park is 15 year old and an update is in the planning stages. The current system is lacking in utilization of current technology and coordination. This could be improved by encompassing more distribution methods such as the internet and the park newspaper. A traveler information needs survey has never been done at this park (14).

The national park characteristics are compared in Table 1 Comparison of National Park Characteristics below.

Table 1. Comparison of National Park Characteristics

	Acadia	Denali	Grand Canyon	Grand Teton	Great Smoky Mountain	Mesa Verde	Rocky Mountain
Recreation Visits (2000)	2,469,238	363,983	4,460,228	2,590,624	10,175,812	452,287	3,185,392
Acres	47,633	6,000,000	1,217,403	309,994	521,621	52,073	265,722
Access Points	20	1	4	3	13	1	15
Fee	yes	yes	yes	yes	no	yes	yes
Personal Vehicle	X	1st 15 miles	X	X	X	X	X
Transit	X	X	X	X	X	X	
Parking Problems	X	X	X	X	X	X	X
Congestion	X	X	X	X	X	X	X

The national park with the greatest number of visits in 2000 was Great Smoky Mountain National Park. Denali National Park had the least number of visits. Denali National Park has the largest acreage while Acadia National Park had the smallest acreage. Acadia National Park has the most number of access points while Denali National Park and Mesa Verde National Park have the least. Great Smoky Mountain National Park, with the most visits in 2000, also is the only park surveyed that does not have an access fee.

Comparison of Information Provided by the National Parks

In the surveys distributed to national parks, the information needs were broken into two types, transportation related and recreation related information. The surveys then had three questions with check boxes for possible answers. The questions included:

1. What type of transportation and recreation information do you supply to visitors en route?
2. How do you relay the transportation and recreation information to visitors en route?
3. Where do you relay the transportation and recreation information to visitors en route?

Information Distributed by National Park

The first question had 17 possible check box answers, including an other category, that were available to the respondents for transportation related information. The findings can be found in Table 2 Transportation Related Information Distributed by National Park. Ten possible check box answers were supplied to respondents for recreation related information pertaining to question one. These results can be seen in Table 3 Recreation Related Information Distributed by National Park.

Table 2. Transportation Related Information Distributed by National Park

TRANSPORTATION RELATED	Acadia	Denali	Grand Canyon	Grand Teton	Great Smoky Mountain	Mesa Verde	Rocky Mountain
Directions to the park and numerous access points	X	X	X	X	X	X	
Directions within the park	X	X	X	X	X	X	
Transit times, paths, and availability	X	X	X			X	
Parking availability	X	X	X	X		X	
Incident information (i.e. construction, accident, fires)	X	X		X			X
Severity of impact to traffic				X			
Expected duration of impact to traffic				X			
Detour/alternate route information	X			X			
Weather information		X	X	X	X	X	X
Prevailing travel times		X					
Prevailing travel speeds		X	X	X			
Mode diversions or transfers (private vehicles to transit)		X	X				X
Traveler advisories	X	X	X	X		X	
Animal warnings	X	X	X	X			X
Roadways closed (i.e. due to fire, weather, accident, seasonal)	X	X	X	X	X	X	
Service information (i.e. roadside assistance and gas)		X	X	X			
Other		X			X	X	

Table 3. Recreation Related Information Distributed by National Park

RECREATION RELATED	Acadia	Denali	Grand Canyon	Grand Teton	Great Smoky Mountain	Mesa Verde	Rocky Mountain
Park pass prices	X	X	X	X		X	X
Backpacking permits and prices		X	X	X			
Reservations (i.e. lodging/camping)	X	X	X	X	X	X	
Electronic tour guides	X			X			
Trail (hiking) maps	X	X		X	X	X	X
Self guided tours	X			X	X	X	
Service information (i.e. food and lodging)	X	X	X	X		X	
Rentals (i.e. bikes, boats, camping equipment, horses, etc)	X			X	X		
Special event times and locations (i.e. Old Faithful times)	X	X		X	X	X	
Other							X

Information Distribution Methods by National Park

Thirteen identical options, for transportation and recreation information, were supplied as answers for the second question. The results for transportation information can be found in Table 4 Transportation Related Distribution Methods by National Park and the results for recreation can be found in Table 5 Recreation Related Distribution Methods by National Park.

Table 4. Transportation Related Distribution Methods by National Park

TRANSPORTATION RELATED	**Acadia**	**Denali**	**Grand Canyon**	**Grand Teton**	**Great Smoky Mountain**	**Mesa Verde**	**Rocky Mountain**
Kiosks	X			X	X	X	X
Television				X			
Highway advisory radio	X	X	X	X	X	X	
Radio				X			X
Phone systems (i.e. cell phone and stationary phone)	X	X	X		X		
Changeable message signs	X	X		X	X		
Travel magazines and newspapers	X	X	X	X	X	X	
Travel books	X	X	X	X	X		
Handouts	X	X	X	X	X	X	X
Mobile navigation systems							
In vehicle navigation systems							
Global positioning system (GPS)							
Internet	X	X	X	X	X	X	X

Table 5. Recreation Related Distribution Methods by National Park

RECREATION RELATED	Acadia	Denali	Grand Canyon	Grand Teton	Great Smoky Mountain	Mesa Verde	Rocky Mountain
Kiosks		X		X	X	X	X
Television		X		X			X
Highway advisory radio	X	X	X	X	X	X	
Radio		X		X			X
Phone systems (i.e. cell phone and stationary phone)	X	X	X		X		X
Changeable message signs		X		X			
Travel magazines and newspapers	X	X	X	X	X	X	
Travel books	X	X	X	X	X		
Handouts	X	X	X	X	X	X	X
Mobile navigation systems							
In vehicle navigation systems							
Global positioning system (GPS)							
Internet	X	X	X	X	X	X	

Information Distribution Locations by National Park

Question three supplied respondents with seven options for transportation and recreation information. The options were identical in each section and contained an other category. The results for the transportation related information are located in Table 6 Transportation Related Distribution Locations by National Park. Recreation related information results are located in Table 7 Recreation Related Distribution Locations by National Park.

Table 6. Transportation Related Distribution Locations by National Park

TRANSPORTATION RELATED	Acadia	Denali	Grand Canyon	Grand Teton	Great Smoky Mountain	Mesa Verde	Rocky Mountain
In the park	X	X	X	X	X	X	X
Visitor (welcome) centers in the park	X	X	X	X	X	X	X
Visitor (welcome) centers outside the park	X	X	X	X	X	X	X
Hotels and resorts	X	X	X	X	X	X	
Restaurants	X	X					
Gas stations		X	X	X			
Gift stores	X	X		X			
Other							

Table 7. Recreation Related Distribution Locations by National Park

RECREATION RELATED	Acadia	Denali	Grand Canyon	Grand Teton	Great Smoky Mountain	Mesa Verde	Rocky Mountain
In the park	X	X	X	X	X	X	X
Visitor (welcome) centers in the park	X	X	X	X	X	X	X
Visitor (welcome) centers outside the park	X	X	X	X	X	X	X
Hotels and resorts	X	X	X	X	X	X	
Restaurants	X	X		X			
Gas stations		X	X	X			
Gift stores	X	X		X			
Other							

ORGANIZATION SURVEY RESULTS

Out of the sixteen organizations contacted, six completed and sent back surveys. One survey was not used due to incomplete information. The organizations that completed surveys were:

- American Automobile Association (AAA);
- American Camping Association (ACA);
- Mountaineers Member;
- Outdoors Club; and
- REI Adventures.

The information gathered in these surveys was divided into two parts. The open-ended questions, questions 1 and 8 through 10, in the survey were used to provide a description of the organization. The check box answers, questions 2 through 7, were used to compare and contrast the information wanted by tourists to the information provided by the national parks. The details of these surveys can be found below.

Organization Descriptions

American Automobile Association (AAA)

According to their website, "AAA is a federation of 98 motor clubs providing its more than 40 million members in the US and Canada with a full line of travel, financial, and automotive - related services (*15*)." The representative who filled out the survey described the organization as representing all types and ages of travelers. The representative also felt that problems with the current traveler information systems in national parks was due to the difficulty in locating updated and accurate information in an ongoing method. Suggestions for improvement included partnering with travel planning organizations that can relay information to visitors (*16*).

American Camping Association (ACA)

The American Camping Association website says that, "ACA is a community of camp professionals and is dedicated to enriching the lives of children and adults through the camp experience (*17*)." This organization has 6,000 members and represents camp groups that do mostly backpacking, canoeing, and sightseeing (*18*). The representative who responded to the interview felt that problems with current traveler information systems had to do with permits and costs at national parks. No suggestion for improvement was listed.

Mountaineers Member

This respondent is a hiker and climber who is a member of numerous hiking and climbing organizations including Mountaineers, Mazamas, Sierra Club, Wilderness Society, and Washington Wilderness Coalition (*19*). This respondent was contacted through the bulletin board on the Mountaineer's website as a suggestion of that organization. A problem faced by hikers and climbers, according to Robert Wallace, is difficulty in locating a knowledgeable person about backcountry information. According to the respondent, improvements could be made by eliminating RV's, climbing reservations, and hiking/backpacking permits in the national parks.

Outdoors Club

According to its website, the Outdoors Club is a member-run organization that helps individuals organize events such as backpacking, hiking, rockclimbing, mountain biking, and kayaking with others interested in the same things (*20*). One of the Outdoors Club organizers from Colorado responded to the survey.

His local "chapter" has members of all ages and is mostly hikers, climbers, and horseback riders (21). The respondent believed that there were not any problems with the current traveler information systems for national parks. The problems visitors have are that they do not know where to look for the information. Improvement suggestions included additional information on hiking versus horseback riding on the same trails.

REI Adventures

REI Adventures is an adventure travel company that represents a wide range of clients. These adventurers range in age generally from 25 to 65+ with a mixture of males and females. The trips range in difficulty with the four trip ratings including easy, moderate, vigorous, and strenuous. Trip size tends to range from 6 to 16 people (22,23). Problems that this organization faces with current traveler information systems in national parks that some parks have little or no information in place. Improvements that would help this organization would be a website updated with daily information and conditions.

Identification of Tourists Information Preferences

In the surveys distributed to organizations, the information needs were divided into two types, transportation related and recreation related information. The surveys then had three questions with check boxes for possible answers. The questions included those below:

1. What type of transportation and recreation information do visitors in your organization want while en route?
2. How do the visitors that you organization represents want this transportation and recreation information relayed to them en route?
3. Where would the visitors that your organization represents want to receive this transportation and recreation information en route?

The possible check box options to answer these questions were identical to those given for the respondents on the national park surveys.

Tourists' Information Preferences

The results of question one for transportation related information is in Table 8 Transportation Related Information Wanted by National Park Tourists. Table 9 Recreation Related Information Wanted by National Park. Tourists shows the results of question one based on recreation information.

Information Distribution Methods Preferred by National Park Tourists

The results for transportation information for question number two can be found in Table 10 Transportation Related Distribution Methods Preferred by National Park Tourists and the results for recreation can be found in Table 11 Recreation Related Distribution Methods Preferred by National Park Tourists.

Information Distribution Locations Preferred by National Park Tourists

The results for the transportation related information in question three are located in Table 12 Transportation Related Distribution Locations Preferred by National Park Tourists. Recreation related information results are located in Table 13 Recreation Related Distribution Locations Preferred by National Park Tourists.

Table 8. Transportation Related Information Wanted by National Park Tourists

TRANSPORTATION RELATED	AAA	ACA	Mountaineers Member	Outdoors Club	REI Adventures
Directions to the park and numerous access points	X	X		X	X
Directions within the park	X	X			X
Transit times, paths, and availability	X	X			X
Parking availability	X	X	X		X
Incident information (i.e. construction, accident, fires)	X	X	X		
Severity of impact to traffic	X				
Expected duration of impact to traffic	X				
Detour/alternate route information	X				
Weather information	X	X	X		X
Prevailing travel times	X	X		X	
Prevailing travel speeds		X			
Mode diversions or transfers (private vehicles to transit)		X			
Traveler advisories	X	X	X		X
Animal warnings	X	X	X		X
Roadways closed (i.e. due to fire, weather, accident, seasonal)	X	X	X		X
Service information (i.e. roadside assistance and gas)	X	X			X
Other	X	X			

Table 9. Recreation Related Information Wanted by National Park Tourists

RECREATION RELATED	**AAA**	**ACA**	**Mountaineers Member**	**Outdoors Club**	**REI Adventures**
Park pass prices	X	X	X	X	X
Backpacking permits and prices	X	X	X	X	X
Reservations (i.e. lodging/camping)	X	X	X		X
Electronic tour guides					
Trail (hiking) maps	X	X	X	X	X
Self guided tours	X	X			
Service information (i.e. food and lodging)	X	X			X
Rentals (i.e. bikes, boats, camping equipment, horses, etc)	X	X	X		
Special event times and locations (i.e. Old Faithful times)	X	X	X		X
Other	X	X	X	X	X

Table 10. Transportation Related Distribution Methods Preferred by National Park Tourists

TRANSPORTATION RELATED	**AAA**	**ACA**	**Mountaineers Member**	**Outdoors Club**	**REI Adventures**
Kiosks					X
Television	X				
Highway advisory radio	X	X			
Radio		X			
Phone systems (i.e. cell phone and stationary phone)		X	X		
Changeable message signs		X	X		X
Travel magazines and newspapers	X				
Travel books	X				
Handouts	X	X			X
Mobile navigation systems					
In vehicle navigation systems	X				
Global positioning system (GPS)					
Internet	X	X		X	X

Table 11. Recreation Related Distribution Methods Preferred by National Park Tourists

RECREATION RELATED	AAA	ACA	Mountaineers Member	Outdoors Club	REI Adventures
Kiosks			X		X
Television	X				
Highway advisory radio		X			
Radio	X	X			
Phone systems (i.e. cell phone and stationary phone)		X	X		
Changeable message signs		X	X		X
Travel magazines and newspapers	X				
Travel books	X				
Handouts	X	X	X	X	X
Mobile navigation systems					
In vehicle navigation systems	X				
Global positioning system (GPS)					
Internet	X	X		X	X

Table 12. Transportation Related Distribution Locations Preferred by National Park Tourists

TRANSPORTATION RELATED	AAA	ACA	Mountaineers Member	Outdoors Club	REI Adventures
In the park	X	X			X
Visitor (welcome) centers in the park	X	X			X
Visitor (welcome) centers outside the park	X	X			X
Hotels and resorts	X				
Restaurants	X				
Gas stations	X				
Gift stores	X				
Other	X		X	X	

Table 13. Recreation Related Distribution Locations by National Park

RECREATION RELATED	AAA	ACA	Mountaineers Member	Outdoors Club	REI Adventures
In the park	X	X			X
Visitor (welcome) centers in the park	X	X			X
Visitor (welcome) centers outside the park	X	X			X
Hotels and resorts	X				
Restaurants	X				
Gas stations	X				
Gift stores	X				
Other	X		X	X	

SUMMARY OF FINDINGS

National Park Surveys

Information Distributed by National Park

Transportation Information

1. The most commonly distributed transportation information (distributed by six out of seven parks) was:
   - directions to the park and numerous access points;
   - directions within the park;
   - weather information ; and
   - closed roadway (i.e. due to fire weather, accidents, and seasonal) information.

2. The least likely transportation information to be distributed (distributed by one out of seven parks) was:
   - an incident's severity of impact on traffic;
   - the expected duration of this impact to traffic; and
   - prevailing travel times within the park.

3. Other transportation information supplied by the national parks included:
   - shuttle bus reservation information at Denali National Park and Preserve;
   - weather information and road closing information provided to state and local agencies, and local hotel/motel operators at Great Smoky Mountain National Park; and
   - road conditions at Mesa Verde National Park

4. Denali National Park and Preserve provides tourists with the most information by supplying them with 14 out of the 17 possible transportation information pieces.

5. Rocky Mountain National Park supplied tourists with the least amount of information with their four pieces out of 17.

Recreation Information

1. The most commonly distributed recreation information (distributed by six out of seven parks) was:
   - park pass prices;
   - reservations (i.e. lodging and camping); and
   - trail (hiking) maps.

A note should be made that the only reason park pass prices was not supplied by 100 percent of the parks surveyed is because one of the parks does not charge a fee and therefore does not distribute that information.

2. The recreation information least commonly distributed (supplied by only one park) was electronic tour guides.

3. Other recreation information supplied included general safety and weather information at Rocky Mountain National Park.

4. Grand Teton National Park supplied the most information by supplying nine out of the 10 options and the option they did not supply was other information.

5. Rocky Mountain National Park supplied the least amount of information with only three of the 10 options and one of their three supplied was the other category.

Information Overall

1. Grand Teton National Park supplied the most information overall to visitors.

2. Rocky Mountain National Park supplied the least amount

Information Distribution Methods by National Park

Transportation Information

1. The most common forms of information distribution (used by all seven of the national parks) were:
   - handouts and
   - internet.

2. The least common methods of distribution (not used by any of the national parks) were:
   - mobile navigation systems;
   - in vehicle navigation systems; and
   - global positioning system (GPS).

3. Grand Teton National Park, using nine out of the 13 methods, had the greatest number of distribution methods for transportation related information.

4. Rocky Mountain National Park, using four out of the 13 methods, had the least amount of distribution methods.

Recreation Information

1. The most common forms of information distribution (used by all or six of the seven national parks) were:
   - handouts;
   - highway advisory radio; and
   - travel magazines and newspapers.

2. The least common methods of distribution (not used by any of the national parks) were:
   - mobile navigation systems;
   - in vehicle navigation systems; and
   - global positioning system (GPS).

3. Denali National Park and Preserve had the most distribution methods for recreation information with 10 out of 13 methods being utilized. The three methods that were not used, are the three that none of the parks used.

4. Mesa Verde National Park and Rocky Mountain National Park had the least amount of distribution methods with only five of the 13 methods.

Information Overall

1. Grand Teton National Park had the most distribution methods when transportation and recreation information were combined.

2. Rocky Mountain National Park had the least number of distribution methods.

Information Distribution Locations by National Park

Transportation Information

1. The most common locations for transportation information (used by all seven of the national parks) were:
   - in the park;
   - at visitor (welcome) centers in the park; and
   - at visitor (welcome) centers outside the park.

2. The least common location for transportation information (used by only two of the parks) was at restaurants.

3. Denali National Park and Preserve had the most transportation distribution locations as they utilized all seven of the locations listed.

4. Rocky Mountain National Park had the least amount of locations by using only the three locations out of seven that all parks utilized.

Recreation Information

1. The most common locations for transportation information (used by all seven of the national parks) were:
   - in the park;
   - at visitor (welcome) centers in the park; and
   - at visitor (welcome) centers outside the park.

2. The least common location for transportation information (used by three out of seven of the parks) were:
   - at restaurants;
   - gas stations; and
   - gift stores.

3. Denali National Park and Preserve and Grand Teton National Park had the most distribution locations as they utilized all seven.

4. Rocky Mountain National Park utilized the least amount with only three.

The other category supplied for this question was not utilized for transportation or recreation information and therefore was not counted as an option.

Information Overall

1. Denali National Park contained the most distribution locations.

2. Rocky Mountain National Park had the least when recreation and transportation information was combined.

National Park Surveys Overall

1. Overall, Grand Teton National Park distributed the most information with the most methods and second most locations of the seven national parks surveyed. This may be due to their understanding of the need for a traveler information system. As seen by the respondent to the survey, the benefits of a traveler information system are that, "better informed visitors expedite the traffic patterns and [that providing] helpful service to visitors enhances their experience of the park." This park also constantly upgrading their system and has had several visitor surveys conducted with the latest done in 1997. Although this park has one of the more comprehensive traveler information systems, it was noted in the survey that they have parking issues and therefore could improve their traveler information system further.

2. Rocky Mountain National Park, overall distributed the least amount of information in the least amount of methods and places. The survey respondent for this park acknowledged the fact that their, "ITS system is very primitive at this time" and that an update to the current traveler information system is being worked on.

3. Great Smoky Mountain Park is the most visited National Park in 2000 of the seven surveyed and the third most visited of all National Parks. This park distributes the second smallest amount of information of all the parks surveyed along with the third largest number of distribution methods and second largest number of locations. The respondent for this survey acknowledged that, "the Park has no system to relay traffic and parking information to visitors en route. It is hoped that eventually a system will be implemented."

4. Denali National Park and Preserve, the least visited national park in 2000 and the largest in acreage, of the seven surveyed had the second largest amount of information and methods of distribution and the largest number of locations. This abundance of information and distribution for a park with low visitation is due to the location of the park. It is a park housed in Alaska with one access point and it is located hours from both Fairbanks and Anchorage, therefore the need to inform the visitors who do travel to this park is great. The respondent for this survey believes that, "the better informed the visitor is on the park area and how to visit the park, the smoother the transportation will flow and the less stress" also "once the basic [recreation] needs are taken care of: bathroom, campground, bus ticket, then the visitor is truly able to enjoy themselves."

Organization Surveys

Tourists' Information Preferences

<u>Transportation Information</u>

1. The transportation information most wanted by tourists (wanted by four of the five organizations) was:
   - directions to the park and numerous access points;
   - parking availability;
   - weather information;
   - traveler advisories;
   - animal warnings; and
   - roadway closed (i.e. due to fire, weather, accident, seasonal).

2. The information wanted by the least amount of tourists (wanted by only one organization) was:
   - the severity of an incidents impact to traffic;
   - the expected duration of impact to traffic;
   - detour/alternate route information;

- prevailing travel speeds; and
- mode diversions or transfers (private vehicles to transit).

3. Other information that was requested for tourists included:
   - lodging and dining information en route and
   - group services

4. AAA felt that their members wanted the most information. This may be due to AAA encompassing a very wide range of members who need a wide variety of information.

5. The Outdoor Club felt their members wanted the least amount of information. The lack of transportation information needed by the hikers and climbers of the Outdoor Club is probably due to their going to the park for a specific reason and the fact that they won't be driving through the park, but rather hiking and therefore need only the information for the limited driving they will do.

<u>Recreation Information</u>

1. The information most wanted by tourists (wanted by all five of the organizations) was:
   - park pass prices;
   - backpacking permits and prices; and
   - trail (hiking) maps.

2. The information wanted by the least amount of tourists (wanted by none of the organizations) was electronic tour guides.

3. Other information that organizations suggested would be useful included:
   - information on areas of the parks with the best views;
   - special children's activities;
   - prices and services for groups;
   - current snow levels and elevations for hitting snow when hiking and climbing;
   - avalanche hazard information;
   - trail erosion/condition;
   - information on what to expect when sharing a hiking trail with horses;
   - recreational limitations or restrictions;
   - possible animal sightings; and
   - peak season and off season dates.

4. AAA and ACA wanted the most recreation information, requesting nine out of 10 pieces of information.

5. The Outdoor Club wanted the least amount of information, requesting four out of 10 pieces of information.

Information Distribution Methods Preferred by National Park Tourists

<u>Transportation Information</u>

1. The transportation information distribution methods preferred most (wanted by three or four of the five organizations) by tourists were:
   - changeable message signs;
   - handouts; and
   - the internet.

- The distribution methods least preferred (wanted by none of the organizations) were:
- mobile navigation systems and
- global positioning systems.

2. Other information that the Mountaineers Member suggested providing information through an informed backcountry ranger.

3. AAA wanted the largest number of options available to their members. Again, this is due to the wide variety of their members.

4. The Outdoors Club wanted the smallest number of distribution methods with only two of 13 being requested.

Recreation Information

1. The distribution methods preferred most (wanted by three or four of the five organizations) by tourists were:
   - handouts;
   - changeable message signs; and
   - the internet.

2. The distribution methods least preferred (wanted by none of the organizations) were:
   - mobile navigation systems and
   - global positioning systems.

3. AAA wants a wider range of distribution methods with seven of 13.

4. The Outdoors Club wants the least amount of distribution methods wanting two of 13.

Information Distribution Locations Preferred by National Park Tourists

Transportation and Recreation Information

1. The most commonly wanted locations to receive information were:
   - in the park
   - at visitor (welcome) centers in the park
   - at visitor (welcome) centers outside the park.

2. The least commonly wanted locations (wanted by one of the five organizations) to receive information were:
   - hotels and resorts;
   - restaurants;
   - gas stations; and
   - gift stores.

3. Other locations where information was wanted included:
   - AAA office and
   - home.

4. AAA wanted the most distribution locations, wanting all eight.

5. The Mountaineers Member and the Outdoors Club wanted the least number of locations, wanting only one of eight.

National Park and Organization Survey Comparison

To compare what information, how, and where National Parks distribute it to what, how, and where organizations want this information, the highest percentage category was chosen. For what information is distributed, there was no information given by all parks, therefore 6 out of 7 was chosen and for organizations 4 out of 5 requests were used. For how and where information is distributed, the methods and locations that all of the parks used were compared with 4 out of 5 for how in transportation, all of them for recreation, and all organizations for where.

The most common transportation information distributed by parks and wanted by visitors is shown below in Table 14.

Table 14. Comparison of Information

National Parks	Organizations
directions to the parks	directions to the park
directions within the park	
	parking availability
weather	weather
roadways closed	roadways closed
	traveler advisories
	animal warnings
reservations	
trail maps	trail maps
park pass	park pass
	backpacking permits

1. As can be seen in Table 14, out of the nine most wanted pieces of information by tourists, five are provided by most of the parks This explains that visitors want more information than they are generally receiving. The additional information tourists want include traveler advisories and animal warnings that only 5 of 7 parks provide, backpacking permits which only 3 of 7 parks provide, and parking availability which 4 out of 7 parks provide. It can also be seen that many of the organizations wanted more information than was part of the survey, and none of the national parks reflected that they distribute this type. Those types of information include, lodging and dining information en route, information on areas of the parks with the best views, special children's activities, prices and services for groups, current snow levels on hiking trails and elevations where

snow will be encountered on hiking trails, avalanche hazard information, trail conditions including erosion, information on what to expect when sharing hiking trails with horses, recreational limitations or restrictions, possible animal sightings, and peak season and off season dates. This supports the hypothesis that visitors want different information than what they are currently provided.

2. National Parks were most likely to distribute their information by handouts and the internet and organizations were most likely to look to the internet. This shows that National Parks know how to get the information out to their visitors and are approaching it correctly.

3. The distribution locations most likely to be used by visitors matched those of the national park. They included in the park, visitor (welcome) center in the park, and a visitor (welcome) center outside the park. This shows that national parks are aware of the best locations to distribute information to their visitors.

RECOMMENDATIONS

Based on the surveys from the National Parks and the Organizations, improvements to the traveler information systems in national parks should include:

1. Provide information to visitors that includes:
    a. parking availability
    b. traveler advisories
    c. animal warnings and sightings
    d. information on areas of the park with the best views
    e. special children's activities
    f. prices and services for groups
    g. peak season and off season dates and times
    h. current snow levels on hiking trails
    i. elevations where snow will be encountered on hiking trails
    j. avalanche hazard information
    k. trail conditions including erosion
    l. information on what to expect when sharing hiking trails with horses
    m. backcountry information
    n. recreational limitations or restrictions
    o. backpacking permit information

2. Maintain the distribution of information through handouts and internet while trying new distribution methods and better advertising these current methods.

3. Continue to distribute information in the park and at visitor centers within and outside the park while trying new distribution locations.

4. Improve communication and cooperation with outside organizations and hospitality providers to provide information to visitors by creating an email list serve and separate phone line for their use.

5. Create a system integrated with the national park internet sites and highway advisory radio to provide updated and current information on park conditions and activities.

6. Post bulletin boards and chat rooms on the national park internet sites for visitors to discuss their experiences and share their "secrets" such as the best viewing spots, animal sightings, and backcountry information.

7. Increase the usage of changeable message signs to provide visitors with information on road closures, traveler advisories, full parking lots, and animal warnings. Link these CMSs to the internet as well.

8. Use pneumatic tubes to count vehicles entering and leaving parking lots to determine the number of open parking spots. Link this to CMSs at the entrance stations.

9. Improve bus system.

10. Explore the possibility of creating an easier and more advertised reservation system.

CASE STUDY

Rocky Mountain National park shown in Figure 1, was chosen as the site for a case study. This is due to the survey results and the survey respondent acknowledging that the park is less advanced in its traveler information system than many of the other parks. Transportation related problems in this park included congestion and lack of parking.

Characteristics of Rocky Mountain National Park

1. There are three main entrance stations along with several minor entrance stations. They include:
   - Beaver Meadows entrance station, located in the north eastern part of the park, is the most popular entrance;
   - Fall River entrance station, located just north of Beaver meadows, is the second most popular; however about half the number of visitors from Beaver Meadows enter through this station; and
   - Grand Lake station, located in the south western portion of the park, has the least number of visitors.

2. Six major roadways run within the park including:
   - Interstate 34, Interstate 36, and Highway 6 run along the perimeter of the park;
   - Trail Ridge Road closed seasonally from October until May;
   - Old Fall River Road cross the north end of the park and is closed seasonally from October until early July; and
   - Bear Lake Road is a dead end road which provides a path to the lake.

3. A voluntary shuttle bus is setup from June through October for the section of the park between the Beaver Meadows Visitor Center and the Lily lake Visitor Center.

4. This park has six visitor centers and one museum located throughout the park. Most are open during peak season only, however two are open all year long.

5. Five campgrounds, three that are open all year long, can be found in this park.

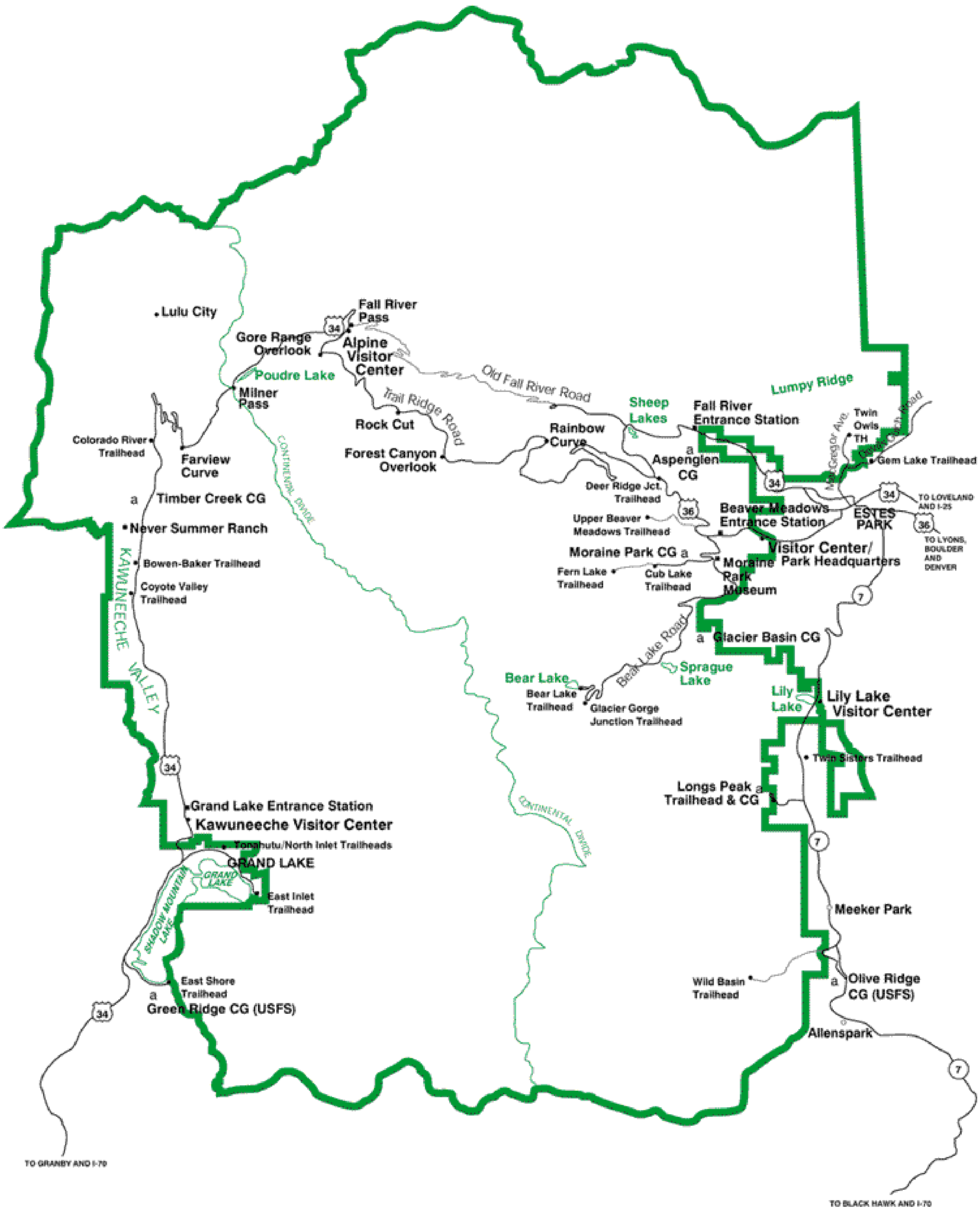

Figure 1. Rocky Mountain National Park Site Map

Recommended Improvements to Traveler Information

1. Improve the Rocky Mountain internet site by:
   - reorganizing it to provide easier access to the information available;
   - integrating the three private websites that are embedded in Rocky Mountain's website or make them easier to access;
   - updating the site to include the information in recommendation number one above;
   - creating bulletin boards and chat rooms for visitors use; and
   - posting current information more frequently.

2. Improve the communication and coordination with outside organizations specifically Estes park.

3. Create a system that links the highway advisory radio, changeable message signs, and the internet to ensure that a message posting on one will update the other methods.

4. Install pneumatic tubes at the entrance and exits of the shuttle bus parking area to calculate parking availability in this lot.

5. The use of changeable message signs (CMSs) and highway advisory radio (HAR) should be implemented in Rocky Mountain Park to:
   - warn visitors of Trail Ridge Road and Old Fall River Road closings;
   - advise visitors of parking availability at the shuttle bus parking area; and
   - display information on traveler advisories in the case of animal warnings, road construction, and incidents.

6. CMSs for Rocky Mountain National park should be located:
   - Beaver Meadows entrance station;
   - Fall River entrance station;
   - Grand Lake entrance station;
   - south of the Deer Ridge Junction; and
   - west of the Alpine Visitor Center.

7. Improve bus system services by distributing a color coded pocket sized card with the bus routes and times on it.

8. Improve the camping reservation system to make it more user friendly.

9. Explore the possibility of distributing GPS responders to hikers and backpackers that will locate them in case of an emergency.

CONCLUSIONS

The increased visitation to the National Parks and its accompanying issues have challenged the National Park Service to provide alternatives to increase the access to the National Parks without destroying the resources. A traveler information system can be used to accomplish these goals. As stated by the survey respondent from Great Smoky Mountain National Park, the benefits of a traveler information system are, "enhanced visitor experience throughout the park, reduced stress on environmental resources, a positive impact on the park's air quality, and information that will allow park visitors to make travel and touring choices appropriate to their schedule." Many of the current traveler information systems need to be updated to provide better information to the visitors as was supported in the surveys. Recommendations for these improvements were established in this paper. By following these recommendations, improvements based on the visitors preferences can be made to possibly enhance their experience while increasing access to the national parks and not destroying the park's resources.

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- Mary Wysong, Denali National Park;
- Judy Hellmich, Grand Canyon National Park;
- Jim Tuck, Grand Canyon National Park;
- Jackie Skaggs, Grand Teton National Park;
- Teresa Cantrell, Great Smoky Mountain National Park;
- Patty Trap, Mesa Verde National Park;
- Debra Perkins-Smith, Mesa Verde National Park;
- Joseph Evans, Rocky Mountain National Park;
- Josette Constantino, American Automobile Association;
- Connie Coutellieu, American Camping Association;
- Robert Wallace, Mountaineer's Member;
- Curt Carroll, Outdoors Club;
- REI Adventures; and
- Bruce Marshall, National Parks Conservation Association.

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APPENDIX A

Traveler Information Survey for National Parks

Name:
Position:
National Park:

I am doing a research project that will help document and improve existing traveler information systems in National Parks. In order to get the correct information on the National Park you represent please take a few minutes to fill this survey out.

Please return this survey by Wednesday June 27, 2001. You can return it by fax (979) 845-6006 or by email j-helmuth@ttimail.tamu.edu depending on how you requested to receive it. If you have any questions please feel free to contact me at (979) 862-8492.
Thank you - Jaime Helmuth

(1) What type of transportation and recreation information do you supply to visitors en route (while driving to and within the park)? *Please check all that apply and fill out the other box with any that are missing.*

Transportation related:

_______ directions to the park and the numerous access points
_______ directions within the park
_______ transit times, paths, and availability
_______ parking availability
______ incident information (i.e. construction, accident, fires)
    _______ severity of impact to traffic
    _______ expected duration of impact to traffic
    _______ detour/alternate route information
_______ weather information
_______ prevailing travel times
_______ prevailing travel speeds
_______ mode diversions or transfers (private vehicle to transit)
_______ traveler advisories
_______ animal warnings
_______ roadways closed (i.e. due to fire, weather, accident, seasonal)
_______ service information (i.e. roadside assistance and gas)
_______ other: ____

Recreation related:

_______ park pass prices
_______ backpacking permits and prices
_______ reservations (i.e. lodging/camping)
_______ electronic tour guides
_______ trail (hiking) maps
_______ self guided tours
_______ service information (i.e. food and lodging)
_______ rentals (i.e. bikes, boats, camping equipment, horses, etc)
_______ special event times and location (i.e. Old Faithful times)
    if so what are the special events ___________________
_______ other: ____

(2) How do you relay the transportation and recreation information to visitors en route (while driving to and within the park)? *Please check all that apply and fill out the other box with any that are missing.*

Transportation related:

_______ kiosks
_______ television
_______ Highway advisory radio
_______ radio
_______ phone systems (i.e. cell phone and stationary phone)
_______ changeable message signs
_______ travel magazines and newspapers
_______ travel books
_______ handouts
_______ mobile navigation systems
_______ in vehicle navigation systems
_______ global positioning system (GPS)
_______ internet

Recreation related:

_______ kiosks
_______ television
_______ Highway advisory radio
_______ radio
_______ phone systems (i.e. cell phone and stationary phone)
_______ changeable message signs
_______ travel magazines and newspapers
_______ travel books
_______ handouts
_______ mobile navigation systems
_______ in vehicle navigation systems
_______ global positioning system (GPS)
_______ internet

(3) Where do you relay the transportation and recreation information to visitors en route (while driving to and within the park)? *Please check all that apply and fill out the other box with any that are missing.*

Transportation related:

_______ in the park
_______ visitor (welcome) centers in the park
_______ visitor (welcome) centers outside the park
_______ hotels and resorts
_______ restaurants
_______ gas stations
_______ gift stores
_______ other

Recreation related:

_______ in the park
_______ visitor (welcome) centers in the park
_______ visitor (welcome) centers outside the park
_______ hotels and resorts

_______ restaurants
_______ gas stations
_______ gift stores
_______ other

(4) Does your park have significant parking and congestion issues? If so, what type and how bad?
(5) How long have these traveler information systems been in place?
(6) When was the last time it was updated? If it was updated within the past five years, what were the changes and how have they helped with the parking and congestion?
(7) What do you see as some of the benefits of a traveler information system
    to transportation?
    to recreation?
(8) What are some of the problems with your current system?
(9) What are some of the top complaints made by visitors to the park about traveler information?
(10) How could your traveler information system be improved?
(11) How do your tourists move throughout the park?
    _______ personal vehicle
    _______ transit
    _______ other:___________________________________
(12) If your park is closed to personal vehicles, how long has it been that way and how do you get the information about parking and transit to the tourists?
(13) Has a traveler information needs survey been done at this national park? If so, when?
(14) How many access points are there to the national park and how many are available for use by the tourists?
(15) Is there a fee at this national park?
(16) Does this national park have any literature about the current traveler information system? If so, would it be possible to get a copy of it?

APPENDIX B

Traveler Information Survey for Organizations
Name:
Position:
Organization:

I am doing a research project that will help document and improve existing traveler information systems in National Parks. In order to get the correct information on what visitors to the National Parks want, I am surveying organizations that represent possible visitors to the parks. Please take a few minutes to fill this survey out based on what the travelers that your organizations represent would want or need.

Please return this survey as soon as possible. You can return it by fax (979) 845-6006 or by email j-helmuth@ttimail.tamu.edu depending on how you requested to receive it. If you have any questions please feel free to contact me at (979) 862-8492.
Thank you - Jaime Helmuth

(1) What type of travelers does your organization represent (i.e. age, single vs. family, reason for going to parks, etc)?
(2) What type of transportation and recreation information do visitors in your organization want while en route (while driving to and within the park)? *Please check all that apply and fill out the other box with any that are missing.*

Transportation related:

_______ directions to the park and the numerous access points
_______ directions within the park
_______ transit times, paths, and availability
_______ parking availability
______ incident information (i.e. construction, accident, fires)
    _______ severity of impact to traffic
    _______ expected duration of impact to traffic
    _______ detour/alternate route information
_______ weather information
_______ prevailing travel times
_______ prevailing travel speeds
_______ mode diversions or transfers (private vehicle to transit)
_______ traveler advisories
_______ animal warnings
_______ roadways closed (i.e. due to fire, weather, accident, seasonal)
_______ service information (i.e. roadside assistance and gas)
_______ other: ____

Recreation related:

_______ park pass prices
_______ backpacking permits and prices
_______ reservations (i.e. lodging/camping)
_______ electronic tour guides
_______ trail (hiking) maps
_______ self guided tours
_______ service information (i.e. food and lodging)
_______ rentals (i.e. bikes, boats, camping equipment, horses, etc)
_______ special event times and location (i.e. Old Faithful times)
    if so what are the special events at your park _______________________
_______ other: ____

(3) Besides the information listed above, what other transportation and recreation information would be useful and helpful to the tourists that your organizations represent?

(4) How do the visitors that your organization represents want this transportation and recreation information relayed to them en route (while driving to and within the park)? *Please check all that apply and fill out the other box with any that are missing.*

Transportation related:

_______ kiosks
_______ television
_______ Highway advisory radio
_______ radio
_______ phone systems (i.e. cell phone and stationary phone)
_______ changeable message signs
_______ travel magazines and newspapers
_______ travel books
_______ handouts
_______ mobile navigation systems
_______ in vehicle navigation systems
_______ global positioning system (GPS)
_______ internet

Recreation related:

- _______ kiosks
- _______ television
- _______ Highway advisory radio
- _______ radio
- _______ phone systems (i.e. cell phone and stationary phone)
- _______ changeable message signs
- _______ travel magazines and newspapers
- _______ travel books
- _______ handouts
- _______ mobile navigation systems
- _______ in vehicle navigation systems
- _______ global positioning system (GPS)
- _______ internet

(5) Besides the methods of information delivery listed above, what other ways of obtaining information would be useful to the tourists that your organization represents?

(6) Where would the visitors that your organization represents want to receive this transportation and recreation information en route (while driving to and within the park)? *Please check all that apply and fill out the other box with any that are missing.*

Transportation related:

- _______ in the park
- _______ visitor (welcome) centers in the park
- _______ visitor (welcome) centers outside the park
- _______ hotels and resorts
- _______ restaurants
- _______ gas stations
- _______ gift stores
- _______ other

Recreation related:

- _______ in the park
- _______ visitor (welcome) centers in the park
- _______ visitor (welcome) centers outside the park
- _______ hotels and resorts
- _______ restaurants
- _______ gas stations
- _______ gift stores
- _______ other

(7) Besides the locations of information delivery listed above, what other locations would it be useful to the tourists that your organization represents to be able to collect information?

(8) What do you see as some of the benefits, for the tourists that your organization represents, of a traveler information system

to transportation?

to recreation?

(9) What do you see as some of the problems with current traveler information systems in National Parks?

(10) Any other suggestions or comments on National Park traveler information systems?

JAIME LEIGH HELMUTH

Jaime Leigh Helmuth earned her Bachelor of Science degree in Civil and Environmental Engineering at the University of Massachusetts Amherst in May of 2000. As an undergraduate, she spent two years working for the Telecommunications Department on campus as an AutoCAD technician. In her senior year at UMass, she worked at Vanasse Hangen Brustlin, Inc in Watertown, Massachusetts as a cooperative education student in the Highway Design Group.

She is currently pursuing her Master of Science degree in Civil Engineering at Texas A&M University while working as a Graduate Research Assistant at the Texas Transportation Institute (TTI). Some of her extra curricular activities include the Texas A&M University Student Chapter of the Institute of Transportation Engineers where she is currently the Vice President, Chi Epsilon National Civil Engineering Honor Society, and a student member of the American Road and Transportation Builders Association. Her areas of interest include geometric highway design, traffic safety, human factors and performance, intelligent transportation systems, and project management.

AUTOMATIC VEHICLE LOCATION (AVL) TO FACILITATE MAXIMUM USAGE OF SPECIALIZED HIGHWAY EQUIPMENT IN TRAFFIC OPERATIONS

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SUMMARY

The goal of this research was to develop a set of implementation guidelines useful to a local or state government interested in using Intelligent Transportation Systems (ITS) technologies to maximize usage and deployment of specialized highway equipment in the traffic operations arena. More specifically, to look at equipping paint, signal and sign installation trucks with appropriate ITS technologies.

Specific information and data regarding these technologies in the traffic operations area was practically nonexistent. Data for this research were gathered from the public works/highway maintenance experience. The data was reviewed, studied, and extrapolated to help develop the guidelines.

Using information gathered from a literature review, telephone interviews with engineers and researchers deploying and evaluating Automatic Vehicle Location (AVL) and Global Positioning System (GPS), implementation guidelines for a traffic operations application were developed. The guidelines include the following steps:

- Clearly establish the goals and objectives of your AVL system
- Establish "Acceptance" from system operators
- Analyze your existing operations to determine design issues for your AVL
- Identify existing, competitive and appropriate AVL systems available for deployment
- Develop communications infrastructure
- Start with a pilot project
- Develop an evaluation plan to measure effectiveness and benefits

To illustrate the use of these guidelines, they were applied to a hypothetical case study in the traffic operation section of the Virginia Department of Transportation Hampton Roads District.

TABLE OF CONTENTS

INTRODUCTION

Public sector agencies throughout the country are under pressure to perform more with less, provide seamless services and operate with private sector efficiency and business acumen. The Internet revolution has played a large part in these expectations. The public is demanding better and faster services from their local, state and federal governments and have little patience for excuses such as: "not enough money", "not enough resources", "too much bureaucracy", "we've always done it this way."

Public officials and managers are looking to advanced technologies to help them meet the new expectations. Many states and local agencies are starting e-government processes where the public can access services on-line such as getting a driver license or bidding on government contracts. This is becoming more of the norm than the exception.

As in the private sector, many public agencies are experiencing a paradigm shift in the way they administer, operate and maintain their assets and resources. They are combining departments, streamlining processes, sharing equipment and assets, and improving communication. They are shifting their focus from managing a bureaucracy to providing a higher level of customer service. Many cities and localities are rated partly on the accessibility and the quality of services they provide to their taxpayers.

An example of the private sector's paradigm shift is the case of Federal Express. The Federal Express chairman stunned his audience at an annual meeting when he advanced the idea of shipping Federal Express packages on United Postal Service (UPS) planes. How is this possible ? UPS is the primary competitor.

"Imagine if you will", the chairman went on to say: "Two planes - one Fed Ex's and one UPS's making the same flight from New York to Tokyo, both have varying degrees of empty cargo space, that's where the sharing comes in. Combine the loads and reduce the number of flights – save money. It's a win – win solution."

The emergence of new technologies like automatic vehicle location (AVL), automatic vehicle identification (AVI), global positioning system (GPS), geographic information system (GIS), hand held computers, digital mapping, video detection, fiber optic networks, and barcode/ magnetic strip readers has opened new opportunities for different methods of doing business, to explore new innovative concepts of maximizing usage of highway maintenance equipment.

Whether working in the public or private sector, "do more with less," "use technology to improve productivity" are familiar phrases heard often. For some it has been the mode of operation for a long time. This is true as well in the area of specialized highway equipment. Funding to upgrade or buy new equipment has diminished. Additionally, the lead-time on procuring new equipment in public agencies is often measured in years. The necessity to effectively utilize and optimally deploy existing equipment has never been greater.

Intelligent transportation systems (ITS) technologies such as AVL, AVI, and GPS, have been used extensively in the bus/transit and fleet management arena. Only in recent years have these technologies made their way to the public works/highway maintenance area.

A need exists to synthesize current agency practices in the use of these technologies for maximizing usage and deployment of specialized highway equipment in a typical traffic operations department and to develop implementation guidelines for these technologies.

Research Objectives

The overall goal of this research is to develop a set of implementation guidelines useful to a local or state government with an interest in using ITS technologies to maximize usage of specialized highway equipment in the operations arena. The specific objectives of this research included:

- Establish how and what ITS technologies are currently used in the area of maximizing usage of specialized highway equipment;
- Determine the obstacles to the implementation of ITS technologies in this arena;
- Develop implementation guidelines of these technologies useful to public officials and managers to help maximize the effectiveness of specialized equipment usage; and
- Apply the guidelines to a case study. The Virginia Department of Transportation Hampton Roads District is considering such an application to determine the viability of acquiring and using ITS technologies in their traffic operations fleet and was used as a case study.

Scope

The scope of this project focused on using AVL technologies systems installed on specialized highway equipment in traffic operations, such as pavement markings, signal repairs and sign installation trucks. The guidelines focused exclusively on identifying the needs, goals and the implementation of such a system. Factors such as obtaining funding sources, public relations campaigns, daily operation, and system improvements are not being addressed as a part of these guidelines.

STUDY PLAN

The procedures followed in carrying out this research consisted of four main tasks: literature review, data collection, guidelines preparation and applying the guidelines to a case study. These tasks are discussed in greater detail in the following sections.

Literature Review

A review of current literature was performed in order to examine previous research and present issues related to ITS technologies deployment in the arena of highway maintenance operations. Specifically, any research or actual deployment in the traffic operations arena.

Data Collection

To supplement the literature search regarding the use of these technologies in a traffic operations setting, officials and engineers from cities and state departments of transportation with current ITS technologies deployment in a highway/operation setting were contacted and interviewed on the telephone. Information was gathered from 12 agencies. The following questions were asked of these officials regarding their organization's use of these technologies in a highway maintenance/operation environment:

- A description/type of technology used?
- What specific purpose was the technology used for?
- What type of asset was the technology used on?
- What constraints or problems were experienced in the planning and implementation of the technology?
- Were implementation guidelines developed for the implementation of the technology, and if so is it possible to obtain a copy?

A copy of the complete survey is provided in Appendix A to this report.

Guidelines Development

Information gathered from the literature review, and conversations with transportation professionals and researchers, were used to develop guidelines for the implementation of an AVL system in a traffic operations environment. The methodology and thought process relied heavily on the experience in the deployment of AVL, GPS, and GIS in snow plowing operations and safety service patrol fleets.

BACKGROUND

A brief description of, GPS, GIS, and AVL technologies is provided here:

Global Positioning System (GPS)

The GPS consist of a constellation of 24 satellites (called NAVSTAR, from NAVigation Satellite Timing and Ranging) arranged in six orbital planes with four satellites per plane. Each satellite orbits the earth once every 12 hours at an approximate height of 26,600 km. The system provides accurate, continuous, worldwide, three-dimensional position and velocity information to users with the appropriate receiving equipment. GPS can provide service to an unlimited number of users since the user receivers operate passively (i.e., only receive). A GPS receiver calculates its position by using the known location of each of the satellites from which it is receiving signals and the time it takes for the signal to travel from each of the satellites to the receiver. This information determines the distance from each satellite to the receiver. Signals from four different satellites are required to calculate the position of the GPS receiver by solving for unknowns: latitude, longitude, altitude, and time. This position calculation process is known as tri-lateration.(*1*)

Geographic Information System (GIS)

A GIS is an organized collection of computer hardware, software, geographic data, and personnel designed to provide for the efficient capture, storage, update, manipulation, analysis, and display of all forms of geographically referenced information.(*2*)

Automatic Vehicle Location (AVL)

Installation of AVL started in Europe in 1964 in Hamburg, Germany. Most cities in Germany and France now have AVL equipment on their buses and light rail cars.(*3*)

Today this technology is widely available and utilized in the US, especially in fleet management of buses, trucks and transit. AVL is a technology that locates vehicles using technologies such as a GPS, monitors activities associated with the vehicle, transmits the location and activity information to a remote site and displays the information on maps that are GIS referenced. An AVL system displays real-time information concerning the location and activity of vehicles and archives that information over an extended time period for later analysis. Such a system can assist managers in tracking a fleet, monitoring and managing fleet activity, and increase the information available for responding to the public. (*4*)

AVL is being used mainly in transit and in commercial vehicle operation (management) systems. In transit applications, the information on the exact location of a vehicle enables the operator to provide more accurate information to its customer as well as to respond to operation related problems.

Most AVL systems provide location information in terms of coordinates. These coordinates have to be matchable with coordinates on a map so that the location of the vehicle can be uniquely identified. In order for the matching process to be successful, the coordinate systems of the map and those of the AVL system must be consistent, compatible and sufficiently accurate. The accuracy requirement is that the

AVL location should correspond to a unique and unambiguous point on the map. For many AVL applications where the various stops or destinations of the vehicle are spread out over a large area this matching process can be achieved even when the accuracies of the AVL system and the digital map are not very high.

The digital map or the GIS on which the location of the vehicle is to be displayed contains information about the vehicle routes and other relevant facilities such as maintenance yards, field offices, intersections, and landmarks. The position of these features must be sufficiently accurate so that if the AVL system indicates that the vehicle arrived at an intersection, that intersection could be clearly identified on the map (GIS).(5)

Typical features in today's AVL system would include: (6)

- 2-Way messaging between base and vehicle;
- Vehicle positioning displayed on GIS based map;
- Vehicle path trace;
- Historical playback of data;
- Browser based, Internet or intranet capabilities; and
- Emergency alarm.

An additional benefit of an AVL system is the higher degree of safety it provides the operators, especially in difficult weather conditions and emergencies. The two way communication capabilities and the exact location of the vehicle can be life saving in an emergency.

CURRENT APPLICATIONS OF AVL SYSTEMS IN SPECIALIZED HIGHWAY EQUIPMENT ARENA

Several localities and states throughout the United States have implemented AVL systems on buses, transit, snow plows, street sweepers, sanitation equipment, and safety service patrol vehicles. Reasons for these deployments vary with individual agencies but have a common theme of better tracking, deploying and managing their fleets. A discussion of twelve existing systems is included in this section.

Arizona, City of Mesa

The city of Mesa will be installing a global positioning system (GPS) based automatic vehicle location (AVL) system on 325 public safety vehicles. The completed installation will allow computer aided dispatch and enhanced fleet management for the city.(7)

Colorado, City of Aurora

In 1998, the city of Aurora installed AVL units on 12 sweepers and 15 snow plows. The system has Cellular Digital Packet Data (CDPD) communication capabilities. Units are movable and can be adapted to different equipment. The city has been experimenting with different chemical materials in their snow plowing operations and hopes to use some of the AVL data to analyze the results. (8)

Illinois, Department of Transportation

IDOT is developing a prototype Automatic Vehicle Location (AVL) system for emergency traffic-patrol vehicles (ETP). This system will initially be placed on five vehicles and includes a proposal to outfit the entire ETP fleet with this equipment. The system uses a Global Positioning System (GPS) where dispatchers will be able to locate and send the vehicle nearest the scene of an incident. The system will also allow patrol drivers to query vehicle and police records for information, such as stolen vehicle reports.(7)

Iowa, Department of Transportation

The Iowa Department of Transportation participated in the development of a concept vehicle for highway maintenance operations. In addition, the Iowa DOT developed an AVL pilot project in 1998 to determine the value of AVL/GPS technology. The pilot program consisted of 18 AVL-equipped maintenance trucks with snow plows in one maintenance facility to track the location and speed of the truck. The pilot vehicles were equipped with sensors to measure pavement and air temperatures, plow and wing-plow positions and material application rates. The data collected were typically sent to the central processor every ten minutes, but could also be triggered by predefined events such as plow position changes or changes in de-icing material application rate or type of material spread. (8,9,10).

Kansas, Highway Patrol

The Kansas Highway Patrol is using AVL to track the location of troopers when on patrol and in pursuit. The system uses GPS to track location and is tied into a GIS based map at the dispatch center allowing dispatchers to more efficiently dispatch troopers and keep track of their location, creating a safer working environment.(7)

Maryland, Montgomery County

In the maintenance arena, Montgomery County has AVL units installed on 10 snow plows. Units are portable (plugs into cigarette lighter) so they can be moved to other maintenance vehicles. The system has the ability to monitor up/down plow position, spreader off/on, and ignition on/off. The system has two way message capability with the vehicle having the option of 30 preprogrammed messages. Future plans include: request for proposal (RFP) for additional AVL capabilities of dedicated 800 MHZ bandwidth for their use in transmitting data from AVL units; and expand the use of AVL beyond snow plows in order to spread the high cost of the units to other functions.(8)

Michigan, Southeast Michigan Snow and Ice Management (SEMSIM)

Since the fall of 1999, a cooperative initiative between the Road Commission of Oakland County, Wayne County, Road Commission of Macomb County, the city of Detroit and ERIM International have resulted in a joint project consisting of 10 AVL-equipped vehicles in each jurisdiction. These trucks are deployed north of Detroit where the four jurisdictions meet. The rest of the four agencies' trucks will be phased in to this program over the next couple of years. Ultimately, approximately 500 snow plows/salt trucks from the four jurisdictions will be part of the project. The vehicles are equipped with sensors to measure pavement temperature, plow up or down and chemical spreader rate. This information is reported in real time to all four jurisdictions. Future plans include equipping up to 500 snow plows with AVL from all participating agencies, moving from Cellular Digital Packet Data (CDPD) communication into 800 MHZ and have real time monitoring of location, plow up/down, spreading rate, pavement and air temperature.(7)

Minnesota, Department of Transportation

Minnesota DOT deployed a total of 34 AVL units (14 snow plows, 4 state trooper cars, 14 transit buses and 2 aircraft) in 1997. The system allows polling for vehicle location on 15-minute intervals. The project was initiated as part of an effort to combine maintenance, highway patrol and transit dispatchers into one base. Due to low amounts of snowfall in 97/98/99, the system experienced limited direct application and/or impact on maintenance operations.

Future plans include: 1) add a plow up/down indicator, spreader activity and pavement temperature to the information collected; 2) improve mapping by adding highway mile markers; 3) reduce polling frequency from 15 minutes to 2 minutes; 4) identify cost-benefits. Additionally, Minnesota DOT is looking into adding AVL to their incident management vehicles (Highway Helper).(8)

Utah Department of Transportation

In 1997/98 Utah Department of Transportation equipped two snow plow trucks with AVL with the ability of 15 minutes polling. These units will be monitored in the future by the Traffic Operations Center. The Winter Olympics 2002 will provide the funding drive for additional units.(8)

Virginia Department of Transportation

Snow Plow Application (8)

As a pilot project, VDOT purchased an AVL system to track in real time with a high degree of positional accuracy its fleet in two maintenance areas in Northern Virginia District. VDOT's purposes in this pilot program were to test the feasibility of and to quantify the benefits achieved by an AVL system in snow-removal operations. The AVL system configuration is shown in Figure 1.

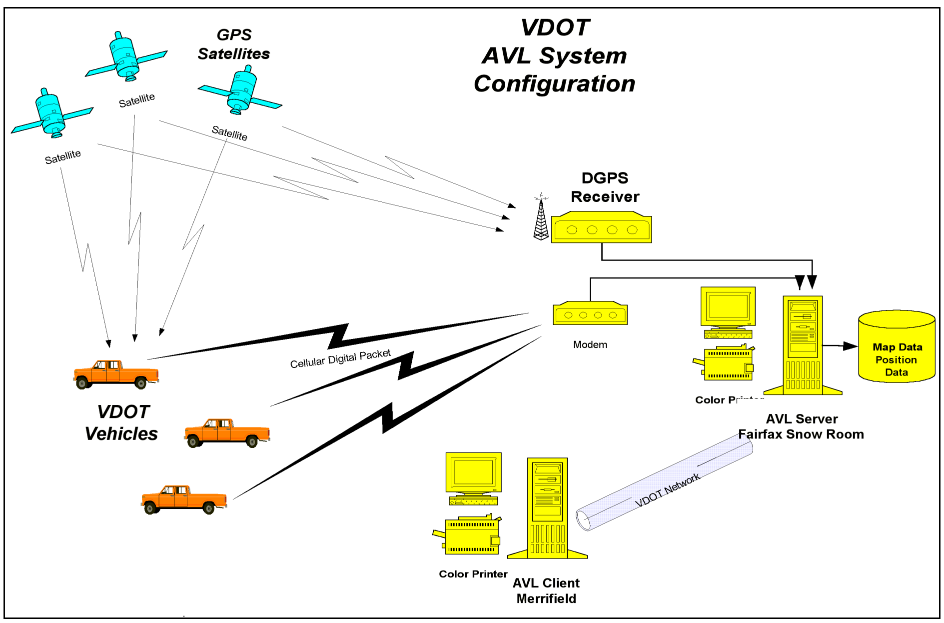

Figure 1. AVL System Configuration

VDOT determined that 80 tracked vehicles were needed to evaluate the AVL system in snow operations. This number was determined from the number of snow removal vehicles in the maintenance areas in the pilot program. The system consisted of:

- 80 GPS tracking receivers;
- 3 networked desktop personal computers installed in three operations and management offices;
- Differential GPS correction station to provide five-meter (15 feet) positional accuracy;
- Two-way cellular telephone data and messaging capability;
- Database of accurate street maps and aerial photos digitized for desktop displays; and
- Data archiving of all captured events for replay and analysis.

The combined GPS tracking receiver and communication device (referred to as an in-vehicle unit, or IVU) installed in each vehicle is shown in Figure 2.

Figure 2. IVU

- The IVU was portable and was moved and reinstalled in different types of equipment. The IVU worked off the vehicle power supply.
- The IVU's signal was differentially corrected at the host computer to report location accurate to five meters (15 feet), 50% of the time, at speeds up to 96 kph (60 mph). This would allow specific lanes traversed to be discerned from the position reports.
- The IVU sensed three on/off status conditions every two seconds for each vehicle and transmitted this information to the host computer every ten seconds. The three conditions sensed were: Plow up/down, chemical spreader on /off, and vehicle engine on/off.
- The IVU enabled communications between the vehicle operator and the base stations via a readable message system. Each of the base stations could send any free-form-text message to an individual vehicle, or any number of vehicles. The vehicle operator had a series of 30 pre-programmed messages that could be sent to the base stations.
- The AVL system generated real-time displays of vehicle location, traced the route of each vehicle tracked and color-coded the traces to identify the activity performed.
- The AVL system displayed a variety of geo-referenced raster and vector maps at varying scales.

All of this information was available in near real-time and historically archived for after-action review.

A map of the screen display for the two maintenance areas is shown in Figure 3. These are the two components of the system visible to most operations people using the system.

Safety Service Patrol (*11*)

The Virginia Department of Transportation is in the process of soliciting bidders for an AVL system for tracking its Safety Service Patrol (SSP) vehicles in three metropolitan areas, Northern Virginia (Arlington), Hampton Roads, and Fredericksburg, Virginia.

The Safety Service Patrol vehicle fleet provides assistance to disabled vehicles on the primary highways in the Commonwealth's major metropolitan areas and on major commuter routes. By providing assistance to disabled vehicles, the SSP fleets provide increased safety margins by removing hazards and obstructions to smooth traffic flow. They also promote good will among the motoring public.

The AVL system would report and display SSP vehicle positions to a central facility in each of the three SSP areas. This AVL tool will thus provide real-time situational awareness of the vehicle dispositions, maintain and display history records of vehicle travel, and record and report AVL assistance provided to

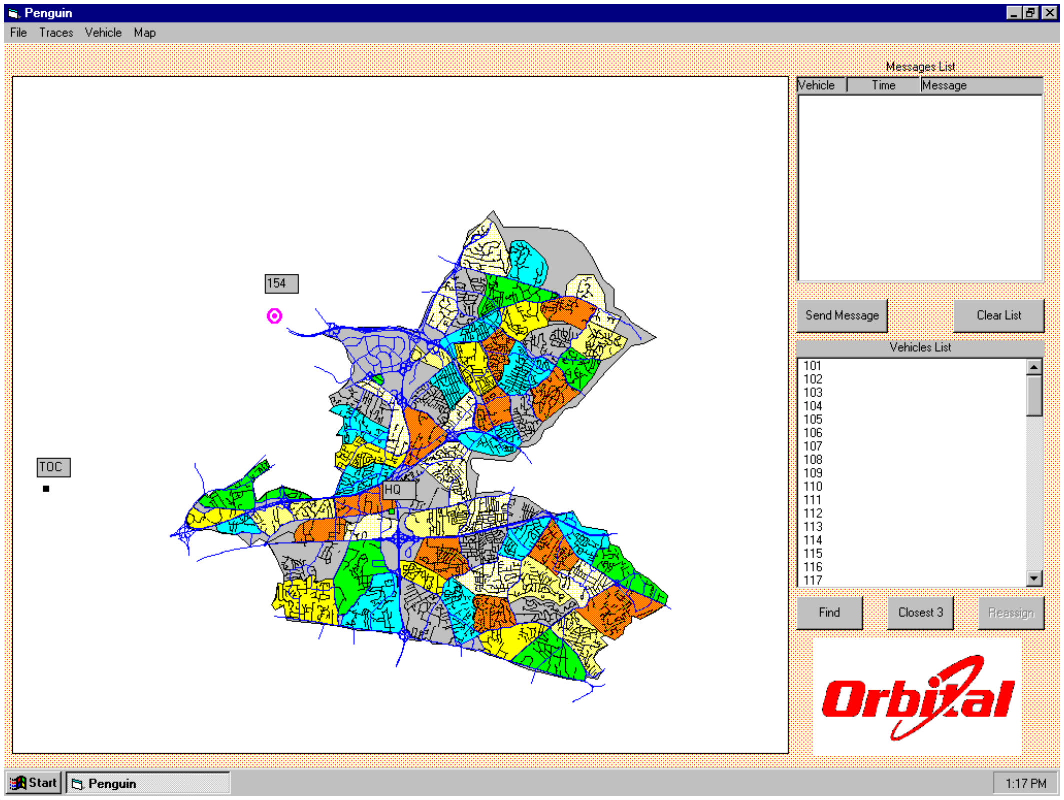

Figure 3. AVL Software Opening Screen

disabled motorists. This AVL system is a pilot system for evaluating the technology in SSP applications. See figures 4 and 5.

Currently, there is no tracking of SSP vehicles in real time. SSP drivers patrol their designated route segments in an autonomous manner, stopping to assist disabled motorists as they happen upon them. Coordination with a central facility and other drivers is ad hoc over vehicle radio links.

With each Stop and Assist, the driver records it for later entry into a database. Currently, different databases are used at each location, a DOS database, a shareware database, and a spreadsheet. At regular intervals, usually monthly and yearly, reports are prepared from these databases to document statistically the accomplishments of the SSP fleets.

A few data elements can also be automatically computed by the AVL system and entered into the *Incident* record, such as duration of the assist (from start and stop time); the time to respond (from the notification or command time to the start time on scene); the route segment or mile marker (from a table lookup).

The last few data elements completing the record should be entered manually by the central facility controller, such as weather conditions, remarks, and other-agency coordination.

The goals for using the AVL technology are to:

- Provide better situational awareness of SSP vehicle deployments,
- Provide decision support tools,
- Improve SSP dispatch and coverage, and
- Streamline the data collection and report generation process.

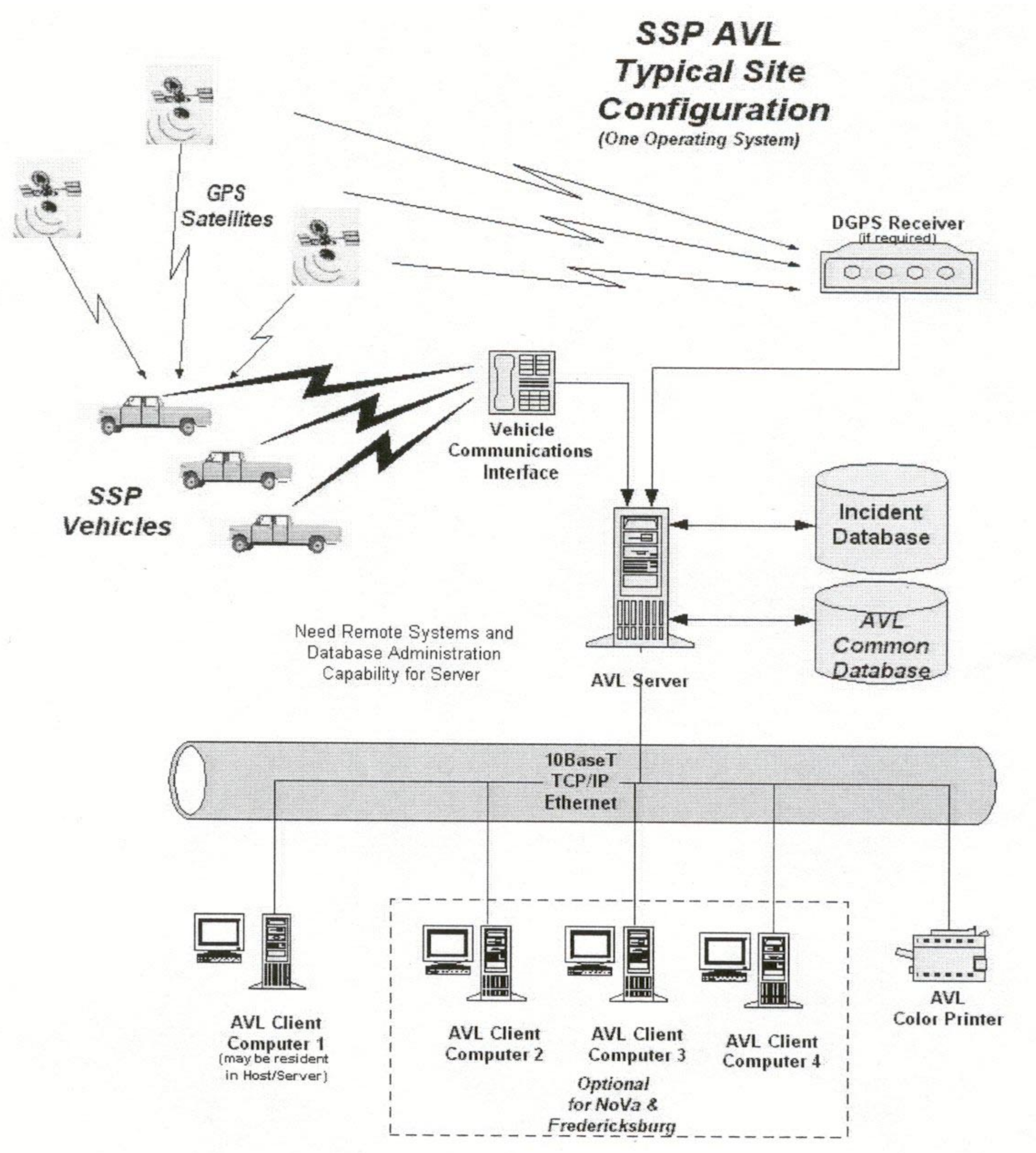

Figure 4. Configuration of Proposed SSP AVL System

Wisconsin

Douglas County

In order to better manage their maintenance contracts and due to the hilly terrain which rendered radio communication useless, the county installed 10 AVL units on maintenance trucks. The system provides two way messaging, real time information, and material tracking.(8)

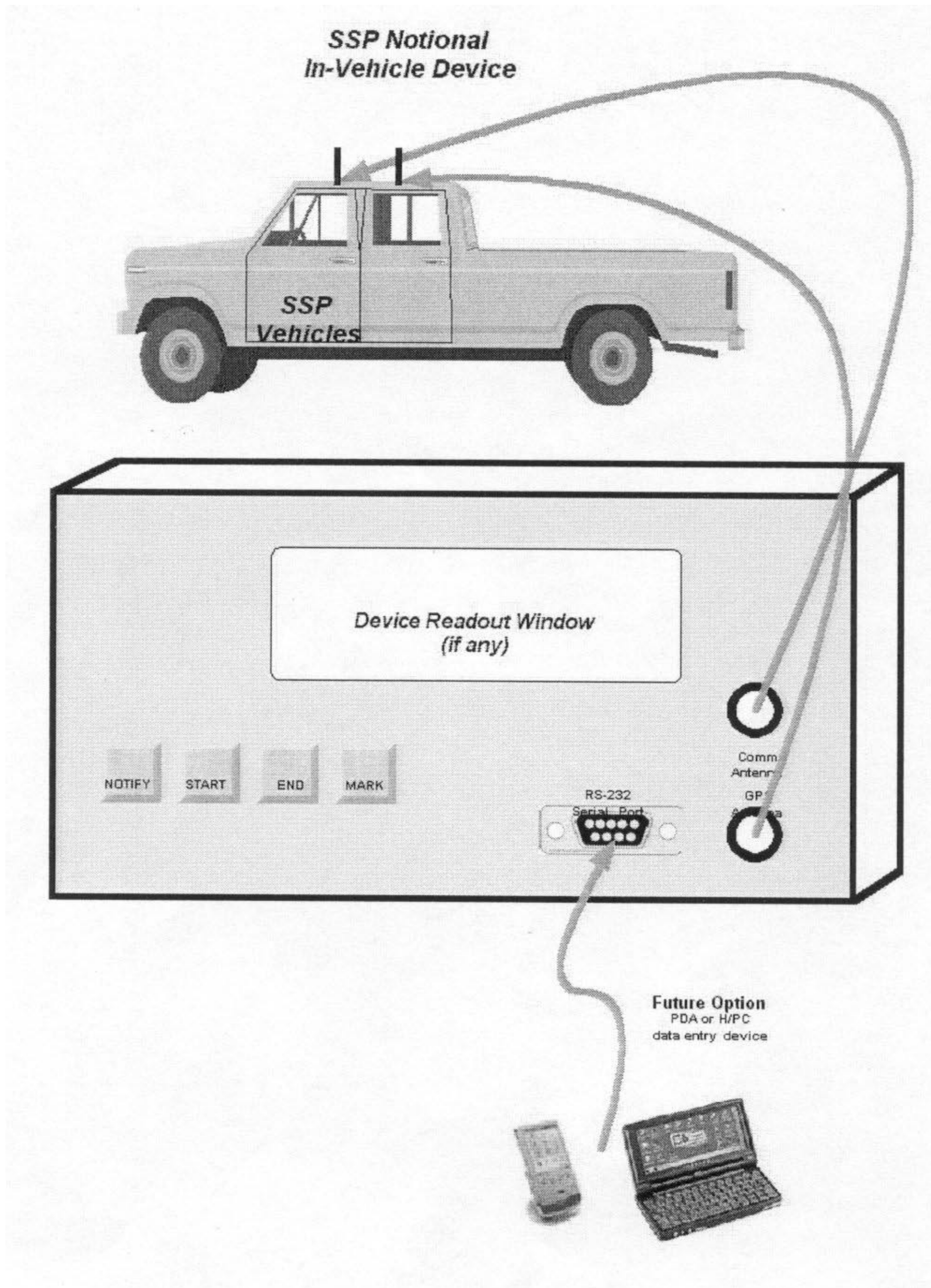

Figure 5. Notional Configuration of In-Vehicle Component

Polk County

The main objective of Polk county was to keep track of spread rates and total materials used for billing purposes. AVL units have been installed on eight county trucks and two supervisor trucks. The system provides communication via cellular voice, monitors plow operations, spreader on/off, two-way messaging, and helps in optimizing work assignments. Future plans include using thermal mapping to fine tune chemical spread rates.(8)

Summary of Findings

The majority of AVL applications throughout the states in the public works/highway maintenance operation arena have been on snow plows operations with a few agencies just recently venturing into the Safety Surface Patrol area. From discussion with DOT engineers and other professionals in the ITS arena, there is quite an interest in moving the AVL technology into traffic operations. Other applications are being considered as well, such as herbicide spraying, state police vehicles and emergency responders.

The findings are summarized below.

System :

1. The experience of the majority of agencies interviewed for this report indicated that the lack of appropriate system design led to numerous problems in the application and maintenance of their AVL. Some advised they were rushed in implementing their system and are still correcting some problems.

2. Others agencies shared that thorough analysis of existing operations and identification of data to be transmitted through an AVL system helped determine the design specification and insured appropriate system matching and application.

3. Improved efficiency of the system. The monitoring capability of the AVL system allows the agency to make better decision about scheduling.

Human factors:

1. Many agencies expressed the essential need for operator's "Buy In" into the AVL system. The experiences showed that many operational problems resulted from lack of interest or enthusiasm from the operators. Some operators expressed the concerns of "Big Brother" watching and viewed the system as another punitive tool for managers.

2. Some agencies reported that training and education programs for operators were very helpful in establishing acceptance of the system. Problems such as computer literacy, language skills, and overall dislike of another "thing" they have to be mindful of in their trucks. They preferred one-on-one training instead of a group setting. Trainers would spend about an hour with each operator in the truck with the unit and answer their questions privately.

Infrastructure/resources :

1. One agency in particular shared that streams of data was coming in without enough computer and network capabilities to manage it. They solicited the help of their information technology department and had to update their communications infrastructure to manage their data.

2. They also realized that they needed dedicate trained personnel to manage and manipulate the data.

Management :

1. All agencies emphasized that clear goals and objectives had to be identified as the first step in a successful AVL application.

2. Many agencies recommended starting with a pilot program on a selected number of equipment to debug the system and work out problems before large scale implementation.

3. Few agencies had and recommend a "Project Champion/Manager". Some systems suffered greatly when the project champion was no longer involved.

4. Many agencies recommended the development of an evaluation plan to measure the effectiveness of the system and the benefits derived.

5. Efficient use of resources. Most public agencies are operating on tight budgets. An AVL system would help utilize the resources more efficiently by improving the vehicle miles traveled (VMT) (*12*)

6. Monitoring and improving performance through fleet tracking. The GPS output helps identify trouble areas and can be used to improve performance(*3*) .

Weather :

1. It was the experience of at least two agencies with snow plow AVL applications that the lack of heavy snow fall in their areas contributed to the difficulties in deploying the system to its full capabilities and generating enough data for proper evaluation.

The following guidelines were developed after reviewing the findings from the experiences of the agencies interviewed. Additionally, numerous discussions with other professionals actively involved in evaluating such systems helped formulate and identify these guidelines.

AVL IMPLEMENTATION GUIDELINES FOR TRAFFIC OPERATIONS APPLICATIONS

The guidelines presented in this section are designed to provide guidance in implementing an AVL system in a traffic operations environment such as traffic signal repair trucks, pavement marking paint trucks and sign installation trucks. Using these guidelines, transportation managers or officials should be able to develop an implementation plan and make educated decisions on the use of AVL in this environment. A summary of the guidelines is shown in Table 1.

Step 1: Clearly establish the objectives of your AVL system

It is important to develop the objectives desired in the installation and use of an AVL system. The objectives will drive the decisions of what type of system to obtain. AVL is not a "one size fits all" system. Each traffic operation has its own requirements and a specifically designed AVL system would be required. Examples of short-term objectives could be to reduce response time on traffic signal calls, or to document through GPS the location of pavement marking passing zones for repainting every year. Long-term objectives may include better management of fleet maintenance, streamlining the deployment process and facilitating resource sharing with other agencies.

Step 2: Establish system "Acceptance" from operators

One of the major obstacles to an effective AVL system is operator's reluctance to make use of it. Some of the reasons cited include, installation and maintenance problems, "Big Brother" watching syndrome, technical and language difficulties. A major factor in achieving operators acceptance is the emphasis on safety. Most In-Vehicle units are equipped with an emergency button where an operator can immediately relay information back to his base. This feature can be life saving and increases the comfort level and morale of the users.

Table 1. AVL implementation Guidelines for Traffic Operations

Guidelines
Step 1: Clearly establish the objectives of your AVL system
Step 2 : Establish “acceptance” from system’s operators
Step 3: Analyze existing operations to determine design issues for your AVL
Step 4: Identify existing, competitive and appropriate AVL system available for deployment
Step 5: Develop communications infrastructure
Step 6: Start with a pilot project
Step 7: Develop an evaluation plan to measure effectiveness and benefits

Another factor in gaining acceptance is training and education. An operator needs to feel comfortable with the in-vehicle unit, understand its functions and capabilities and have one-on-one hands-on training. Having an experienced AVL operator share his/her experience can go a long way in removing some of these concerns.

Step 3: Analyze existing operations to determine design issues for your AVL

With the objectives established, the next step is crucial as well. A detailed step by step examination and documentation of the processes that exist today must take place. For example, in a traffic signal repair application, the information presently documented on field repair reports as to the cabinet location, type of electronic equipment inside the cabinet (processors, controllers, conflict monitors etc.), problem diagnosis, other information such as time and date, name of operator etc. Once this is accomplished then it will be necessary to identify what data can be sent back to the base computer through AVL, and what impact will the AVL system have on the existing process.

Step 4: Identify existing, competitive and appropriate AVL systems available for deployment

A transportation professional considering an AVL system will soon realize that there are no national guidelines on the implementation of such a system, especially in a traffic operations environment. This coupled with the wide variety of systems and capabilities available from vendors results in a large number of choices that could be considered. In order to make informed evaluations and decisions of the most appropriate system for an application, the transportation professional must have adequate knowledge of systems available for use that would fit the requirements and objectives of the project. The following issues should be explored:

- Is real time tracking needed for this operation ?
- What level of two way communication is required ?
- What type of information is needed to be conveyed and what types of sensors would be needed to collect this information?
- Is the system expandable to meet long term objectives?

- Will the units be removable for use in other vehicle (cigarette lighter plug in)?

These issues will not only impact the proper fit and success of a system but also the cost and maintenance. Many vendors are available to show case their products and provide detailed information, estimates, specification and training material for evaluation.

Step 5: Develop communications infrastructure

An AVL system is as good as its capability to provide managers with pertinent data for decision making. Before the streams of data begin to flow back to the office, proper communication infrastructure needs to be in place to store, process, manage, and manipulate the incoming data. Soliciting the help of Information Technology department of the organization is essential to evaluate and install proper trunk lines, servers, computers and other related hardware. Additionally, a position "data manager" should be created and dedicated to the operation, up-keep and maintenance of the database.

Step 6: Start with a pilot project

Almost all the AVL projects reviewed for this research started with a pilot. The opportunity to deploy, test, reconfigure and evaluate new technology serves the objectives of the organization well. Before a major capital investment, the pilot project would be instrumental in helping work out the difficulties that normally arise when introducing a new technology. Many projects reviewed for this research experienced technical and installation difficulties. There were many maintenance and breakage problems especially in the snow plows application. The units remained unused for the summer and were damaged in-place or removed and re-installed the next winter generating a long list of wiring and installation problems.

To have a successful pilot project it is essential to have a project champion. Someone in the organization must have ownership of the project, and will manage, monitor and evaluate the project from inception to deployment, evaluation and maintenance.

Step 7: Develop an evaluation plan to measure effectiveness and benefits

This will most likely be the most difficult task. Very little information or research presently exists on evaluation of AVL in the public works arena, especially not in the traffic operations environment. There will be some quantifiable measures that one can collect and analyze . In the case of a traffic signal repair operations, reduction in response time to malfunctioning signal calls can be archived and analyzed . The types of repaired equipment can be tracked giving the manager clues on possible system wide electronic equipment problems. Better tracking of truck usage would lead to timely preventative maintenance and help reduce major breakdowns rendering the trucks out of service for a long periods of time. All these benefits can be translated into dollar values. Other less quantifiable benefits will be in increased operator safety, better morale and overall better good will from the traveling public.

HYPOTHETICAL APPLICATION

The following is a discussion of the guidelines developed above applied to a hypothetical situation. The situation is presented as follows.

A large traffic engineering signal operation district has over 1000 traffic signals under its jurisdiction. There are 20 trucks available, 25 technicians and 3 supervisors. The system (signals and the equipments inside the cabinets) is old and the supervisors have noticed a marked increase in repair calls over the last year. It is a major metropolitan area and the traffic congestion is ever increasing adding more time to the technicians travel time and reducing their ability to respond to more calls per day even with overtime. Additionally, the supervisors in certain instances have been sending two technicians out on the same call in the same truck due to personal safety concerns. The manager is charged with implementing an AVL system that is workable and will provide long term solutions to these continuing problems especially when the number of signals is going up by 5 percent this year and there are no additional resources or manpower allocated for this operation.

Step 1: Clearly establish the objectives of your AVL system

The objectives of this manager are to efficiently deploy repair trucks, reduce travel time, increase technicians personal safety, and evaluate the system. If designed well, this system should be able to keep track of the equipment inside the cabinet for further analysis and, detection of possible system wide equipment failure. It will also provide pertinent information to help develop appropriate maintenance schedule for the trucks.

Step 2: Establish system "Acceptance" from operators

An extensive effort to explain the system to technicians /operators should be made to facilitate the acceptance of the new tracking system. Human factors issues need to be addressed. The impression of "Big Brother" watching is alive and well and should not be discounted. A level of trust between management and technicians needs to exist or be built before this system is applied. One of the added benefits that should be emphasized in this area is the additional safety factor that this system will provide with the inclusion of an emergency button on the In-Vehicle units. The vendor representative can be brought in to provide technical details and training to help alleviate some of the anxiety that comes with new tracking type technology.

Step 3: Analyze existing operations to determine design issues for an AVL tracking application

AVL systems have numerous capabilities. In order to identify what type of system is needed for this case, an in-depth analysis of the existing operation is needed to develop the parameters and essential functions that this system would be designed to meet. Here are the tasks of a typical service call:

- Receive assignment from supervisor,
- Ride in the truck to the location,
- Diagnose the problem, if it is an overhead signal head, than use the bucket and fix the problem . If the problem is in the cabinet or in the loops, then go ahead and fix it.
- Fill out repair logs,
- Get back in the truck and head back to home base.

Next, develop a list the information that will be conveyed through an AVL system . This will include: Problem location, total daily travel time per vehicle, number of daily stops/calls made, responder's identification including equipment type and capabilities, bucket up/down position, problem identification (what piece and type of equipment, inside the cabinet, or is it just a burned out light bulb), and number of incidents related to personal safety/emergencies. This process is essential to help determine what exactly the system will be designed for and what type of system will be required.

Step 4: Identify existing, competitive and appropriate AVL systems available for deployment

Based on the results of steps 1, 2 & 3 the preferred AVL system should is determined so that these characteristics can be written into the design specifications:

- Real time tracking and vehicle display
- Two way communications with both pre-programmed and custom messages; base to vehicle and vehicle to vehicle
- Portable units to be used on different vehicles and work off the vehicle power supply

- Ability to sense bucket up/down position, and vehicle engine on/off
- System to archive data for later review and manipulation

Other factors such as warranties, durability and reliability must be determined for each of the competing AVL systems. The maintenance of these units must be explored and the responsibility assigned to in-house personnel, or included in the purchase contract. Many vendors are willing and able to supply a variety of individually designed systems to fit the requirements identified earlier. Consideration should be given to other existing AVL systems existing within the agency, providing these systems can meet the need of the project, the manager can decide to use the same approach.

Step 5: Develop communications infrastructure

The Information Technology department completed an assessment of the existing data processing capabilities. They recommended and develop a plan for upgrading computers and other hardware. The implementation of these upgrade should be completed before the installation of the new AVL system. It is essential not to become "data rich and valuable information poor". The streams of data that will be coming in to the home base would be useless unless it is processed, stored, manipulated and maintained. A dedicated "data manager" position is assigned to the AVL system and proper training will be available.

Step 6: Start with a pilot project

The pilot program will consist of 10 AVL units installed on the signal repair trucks and would be outfitted with In-Vehicle units with emergency buttons with future option for PDA or H/PC data entry device. This pilot program will allow trouble shooting problems associated with the installation of this type of technology. One of the supervisors, has been designated as project champion and will be responsible for managing the project from inception through evaluation.

Step 7: Develop an evaluation plan to measure effectiveness and benefits

The evaluation plan should have the following goals: (*8*)

- Identify all relevant costs and benefits associated with the use of the AVL system; and
- Determine if the use of the AVL system on this pilot project resulted in sufficient benefits to the agency and ultimately to the taxpayers to warrant the investment.

Costs would normally include: *Startup costs* which would be available from your vendor, *annual operating costs* would include communications and labor cost for system monitors. *Annual maintenance costs* include costs for repair and replacement of the system hardware and cost for software support.

CONCLUSIONS

As the demands on public agencies continue to mount to do more with less and find ways to operate more efficiently, and as growth continues in our suburbs, more maintenance responsibilities will be added to an already overburdened agency. The need to effectively manage the maintenance and operation of traffic related assets will continue to rise. The use of AVL will only become more widespread in the future as a useful management tool.

When planning to use an AVL system for a traffic operation, it is important to consider first, the functions the system will be tracking and second, the acceptance or "buy-in" from the operators. These two elements are essential to the success of an AVL system.

The guidelines developed for the implementation of an AVL system in a traffic operations environment provide means for transportation professionals to develop and design a system that will help them manage their fleet deployment, keep track of equipment breakdowns and repairs and provide an added element of safety to the operators. These guidelines were applied to a hypothetical case study in order to illustrate the development process, which can be used by any agency that requires an AVL system in a traffic operations arena.

A need exists for future research in the area of AVL technology in the traffic operations environment. There are a very small number of AVL deployments in areas outside snow plowing and highway maintenance. Presently there are no national guidelines for deployment of this technology.

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APPENDIX A

Telephone Questionnaire

- A description/type of technology used?
- What specific purpose was the technology used for?
- What type of asset was the technology used on?
- What constraints or problems were experienced in the implementation and/or operation of the technology?
- What shortcomings/advantages have been identified with the application of this technology on this asset?
- What would you do differently if you were to deploy similar technology on a different asset?
- What aspect(s) of your implementation/operation have worked especially well, to the point where you think they should be a part of other assets and resources?
- Were implementation guidelines developed for the implementation of the technology, and if so is it possible to obtain a copy?
- Are there other documents that you found useful in implementing and/or operating your technology?
- Are you aware of other DOTs/municipalities that have used similar technologies for similar applications?
- Are there figures and pictures describing the technologies you used on your assets, and if so, is it possible to obtain a copy?

RAYMOND J. KHOURY

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GUIDELINES FOR A UNIFIED MANAGEMENT PLAN FOR MAJOR INCIDENTS

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SUMMARY

In today's economy it costs considerably more to build a new freeway than to manage an existing one. Although this may be true, the annual cost of congestion in the Dallas/Fort Worth area alone is $3.9 billion (*1*). The main purpose of a major incident management plan is to improve efficiencies in responding to major freeway incidents in order to minimize disruptions in traffic flow. More efficient incident management reduces the need for additional highway capacity to accommodate accident-related traffic congestion (*2*).

The congestion caused by major incidents such as hazardous chemical spills, truck overturns, and large loads spilled from vehicles can cause many lanes and, in some cases, an entire highway to be shut down for many hours during the cleanup. Coordination, cooperation, and communication between the different traffic management agencies and the emergency response units are essential if the roadway is to be cleared and debris removed in order to restore the normal flow of traffic in a timely manner. By having a formal written major incident management plan in place it is possible to establish a clear understanding of each agency's role in clearing major incidents, so that the appropriate response is identified and implemented as quickly and efficiently as possible

The goal of this study was to determine what should be contained in a major incident management plan. This was accomplished through examining existing incident management plans and talking with transportation professionals and law enforcement personnel who deal with incident management on a daily basis. A survey was also sent out to numerous agencies to determine what the current state of incident management is around the country. Once this was completed, it was possible to establish a set of guidelines to create or improve upon an existing incident management plan. Finally, these guidelines were applied to a large metropolitan area that does not currently have a formal written plan in place.

The sample incident management plan that was created for this research contains numerous sections which contain contact lists, emergency equipment lists, detour routes, and an incident management scheme. There are many other items that can be included in a major incident management plan. It is up to the agencies involved with incident management to decide what their needs are, how their plan is to be created, used and updated, and finally what responsibility and role each agency will perform during a major incident.

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INTRODUCTION

Problem Statement

There are typically many different agencies required to participate in onsite incident management. In some jurisdictions, there may not be a distinct multi-functional traffic management center (TMC), but instead there are several facilities that provide freeway management, emergency traffic patrol, traffic system control and interagency communication. Most of the time, incidents are fairly minor in that emergency medical services (EMS), police and fire-rescue units are called to the scene depending upon the type and severity of the crash. Major incidents such as hazardous chemical spills, truck overturns, and large loads spilled from vehicles (see Figure 1) are just a few of the situations in which the traffic management agencies and emergency response agencies play an important role. This role entails not only the identification of the incident, but also the mitigation of the resulting congestion. The congestion caused by these types of major incidents is typically worse than that caused by minor incidents because many lanes and, in some cases, an entire highway in both directions may be shut down for many hours during the cleanup. A recent example of this type of major incident occurred in December 1999 at a critical interchange in San Antonio, Texas when a major hydrochloric acid spill occurred during an accident involving an 18-wheel tanker truck that resulted in the interchange closure for twenty-five hours.

Figure 1. Example of a Major Incident Blocking the Highway (3)

Coordination, cooperation, and communication between the different traffic management agencies and emergency response units are essential if the roadway is to be cleared and debris removed in order to restore the normal flow of traffic in a timely manner. Firefighters typically have a primary responsibility to rescue people and handle hazardous spills, police are trained to investigate and document incidents, and EMS units are qualified to save lives. Traffic management agencies have the ultimate responsibility of restoring the traffic flow again as quickly as possible. It is crucial that these agencies, along with several other organizations (i.e., towing services, heavy equipment operators, and HAZMAT teams) work together as one cohesive team.

Personnel at all the agencies listed previously may have plans already in place in order to deal with the different types of major incidents. These plans are often informal, unwritten, incomplete or out-of-date.

Traffic management agencies may have a "handshake agreement" with other organizations that details the responsibilities of each agency during a major incident. As people move to other jobs or retire and agencies change, these agreements may be forgotten and become a source of conflict and confusion in the event of a major incident. Therefore, it is crucial that a formal written incident management plan be in place. This plan can be the basis for a comprehensive unified incident command structure that details each agency's responsibility during a major incident. By having a major incident management plan in place, it is possible to establish a clear understanding of each agency's role in clearing major incidents, so that the appropriate response is identified and implemented as quickly and efficiently as possible.

Research Objectives

The overall goal of this research was to develop a set of guidelines that will be used to create a major incident management plan. This plan will be useful to freeway traffic management agencies as well as law enforcement agencies, fire-rescue units and any other agencies that have a role in dealing with major incidents on our highways. The specific objectives of this research were to:

- Demonstrate the importance of a formal incident management program for major incidents;
- Determine the current state of major incident management plans at a number of locations across the country;
- Identify what information should be contained in a major incident management plan;
- Develop a set of guidelines for creating a major incident management plan that can be used by any traffic management agency or emergency response agency; and
- Apply these guidelines to the Dallas/Fort Worth area to assist this region in the creation of their own major incident management plan.

Scope

This research was limited to the development of guidelines for the creation of a major incident management plan that focuses on coordination, cooperation, and communication between the agencies involved with incident management. These guidelines were intended to assist agencies in creating a major incident management plan of their own, or to update and improve upon a plan than is currently in place. Additional research is needed to examine the issue of rerouting traffic, providing motorist information and congestion management. This research focused on the quick, coordinated removal of debris, overturned trucks, and spilled loads.

STUDY DESIGN

The procedure followed in developing guidelines for a major incident management plan consisted of seven primary tasks: literature review, develop contact list for surveys, develop survey, conduct surveys, analysis of existing incident management plans, guideline development, and application of these guidelines. These tasks are expanded upon in the following sections.

Literature Review

A review of the literature was conducted with regard to incident management and in particular the development of a major incident management plan. Earlier research has proven how important incident management is with regard to incident related congestion. Although this was proven decades ago, it was not until the last decade that major incident management plans started to appear with any regularity throughout the United States. This literature review provides the background necessary to determine what issues should be addressed in a major incident management plan in order to reduce incident related congestion.

Develop Contact List for Surveys

As mentioned earlier, there are many agencies involved with incident management. Although this is the case, the development of a major incident management plan usually originates from transportation focused agencies. This is why a large portion of the contact list that was developed originated from the Institute of Transportation Engineers (ITE) Traffic Incident Management Committee. Over one-hundred transportation, transit and law enforcement professionals interested in incident management are on this committee. There was also a need to personally contact professionals within the State of Texas that deal with incident management and freeway operations to get a first hand look at how they deal with incident management issues. Finally, three private consultants with experience in creating major incident management plans were also sought out to examine the incident management experiences they have had in many different places throughout the United States.

Develop Survey

A short survey was developed to ascertain the current state of incident management plans around the country. This survey, which can be found in Appendix A, was primarily developed to determine:

1. What agencies have a major incident management plan in place?
2. What is contained in this plan?
3. What is missing from this plan?
4. What agencies are involved with incident management?
5. What difficulties exist between these agencies with regard to cooperation, communication and coordination?
6. How is this plan used? and
7. What is important to the agencies in regards to incident management?

There were a total of sixteen questions on this survey. Agency responses to these questions were used in the development of guidelines to create a major incident management plan. Another important question that was contained in the survey asked "what is the reason for not having a written plan if there was not one in place." The answers obtained from this question also assisted greatly in creating the guidelines for an incident management plan.

Conduct Survey

This survey was administered in several ways. An email survey was sent out, personal interviews were conducted, and three telephone interviews were also conducted. These different methods of surveying were used in order to maximize the possible number of locations and professionals that were contacted.

Email Survey

First, an email survey was sent to over one-hundred professionals from the ITE Traffic Incident Management Committee. Many of these professionals are researchers, consultants and State DOT employees, along with a few law enforcement officers, fire-rescue personnel and transit authority employees. Twenty-five (21 percent) of the emails were instantly returned because of faulty email addresses. Another twenty percent (17 percent) were returned with the comment that the survey was forwarded to the appropriate personnel to respond to such a survey or that they no longer worked in the incident management profession. Over the course of three weeks, eight surveys were completed and returned either by email or fax for a response rate of seven percent. Although more responses were desired, these responses from different agencies and professionals were enough to get a sampling of the state of incident management plans across the country.

Personal Survey

In order to get a better understanding of incident management, five operations engineers representing the five largest metropolitan areas in the State of Texas were interviewed. These interviews were conducted in conjunction with a state traffic operations conference that was held in San Antonio, Texas. These five individuals represented Austin, Dallas, Fort Worth, Houston, and San Antonio are were very knowledgeable leaders in the field of freeway operations and traffic management. Their insight into this research topic was extremely beneficial.

Personal interviews were also conducted during a site visit to the TransGuide Traffic Management Center in San Antonio and the TranStar Traffic and Emergency Management Center in Houston. These interviews provided a different aspect of incident management because they included two law enforcement officers and three freeway management operators. These individuals deal with freeway incident management on a daily basis and they provided different views from the other administrators and professionals that were interviewed earlier.

Telephone Survey

Three telephone surveys were conducted with private consultants who have created and implemented numerous major incident management plans across the United States. Although these professionals did not directly respond to the survey, they provided an insight into incident management that assisted in the creation of the guidelines developed in this research paper.

Analysis of Existing Incident Management Plans

Three different cities responded to the survey that was sent out with a copy of their incident management plans. These cities included the Kansas City Metropolitan area; Houston, Texas; and Chattanooga, Tennessee. These plans were very useful during the creation of the guidelines developed in this research paper.

Guideline Development

The primary goal of this research project was to develop a set of guidelines that can be used to create a major incident management plan. It was the intent that these guidelines be all encompassing so that they can be used by any agency or organization and cover many incident scenarios that can occur on a highway. However, it was necessary that these guidelines be flexible enough to allow different locations and jurisdictions to use them and incorporate them within their own incident management plan. Every agency is different and each has their own set of strengths and weaknesses. Some agencies have authority over a large area, while some locations are managed by many smaller jurisdictions sharing the responsibility of incident management.

Guideline Application

Once the guidelines were developed for a major incident management plan, these guidelines were applied to the Dallas/Fort Worth Metroplex area. This region currently does not have a written incident management plan for reasons that will be discussed later in the paper. The main focus point during the application of these guidelines was on improving the cooperation, coordination and communication between the agencies and municipalities responsible for incident management in this metropolitan area.

LITERATURE REVIEW

Incident Management

Incident management is a very complex and demanding process. The Federal Highway Administration defines incident management as "the systematic, planned and coordinated use of human, institutional, mechanical and technical resources to reduce the duration and impact of incidents, and improve the safety of motorists, crash victims and the incident responders" (4). These goals are accomplished by the following:

- Reducing the time required to detect and verify an incident;
- Reducing the time required to respond to an incident;
- Effectively and properly managing personnel and traffic; and
- Reducing the time to clear the incident.

As illustrated in Figure 2, time is the important factor in incident management. The longer it takes to clear an incident, the worse the congestion will get. A major incident can last for 90 minutes or more and cause 1,200 to 1,500 vehicle-hours of delay (5). If the incident duration time was reduced from 45 to 30 minutes through the use of a major incident management plan, the total delay would reduce by over 50 percent (6).

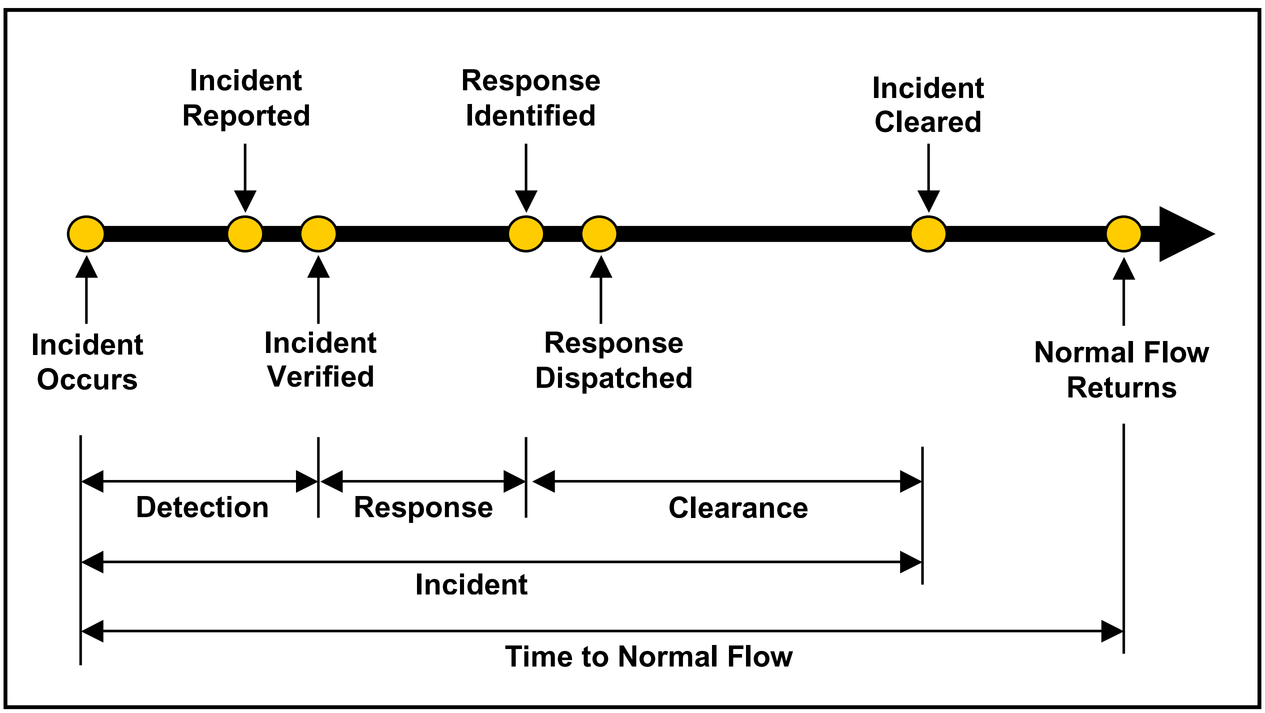

Figure 2. Incident Management Timeline

Incident Detection

Incident detection time for major incidents is usually shorter than it is for minor accidents and breakdowns. During a major incident many lanes are frequently impacted. There are numerous ways to reduce the time to detect an incident including:

- Adding more freeway service patrols or motorist assistance patrols;
- Increased usage of a 511 traffic incident telephone number and cell phones;
- Increased usage of closed-circuit television cameras along the freeway; and
- Automated incident detection algorithms based on traffic surveillance.

Incident Verification

Once an incident is detected, it has to be verified in order to pinpoint the exact location and nature of the incident. Verification can be accomplished through multiple cell phone calls about the same incident, closed-circuit television cameras, or through law enforcement and Department of Transportation personnel. Incident verification is an important process that ensures the appropriate equipment and personnel are deployed to the scene. Verification is also needed to prevent false or erroneous incident reports from being made and tying up valuable resources.

Incident Response Time

The amount of time required to respond to an incident is dependent on a number of factors including:

- Location of the incident;
- Time of day and day of week the incident occurs;
- Severity and type of incident;
- Existing traffic conditions; and
- Type of equipment and personnel responding to the incident.

Clearance Time

Clearance time is the amount of time taken to remove any stalled vehicles, wreckage, debris or spilled material from the roadway and its shoulders and is not completed until the full capacity of the road is restored. This time is measured from the time the response is identified until the last vehicle departs the incident. Clearance time is the element of incident management that is effected the greatest by efficient and coordinated incident management (*7*).

Benefits of an Incident Management Program

There are numerous benefits that an incident management program can have once it is in place. These benefits can be both quantitative and qualitative. A quantitative analysis of benefits from a before-and-after analysis of the San Antonio TransGuide System can be found in Table 1. A more general list of benefits include:

- Motorist delay and frustration reduced;
- Increased survival rate of crash victims;
- Improved public perception of agency operations;
- Reduced occurrence of secondary crashes;
- Improved safety of responders, crash victims and motorists; and
- Improved coordination and cooperation of response agencies. (*4*,*8*)

Table 1. Benefits of the TransGuide Incident Management Program (*9*)

Quantitative Benefit	Percentage Reduction (%)
Reduction in total accidents	35
Reduction in secondary accidents	30
Reduction in accidents during inclement weather	40
Reduction in overall accident rate	41
Reduction in incident response time	20

Advance planning for handling traffic when emergency lane closures or freeway closures occur is essential to the orderly movement of traffic. Adequate advance planning minimizes incident effects on highway traffic and reduces the normal congestion that develops because of these incidents (*10*).

Reduction in Capacity

The impacts of an incident on the capacity of a freeway are significant. This is especially true with major incidents which tend to block more lanes. Incident caused congestion can lead to secondary incidents or accidents by causing unexpected stops or slowdowns. Even if an incident is located on the shoulder and not blocking any lanes, capacity is reduced due to motorists slowing to look at the incident. Table 2 details the reduction in capacity due to lane blockage.

Table 2. Total Capacity Reduction Due to an Incident (*11*)

Number of Lanes Obstructed Due to Incident	Total Capacity Reduction (%)
Shoulder blockage or closure (no lanes blocked)	20
One lane of a three lane section	50
Two lanes of a three lane section	80
One lane of a four lane section	33

SURVEY FINDINGS

Survey Respondents

One of the objectives of this research was to investigate the current state of major incident management plans across the country. The agencies responded to an email survey that was sent out to 118 agencies for a response rate of seven percent.

1. Arizona Department of Transportation, Traffic Operations Center
2. Bergen County Police Department, New Jersey
3. Iowa Department of Transportation
4. Maryland State Highway Administration
5. New York State Department of Transportation
6. North Carolina Department of Transportation
7. Ontario Ministry of Transportation
8. Texas Transportation Institute, Arlington Office (Dallas/Forth Worth Area)

Arizona Department of Transportation, Traffic Operations Center

Arizona DOT(ADOT) has a Statewide Alternate Route Plan, which is currently being developed as a PC-based software system. ADOT also uses the Phoenix Emergency Route Plan and the Phoenix Traffic Operations Center (TOC) Operations Manual to serve as their major incident management plan. The alternate route plan shows various alternate routes in the event of emergency. The duration and severity of the incidents are the main focus for ADOT in regards to incident management. Other issues ADOT believes their plan should cover that are not currently covered include more organized and orderly coordination and functions among agencies responsible for incident management. ADOT reviews and updates their plans every few years. ADOT conducts training exercises (including mock exercises and incidents) and holds meetings after each major incident to determine if their plans are adequate and up to date. ADOT works with numerous agencies in regards to major incident management including:

- Local police;
- Highway patrol;
- Fire department;
- HAZMAT teams; and
- Local cities, towns, and Maricopa County.

ADOT has not had any difficulties with coordination or cooperation between agencies, but they have had infrequent difficulties with communication between agencies. The major incident response plan has been implemented approximately once a year (*12*).

Bergen County Police Department (New Jersey)

Bergen County currently has a major incident response management plan in place for State Highways in the County. It has had a plan in place for the last four years. It is a 150-page document that details at least one alternate route plan for each segment of highway. It contains contacts for each local municipality so that a command post type operation can be conducted. The plan also contains procedures to notify the Transportation Operations Coordinating Committee (TRANSCOM) for public information dissemination to local news and traffic services. The movement of traffic through the County and the minimization of the impact and frustration to the public are the issues that are most important to the Bergen County Police Department in regards to incident management.

The major incident response management plan is updated and reviewed as needed, with a plan overview is given to local police, fire and EMS agencies once per year. This plan is implemented between 10 and 15 times a year. The Bergen County Police Department works with NJDOT most directly in regards to major incidents, but they also work with the local emergency services and State Police. Cooperation and coordination between agencies is dealt with by the leveraging of personal relationships in order to move the process in the right direction. There have been difficulties with communication between agencies because they are all on different frequencies so it generally requires a member of the incident management team to respond to the scene (*13*).

Dallas/Fort Worth Area (Texas Transportation Institute – Arlington)

The Dallas/Fort Worth area does not have a major incident response management plan in place because of the inability to bring so many jurisdictions and municipalities together to agree on a common plan. Training is being developed at the North Central Texas Counsel Of Governments (NCTCOG) that may eventually lead to a region-wide incident management plan. Texas Transportation Institute is concerned with finding ways around problems that continue to affect mobility and safety when major incidents occur. An enforceable policy on quick clearance is needed across the region; champions are needed in every organization to provide training and motivation to succeed in bringing down clearance times. Agencies the Dallas/Fort Worth area works with in regards to major incident include:

- TxDOT;
- Dallas County Sheriff's Department;
- Local police (33 cities in Dallas County, another 33 in Tarrant County);
- Fire departments; and
- Dallas Area Rapid Transit (DART) is involved if HOV lanes are affected.

There have been difficulties regarding cooperation and coordination between agencies which depends on which city is being dealt with. In some cases, cooperation is an issue; in others, training is the main issue. There have also been difficulties with communication between agencies regarding hardware because police and fire use different radio equipment. The Dallas/Fort Worth area has worked toward the day when they will have a plan for many years. They are coming closer to this plan with a recently held regional meeting at NCTCOG to help develop training curricula (*14*).

Iowa Department of Transportation

Iowa has several locations with urban freeways that are working with multidisciplinary teams, but none of these teams have a formal written major incident response management plan in place. The reason they do not having a formal written plan in place is due to the lack of staff time they have to devote to writing a plan. In regards to incident management, motorist safety and traffic delay is the most important issue to Iowa DOT. The agencies Iowa DOT works with in regards to major incident management include:

- City and County engineering;
- Fire-rescue units;
- Local police departments; and
- Iowa State Highway Patrol.

Coordination and cooperation between these different agencies for the most part has been good. There have been some difficulties with communication between agencies because of differing radio frequencies and this is a challenge that needs to be overcome (*15*).

Maryland State Highway Administration

Maryland SHA has had a major incident management plan since 1994. Their current plan has been in place since Fall 1998 and contains:

- Guidelines for implementation;
- Strategy deployment;
- Device usage;
- Partners/Contacts;
- Records; and
- Policies.

After tending to the injured and any HAZMAT conditions, getting the road open and avoiding secondary incidents are the main priorities for Maryland SHA. Training exercises are conducted under both field and classroom conditions and workshops are conducted to ensure their plans are adequate and up to date. Maryland implements the major incident management plan an average of one or two times a month. There are numerous agencies involved with major incidents in this region including:

- Local police;
- Fire departments;
- EMS;
- Fire marshal;
- HAZMAT agencies;
- Traffic reporters;
- Natural resource agencies;
- Environmental agencies; and
- Local governments.

To help eliminate problems with cooperation, coordination, and communication between agencies, the first thing Maryland SHA did was get the top decision makers (local politicians and policy makers) together to agree on a vision. This vision was to keep Maryland's roads open at all times and, when closed, to reopen them as quickly as possible. Next, they learned how to work incidents together without interfering with each other. Each agency helped one another and did not try to do the other agency's job. To reach their vision, they learned to talk to one another after each incident about how they could do better the next time. This success has not been universal across the entire state and it works better in some areas than others. Problems with cooperation still occur with some of the rural volunteer fire departments. Overall, the agencies seem to work together better the worse the crisis is. Maryland SHA believes every state should have a major incident response plan that applies to all users – one state, one plan (*16*).

New York State Department of Transportation

The New York State Department of Transportation (NYSDOT) has had a major incident management plan in place since January 1999 and it is implemented on average every month to two months. This plan is part of their overall response plan which covers everything from disabled vehicles to highway closures. The plan contains only detour routes and a contact list. There have been no training exercises conducted as of July 2001 with this plan, but they are planning to start them soon. The major incident management plan that is in place is updated occasionally, usually after major incidents occur. The important issues NYSDOT addresses with respect to incident management included reducing secondary incidents, providing scene safety for responders and reduction of delays. Issues that are not addressed but are needed in this plan include specific detour post assignments and necessary static signage. Agencies that NYSDOT works with in respect to incident management include:

- State and local police;
- Fire;
- EMS;
- Transit agencies; and
- Traffic reporting firms.

There are been few problems with coordination and cooperation between these agencies. Most of the problems have been with communications between agencies because they do not share common communications. This was solved by putting DOT, police and other supervisors together in the field. DOT and state police also jointly operate the traffic management center and cross monitor radio transmissions during major incidents (*17*).

North Carolina Department of Transportation, Traffic Operations Center

North Carolina Department of Transportation (NCDOT) has had a major incident management plan in place since 1993. The state has predetermined detour routes for the majority of the interstates that show a number of proposed detour routes in case of an incident that closes the interstate. The plan also includes emergency contacts, staging areas, officer locations, and authorized vehicle crossover locations. This plan was finalized by the local incident management interagency teams and is in a notebook format to be given to all the members of these interagency teams. The important issues NCDOT has in regards to incident management include shortening the duration of road closures to lessen the exposure of emergency response personnel, reducing the exposure of the motorists to secondary accidents, and reducing travel delay to the extent possible.

The incident management interagency teams conduct meetings that vary from a monthly to a quarterly basis to discuss issues related to incident management. In order to determine if their plans are adequate and up to date they perform "table top" incidents involving various situations. NCDOT works with many agencies in regards to major incident management including:

- NCDOT construction personnel;
- State Highway Patrol;
- Local law enforcement;
- Emergency management;
- Fire-rescue units;
- Department of Motor Vehicles; and
- Traffic reporters (if available in the area).

North Carolina reports they have had difficulties with coordination and cooperation between agencies and that some of the local teams still have problems with jurisdictional issues. However, the regular team meetings have helped improve the relations between agencies. They also reported communication problems between agencies due to the different radio frequencies; however, the interagency team meetings have improved communications tremendously (*18*).

Ontario Ministry of Transportation

The Ministry of Transportation in Ontario has had a major incident management plan in effect for over ten years that includes plans for both nuclear and non-nuclear incidents. There is a nuclear research lab and three nuclear generating stations in the Province as well as a nuclear generating station located in the State of Michigan (FERMI 2) that could impact Ontario. For a nuclear emergency, the plan encompasses a traffic management plan that is used for diversion of traffic around the facilities. The non-nuclear plan is utilized for other abnormal incidents that are of a severe nature that impacts the transportation system. They are currently working with a red tape commission for a process of quick clearance involving commercial vehicles on the freeway system. A road closure action plan has also been developed in conjunction with local road authorities. This plan has predetermined alternate routes for diversion of traffic from the freeway during major incidents. The incident management plans contain numerous items including:

- The overall structure and organization of the agencies involved;
- Standard operating procedures;
- Traffic control plans;
- Training; and
- Responsibilities of the Federal Emergency Management.

The Ministry of Transportation in Ontario is interested in mitigating disruption to other motorists and maintaining the traffic flow and throughput in the best manner possible. They believe it is important to minimize the time that a capacity-reducing incident remains on the roadway. Two issues that are not currently contained in their plan that they believe would be beneficial are the creation of an incident command structure and a major incident response team.

The plans are reviewed on a bi-yearly basis and their emergency contact list for staff is updated on a monthly basis. A yearly training exercise is held to judge response and actions as it relates to the Nuclear Emergency Plan with one of the sites tested per year on a rotational basis. Ontario's major incident response plan is also tested on a yearly basis and has been enacted on a stand-by level at least six times in the past year. As with all major incidents a post debriefing exercise is conducted with all emergency agencies.

The Ministry of Transportation in Ontario works closely with numerous agencies including:

- The Ontario Provincial Police;
- Emergency Management Ontario;
- The Federal Government of Canada;
- The Canadian Coast Guard;
- Regional police services; and
- Municipalities and local levels of government.

There have been difficulties with both coordination and communication between agencies. There is a lack of good information that is passed on during an incident that can be attributed to competing interests both from a field point of view and from a control center atmosphere. Police agencies are interested in protecting the scene for investigation and evidence purposes, whereas the road authority is interested in reopening the road as soon as possible. Having a central control point would minimize this, as all decisions would then be communicated to field level staff. There have been difficulties with cooperation between agencies at times, but for the most part cooperation is very good (*19*).

Personal Interviews

The survey was also presented during personal interviews with the following agencies:

1. Texas Department of Transportation, Austin District ;
2. Texas Department of Transportation, Dallas District;
3. Texas Department of Transportation, Fort Worth District;
4. TransGuide, Texas Department of Transportation, San Antonio; and
5. TranStar, Texas Department of Transportation, Houston.

Texas Department of Transportation – Austin District

Austin does not have a written major incident management plan in place, but one is currently being developed. This plan should be in place when they move into the new traffic management center in 2003. TxDOT foresees a plan such as this being implemented a couple of times a week. The main focus of this plan addresses the issue of who is in charge at the scene. Currently, if an incident occurs, the courtesy patrol and law enforcement agencies on the scene determine what needs to be done and they contact the other agencies necessary to clear the scene. Police units are in charge at the scene unless there is a HAZMAT situation, in which case the fire department is in charge.

Austin is currently developing an incident management team that is just starting to meet periodically. An initial difficulty with this team is over the use of its funding. Capitol Metro has already funded $500,000, but the agencies have not decided who is in control of this money and how to spend it. TxDOT is trying to convince the other agencies that a part of this money should go towards the training of the police officers to handle major incidents on the freeways. In the past, TxDOT has offered to help train officers and develop a training video, but the police academy claims there is not enough time to fit it in with all the other training the officers are receiving.

The main objective of the Austin District is to provide good response to incidents so that the scene can get cleared and traffic moving again. Cooperation is often a problem between agencies. Police officers are trained that they are out there by themselves and that they need to take charge of a situation. On the other hand, transportation agencies are trained to treat major incidents as a team effort (20).

Texas Department of Transportation – Dallas District

Dallas currently does not have a major incident management plan in place. They have used a courtesy patrol manual for the last four or five years that discusses how to handle minor and major incidents. The manual describes what the courtesy patrol should do to provide traffic control at the scene and how to cleanup small HAZMAT spills. The reason they do not have a formal written plan is because they have been unable to get so many different agencies and jurisdictions in the Dallas area together to agree on a common plan.

One item they would like to see included in any future Major Incident Management Plan is a contact list for all the other agencies including towing companies and the TxDOT maintenance section in particular. The most important goal of the Dallas area is to get the incident clear so they can restore the freeway and get the traffic moving. The Dallas County Sheriffs Department is starting to take on a greater responsibility to work major incidents. This is the first step towards the goal of having a dedicated police agency to cover all the freeways in the Dallas area to help clear incidents. Once this happens they foresee a formal written major incident management plan being in place in the future. Some of the agencies the Dallas District works with regarding incident management include:

- Local police agencies;
- Local fire departments;
- Department of Public Safety (DPS);
- Towing companies; and
- TxDOT maintenance.

Dallas does not currently conduct incident management training exercises with these agencies, but the Metropolitan Planning Organization (MPO) is about to start incident management training. There have been problems with coordination and cooperation within these agencies. Increased freeway management training is needed for local law enforcement units in order to help them better manage the freeways during a major incident. Another problem in the past is the interpretation of the state law allowing TxDOT to remove personal property from the freeway. Some agencies believed that this did not include removing vehicles from the highway. This has recently been overcome with the passing on a new law that specifically allows TxDOT to remove vehicles from a highway. Communication is not as big a problem since regular meetings are held on a regular basis between law enforcement agencies, fire departments and the courtesy patrol units (21).

Texas Department of Transportation – Fort Worth District

Fort Worth currently does not have a major incident management plan in place. There are approximately twenty-three incorporated cities in the Fort Worth area. Each of these cities has their own unique way of doing things with their own jurisdictions and relationships between fire departments and police departments. In some of these cities, the fire rescue is in charge of a major incident, while in others it is the police department that is in charge. It has been the experience of the Fort Worth area that once a formal written plan is in place, they become involved with the risk management departments of these cities who will turn down any plan they have in place. The risk management people are hesitant to allow the city to assume the liability of moving and towing vehicles, as well as the liability of having a written (legally binding) plan which can be used against them in court. For this reason, the Fort Worth area has used an informal incident management plan for the last twenty years. The lack of a formal plan has not effected the Fort Worth area even with a turnover of personnel over the years. The Fort Worth district does not foresee a formal plan written for the district in the near future.

Fort Worth has on average two or three major incidents a week. They focus on getting the traffic moving safely through the incident scene and getting the incident scene cleared as soon as possible. Texas House Bill 312 provides formal protection for TxDOT from lawsuits in the event they have to move a vehicle or a spilled load off the roadway as long as they are not reckless in doing so. This protection was not initially given to law enforcement agencies. Another interesting point is that the Fort Worth District does not have a contract with the local wrecker companies or the commercial airbag companies to assist in removing vehicles during an incident. It is up to the company that caused the incident to pay for the removal of the vehicle and for the cleanup of any spilled loads.

The Fort Worth area is assisted by many agencies in regards to incident management including:

- County Sheriff;
- Department of Public Safety (DPS);
- City police;
- Fire departments; and
- HAZMAT cleanup companies (22).

TransGuide – San Antonio, Texas

San Antonio currently does not have a major incident management plan in place, but they are in the process of finalizing one and should have a plan in place by Fall 2001. The reason they do not have a formal written plan in place is because there has been an excellent working relationship with the other agencies that deal with incident management in San Antonio, therefore they saw no need for a formal plan. This thought process changed last year when a major acid spill involving an 18-wheel tanker truck occurred at a critical interchange. This accident impressed upon TransGuide the need to have a formal written plan so that when these major incidents occur, everyone knows their responsibilities. During this incident, problems occurred because people at other agencies, who were unfamiliar with the unwritten policies that some agencies had with one another had to be dealt with.

TransGuide foresees this forthcoming plan being implemented on a weekly basis. This plan will categorize the severity of incidents as well as feature a flow chart for each type of event. The flow chart will tell everyone involved who is going to respond, who is in charge of that incident and how everybody will support the incident commander. This plan will include an established unified incident command structure so every agency that responds will have a spokesman that will be available to the incident commander. This way decisions can be made with input from all the agencies rather than just one agency. This plan will outline areas of responsibility so agencies will not take over the duties of other agencies. This has to be accomplished without getting too specific so that there is some flexibility between agencies. There are numerous agencies TransGuide have been involved with while handling major incidents including:

- San Antonio police department;
- San Antonio fire department;
- EMS;
- County medical examiners (Coroner);
- Texas Natural Resource Conservation Commission;

- HAZMAT companies;
- Environmental Protection Agency;
- Local military bases; and
- Towing/recovery companies.

TransGuide has many priorities during a major incident including:

1. Get emergency care to those that need it right away;
2. Use the cameras and communications equipment TransGuide has deployed to help administrators see what is going on at the scene so these administrators can make decisions without having to go to the scene;
3. Minimize the number of closed lanes; and
4. Give advanced warnings and information to the drivers approaching the scene.

One of the concerns San Antonio has is with the large number of military bases located near the city. Military ordinance and shipments are not required to have hazardous cargo labels that other non-military hazardous cargo is required to have. Many times the drivers of these vehicles have no idea what they are transporting. This can cause a large disaster if an incident were to occur with one of these vehicles (23,24).

TranStar – Houston, Texas

Houston TranStar is the traffic and emergency management center for Houston. They have had an incident response manual since 1997 that is currently being updated and reevaluated with the help of the lessons learned during the last few years. It covers the roles and responsibilities of the participating agencies during an incident and establishes a clear chain of command during an incident. TranStar also has a Freeway Incident Management Contract which is a one-page form that is filled out whenever a major incident occurs within the 610 Loop around the city. This contract has some basic contact numbers and procedures laid out so the operators at TranStar can quickly enact a response once an incident is detected. This contract has been used for the last four years and is renewed every two years.

Due to the lack of capacity and alternate routes in the Houston area, clearing the scene quickly and opening the affected lanes is the most important aspect of incident management. The congestion caused by major incidents often makes it difficult to get the proper equipment and personnel to the scene in a timely manner. Major incidents occur almost daily in the Houston area with instances of up to five overturned trucks occurring in one day. These major incidents are compounded by the fact that the Houston area has one of the largest concentrations of petrochemical facilities and refineries in the nation.

The state of Texas has a multi-jurisdictional law enforcement approach that complicates incident management and adds confusion as to who is in charge at the incident scene. TranStar is currently working on an automated incident detour system similar to the one currently in place in San Antonio. Fifty additional Dynamic Message Signs (DMS) are to be built to help with this automated incident detour system. Houston METRO is developing a response bus that will serve as a Mobil Command Center (MCC) during major incidents. Based on current estimates, this MCC would be used approximately once a year.

Houston currently does not conduct training exercises but they commonly perform an after action review to determine the lessons learned during a major incident. Houston works with many agencies during major incidents including:

- Houston fire department;
- Houston police department;
- EMS;

- HAZMAT companies;
- Houston METRO;
- Harris County Sheriff Department;
- Department of Public Safety (DPS);
- Towing companies; and
- The Office of Emergency Management.

There have been problems with coordination between many of these agencies because of the policies and competing interests among the agencies. TranStar has an understanding with the county medical examiner that a deceased motorist may be moved in order to clear a scene as long as the scene is well documented and photographed. The EMS and fire rescue units still do not want to move a body until the coroner arrives at the scene. Communications have also been a problem since these agencies all have different frequencies and communication equipment. This is true even within a single agency where one unit of an agency has problems communicating internally with another unit within the same agency. A regional communication system is needed to help overcome this obstacle. Cooperation is another problem between these agencies because different concepts of enforcement among the patrol units. Policy makers and operators in the management centers tend to have more of a propensity to work better together. These policy makers and operators have a better understanding of what needs to be done to clear a major incident but the responding unit is unaware of what to do and sometimes is not given enough information in a timely manner in the field (*25*,*26*,*27*).

Further Results from Incident Management Plans

Some organizations that were sent a survey replied with a copy of their incident management plans and procedures. These written plans provided a way to evaluate the different incident management programs in place in different areas across the country. Evaluating these plans is a great way to start developing a guideline that can be used to create a major incident management plan. By observing what other communities have written, it is possible to build upon those plans and mold them into a new plan.

Kansas City Metropolitan Area

Kansas City provided a copy of their formal incident management plan. It is a unique plan in that it covers a metropolitan area that extends into two separate states. With two different State DOT's contributing to this plan, it is further proof that multi-jurisdictional areas can cooperate with one another and come together to create a plan (*28*).

Chattanooga, Tennessee

Chattanooga-Hamilton County also provided an overview of their incident management plans. This is a new plan that was finalized in June 2001. It describes the process of forming an Incident Management Task Force, through to the creation of a formal written plan. This plan took a year-and-one-half to write. During this time a good working relationship with many different agencies and jurisdictions was established (*2*).

Summary of Survey Results

Nine of the organizations that responded had a written major incident management plan in place. The five organizations that did not have a written plan are listed in Table 3 along with the main reason why they did not have a written plan in place. Of the agencies that did not have a written plan in place, San Antonio will have one soon while Austin plans on having one in the next few years. The Dallas/Fort Worth area might have one in the distant future, but they have many issues to work out between the numerous communities in the Metroplex area.

Table 3. Locations Without a Written Major Incident Management Plan in Place

Location	When will there be one in place?	What is the main reason for not having a plan in place?
Austin, TX	2003	No reason given
Dallas, TX	Unknown	Too many municipalities and jurisdictions, they use the courtesy patrol manual for incident management
Fort Worth, TX	Unknown	Too many municipalities and jurisdictions, also the risk management people did not approve of creating such a plan
Iowa DOT	Unknown	Lack of staff time to devote to writing a formal plan
San Antonio, TX	Fall 2001	Have had an excellent working relationship between agencies, so there was no need for one

Those agencies that have an incident management plan in place update it every one to two years. A summary of those agencies with a plan in place can be found in Table 4. Some of the surveys reported some sort of problem with either cooperation or coordination between agencies. The cooperation and coordination problems are typically minor problems that can be solved through regular meetings and increased training between agencies. Most of the problems reported in the surveys were with communication issues and seemed to stem from the different equipment and frequencies the separate agencies are using. Many of these agencies have different goals and priorities in the area of incident management. A summary of these goals as well as some of the problems each agency has can be found in Table 5.

Table 4. Locations With a Written Major Incident Management Plan in Place

Location	How long has it been in place?	How often are plans updated and reviewed?	Are training exercises conducted?	How often is the plan implemented?
Arizona DOT	1991	Every few years	Post incident meetings held as well as mock exercises	Once per year
Bergen County, N.J.	1997	As needed	A plan overview given to other agencies every year	10 – 15 times per year
Chattanooga, TN	2001	New plan (no update schedule set)	Once or twice a year	Once a month
Houston, TX	1997	Every two years	No training exercises conducted, but an after action review is usually held	Daily
Kansas City	1998	Every six months	Wrap up sessions after major incidents	Once a week
Maryland SHA	1994	As needed (first plan created in 1994, updated in 1998)	Yes, under both field and classroom conditions	Once or twice a month
New York State DOT	1999	Occasionally (usually after major incidents occur)	Not yet (they plan to)	Every month or two
North Carolina DOT	1993	Monthly/quarterly meetings to review the plan	Classroom exercises are conducted	Monthly
Ontario Ministry of Transportation	1991	Bi-yearly (contact list updated monthly)	Yes	Six times in the past year

Table 5. General Responses from Surveys Concerning Incident Management

Location	Where is training and help needed?			What is important to your agency with regards to incident management?
	Coordination	Communication	Cooperation	
Arizona DOT	No problems	Sometimes	No problems	Reducing the duration and severity of the incidents
Austin, TX	Need more interagency meetings and team training	No problems	Issues concerning control over the scene	Good response to incidents, clearing the scene and restoring the flow of traffic
Bergen County, N.J.	No problems	Differing frequencies is a problem	No problems	Movement of traffic and minimization of the impact and frustration due to incidents
Dallas, TX	Need increased freeway incident management training for law enforcement	No problems	Unable to create a written plan due to liability and legal issues	Clearing the incident to restore the freeway and get traffic moving again
Iowa DOT	No problems	Differing radio frequencies	No problems	Safety and traffic delay
Kansas City	No problems	No problems	Problems at the onset of the plan, but it is much better now	Better management and clearing of incidents
Maryland SHA	Have been problems but are now avoided due to training and workshops	Technologically no, occasionally an agency has problems communicating with the other agencies	Issues between rural volunteer fire departments and other agencies	Tending to the injured and any HAZMAT conditions, getting the highway open and avoiding secondary incidents
New York State DOT	No problems	No sharing of communications between agencies	No problems	Reducing secondary incidents, scene safety for responders and reduction of delays
North Carolina DOT	Problems with solving jurisdictional issues	Different radio frequencies have caused problems	Increased meetings and team training needed between agencies	Shortening the duration of road closures, lessen exposure of emergency response personnel and motorists with secondary accidents and reducing travel delay
Ontario Ministry of Transportation	Police agencies and road authority have competing interests	Lack of good information that is passed between agencies	Problems at times	Mitigating disruption to motorists, maintaining traffic flow and minimizing capacity-reducing incident time
San Antonio, TX	Unfamiliar agencies dealing with each other during a major HAZMAT spill	No problems	No problems	Expedite emergency care, use cameras and communication equipment to assist administrators, minimize number of closed lanes and get advanced warnings and information to drivers

INCIDENT MANAGEMENT PLAN FINDINGS

Contact List

A contact list is one of the most important items contained in a major incident management plan. The list should be updated frequently. This can easily be accomplished by providing the contact information for the person who updates the plan. There should be a table of contents for easy reference with the contacts listed in alphabetical order for each section. A sample listing of agencies that might be included in a plan can be found in Table 6. The contact list should contain the following information (*28*):

- Office, home and mobile telephone numbers;
- Emergency 24-hour numbers;
- Pager numbers;
- Fax numbers;
- Physical address;
- Email address;
- Statement of responsibilities, and
- Coverage area for that contact.

Table 6. Sample List of Contacts (*29*)

Police • State Police • County Police • City Police • Local Police • Transit Police	**Local and State Agencies** • Health • Agriculture • Air Control • Pollution Control	**News Media** • Radio Station • Television Stations • Newspapers • Internet Sites	**Towing and Road Service** • Tow Truck Operators • Gas Stations • Garages • Service Patrol • Highway Authority
Special Hazard Teams • Chemical • Mechanical • Electrical • Radioactive • Biological • Ordinance Disposal	**Highway Department** • Engineering • Maintenance • Cleanup • Traffic Management Center • Tollway Authority • Traffic Management Team	**Fire/Rescue** • State • City • County • Volunteer • Airport • Military • Industrial	**Emergency Medical Services** • Coroner • Red Cross • Helicopters • Emergency Room • Rescue Squads • Ambulance
Utilities • Telephone • Gas • Water • Sewer • Cable • Electric • Oil • Pipeline Companies	**Federal Agencies** • Nuclear Regulatory Commission • Federal Aviation Administration • Department of Defense • Federal Emergency Management Association • Postal Service • Department of Agriculture • U.S. Public Health Service • Environmental Protection Agency	**Other** • National Guard and Reserve Units • Crash Investigation Teams • Military Personnel • Railroads • Weather Bureau • Scuba Divers • Water Authorities • Game Warden • Humane Society • Animal Control • Coast Guard	**Special Vehicle & Equipment** • Cranes • Tanker Truck • Oversized Wreckers • Livestock Trailers • Trucking Companies • Local Transit Service • Earthmoving Equipment • Crash Cushions /Air Bags

List of Available Emergency Equipment

An up-to-date inventory and quantity list of emergency equipment along with the location and contact information of this equipment is a very important part of any written incident management plan. A sample list of emergency equipment can be found in Table 7. This list can either be an inventory list of equipment maintained by a single organization (i.e. State DOT maintenance shop), or it can be a list of available equipment from all parties involved with incident management (i.e. Motorist assistance vehicles, fire/rescue units, HAZMAT companies, towing companies, heavy equipment companies). Certain pieces of equipment may be stored on the response vehicles themselves to save time during an incident.

Table 7. Sample List of Emergency Equipment (28,29)

• Air Bags/Cushions • Air Compressor • ARC Welder • Arrow Board • Backpack Air Blower • Broom • Cellular Telephone • Chain Saw • Concrete/Asphalt Saw • Concrete Safety Barrier Grip • Concrete Wheel Saw • Coveralls • Crawler Loader • Fire Extinguishers • First-aid Kits • Flares • Flashlights • Flat Bed Truck	• Flood Lights • Fork Lift • Fuel Tank Sealant • Generator • Hard Hats • High Volume Pumps • Heavy Duty Dump Truck • Heavy Duty Tandem Truck • Hydraulic Crane Truck • Loader • Loader/Backhoe • Magnetic Road Sweeper • Marking Paint • Medium Duty Dump Truck • Medium Duty Stake Bed Truck • Message Board • Mobile Crash Attenuator • Motorgrader	• Portable Sign Trailer • Radio • Shovel • Skid Loader • Snow Loader • Street Flusher • Street Sweeper • Sweeper/Vacuum • Tilt Bed Tandem Dump Truck • Tilt Top Trailer • Traffic Cones • Traffic Vests • Trailer • Trash Cans (full of absorbent, sand and white foam pads) • Water Pump

Incident Classification Scheme

In order to assist agencies communicate better, there has to be a common classification of major incidents. This will help responding agencies determine the appropriate level of response needed. If there is not enough response to an incident, it may delay the clearing of the freeway. If the level of response is too great, there may be too many people on the scene and they may end up getting in each others way or pulling important resources away from other duties. This can also contribute to secondary accidents from "rubber-neckers" gawking at a large number of emergency vehicles on the scene. Table 8 provides a great example of an incident classification scheme.

Table 8. Example of an Incident Classification Scheme (29)

	Incident Classification				
	Level I	Level II	Level III	Level IV	Level V
Types of Incidents	Vehicle stall on shoulder	Vehicle stall in travel lane	Minor accident (no injuries) Minor load spill	Serious accident (potential injuries) Spilled load (possible hazardous materials)	Serious accident (with major injuries) Hazardous material spill Several vehicles on fire
Anticipated Duration of Lane Blockage	None	0-30 minutes	30-60 minutes	60-120 minutes	>120 minutes
Type of Response Activities	Motorist assistance	Motorist assistance with minimal on-site traffic control	Police assistance with on-site traffic control Possible implementation of traffic diversion strategies Debris removal	Police assistance with extensive on-site traffic control Fire department response HAZMAT response Traffic diversion strategies Debris removal	Police assistance with extensive on-site traffic control Fire department response HAZMAT response Traffic diversion strategies Neighborhood evacuation Debris removal

GUIDELINES FOR A MAJOR INCIDENT MANAGEMENT PLAN

An important objective of an incident management manual is it has to be easy to use. It should be clear and concise without a lot of jargon that may not be understood by all agencies. The manual should be reviewed and updated frequently. Training exercises involving all agencies should be conducted on a regular basis. An after action review should also take place following a major incident to review what went right and what did not go so well. Frequent meetings should be held with representatives from all the agencies involved with incident management.

Every location that is creating a major incident response plan will have to evaluate what the local agencies want to have included in their written plan. Getting upper level management, politicians and policy makers involved from the beginning stages of an incident management plan is very important because every agency within a metropolitan area has a different set of needs and goals they want to accomplish. Items a good incident management plan should include are:

- Objectives, goals and purpose of the incident management program;
- Procedures for incident response (both on and off-scene);
- Interagency responsibilities and agreements;
- Joint operational policy statements;
- Communications procedures;
- Listing of approved detour/alternate routes;
- Information on how to keep the public informed;
- Listing of all the agencies involved including their role, responsibility, and jurisdiction;
- Updated contact list;
- Training program;
- Incident classification scheme;
- Emergency equipment list;
- Incident management team procedures;
- Definitions, acronyms and abbreviations;
- Highway maps;
- Review process and updating schedule; and
- Emergency plans.

Many agencies including law enforcement, fire/rescue units, transit agencies and local governments may have already documented or created many of these items listed above. Police and fire agencies often have similar agency plans for a variety of incident types and often do not combine the plans or coordinate efforts. Their plans are usually directed at specific types of large and unusual incidents such as HAZMAT spills, hurricanes, planes crashes, etc.(*30*) If this is the case, they need to be consolidated and shared between all the agencies involved with incident management.

SAMPLE APPLICATION OF PROPOSED GUIDELINES

Dallas/Fort Worth Area

The Dallas/Forth Worth area does not have a written major incident management plan in place nor is it planning to have one anytime if the near future. The main reason that was given during the surveys for not having a formal written plan in place is due to the large number of municipalities in the Dallas/Fort Worth Metroplex. With two very large cities in such close proximity to one another and all the associated smaller cities and suburbs surrounding them, the Dallas/Fort Worth Metroplex is a very large urbanized region (Figure 3). The Dallas/Fort Worth area is anticipating to continue the recent trend of rapid growth over the next 25 years. The population for the Metropolitan area is projected to grow by 44 percent during this time. With four major interstate highways (I-20, I-30, I-35 and I-45) running through the area and the recent increase in truck traffic due to the North America Free Trade Agreement (NAFTA), the number of major incidents occurring in the region are certain to increase in the coming years. There are 151,300 accidents that already occur in the Dallas/Fort Worth area annually (*1*). It is imperative for this area to develop and implement a formal major incident management plan as soon as possible.

Presently, parts of the City of Dallas that are in the Fort Worth TxDOT district and parts of the City of Fort Worth that are in the Dallas TxDOT district. This is just one example of how difficult a problem the above scenario is going to be to solve. The different jurisdictions may be willing to talk to one another and cooperate on certain issues, but there is not a single agency, besides the State of Texas that is over all of these communities and jurisdictions. There is a need for a champion consisting of a single agency that all of the communities in the area are a part of in order to work towards a common goal. This champion is the North Central Texas Council of Governments (NCTCOG).

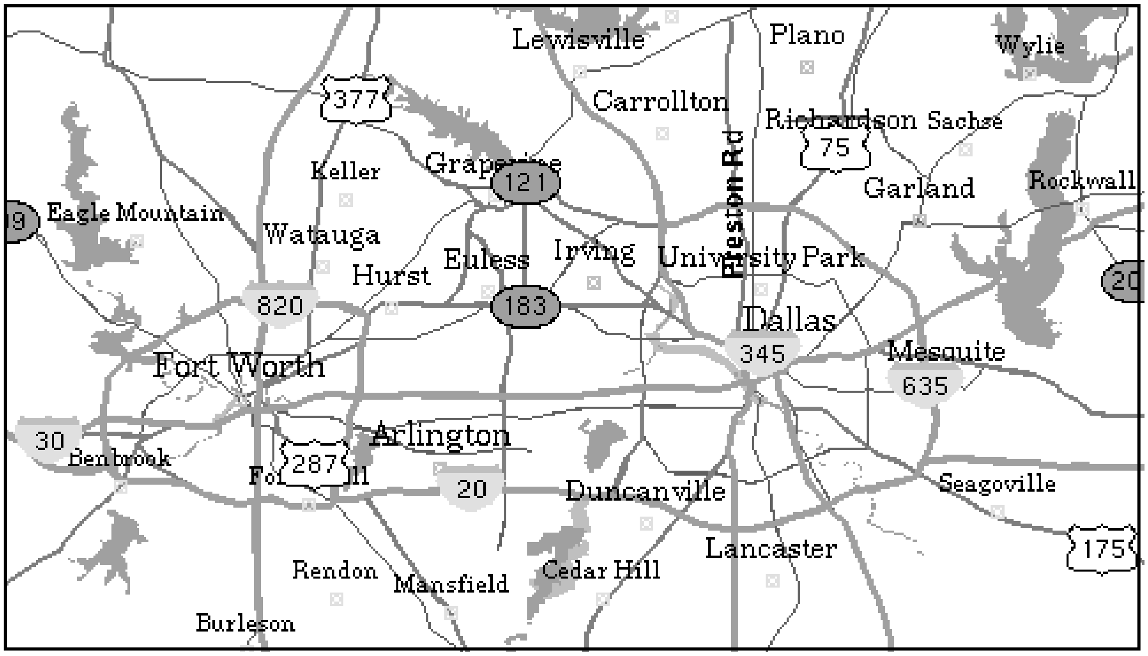

Figure 3. Map of the Dallas/Fort Worth Metroplex (*31*)

North Central Texas Council of Governments (NCTCOG)

The North Central Texas Council of Governments (NCTCOG) is a voluntary association of local governments within the 16-county North Central Texas region. The agency was established in 1966 to assist local governments in planning for common need, cooperating for mutual benefit, and coordinating for sound regional development. North Central Texas is a sixteen-county region with a population of 4.2 million and an area of approximately 12,800 square miles. NCTCOG has 231 member governments, including all 16 counties, 163 cities, 26 independent school districts, and 26 special districts. Since 1974, NCTCOG has served as the Metropolitan Planning Organization (MPO) for transportation in the Dallas-Fort Worth Metropolitan Area. The Regional Transportation Council is the policy body for the Metropolitan Planning Organization. The Regional Transportation Council consists of 35 members, predominantly local elected officials, overseeing the regional transportation planning process (*1*).

There is a huge advantage by having the Regional Transportation Council consist primarily of local mayors, city councilmen and county judges from the Dallas/Fort Worth area. It makes it possible to have this organization spearhead a plan to bring all of these local governments together to develop a major incident management plan for the entire region. As long as this organization has the common goal of reducing congestion and clearing incidents faster, it will be possible to get all the agencies together so that a common plan can be created for the entire region.

Cooperation, Coordination and Communication

Cooperation, coordination, and communication are the three most difficult obstacles to overcome before a plan can be developed. The agencies involved with incident management have to be able to get together on a regular basis and decide how this plan will be carried out. Cooperation is needed to overcome the personality conflicts that will develop. The local governments in this region are going to have to allow outside agencies to assist them during a crisis, yet they will be asked to return this assistance if the outside agencies need help handling a crisis.

The coordination problem can be solved by getting together on a regular basis, having a formal written document that everyone will agree with and live by, and selecting key personnel to lead the organization. As long as everyone has a copy of the plan, everyone will know what is expected of them, and they will know what to expect from the other agencies and governments. There will no doubt be a lot of issues that will need to be worked out, but as long as everyone works together as a team and not against each other, it will be possible to overcome the problem of coordination.

Communication will be another obstacle that will need to be overcome. There will most likely need to be some sort of communication network that will need to be developed to allow all the agencies the ability to talk to one another during an incident. Whether it is by cell phone or two-way radio, a common method of talking between agencies is critical. There also has to be a common method of verbal communication between agencies. It is important that a common incident classification scheme be developed so that agencies can talk to one another in a common language and still know what is going on and what level of response is needed. The three obstacles listed previously will be difficult to overcome.

Training will need to be conducted on a regular basis on all levels. It is important to conduct training not only within an organization, but also between organizations. Let the traffic engineers and operators ride with the police and fire department for a few hours to get their perspective on incident management. Also, let emergency services personnel and enforcement personnel come to the traffic management center so they can have a better understanding of the situations the traffic operators are facing daily (*32*). As long as people work together as a team with the common goal of clearing the incident and getting the traffic flowing as quickly as possible, this plan can be a great success not only for this region, but as an example for other locations around the country as well.

Formation of an Incident Response Team

The formation of an incident response team can greatly help agencies coordinate the fast arrival and recovery of an incident scene. Officials from the California Department of Transportation (CALTRANS) estimate a delay savings of approximately 500 vehicle-hours for each major incident and a reduction of one secondary crash for every two incidents in which response teams are used. The incident response team approach is credited with resulting in the key players arriving at the scene of an incident in a shorter amount of time (*33*). This incident response team does not have to be deployed with every major incident. Their response can be a set to a level from the incident classification scheme.

Tow Trucks and Heavy Equipment

Agreements with tow truck operators to respond to an incident in a freeway corridor can significantly reduce response time and clearance times for incidents requiring the use of a tow truck. All of these tow truck operators must respond within a target response time that is not be exceeded (*34*). The tow trucks should be able to respond 24-hours a day, seven days a week. If a rotation system is used to select the towing company, then all of these companies should be able to provide the necessary equipment. If it is common practice for the wrecker service to furnish inflatable air bag systems to lift a truck that has overturned, then all the wrecker services should be ready to deploy those systems if needed. Otherwise, there may be the possibility of the wrecker showing up at the scene without the proper equipment that is needed. If this happens often, there should be a process in place to remove that wrecker service from the rotation list. The wrecker service should have heavy wreckers large enough to tow a large truck like the one in Figure 4.

Another option may be to have a single public agency provide relocation service to avoid the hassle of dealing with private towing companies. This public agency could have the tow trucks and other heavy equipment available at a moments notice to relocate any vehicle, truck or spilled load off of the highway. It would then be possible for a typical wrecker service to come in and tow the vehicle away once it is cleared from the highway.

Figure 4. Use of a Heavy Tow Truck Clearing a Major Incident (3)

It is important that this incident management plan contains contact information for heavy equipment operators. Heavy equipment such as cranes (Figure 5), sweepers, dump trucks and front end loads are crucial to clearing a scene when a major incident occurs. These companies or agencies must be ready to respond very quickly since the use of this equipment usually means that a large load has been spilled or a large truck may be blocking many lanes.

Figure 5. Use of a Heavy Crane Clearing a Major Incident (3)

LESSONS LEARNED

There were numerous lessons learned throughout this research report. Some of the management plans that were reviewed dealt heavily with one or two topics such as rerouting of traffic and congestion management, but did not address other incident management topics such as how agencies coordinated and cooperated with each another to clear a major incident scene. A lot of law enforcement agencies are unfamiliar with the level of technology that some of the larger traffic management centers have and are not taking full advantage of using this technology to help them deal with major accidents on the highway.

The lack of an open channel for communications is one of the main obstacles that will need to be overcome. This goes beyond the issue of different equipment and frequencies, but instead addresses the need for agencies to actually sit down together and talk about incident management and the role each agency plays. These meetings need to take place regularly and should focus on improving the overall incident management plan for the community.

Another lesson learned was the importance of getting upper level personnel involved with the creation of an incident management plan at the very beginning. By addressing the needs of the influential politicians, policy makers and other top-level decision makers, it will be easier to get approval and funding for the major incident management plan.

The survey contained in Appendix A could have been reworded differently to provoke more detailed responses to some of the questions that were asked. Some of the survey responses contained one word responses like "yes" or "no" which were not very helpful responses. This is especially true of the questions asking if there had been any difficulties with coordination, cooperation and communication. The questions could have been changed to read "What challenges have there been with coordination, cooperation and communication between agencies."

CONCLUSIONS

The guidelines that have been developed in this report for a major incident management plan are just guidelines. It is nearly impossible to develop a set plan for every agency that covers everything they might have to deal with. Every agency that handles incident management has its own unique set of circumstances and every incident has its own unique characteristics. By developing a major incident management plan, it is possible to get all the agencies following the same set of guidelines and standards. This plan will also help foster better communication between these agencies. Without good communication, confusion at the scene and congestion on the highway are the unpleasant results. Good cooperation and coordination are attributes that every agency in the world should strive for. An incident management program can not be successful unless there is a cooperative attitude among the agencies involved. The positive working relationship among traffic engineering, maintenance, emergency services and enforcement is critical (*35*).

The success of an incident management team starts with the selection of responsible and responsive members. Members should represent the agencies associated with the transportation facility and include those with authority to make decisions and commit their agencies to a course of action. An important part of this team is the ability to get together before an emergency and plan how each of the agencies can coordinate its work with that of the other members of the team. It is also necessary that this team establishes basic objectives, which typically include:

- Minimize delay associated with freeway incidents by reducing detection, verification, response and clearance times;
- Minimize safety impact resulting from incidents;
- Expedite emergency care;
- Provide management of personnel and traffic at the scene; and
- Provide information to the public (*35*).

Further research into the implementation and analysis of the benefits of a major incident management plan are needed. By examining the response and clearance times of major incidents before and after the implementation of a major incident management plan would be of great interest to any agency contemplating the creation of such a plan. A cost-benefit analysis of such a plan would also be a good topic for future research.

ACKNOWLEDGEMENTS

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- Michael Ogden, Klotz Associates, Inc., Houston, TX
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- Joseph Snyder, Houston TranStar, Texas Department of Transportation
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- Carol Walters, Texas Transportation Institute, Arlington Office
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APPENDIX A: MAJOR INCIDENT MANAGEMENT PLAN SURVEY

The purpose of this survey is to determine the current state of major incident management plans around the country. This information will be used for a research paper that is being prepared for the summer graduate course *Advanced Surface Transportation Systems* at Texas A&M University. The information gathered for this research paper will be used to develop a set of guidelines for the creation or improvement of a major incident management plan that can be used by any agency that deals with major incidents on the highway. If you have questions or additional comments please contact Sean P. Merrell via email: s-merrell@ttimail.tamu.edu or by phone: (979) 862-7253.

Please complete and return to Sean P. Merrell by Fax (979) 845-9873 on or before **July 8, 2001**.

If return by Fax is not possible, please mail to:

Sean P. Merrell
Texas Transportation Institute
Texas A&M University System
3135 TAMU
College Station, TX 77843-3135

Agency:

Contact:

Address:

Phone: ( ) Fax: ( ) Email:

1. Do you currently have a Major Incident Response Management Plan in place?
2. If yes, may I obtain a copy of it?
3. If no, what is the reason for not having a plan in place?
4. What is currently contained in your plan?
5. What is important to you and your agency in regards to incident management?
6. What other issues do you believe this plan should cover that might not be there now?
7. How often are your plans reviewed and updated?
8. Are training exercises conducted to determine if these plans are adequate and up to date?
9. What other agencies do you work with in regards to major incident?
10. Have there been any difficulties with coordination between agencies?
11. Have there been any difficulties with communication between agencies?
12. Have there been any difficulties with cooperation between agencies?
13. How often has your Major Incident Response Plan been implemented?
14. How long has this plan been in place/when will you have one in place?
15. Do you have any other comments or concerns about Major Incident Response Plans?
16. Would you like a copy of this research upon completion?

SEAN P. MERRELL

Sean P. Merrell received his Bachelor of Science degree in Civil Engineering at Texas A&M University in December 2000. After serving in the U.S. Army for six years, Sean decided to return to college. As an undergraduate, he spent four semesters working at the Texas Transportation Institute (TTI) as an undergraduate student researcher and also participated in the Summer Undergraduate Transportation Engineering Fellows Program. Sean has also interned with the Metropolitan Transit Authority of Harris County (METRO).

He is currently pursuing a Master of Engineering degree in Civil Engineering at Texas A&M University. He is currently employed as a Graduate Research Assistant at TTI in the TransLink Research Center. Sean has been active in numerous student organizations including the Texas A&M student chapter of the Institute of Transportation Engineers, where is he is currently serving as Public Relations Director, and the American Society of Civil Engineers (ASCE) where he is currently the graduate advisor for the student chapter. As an undergraduate student he served as the President of both the Chi Epsilon National Civil Engineering Honor Society and the ASCE Student Chapter. Sean is the recipient of the D.C. Greer Highway Engineering Scholarship. Sean's career interests include traffic operations, transportation planning, and intelligent transportation systems.

COORDINATING SCHEDULED WORK ZONES ON URBAN FREEWAYS

by

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SUMMARY

In urban areas across the country, freeways are aging requiring extensive maintenance activities. Many of these freeways have such high average daily traffic that maintenance work zones create significant problems (*1*). Three problems are encountered in planning and operation of work-zone activities. These problems are (*2*):

- Optimum time to perform the work;
- Measures to take to warn the public; and
- Alternative means to protect the highway workers from errant motorists.

Utilizing the road type categories and restricting the motoring public's delay to 30 minutes or less, the optimum time for lane restrictions can be determined. (*2*). Advanced signing and media notifications are measures utilized to warn the public of lane restrictions. Traffic control plan approval prior to implementing the lane restriction and police presence at the work zone are means to protect the workers in the work zone.

These problems are compounded if concurrent lane closures on nearby sections of the freeway are allowed according the FHWA Core Business Unit web-site (*3*).

Through the survey responses and the literature review, various components have been identified as effective. These components would be significant to other agencies that are developing a procedure to coordinate scheduled work zones. These components are: permitting process, public notification, and, work zone safety.

With these components in mind, guidelines for coordinating scheduled work zones were developed. The guidelines developed appear below:

- Define the agency's role
- Define Work Zone Parameters
- Establish interagency cooperation prior to implementing procedure

These guidelines and components were utilized to develop a procedure for the Illinois Department of Transportation – District 8.

TABLE OF CONTENTS

INTRODUCTION

Effective management of a transportation system is a goal or an objective of all agencies that are responsible for the roadways that make up the system. In most metropolitan areas, the roadways are aging quicker than repairs or reconstruction can be completed. To compound the problem, the number of vehicles that utilize the roadway continue to increase. Most repair work requires lane reductions or lane restrictions that can adversely effect the flow of traffic. To ensure that lane reductions or lane restrictions are not conflicting; the agency with jurisdiction over the roadway should coordinate these work zones.

With the increased use of the Internet and electronic devices, the public's expectation of the information provided to them is rising. If a transportation agency can not provide accurate and reliable traffic information, the agency loses credibility and the public's trust. Coordinating work zones and verifying that the work zones actually takes place will allow transportation agencies to provide better information to the public.

District 8 of the Illinois Department of Transportation is located east of St. Louis, Missouri and is bounded by the Mississippi River. Within District 8 there are three counties that are experiencing tremendous population growth due to urban sprawl with four bridges that connect Illinois and Missouri in the bi-state metropolitan area. These bridges carry the majority of the commuter traffic during the peak periods. Presently, the district traffic operations engineer is responsible for coordinating scheduled lane restrictions and does not have a procedure to coordinate scheduled work zones. There is a need to establish and develop a procedure for District 8 to coordinate scheduled work zones for more effective transportation management.

Research Objectives

The overall goal of this research is to develop a procedure to coordinate scheduled work zones on the interstate system within District 8 of the Illinois Department of Transportation. The specific objectives of this research were to:

- Determine what procedures other state transportation agencies are utilizing to coordinate scheduled work zones;
- Determine the positive and negative attributes other state transportation agencies have experienced when implementing procedures of this nature;
- Develop a procedure that will be useful and effective and will minimize the impacts on through traffic; and
- Deploy this procedure in District 8 and evaluate a means to maximize the effectiveness and usefulness of the procedure.

Scope

This research was limited to developing a procedure to coordinate scheduled work zones on urban freeways. Due to time restraints, this research did not include arterials.

STUDY DESIGN

The process followed in developing a procedure to coordinate scheduled work zones encompassed 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 coordinating work zones was conducted to determine procedures that are being utilized by other state departments of transportation and local highway agencies. Identifying effective components of these procedures was also an objective of this review. The Minnesota Department of Transportation Maintenance/Construction Lane Closure Manual was reviewed. There was some difficulty in locating literature on this topic since most departments of transportation do not publish the procedures they utilize.

Survey State Departments of Transportation and Local Highway Agencies

To expand on the literature reviewed, an e-mail survey was developed and conducted. Responses were received from four agencies that have procedures in place that are utilized to coordinate scheduled work zones. These agencies included: District 1 of the Illinois Department of Transportation, District 7 of the California Department of Transportation, District 6 of the Kentucky Transportation Cabinet, and the city of St. Peters, Missouri. Additional agencies were contacted, but due to time constraints they were not able to complete the survey. A detailed contact list including names and telephone numbers is available in the Appendix of this report, in addition, a copy of the questionnaire used in the e-mail survey.

Development of Procedures

The data collected from this survey and the literature are the basis for developing the procedure to coordinate scheduled work zones. This procedure can be utilized to coordinate work zones on freeways throughout the country.

Application of Findings

For more effective management of the urban freeways in District 8 of the Illinois Department of Transportation, the procedure that was developed from the literature and survey were then applied to the district

BACKGROUND

In urban areas across the country, freeways are aging and requiring extensive maintenance activities. Many of these freeways have such high average daily traffic that maintenance work zones create significant problems (*1*). Three problems are encountered in planning and operation of work-zone activities. These problems are (*2*):

- Optimum time to perform the work;
- Measures to take to warn the public; and
- Alternative means to protect the highway workers from errant motorists.

Traffic congestion is compounded if concurrent lane closures on nearby sections of the freeway are allowed (*3*).

To reduce impacts on traffic, categorizing road types and restricting the motoring public's delay to 30 minutes or less, the optimum time for lane restrictions can be determined. (*2*). Advanced signing and media notifications are measures utilized to warn the public of work zones. Traffic control plan approval prior to implementing the work zone and police presence at the work zone are means to protect the workers in the work zone.

LITERATURE FINDINGS

Minnesota Department of Transportation – Metro Division

The Minnesota Department of Transportation prepares a Maintenance/Construction Lane Closure Manual on a semi-annual basis (*4*). The manual contains traffic volumes for all major roadways in the 8 county metropolitan area surrounding and including Minneapolis and St. Paul. The traffic volumes are collected from loop detectors. As long as maintenance activities meet the parameters set in the manual, the work zone can be deployed without contacting the Division Traffic Control Engineer. If a work zone is required to be implemented when lane restrictions are not allowable according to the manual, then the Division Traffic Control Engineer must be contacted and a solution is determined.

SURVEY RESPONSE

District 1 of the Illinois Department of Transportation – Chicago

District 1 of the Illinois Department of Transportation (*5*) in Chicago requires a permit approval for work zones that include freeway shoulder or freeway lanes. The permit process is administered by the District's Bureau of Traffic Expressway Operations. On average, the bureau reviews and approves 40 applications a day. In addition to the permit process, the District's Bureau of Traffic Expressway Operations also recommends traffic control for the work zone. All applicants, which includes bureaus within IDOT and outside agencies, are required to fax or call their request for closures on a daily basis. Applicants are given priority on a first come first serve basis and are only accepted two to three days in advance. However, the unwritten rule is emergency work is the first priority and then contractors who have a completion date. Time of day deadlines for submitting applications is dependent on the type of work being done.

The department has a special events schedule for all sporting events, concerts, and Lake Front events that may impact traffic patterns. Prior to approving a closure, the special event schedule is referenced to evaluate additional traffic impacts caused by a scheduled event. The allowable work zone hours are adjusted to accommodate traffic flow to and from the special event. Traffic impacts on adjoining routes are not taken into account. Consideration is given to traffic impacts on alternate routes for major projects. There are also attempts made to combine as many different work zones as possible.

The department does not have a formal verification process that the work zone activities actually occur. If the work does not get done, the contractor is required to receive approval again. The freeway service patrol is given a list of closures for the day and each driver verifies that the lane restrictions are approved. If the lane restrictions are not approved, the freeway service patrol notifies the contractor that they have to open the lanes. The department sets the allowable work zone hours based on traffic volumes and the type of work that is proposed. The freeway service patrol also monitors and enforces the allowable work zone hours. If the contractor does not cooperate with the freeway service patrol, then Illinois State Police is notified. Traffic reporters also monitor these closures. If a work zone is causing a traffic problem, the traffic reporters contact the department.

All work zones are approved conditionally that weather will permit them. The contractor or the resident engineer is responsible for determining if the work zone should be implemented. It is specifically stated in the department's special provisions, the work zone should not be set up during inclement weather. However, if the work zone is in place and inclement weather moves in, the work zone does not have to be removed unless there are adverse impacts to traffic. The safety of the motorists and the workers removing the work zone are taken into account prior to deciding to remove the closure.

If an incident occurs within the work zone and the lane can be safely opened to traffic, the work crew is asked to remove the work zone. If they are slow to respond, the freeway service patrol adjusts or moves the traffic control devices. If an emergency work zone is required, then the Traffic Expressway's Operations section is immediately notified for approval. If the emergency work zone conflicts with a scheduled work zone, the appropriate personnel is notified that the approved closure is cancelled.

Procedures outlining scheduling work zones are annually sent to the district's maintenance yards. Special provisions regarding work zones are included in all construction projects and permits. The procedures utilized are routinely evaluated. A list of approved work zones is sent daily to the media, traffic control companies, and local agencies. Press releases are utilized for weekend projects or changes to traffic patterns in an existing work zone. Work zone information can also be obtained from the Gary-Chicago-Milwaukee Corridor web-site, www.gcm.travelinfo.org.

District 7 of the California Department of Transportation –Los Angeles

District 7 of the California Department of Transportation (CalTrans) requires a permit for all work zones (*6*). Permits are submitted electronically to the Office District Traffic Manager – Traffic Manager Unit for approval. The Office District Traffic Manager – Traffic Manger Unit provides approval and coordination of the work zones, and sometimes provides guidance on traffic control for the work zone. It also categorizes applicants into construction, permits, or maintenance. Priorities for the work zones are set assuming that the application is submitted in a timely manner. Construction has the first priority, then permits, and then maintenance. The deadline for submitting an application is no later than noon on Tuesday for the upcoming workweek. CalTrans has designated the workweek as Friday noon to Friday noon. Applications that are not submitted within this timeframe are accepted as long as they are submitted 3 days prior to the day of the work. At times the long advanced notice can be an impediment because a shorter notification provides a more accurate idea of the location of the work zone and the traffic impacts. It should be noted that priority is given to the applicant that meets the application deadline no matter what category of work is being performed.

CalTrans District 7 also utilizes applicant categories mentioned previously to evaluate the impact of the work zone on traffic. For construction projects, hourly traffic charts and tables are provided within the contract. All construction and permits projects are based on zero delay with a few exceptions like slab replacement or paving projects. These types of projects have built in delays for the curing or setting process. For maintenance activities, charts have been developed which incorporate 15-minute delay. District 7 allows a delay of 15 minutes for planned maintenance activities. It should be noted that all charts are created based on traffic counts that are obtained from loop detectors and all charts include time intervals during the day that work zones are restricted.

Traffic impacts to adjoining routes are also taken into consideration. The district is divided into three areas. Each area is assigned an area coordinator who is responsible for reviewing the work zones and evaluating the impacts to adjoining routes. Work zones can be removed prior to the completion of the work if it is safe to remove the traffic control devices. For construction projects where slabs are being replaced, the contractor is required to have a contingency plan. This contingency plan would require the contractor to have enough temporary structural material available to fill the void in the event they are instructed to remove the closure. Emergency or unscheduled work takes precedence over all planned activities especially if safety is an issue.

When an incident occurs within a work zone, for the most part the applicants will remove the work zone on their own. If not, the district's office has the authority to remove all on-going activities. Work zone permits can also be cancelled in advance electronically through the district's system. The applicant can also contact the Transportation Management Center to cancel the work zone. The cancellation time is entered into the district's system. When work zones are cancelled due to inclement weather, they are rescheduled for the next day. Work zones cancelled due to incidents are rescheduled for the next day provided there are no conflicts with other preplanned activities.

All work zones that are approved require a start and end time or if the work zone has been cancelled a cancellation time. These times are utilized to verify that the work zone was implemented. Other means the district monitors the work zone activities follows:

- Closed circuit television cameras;
- Motorists; and
- Vehicle detectors.

Motorists are listed as a means of monitoring work zone activities because they contact CalTrans if the traffic queues are lengthy or if a work zone is deployed at an unusual time of day, i.e. during rush hour. Since the district has vehicle detectors and closed circuit televisions throughout the district, CalTrans can monitor traffic conditions closely. Therefore, unapproved work zones rarely occur. However, when they do, the applicant performing the work will be instructed to remove the work zone either by the district or by the Transportation Management Center. All work zones within the district are displayed on the web-site, www.dot.ca.gov/dist07/laneclosures.

District 6 of the Kentucky Transportation Cabinet –Covington

The Kentucky Transportation Cabinet requires a permit for any work zone for all agencies other than the Kentucky Transportation Cabinet (7). The permit requires coordinating the applicant's work zone with any active maintenance or construction work zones. The permit also approves traffic control for the proposed work zone. The applicant submits an application to the district permit section, which is part of the district's traffic branch. If the work zone is proposed to be in an existing construction or maintenance operation, then the appropriate section approves the permit. Work zones for construction or maintenance activities are given first priority. The district is divided into section with an engineer designated to be in charge of that section. The engineer in charge then assigns priority to other work zone applicants. The engineer in charge also reviews traffic impacts, which may have a bearing on the approval process.

Time intervals during the day that work zones are restricted are implemented on a case by case basis and are up to the engineer in charge. The engineer in charge coordinates emergency or unscheduled work zones and coordinating concurrent scheduled work zones. If an incident occurs, the agency that implemented the work zone is responsible for removing the traffic control devices. The permit allows the Department to cancel or postpone any work zone when a conflict arises that can not be coordinated. The engineer in charge is also responsible for evaluating impacts of weather conditions on the work zone. Road condition reports informing the public of impacts on traffic are provided to the media weekly and updated daily if necessary.

St. Peters, Missouri – Traffic Department

The city of St. Peters, Missouri utilizes a permit process to coordinate scheduled work zones (8). The director of engineering administers this permitting process. Permits are approved if they meet the traffic control requirements in the Manual of Uniform Traffic Control Devices. All in-house crews and agencies outside of the city are required to submit an application. The city does not have a deadline for submitting an application and priority is given on a first come first serve basis. Time restrictions for work zones are utilized to reduce traffic impacts. To evaluate the impacts that trucks hauling dirt have on traffic, the city requires that the hauling route be designated. Otherwise, traffic impacts on adjoining routes are not taken into consideration.

The city does not have a process to verify that work zone activities actually take place. When emergency work zones are required, the work is normally completed and a permit is completed after the fact. The crew performing the work is required to remove the work zone in case of an incident. The city does not have the opportunity to combine work zones very often. When the city is notified that a work zone exceeds the allotted time, they investigate and notify the crew that it should be removed. If an unapproved work zone is encountered, the city contacts the crew and requires them to obtain a permit.

The city has encountered political obstacles in deploying the permitting process, which has at times made it difficult to be fair and consistent during the approval process. The city recommends that having an adequate number of inspectors to enforce the Manual on Uniform Traffic Control Devices requirements is essential. The city does not currently share work zone information with the public. However, they are working on upgrading their web-site to include this information.

DEVELOPMENT OF PROCEDURE TO COORDINATE SCHEDULED WORK ZONES

Identification of Effective Practices

Through the survey responses and the literature review, various components have been identified as effective. These components would be significant to other agencies that are developing a procedure to coordinate scheduled work zones. The following section identifies and explains these components.

Table 1 summarizes the effective practices utilized by the survey respondents for coordinating scheduled work zones.

Permitting Process

Agencies that issue permits have more control and knowledge of the work zones that are implemented on their freeway system than agencies that utilize a clearinghouse process. The clearinghouse process allows the agency to have neither authority nor responsibility to approve or reject a work zone. The clearinghouse process is a focal point through which all proposed work zones are funneled in advance of deployment so that conflicting work zones can be identified and brought to the attention of the appropriate agency regulating the work zones. The clearinghouse process is also a means to provide the media and public the scheduled for work zones (*9*).

The work zone permits are reviewed and approved by highly qualified personnel who are familiar with the impacts that work zones will have on the freeway system. This process also allows the agency to determine the following:

- Application deadlines;
- Work zone priorities;
- Applicants – who is required to submit an application for work zone approval;
- Lane closure requirements;
- Work zone time restrictions;
- Special event requirements;
- Weather conditions; and
- Incident management within the work zone.

Public Notification

To lessen the impact on traffic, the public should be notified of the proposed work zones. Informing the public will allow motorists to make informed decisions about their trip planning for the day and possibly

Table 1. Effective Practices

	Effective Practices		
Agency	**Issue Permit**	**Public Notification**	**Work Zone Safety**
Illinois Department of Transportation – District 1	Yes	Media, Web-site, Highway Advisory Radio, Other Public Agencies	Regulate & Approve Traffic Control Devices
California Department of Transportation – District 7	Yes	Web-site	Provides Guidance on Traffic Control Devices
Kentucky Transportation Cabinet – District 6	Yes	Weekly Media Updates	Approves Traffic Control Devices
City of St. Peters – Traffic Department	Yes	Web-site (in future)	Approves Traffic Control Devices

reduce the amount of traffic travelling through the work zone. It is important that the information provided to the public is accurate and current. Otherwise, the agency providing the information will lose credibility. The public can be notified through any of the following means:

- Media;
- Highway advisory radio;
- Dynamic message signs;
- Advance work zone signing; and
- Internet.

Another means to get information to the motorists is through the use of automated phone call-in hotlines (*10*). In addition to notifying the public, local agencies whose daily operations could be impacted by the work zone should be notified. The Illinois Department of Transportation – District 1 sends daily work zones to the following agencies (*5*):

- Chicago Department of Transportation;
- Illinois State Police; and
- Illinois State Toll Highway Authority.

Work Zone Safety

All agencies surveyed stated that the work zone traffic control is required to at a minimum meet the Manual on Uniform Traffic Control standards. Many highway workers believe that they are safer when a queue of vehicles moves slowly through the work zone (*2*). However, when there is a queue of slow moving vehicles on a high-speed freeway, the likelihood that an accident occurs in the queue increases. Experience has shown that keeping the public informed the work zone that the public is more likely to be patient and less likely to harm the workers in the work zone (2). Utilizing this same train of thought, it can be assumed that coordinating scheduled work zones and approving the traffic control plan for the work zone should enable it to be implemented safely.

GUIDELINES FOR COORDINATING SCHEDULED WORK ZONES

Define the agency's role

The agency should define its role as either permitting or clearinghouse. A permitting role would give the agency the responsibility for approving the work zone, resolving conflicting work zones, and setting priorities. If the agency determines to have a permitting role, they can control the work zones that are implemented on the freeway system. A clearinghouse role would merely gather the work zone information and require the work zone-regulating agency resolve conflicting work zones.

Define Work Zone Parameters

No matter whether the agency chooses to have a permitting role or a clearinghouse role, the agency should select work zone parameters required to be met. Examples of parameters follow:

- Number of lane restrictions allowable on freeway section;
- Time of day restrictions for implementing lane restrictions;
- Type of work activities;
- Work zone priorities;
- Application deadlines;
- Identify applicants;
- Incident responsibility; and
- Verification responsibility.

Establish interagency cooperation prior to implementing procedure

Cooperation between in-house bureaus of the agency is required for this coordinating procedure to be successful. The agency should rely on personnel from different bureaus to verify that only approved work zones are implemented. Also, the agency should require bureaus within their agency to submit an application for scheduled work zones. If necessary, the agency will rely on the cooperation of the policing agency in the area to remove an unapproved work zone. The agency will also require the cooperation of other agencies that has the need to implement work zones on the agency's freeways to submit applications. In most instances, the agency will have jurisdiction on the freeways. However, the agency may not have jurisdiction on roadways that impact the traffic on the freeways.

CASE STUDY: IMPLEMENTING A PROCEDURE TO COORDINATE SCHEDULED WORK ZONES

Description of Existing Procedure

As stated in the introduction, District 8 of the Illinois Department of Transportation is located east of St. Louis, Missouri and is bounded by the Mississippi River. Interstates 55/70, 64, and 270 from the Mississippi River to Interstate 255 carry the majority of the commuter traffic during the peak periods. The Freeway Service Patrol also patrols and responds to motorists requesting aid via call boxes along these interstates. Figure 1 provides the 2000 Average Daily Traffic for the metropolitan area.

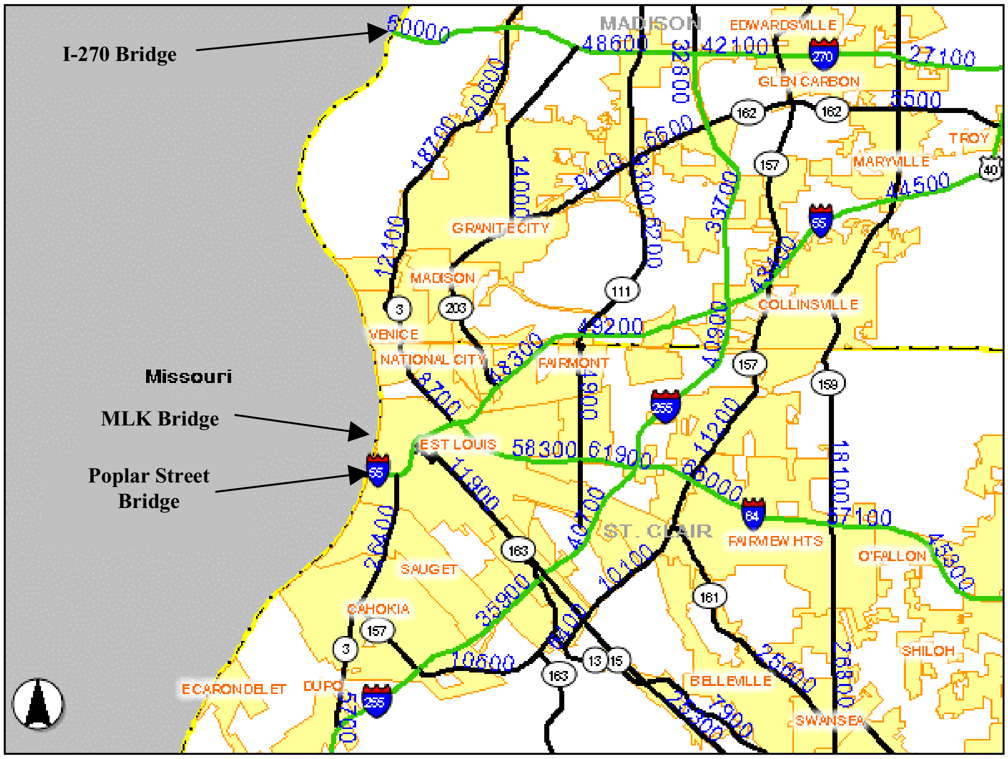

Figure 1. 2000 Average Daily Traffic

Presently, coordinating maintenance activities on the freeways within the district consists of contacting the District Traffic Operations Engineer. It is then the responsibility of the Traffic Operations Engineer to inform the appropriate personnel within the district to ensure that there will not be any work zones that conflict with other work zone. If there are conflicting work zones, the Traffic Operations Engineer is then required to coordinate the conflicting work zones and resolve the problem. If a resolution cannot be met, the District Operations Engineer and possibly the District Engineer will determine which work zone is more important. Besides coordinating work zones within the District, the Traffic Operations Engineer must also coordinate with the Missouri Department of Transportation and the city of St. Louis. The district is divided into section and an engineer is responsible for the maintenance or the construction activities in that section. The section engineer is responsible for notifying the media of the work zone.

The Department requires that traffic control authorization be given to all construction projects and utilities projects that include lane or shoulder closures. This authorization is utilized to approve the traffic control devices and the method utilized to close the lane or shoulder closure. To receive authorization, an application must be submitted prior to implementing the work zone. There is not a set deadline. The following information is required on the application:

- Route;
- Direction;
- Lanes effected;
- Location;
- Description of work being performed;
- Highway standards that are being followed;
- Emergency contacts; and
- Anticipated dates of work zone deployment.

The District's Traffic Control Supervisor and the Traffic Operations Engineer review the requests for authorization and the District's Operations Engineer approves them. Usually the applications merely state that the work will take place in the next month or the next couple weeks. There is no notification that the work zone is implemented or when. The District does not allow any temporary lane closures on weekdays for westbound traffic on the freeway prior to 9:00 a.m. and for eastbound on the freeway traffic after 3:00 p.m. on the freeways. The District has utilized lane rental and has required a minimum of two lanes of traffic remain open throughout the limits of freeway construction projects. When the district includes lane rental in a contract, the contractor is charged a set dollar amount per day for closing a lane within the construction project. The premise behind lane rental is to discourage the contractor from closing a lane and to minimize the length of the closure when it is necessary.

Maintenance crews are not required to receive authorization prior to deploying a work zone regardless if it requires lane closures. They are not required to receive approval because the crews are required to follow the Department's Work Site Protection Manual. When maintenance activities require lane or shoulder closures on the freeway system, a press release is issued to notify the public. The Bureau of Construction also issues press releases when a project begins. However, these press releases are generally vague and do not provide exact dates that the work zone is going to be implemented. All press releases are stored on a shared computer drive on the network that everyone in the district has access to.

Figure 2 is a picture of a traffic queue during a non-peak travel time in the St. Louis Metropolitan area due to two lanes being close in a work zone Area motorists experienced a 45 minute delay getting through the work zone.

Figure 2. St. Louis Metropolitan Traffic Queue in Work Zone

A future method to notify the public of these work zones is the regional Intelligent Transportation System (ITS) that is being deployed by the District and the Missouri Department of Transportation. This system will complement the existing Freeway Service Patrol and incident management equipment. This system will include the implementation of vehicle detectors, traffic surveillance cameras, and permanent dynamic message signs. It is anticipated that the first phase of this deployment will be operational by early 2002.

The District currently has a communications center that is utilized to dispatch and manage incidents. This center is operated 24 hours a day, 7 days a week.

The communication center is staffed with radio dispatchers that have recently starting utilizing computers to keep their daily logs. Due to budget constraints, additional personnel will not be hired as operators for the traffic operations center. Instead, these dispatchers will be utilized as operators for the traffic operations center. It is anticipated that these dispatchers will require extensive training to be able to properly respond to the information received from the traffic data collected by the ITS field devices.

Presently, the District utilizes portable message boards along the interstate freeways to inform motorists of lane closures caused by incidents or work zones. As previously stated the District Traffic Operations Engineer coordinates the work zones to ensure that work zones that conflict with one another are not scheduled. However, there is no verification procedure followed that ensures that these work zones actually occur. In addition to the lack of verification, another problem that occurs within the District is coordination with the Bureau of Construction. On several occasions, the Bureau of Construction is detouring traffic from their work zone to an interstate that has a work zone in place for maintenance activities.

Recommendations for District 8

The District needs a procedure that will coordinate scheduled work zones within the District. Specifically, this procedure should provide a means to ensure that work zones that conflict with one another are not scheduled, verify that scheduled work zones actually occur, and ensure that traffic will not be detoured from one work zone through another work zone. The procedure also must consider any work zone that has an impact on traffic on an interstate freeway, how to remove or cancel a work zone an incident occurs, and how to tie this procedure into existing traveler information sources.

Defining the Agency's Role

Based on the existing traffic control authorization process, the district should be in the permitting role. The Department has jurisdiction of the freeway system and is responsible for maintaining the flow of traffic on this system. Therefore, it should be the Department's responsibility to coordinate and restrict work zones.

Define Work Zone Parameters

As previously stated, the district has begun to utilize lane rental charges and require minimum number of lanes to remain open to traffic through a workzone. The district should segment the freeway system based on number of lanes and traffic volumes. Presently on weekdays, the district does not allow work zones on westbound freeways before 9:00 a.m. and after 3:00 p.m. on eastbound freeways. Utilizing these work zone time restrictions and minimizing the motorist's delay to 30 minutes, each segment of freeway should be analyzed to determine the number of lanes that are required to be open to traffic. This process should be reevaluated semi-annually and provided to work zone applicants. Presently, District 1 of the Illinois Department of Transportation utilizes a Microsoft Access database to coordinate work zones within their limits (*5*). District 8 should be able to modify the database that District 1 is utilizing to meet their needs.

The district also should consider the type of activities that will be deployed prior to approving a work zone. The district should prioritize the work zone activities in the following manner:

- Emergency work;
- Construction projects with a completion date;
- Maintenance activities;

- Consultants;
- Contractors;
- Utilities; and
- Other agencies.

Since work zones deployed on the shoulder have an impact on traffic, the district should require anyone that anticipates working within the right of way of the freeway system to complete and receive authorization prior to beginning the work. The department should also require that any workzone that involves moving operations to also receive a permit prior to beginning the work. The department should specify when authorizing a work zone, that it is the applicant's responsibility to remove the traffic control devices prior to the work being completed if requested by the district. The district would make such a request when an incident has occurred or there is inclement weather. The district should also specify that work zones are not to be put in place during inclement weather.

The district should require that the application be submitted daily by noon the day prior to deploying the work zone. However, it should not be submitted more than one workweek prior to deploying the work zone. Union contracts within the district define the workweek as beginning at 12:01 a.m. on Monday and ending at midnight on Sunday. This workweek definition should also apply for the work zone permit. The application should be faxed, e-mailed, or mailed to the Traffic Control Supervisor with the application for traffic control approval. The traffic control supervisor will be reviewing the traffic control plan and the workzone applications. If the traffic control application is rejected, the traffic control supervisor will work with the applicant and provide guidance on the appropriate traffic control requirements. The information included on the work zone application will include:

- When;
- Who;
- Where;
- What activities are scheduled;
- Lane closures;
- Contact;
- Anticipated start time; and
- Anticipated end time.

The Traffic Control Supervisor will evaluate the application based on the following parameters:

- Work zone applies to freeway system;
- Submitted within appropriate time frame;
- Category of work;
- Traffic impacts;
- Special events;
- Time of year;
- Duration; and
- Impact on other scheduled work zones.

If the Traffic Control Supervisor denies an application, the Traffic Operations Engineer should be notified. The Traffic Control Supervisor should make every effort to work with the applicants to get the work zones coordinated and approved. Once an application has been approved it should be entered in the work zone database. This database will provide a tool to manage the work zone. The database should be able to produce the application information in a text format, audible format, and a map format. The Traffic Control Supervisor will be responsible for providing the approved work zone schedule to the media, the Bureau of Operations, the Bureau of Construction, the Illinois State Police, the Missouri Department of Transportation, and the city of St. Louis. The database will broadcast the schedule on the appropriate highway advisory radio transmitters throughout the district Incident information and special event information will take precedents over broadcasting the scheduled work zones. The map will be displayed on the Illinois Department of Transportation's web-site and also the GatewayGuide, the regional Intelligent Transportation System, web-site.

Once approved, the applicant will be responsible for contacting the District's communications office to notify when the work zone has been implemented and when it has been removed. The freeway service patrol will be responsible for verifying that the only approved work zones are deployed within their patrol area.

The Communications Office Supervisor reports to the District Traffic Operations Engineer. Adding the work zone approval process the Communications Office Supervisor's duties will not require additional personnel to be hired. Since this position will be responsible for overseeing the Intelligent Transportation System equipment also, this position seems the most logical to assignment. There will be some cost to the District for the development of the software and database.

Establish interagency cooperation prior to implementing procedure

In order for this procedure to be successful, the District Engineer must support it. With the District Engineer's support, special provisions will be added to future construction contracts, utility permits, maintenance contracts, and consultant contractors that require that work zone permits are submitted. For existing contractors, the district will have to work with the contractors and the resident engineers to begin utilizing the process. The media will also be informed of the process and the information that will become available.

The Illinois Department of Transportation – District 8 and the Missouri Department of Transportation – St. Louis have tried to notify each other when work zones are going to be implemented that may impact the traffic in the other state. The Missouri Department of Transportation and the city of St. Louis do not have a procedure in place to coordinate scheduled work zones. (*11*) Encouraging both of these agencies to not only participate in the district's permitting process but also develop their own, will ensure that the regional transportation system is more effectively managed. Working with other entities such as utility companies, contractors, and consultants so they understand the importance of this procedure is vital for its success. The freeway service patrol and the Illinois State Police must also be in agreement to cooperate in verifying and enforcing that only authorized work zones are implemented.

Benefits of Coordinating Scheduled Work Zones

Coordinating scheduled work zones will provide the department the opportunity to control the number of work zones on the freeway system and ensure that there are no work zones that conflict with one another. Coordinating the scheduled work zones will also allow the district to compile a list of work zones that can be distributed to the public daily. This list should include the anticipated starting and ending time of the work zone and the effected freeways. This list should be provided to the media, broadcast on the HAR system, and located on the Illinois Department of Transportation's web-site (www.dot.state.il.us) and on the Gateway Guide web-site (www.gatewayguide.com). Compiling and distributing this list will allow the department to provide the public with more up-to-date and accurate traffic information. This list can also be provided to the emergency responder agencies and the 911 centers to ensure they are aware of possible delays due to work zones.

CONCLUSIONS

Coordinating scheduled work zones provides agencies the opportunity to manage the number of work zones on the freeway system and ensure that they are implemented with minimal impacts to traffic.

Agencies developing a procedure must determine what their role will be in coordinating these work zones and who is required to adhere to this procedure. Other considerations that should be taken into account include: incident management in the work zone, work zone removal responsibility, and traffic impacts on adjoining freeways. When utilizing this procedure, the agency should realize that the success of the procedure is dependent on cooperation within the agency and with outside agencies. The agency should continually reevaluate the procedure to ensure that it is as effective.

Further research in coordinating work zones is needed. An in depth analysis of coordinating arterial work zones, work zone effects on adjoining arterials, and verification of work zone implementation would be of interest to transportation agencies.

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- Mr. Tim Myers – City of St. Peters, Missouri
- Mr. Larry Trenkamp – Kentucky Transportation Cabinet
- Ms. Teresa Krenning – Missouri Department of Transportation

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APPENDIX A: COORDINATING SCHEDULED WORK ZONES ON URBAN FREEWAYS SURVEY

Name: ______________________________
Agency: ______________________________
Address: ______________________________
City: ______________________________
State: ______________________________
Phone: ______________________________
E-mail: ______________________________

Most maintenance and construction activities on the roadway are conducted in work zones through which there are lane restrictions and traffic travels adjacent to the work area. To ensure that these activities minimize the effect on traffic and maximize safety in the work zone, work zone should be coordinated to ensure that conflicting work zones are not implemented and to ensure that traffic is not being detoured from one work zone to another.

The purpose of this survey is gather information on the procedure utilized to coordinate scheduled work zones. The information gathered will be incorporated in a research paper for the Advanced Surface Transportation Systems 2001 Mentor Program for the Texas Transportation Institute at the Texas A&M University. This paper will be the basis for developing and implementing a procedure to coordinate scheduled work zones for Illinois Department of Transportation, District 8, in Collinsville, Illinois.

Please respond to the following questions and return your survey results to Jennifer Obertino via e-mail: obertinojl@nt.dot.state.il.us or by fax at 618-346-3266 by July 9, 2001. If you have any questions about the survey please contact me via e-mail or by telephone at 618-346-3284.

I appreciate your willingness to participate in this survey and look forward to your responses.

1. Is the procedure utilized as a clearinghouse or as a permitting process?

2. Who supervisors or administers the clearinghouse or approves the permits?
3. Does the procedure only provide approval/coordination of the work zone or is there also approval for the traffic control?
4. How do applicants request permission to perform work zone activities?
5. Who is required to apply for approval? – In-house users, utilities, local agencies?
6. How is priority set between applicants?
7. Are there deadlines for submitting work zone activities? If so, what are they?
8. Are traffic impacts taken into consideration prior to approval? If so, how?
9. Are traffic impacts on adjoining routes taken into considerations prior to approval? If so, how?
10. Are there time restraints in place that restrict work zone activities? If so what are they?
11. Is there verification that the approved work zone activities actually occur?
12. When and how are temporary work zones removed prior to the completion of the work?
13. How does needed emergency or unscheduled work affect the procedure?
14. Who is responsible for removing the work zone in case of an incident?
15. Are approved work zones ever canceled? If so, how is this done?
16. Are work zones combined with other work zones?
17. How is compliance monitored and enforced, especially when lane restrictions remain after allowed time period?
18. How are unapproved work zones handled or removed?
19. How do incidents and weather affect approved work zones?
20. What obstacles were overcome during the implementation of these procedures?
21. What institutional obstacles were encountered? How were they overcome?
22. If you were developing your system, what would you do differently?
23. Is your procedure documented? If so, is it possible to obtain a copy?
24. Are there other documents that you found useful in implementing your procedure?
25. Are you aware of other agencies that are utilizing a similar procedure?
26. Do you routinely re-evaluate your system or only when conflict occur?
27. How is this information shared with the public? Media?

JENNIFER OBERTINO

Ms. Obertino is the Traffic Operations Engineer for the Illinois Department of Transportation - District 8, in Collinsville, Illinois. In this role, she is responsible for the development, coordination, and deployment of the ITS in District 8. She works closely with the Missouri Department of Transportation, St. Louis Metropolitan District to ensure that a regional integrated ITS deployment occurs in the bi-state St. Louis area. She is also a member of the IDOT statewide ITS committee which is developing a statewide business plan. In addition to ITS, her responsibilities include supervising the Emergency Patrol, the Communications Office, and the Signing and Striping Section.

Ms. Obertino received her Bachelor of Science degree in Civil Engineering from the University of Missouri - Columbia in 1994. She is a registered professional engineer.

FREEWAY TRAVEL TIME ESTIMATION AND APPLICATIONS IN REAL TIME

by

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SUMMARY

The rapidly growing congestion on highways, especially urban freeways, demands transportation engineers to provide innovative solutions for safe and effective management of highway network. Real-time surveillance and monitoring is becoming essential to achieve these goals. The real-time information provides motorists opportunities to make informed decisions. It is also used to implement traffic management applications and strategies for optimizing network productivity.

Real-time travel time is one such variable being used by several agencies. This study was performed to improve understanding of current practices related to real-time travel time data collection, applications, issues, and effectiveness. A survey of thirteen transportation agencies was conducted in addition to extensive literature review. The survey results indicate that motorists like this information and would like to have more reliability, coverage, and predictability. The findings were then used to develop guidelines for agencies that are interested in deploying such a system. The guidelines included following steps:

- Clearly establish the objectives of Travel Time Estimation/Prediction System (TTEPS);
- Identify/determine possible information dissemination modes and the level of accuracy;
- Develop message content;
- Identify/evaluate existing detection technologies and current/planned ITS infrastructure;
- Estimation of missing data;
- System design, development, and integration; and
- Implementation and evaluation.

The guidelines were applied to Maryland's CHART system to illustrate the process. The scenarios included travel time information for alternative routes and HOV lanes.

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INTRODUCTION

Travel time has been regarded as one of the most fundamental and important determinants of travel behavior. Travel times measurements in real-time are important both for an effective Advanced Traffic Management Systems (ATMS) and Advanced Traffic Information Systems (ATIS).

Different methods are used to estimate travel time information in real-time. Some of these methods include use of loop detectors, automated vehicle identification (AVI) technologies, global positioning systems (GPS), and license plate identification. Though some transportation agencies have been estimating travel time information for several years, there are still issues and concerns related to its estimation and application.

Discussions with transportation professionals revealed that there are several issues related to real-time travel time estimation and application. Due to these issues and/or concerns, transportation agencies often decide not to implement travel time information systems. Some of these issues include reliability of data and losing public respect for messages displayed on dynamic message signs (DMS), selection of appropriate travel time estimation method, significant amount of time spent on retrieving and displaying travel time information as traditionally this process has been manual, effectiveness of travel time information, and public perception of its benefits.

Research Objectives

The overall goal of this research was to propose recommendations for an effective implementation of travel time estimation program in Maryland's CHART system. The specific objectives of this study were to:

- Identify the current practices for travel time estimation and evaluate their effectiveness;
- Identify the possible applications of travel time estimation and evaluate their effectiveness;
- Identify issues/concerns, and research possible solutions;
- Develop guidelines for successful implementation of Travel Time Estimation/Prediction System (TTEPS); and
- Apply the research findings to Maryland's CHART system and propose recommendations for the collection and the use of travel time information.

Work Plan

The Tasks undertaken to accomplish the objectives are briefly described below.

Task 1: Review literature

Literature review was performed to examine data collection methods, possible applications, current issues and their possible solutions, and effectiveness of real-time travel time estimation/prediction systems.

Task 2: Conduct survey of transportation agencies

In this task thirteen transportation agencies were surveyed to get more information on current practices, issues, and public perception related to real-time travel time estimation/prediction system.

Task 3: Interview with human factors expert

A human factors expert was interviewed to identify issues and effectiveness of real-time travel time estimation/prediction system.

Task 4: Develop guidelines for travel time estimation and application

In this task, guidelines were developed for transportation agencies considering implementation of TTEPS. These guidelines were developed using the information gathered in the above tasks.

Task 5: Application of guidelines to Maryland's CHART System

The guidelines were applied to Maryland's CHART System to illustrate the implementation process of TTEPS. This task also included discussions with transportation professionals associated with CHART system to develop an understanding of current capabilities and future plans.

LITERATURE REVIEW RESULTS

Travel time is defined as "the time to traverse a route between any two points of interest". Travel time is composed of running time, or time in which the mode of transport is in motion, and stopped delay time, or time in which the mode of transport is stopped (or moving sufficiently slow as to be stopped, i.e., typically less than 5 mph).

Travel Time Data Collection

Traffic data collection technologies are emerging and continue to improve every day. In this paper, only the most widely used and promising new techniques related to automated freeway travel time data collection, will be discussed with a brief overview of their quality and cost comparison. There are fundamentally two methods for automated travel time data collection: point-based and probe-based (*1*).

Point-based Methods:

In point-based methods, extrapolation methods are used to estimate average travel times by assuming that spot speeds can be applied for short roadway segments between detection devices. In such cases, travel times can be simply calculated by dividing the length of the segment by the speed at the detector station.

Factors affecting the accuracy of point-based methods are:

- Type of facility (freeway vs. arterial);
- Distance between point detection devices (generally ¼- to ½ mile);
- Traffic conditions (free flow vs. congested conditions); and
- Accuracy of the detector device itself.

The most common and widely used point detection device is the inductance loop detector (ILD) (*2*). The most accurate method to measure speed with loop detectors is to place two detectors in series, which is referred to as a "speed trap" or "loop trap". A Texas Transportation Institute study determined that the optimal distance between loops is 30 ft. Many ILDs currently in place are single loops primarily designed to collect vehicle counts and lane occupancy. Many attempts have been made to utilize speed-flow relationships to estimate vehicle speeds from single loop detectors. The Chicago Area Traffic Systems Center assumes a vehicle length of 21.5 ft and uses the following equation to estimate spot speed:

$$\text{Spot speed} = (\text{volume} \times 21.5\text{ ft}) / (\text{lane occupancy} \times 40.9);$$

where (40.9/21.5) is called g-factor or speed correction factor.

Other effective point-based detectors include video image detection systems (VIDS), microwave radar (true-presence and doppler types), and infrared detection systems (active and passive). Side-fired microwave radars and VIDS can provide data for multiple zones using single sensor. These detectors are roadside and overhead devices, which as compared to ILDs have an advantage of not being subject to pavement deterioration and require relatively lesser maintenance. However, studies have shown that ILDs provide more accurate results for spot speeds as compared to any other point-based detector (*3*).

Probe-based Methods:

Probe-based data collection techniques are primarily ITS applications designed for data collection in real-time. These techniques include signpost-based automated vehicle location (AVL), automated vehicle identification (AVI), ground-based radio navigation, cellular phone as data probes, and global positioning system (GPS). In this paper the main probe-based technique (i.e., AVI) currently being used by transportation agencies and one promising technique (i.e., cellular phone based technology) will be discussed.

General advantages of these probe-based systems include low cost per unit of data, continuous data collection (as long as probe vehicles are travelling), automated data collection, electronic format, and no disruption of traffic (except AVI). These methods provide speed and travel time estimates for individual vehicles on link basis. Probe vehicle travel time data has been shown to be capable of detecting incident congestion (*4*) at a rate nearly comparable to that of inductive loop detector surveillance systems if conditions are favorable (mainly adequate probe density and heavy traffic volumes). Disadvantages of such systems include high implementation cost, fixed infrastructure constraints (except GPS), requirement of skilled engineers, privacy issues, unsuitable for small scale data collection, significant probe density, and high maintenance costs.

Two successful implementations of AVI technology have been in New York/New Jersey area and in Houston, Texas. The primary reason of this success is the significant presence of toll lanes, and thus a very large number of vehicles equipped with AVI tags or transponders. A study of Houston's AVI system showed that, for a 90 percent confidence level with 10 percent relative error, 2 or 3 probe vehicles every 15 minutes were sufficient to collect useful travel time data (*3*).

Current estimates from the Cellular Telecommunications and Internet Association show that there are approximately 110 million cellular phones in the U.S., and a recent study by Goldman Sachs reported that 50 percent of all cell phone usage is in vehicles and 80 percent of calls are initiated from vehicles. Cellular geo-location refers to the technology of collecting speed and travel time data by discretely tracking cellular telephone call transmissions. One such system developed by U.S.Wireless Corporation (USWC) is called "RadioCamera" (*5*). The manufacturer states that pattern matching technology determines a location, instantaneous speed, bearing and acceleration approximately every 2 seconds during an active cellular call. These data are processed to assure their quality, and are snapped onto a digital map. The snapped data is then averaged over a user defined time period and highway segment. The output is displayed as a speed map, which essentially provides the average travel speed for the defined link and the selected time period. Travel times are then calculated from the series of average speeds between any two user defined nodes. A major difference between this technology and other alternatives is that the alternatives can provide data only for the point at which they are installed (such as loop detectors) or for a roadway segment between two fixed points, usually fairly widely spaced (such as AVI). Cellular technology provides data for any and/or every point on network (freeway, arterials, etc) and thus makes it possible to have travel times between any two selected points. The limitations of this technique include sample size (i.e., active calls to gather data) and the need for calibration of the roads to be monitored. The calibration involves running a GPS-equipped vehicle to establish a location truth table and simultaneously broadcasting on the various cellular protocols to obtain the patterns that correspond to those locations. USWC's internal evaluations show that speed accuracy is approximately $\pm$ 6 percent. However, Universities of Maryland and Virginia are working in partnership with USWC, the Maryland State Highway Administration and Virginia Department of Transportation to perform an independent evaluation of a prototype system in the Washington D.C. metropolitan region. The initial evaluation results appear promising.

The effectiveness of different detection technologies to provide quality speed, occupancy, and volume data is summarized in Table 1. The cost comparison of these detection technologies in terms of initial capital costs and annual operating/maintenance costs is summarized in Table-2. Information in Table 2 is based on the example of an area in South Florida between Fort Lauderdale and Miami that covers I-95, Florida's Turnpike, and Highway A1A. The area comprises approximately 60 miles of Interstate highway, 210 miles of US highway, state highways, major connector roads, and 85 major interchanges.

Improved Estimation/prediction:

Recent studies have shown that improved estimation techniques allow fairly reliable estimation of freeway speeds using single loop detectors. Dailey (*6*) and Petty et al. (*7*) suggested cross-correlation techniques while Wang et al. (*8*) showed that using proper speed estimation parameter values calculated at each time interval on the basis of real-time mean of effective vehicle length (using log-linear regression model) provided more accurate speed estimates from single loop detectors.

Studies (*9*) have shown that travel times can be predicted fairly accurately using current and historical travel time information. A study (*10*) was conducted using real data (flow and occupancy from single-loop detectors) from I-880. The current traffic conditions proved to be a good reliable predictor for the near future, up to 20 min, whereas historical data are more informative for long term predictions.

Detector data screening for erroneous data is very important. Comprehensive well-designed quality checks system could be implemented to perform quality checks on detector data before its use in ATIS and/or ATMS (*11*).

New technologies such as tracking of cellular phones will provide cost-effective detection capabilities. Moreover, new traffic models such as dynamic traffic assignment will provide new opportunities for estimation, prediction, and guidance in real-time (*12*). Well-designed incident detection algorithm can also improve the reliability of the system.

Table 1: Summary of Vehicle Detection Device Effectiveness (*13*)

Detector Technology	Average Speed	Lane Occupancy	Volume	Other
Inductive Loop	High (in pairs)	High	High	
Infrareds	High	High	High	
Radar	High	High (except stopped vehicles)	Moderate	Multi-lane
Video Image	High	High	High	Multi-lane
AVI	High*	Moderate*	High*	
GPS	High*	High*	High*	
Cellular phones	High*	NA	NA	

* If market penetration is significant

Table 2: Cost Comparison for different technologies under different sensor spacing scenarios (5)

Detection Technology	0.5 Mile Spacing		1.0 Mile Spacing		Every Major Interchange
	Capital	Annual O&M	Capital	Annual O&M	
Loop detector	$7,650,000	$432,000	$3,825,000	$216,000	$4,862,000
Microwave radar	$6,690,000	$216,000	$3,345,000	$108,000	$4,182,000
Active infrared	$16,524,000	$81,000	$8,261,500	$40,000	$10,455,000
Video image proc.	$16,740,000	$270,000	$8,370,000	$135,000	$10,710,000
AVI*	$15,120,000	$324,000	$7,560,000	$162,000	$9,724,000
Cell phones	$1,400,000	$300,000	$1,400,000	$300,000	$1,700,000

*Cost excludes in-vehicle transponder (approx $25 ea.)

Travel Time Applications

Travel time or speed is considered the most effective measure of transportation system performance. It is a key element in almost all types of travel modes and a sensitive decision-making variable that transcends the value of travel behavior and the impact of traffic conditions.

Following are some applications for a real-time TTEPS.

- Used in real-time traffic adaptive control to optimize network productivity
- To provide real-time traveler information for informed motorist decisions and reduce trip uncertainty
- To provide real-time route guidance and navigation
- Used in traffic management applications such as real-time incident detection
- Input/calibration of traffic models such as dynamic assignment models
- To develop a historical database of traffic conditions
- Congestion management by tracking trends over time of travel-time based measures
- Measure effectiveness and benefit of improvement by providing before-and-after travel time data
- Identify congested locations or bottlenecks
- Research and development

Travel Time Effectiveness and Human Factors

Providing real-time travel time information can help in the more efficient use of transportation network. Commuters are more likely to take free following tolled lanes as compared to congested free lanes when given pre-trip information of severe traffic conditions than when no such information is given. This is also true of commuters' lane-switching decisions en route (*14*). Also, people who plan to take toll lanes, based on pre-trip information, are unlikely to switch to free lanes because they have taken advantage of travel time saving and reduced travel time uncertainty by shifting departure times later.

The USDOT ITS program fielded qualitative market research in 1996 on various traffic information concepts with drivers in congested regions. Direct measures of speed and travel times between two points were identified as one of the nine user requirements. Since the traffic conditions are dynamic in nature, advanced users recommended that ATIS use current information with historic data to provide customers with near-term predictive information on their route conditions (*15*).

A market research survey in Minnesota indicated that travelers are anxious to receive traveler information. Highest priority is for information on lane closures and incidents (*16*). Medium priority is indicators of congestion such as speed or travel time, and the lowest priority was given to parking information. A database with timely and accurate travel time information will provide an incentive for private sector information providers to develop effective and extensive delivery systems.

A focus group study of the Advanced Traveler Information System (ATIS) was conducted in 1998 to collect information about the San Francisco Bay Area consumer needs and desires. The focus group participants recognized the benefits of traveler information. Desired additional information included estimated travel time, expected incident clearance time, and up-to-the-minute information on traffic conditions. The chief benefits of obtaining traffic information expressed by the participants were relieving stress, gaining a sense of control over traffic situation, knowing whether to inform employer or others of being late, and being able to get to work on time by leaving early or taking alternative route (*17*). Another case study of Washington, DC metro area showed similar main benefits for ATIS consumers, i.e., on-time reliability and predictability, and the resulting reduced commuter stress (*18*). In general, motorists refer to past anticipated travel times in the absence of any current traffic information. Commuters shift departure times earlier in response to increase in travel time uncertainty. With the availability of estimated current travel times, drivers can predict near-term travel times with less reliance on past-anticipated travel times. This improves trip reliability. Similarly, pre-trip information may also allow later departure times.

SmarTraveler was implemented as an operational test of an ATIS in Boston metropolitan area. Callers to SmarTraveler choose to hear a recorded report on 1 or more of 23 monitored highway segments. The real-time reports included conditions, travel times, and anomalies like accidents. Current users were asked to describe the benefits of this system. The most widely perceived benefit was the reduction of anxiety, reported by two-thirds of respondents. About half of the respondents perceived the following benefits: avoid traffic problem, save time, and arrive on time (*19*).

An evaluation of Seattle's Smart Trek Metropolitan Model Deployment Initiative (MMDI) was performed in 2000. The evaluation of the web site (http://www.wsdot.wa.gov/PugetSoundTraffic) included an on-line survey. Among the choices presented, the most popular suggestions for additions to the web site were filling in the gaps on freeway network where traffic flow data were currently not available (59.1 percent). 44.7 percent of the users wanted estimates of travel times between two points, and 34.5 percent were in favor of direct measures of speed for each freeway segment (*20*). The high number of users looking for travel times is also evident from the fact that the second most requested page on the Gary-Chicago-Milwaukee ITS Corridor's web site (http://www.gcm.travelinfo.org), after the main menu page, is text-based overview of the freeway travel times (*21*).

A behavioral survey of 1492 peak period automobile commuters crossing Golden Gate Bridge in San Francisco consisted of five hypothetical scenarios. The results showed that 27 percent of travelers would switch to the alternative route when qualitative information was provided to them. This increased to 52 percent when quantitative information is provided, 55 percent when predictive information for usual route is provided, 58 percent when delay information on usual route and travel time on the best alternative route are available, and 61percent when prescriptive information to take the alternative route is provided (*22*).

A modeling analysis of ITS impacts of Seattle's MMDI was performed to study the effects of providing arterial travel times in addition to freeway travel times. The results showed that provision of arterial data roughly triples the overall system impact of ATIS. The provision of travel time estimates on the primary alternatives to I-5 allows travelers to make more efficient route choice decisions (23).

Desired Accuracy

A study was conducted to determine the effects of congestion information accuracy of ATIS on user trust and compliance (24). Participants drove through a simulation with the goal of avoiding congestion under different levels of ATIS information accuracy. The results indicated that 60 percent appears to be an acceptable initial accuracy level, provided that the user's first experience is not below 60 percent. The results of this study were consistent with those of Kantowitz et al. (25), who found that at 43percent, trust significantly degraded, but that at 71percent, trust remained consistently high.

Dynamic Message Signs (DMSs)

Dynamic Message Signs are programmable traffic control devices that convey non-personlized real-time information on network traffic conditions to drivers encountering them.

Dynamic Message Signs along the freeway are used to provide drivers with travel time information in a number of European countries. One of the most impressive examples of this practice was found in Paris where more than 200 DMSs on the outer ring freeway, its entrance ramps, and the inner ring provide real-time travel times to upcoming junctions (26). An evaluation of this system in 1994 found that 65 percent of the motorists preferred travel-time information over congestion information. Another evaluation study (27) of the DMSs on Amsterdam Orbital Freeway showed that total congestion, and the variability of both congestion and average travel speed decreased. The signs were installed before the major junctions and displayed queue lengths for alternate routes. The study results indicated that traffic conditions improved as travel times became more reliable. An evaluation (28) of the Integrated Traffic-responsive Urban Corridor Control Strategy in Glasgow, Scotland indicated that the throughput of the motorway increased with a decrease in travel times. In this strategy, DMSs play a major role as they display messages to effect the driver's behavior to achieve the required diversion based on the concept of equalization of travel times between alternate routes.

An important choice related to the DMSs is the choice of prescriptive vs. descriptive messages. A potential gain of descriptive messages is that driver acceptance could be high because drivers would appreciate the freedom to make their own choices. Moreover, it could achieve a level of fine-tuning of traffic streams to the capacities that would be unattainable with prescriptive messages. A study (29) was conducted to evaluate the effectiveness of different modes of variable information, i.e., length of congestion (in kilometers); delays relative to normal travel times (in minutes); and travel time (in minutes). Also, the reliability of information was varied. By providing descriptive information, divergence levels were found to vary widely over the range from 0 to 100 percent, as a function of the actual information given. This can be compared to the inflexibility of prescriptive signing. User optimum was often reached by presenting travel time information. Such information also proved to be most resistant against degradations in reliability.

An on-site survey (30) in the Borman Expressway region in northwest Indiana identified some key factors that influence driver decisions under DMSs. The survey results showed that the messages displaying occurrence and location of accident have similar effects on driver's diversion behavior, all other factors being equal. Expected delay (difference in travel times under normal and congested conditions) and best detour strategy are considered valuable information. Location of accident and occurrence of accident have added value only in conjunction with information on expected delay or best detour strategy. When the expected delay on the current route is at least 10 min, 53 percent of respondents indicated they would divert.

A study conducted by Texas Transportation Institute showed that 90 percent of the 260 individuals, selected from five cities (Dallas, Houston, El Paso, Fort Worth, and San Antonio), interpreted travel time messages on DMSs as approximate. The results showed that displaying messages with the time-of-day information did not make much difference in terms of driver's understanding that travel times are not exact. However, displaying the time-of-day information may help some drivers to predict a current travel time based on when that most recent travel time information was gathered (31).

SURVEY RESULTS

A survey of several State DOTs was conducted to explore current practices related to TTEPS. Following are the survey results.

NAVIGATOR (Georgia DOT) (32,33)

NAVIGATOR is Georgia DOT's ITS initiative in Atlanta and surrounding counties. Travel times are estimation in real-time using video detection system (Autoscope). Average speed of a series of detection stations (usually 6-10 miles) is received every 20 seconds. Travel times are based on the last 3 cycles of data (1 min). The value of average speed is put into a lookup table (4x4 matrix with 16 possible travel time messages for each sign) to display an appropriate pre-conceived message. Video detection cameras, at 1/3-mile intervals, are separate from the network of regular surveillance cameras, about 2/3 to 1 mile apart. Video detection was preferred over loops for installation and maintenance reasons. The accuracy is above 85 percent for volume counts and above 90 percent for speed. In general, the agency is very pleased with the system performance.

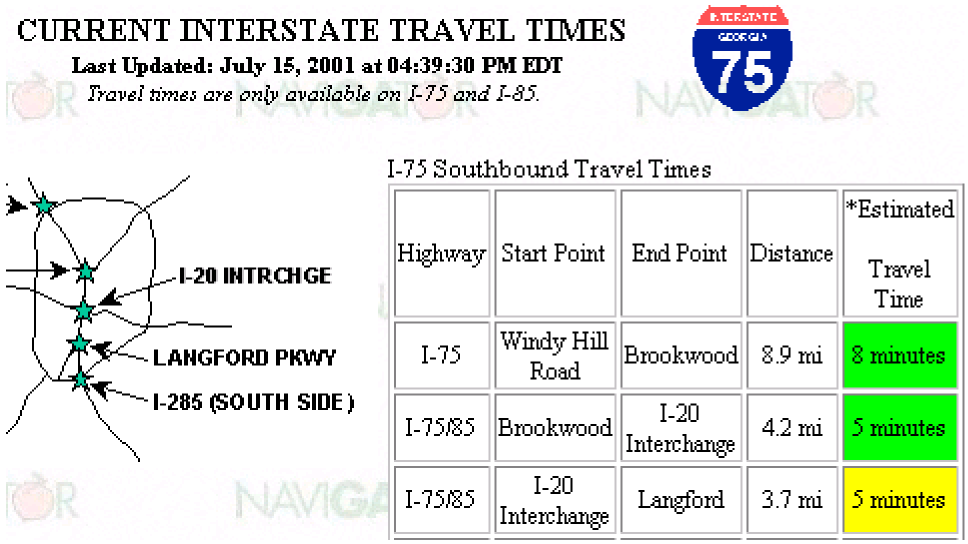
Information dissemination modes include DMSs and Internet. Public Perception is generally good. Public liked the improvement from older system of "Traffic Moving Slowly" type messages. All messages on DMSs are also displayed on Internet.

Travel times are displayed on DMSs from 6 AM to 9 PM weekdays and 8 AM to 8 PM weekends. This has squashed the blank sign complaint. However, still there are some minor complaints primarily due to incorrect interpretation or understanding of messages and travel time concept. Accuracy checks, for estimated travel times, are run consistently to keep the system reliable.

GaDOT is considering an algorithm change to further improve accuracy. The new method will allow message creation in real-time based on estimated travel time. Typical DMS travel time messages are shown in Figure 1. Travel time information shown on NAVIGATOR'S web site is shown in Figure 2.

Typical DMS messages:

Figure 1. Typical Travel Time Messages in Georgia



I-75 Southbound Travel Times

Highway	Start Point	End Point	Distance	*Estimated Travel Time
I-75	Windy Hill Road	Brookwood	8.9 mi	8 minutes
I-75/85	Brookwood	I-20 Interchange	4.2 mi	5 minutes
I-75/85	I-20 Interchange	Langford	3.7 mi	5 minutes

Figure 2. Travel Time Information on Navigator's Web Site

TransGuide (Texas DOT) *(34)*

TransGuide is Texas DOT's ITS program in San Antonio region. Point travel speeds from loop detectors, in double or trap-loop configuration, are used to estimate travel times from a DMS to major destinations, intersections, and/or interchanges. Loop detectors have been installed in every lane at a maximum spacing of 0.5 miles. Local Control Unit (LCU) keeps a moving average of speed, occupancy, and volume rates, which is sent to ATMS mainframe at a period of 10 to 100 seconds (nominally 20 seconds).

Information dissemination modes include DMSs, Internet, local radio and TV stations. Travel times and video images were added to the TransGuide's web site in early 2000. From mid 1995 through December 31, 1999 there were 7.5 million hits on the site. From January 1, 2000 through December 31, 2000 there were over 32.7 million hits on the web site.

Public perception has been very good. In a recent survey, TransGuide travel time information received an average score of 7.8 on a scale of 1 to 10 (10 being most accurate). Also TransGuide DMSs, which display travel times FROM 6:00 AM to 10:00 PM unless other important information (construction, incident, lane closure, etc) needs to be displayed, received a rating of 7.6 on a scale of 1 to 10 (10 being extremely helpful)

Travel time messages are sometimes used in combination with congestion limit signs for more effective congestion management. This whole process is designed to be as automated as possible to minimize the burden on the operations staff. A typical travel time message displayed on DMSs by TransGuide is shown in Figure 3. Travel time information displayed on TransGuide's web site is shown in Figure 4.

Figure 3. Travel time Message Displayed by TransGuide

Travel times are displayed in different forms such as common travel times, table based personal route selector, map based dynamic route builder, individual freeway pages, and current DMS displays.

Highway	Starting Point	Ending Point	Distance	Segment Travel Time	Average Speed (MPH)
IH 10 Eastbound	Loop 1604	Loop 410	7.0 mi.	7 min.	>60
	Loop 1604	I 35 Interchange North of Downtown	13.2 mi.	13½ min.	>60
	Loop 410	I 35 Interchange North of Downtown	6.2 mi.	6½ min.	58
	Huebner	Hildebrand	6.7 mi.	7 min.	>60

Figure 4. Travel Time Information on TransGuide's Web Site

TranStar (Texas State DOT) (35,36)

Houston TranStar is responsible for providing Transportation Management and Emergency Management services to the Greater Houston Region. TranStar has a real-time travel time estimation/prediction system based on AVI. The main sources of vehicle probes are commuters using the AMTEK tags automated toll collection system (approximately 600,000 in Harris County). Transponder tag readers are placed at 1-5 mile intervals along freeways and HOV lanes. The information dissemination modes include DMS, Internet, and local media. Internet display includes travel time (in minutes) along with distance and speed, travel times for special-purpose lanes, and historical freeway travel times and speeds. Public perception is very good. In fact, public wants more coverage in a faster and timely manner.

Future plans include improvement in system to provide more accurate estimation, and incorporating travel assignment/expert decision support tools to predict traffic conditions and implement pro-active traffic management applications.

AMTEK tags continue to be proprietary in nature and have a high maintenance cost associated with them. This is an area where continued research and development is needed to take full advantage of technology.

GCM-ITS Priority Corridor (Illinois State DOT) *(37,38)*

The GCM-ITS corridor covers the area from Gary (Indiana), through Chicago (Illinois), to Milwaukee (Wisconsin), and is managed by Indiana, Illinois and Wisconsin Departments of Transportation. Illinois State DOT has implemented a real-time travel time estimation system in Chicago region using loop detectors. Occupancy and volume data from single loop detectors (center or left lane of travel) is used, along with the average vehicle length to calculate the estimated speed. This information is used to calculate the travel time over ½ mile segments of the expressway system. Failed or malfunctioning detectors are averaged to approximate travel times. The tollways will use anonymous information from I-Pass electronic toll collection system to calculate travel times, congestion limits, etc.

The information dissemination modes include Internet, local media, HAR, and dial-up phone. Public perception has been very good. Field measurements and feedback from the media/public show that travel times are quite accurate. Recent system upgrades may allow the provision of automated display of travel times on DMSs. However, the current IDOT management does not feel the advantages outweigh the perceived disadvantages.

DMS displays the congestion limits during rush periods, and normally shows lane closure, special event or emergency messages. It is usually blank for very short duration.

MONITOR (Wisconsin State DOT) *(39,40)*

MONITOR is Milwaukee's freeway traffic management system. Real-time travel times are estimated using ILDs. The ILDs are located in the field at ½ mile to 2 mile spacing (1/2 mile in dense urban areas out to 1 mile, and then 2 mile spacing in rural areas). The travel times are usually estimated for overall trip lengths of 15 miles or less as reliability is an issue at greater distances. The information dissemination modes include DMSs, Internet, local radio, and television stations. The program has received good public acceptance and support. The travel times web page has received maximum hits on Wisconsin DOT's web site.

Travel time predictions are required to provide motorists better information specially at the beginning of a rush hour period. The Smart Trek project may consider using a travel time prediction algorithm to solve this problem. One such algorithm is being currently researched by VDOT/University of Virginia. A typical DMS message is shown below.

TRAVEL TIME TO ________ X MINUTES

Below is a typical internet message

I-94 EB Moorland – Zoo … 3:40 minutes. (4 min) No Delay

where time in parentheses is free-flow (normal) travel times.

SunGuide (Florida State DOT) *(41)*

SunGuide is Florida DOT's ITS program. Florida DOT provides real-time delay and congestion limit information in Orlando region using loop detectors. Loop detectors are installed on 40-mile section of I-4 at 0.5-mile spacing. Information dissemination mode is primarily DMSs. According to FDOT, the system has been in place for 8 years and works well. Public likes the system and wants more coverage and predictability. An example of messages displayed is shown below.

HEAVY CONGESTION X MILES AHEAD X MIN DELAY	HEAVY CONGESTION FROM A TO B

University of Central Florida (UCF) is evaluating travel time algorithm to replace current format of displaying delay, in minutes. UCF has remote access server taking data directly from DOT's TMC.

Compass (Ontario, Canada) *(42,43)*

COMPASS is a high-tech freeway traffic management system developed by the Ontario Ministry of Transportation (MTO). COMPASS has a real-time travel time estimation system using loop detectors. Travel time at each loop detector station is calculated by dividing the link length by the average speeds measured at the detector station. Traffic conditions are updated every polling cycle (20-sec intervals). Traffic conditions determined by travel times and speeds are then converted to three levels of information ("Moving well", "Moving Slowly" and "Very Slow") for display on DMSs. The whole process is automated.

The main objective of the traffic condition information system is to best inform drivers about traffic conditions ahead in a way that would Other considerations included short message, maximum three levels of congestion severity, relatively short segment lengths, and improved data screening for accurate information.

Average travel time information was considered unsuitable due to too many routing combinations on Highway 401 roadway system. Also, it was considered unsuitable for the implementation objective of traffic condition information system, i.e., to assist motorists in making accurate diversion decisions using the DMSs as a primary tool.

According to Ontario MTO, congestion information is conceived secondary when the DMS is within congested queue. Therefore, COMPASS system displays congestion information with the start/end of queue (congestion area boundaries) respective to each sign so that motorists can make a more informed decision to stay or take nearest exit.

VicRoads (Victoria, Australia) *(44,45)*

VicRoads has implemented a real-time travel time estimation system in Melbourne region. Speed is calculated using dual-loop detectors, and 20-second average speed is transmitted to the central computer for the calculation of average travel time over the 20-second period. Detection stations are 500 m apart. Travel time information dissemination modes include DMSs, Internet, and pay telephone service (test phase). The system has been well received by community. The estimated travel times are accurate to $\pm$ 5 percent. The accuracy reduces at distanced greater than 20 KM.

A before and after study showed that 28 percent of motorists noted the information on DMSs and some of these would take alternative routes. A project is underway to provide travel time estimation capabilities for alternate routes and arterials. Also, the agency is trying to improve predictions for long distances. A typical DMS message is shown below.

ESTIMATED TRAVEL TIME TO _______ X MINS

Estimated travel times, in minutes, for both important links and overall trip are displayed on a web site. Along with the travel times, traffic congestion in terms of Light, Medium, Heavy, or Unknown is also displayed. DMS messages, if any, are also shown on the same web page for the selected trip.

New York State DOT *(46)*

New York DOT currently does not have a real-time travel time estimation system. The only place, where currently real-time travel time information is used, is on George Washington bridge to provide motorists travel times on the two bridge decks, and thus balance traffic on the two decks.

NYDOT, in the Westchester County area, is starting a project where they would use real-time data, from EZ Pass probes, along with Traffic Estimation and Prediction System (TrEPS) to perform off-line evaluations of different ITS strategies and determination of effective locations for ITS devices, inform motorists best North/South routes in real time, and real-time traffic control strategies using real-time data with MITSIM simulation model.

Smart Trek (Washington State DOT) *(47,48,49)*

Smart Trek is Washington State DOT's ITS initiative in the Puget Sound Region. The Smart Trek project has made several attempts with third party private companies to provide real-time travel time information. However, all these attempts are defunct. System-wide application of real-time travel time estimation is in future plans.

A travel time estimation system, based on license plate readings, is being implemented on four routes leading to border crossings. Travel time measured for these alternate routes will be displayed on DMSs. Loop detectors are also being installed to measure travel times if the license plate based system fails.

Virginia State DOT *(50,51)*

VDOT currently does not have a real-time travel time estimation and prediction system. VDOT has sponsored a research project being conducted by Virginia Tech and University of Virginia to develop algorithms for reliable travel time estimation and prediction. The primary concern is that estimates be reasonably accurate to maintain credibility of VDOT public information. However, if the research project proves that the travel times are sufficiently accurate, VDOT will consider displaying travel time information on DMS. VDOT is (and will) engage in private-public partnership to make traveler information available to general public using various modes including Internet.

GuideStar (Minnesota State DOT) *(52,53)*

Minnesota Guidestar is the state's ITS program with a primary focus on the Twin Cities (Minneapolis/St. Paul) metropolitan area. Guidestar currently does not have a real-time travel time estimation/prediction system.

Seventy-five percent of the metro area freeway network is instrumented with loop detectors (0.5-mile spacing) including exit and merge ramps. The agency is considering travel time information display on DMS and Internet, and making it available to TravInfo service providers. However, this is not expected soon. There are no plans at the moment to implement real-time travel time system for the rest of Minnesota since there is no detection infrastructure to support such an effort.

The State Patrol has expressed concern about displaying the information on DMS. Their concern is that there is already too much information along the roadway that distracts drivers and such a system may take away the effectiveness of signs for incidents. DMSs are kept blank and used whenever necessary.

There is a system for alternate routes but it is not based upon travel time. It is based upon congestion level, incidents, and lane/road closures. Alternate route information is disseminated via DMSs, traffic radio, traffic TV, and web site. Usually several alternative routes are recommended to spread the diversion.

CHART (Maryland State DOT) *(54,55)*

CHART (Maryland's ITS program) is a joint effort of the Maryland Department of Transportation and the Maryland State Police. CHART currently does not have a real-time travel time estimation system. CHART is currently focussed on improving incident management capabilities. Real-time travel time estimation system is not a high priority. The management believes that such information will be provided by private industry. Also, the agency does not want to invest heavily in deploying an extensive detection infrastructure.

HUMAN FACTORS RELATED DISCUSSION

The human factors related issues were discussed with a human factors consultant with experience in traffic related issues (*56*). Following is the summary of suggestions made by the human factors expert:

- Travel time would be most "meaningful traffic information" for drivers. Delay needs more information processing time by drivers, and would need to be converted to travel time anyway. Same is true for queue length which will need maximum processing time when compared to travel time and delay.

- It is not clear if aggressive driving is a reaction to stress and uncertainty resulting from recurrent and/or non-recurrent congestion. However, it is expected that information such as travel times and congestion limits may reduce driver's stress and anxiety level, and thus improve safety.

- If alternate route information is provided, these routes should be well known/obvious routes.

- In regards to descriptive vs. prescriptive traffic information, travel times on two alternate routes will be helpful for drivers if the difference in travel times is significant (e.g., greater than 10 minutes). However, in case of travel time information on two equal alternatives, the drivers might face a dilemma of which route to choose. The human factors principle is that if people cannot make a decision then the agency should provide them a solution.

- Travel time information should be provided on DMSs, provided the information is reasonably accurate, updated continuously with small time intervals, and the link lengths (for which travel time information is being provided) are not too short.

- DMSs with information may be more effective than blank signs as in first case drivers at least know that the system is working. To catch motorist attention for incidents and other emergency information, flashing beacons can be used.

- Travel times should be provided in the range format (e.g., 5-7 MIN).

SUMMARY OF FINDINGS

Following are key findings based on literature search and surveys.

- Evaluations of current deployments show that the motorists believe there are benefits of TTEPS. These benefits include reduced anxiety and stress, travel time savings due to diversion to alternate routes or changing departure times, and increased trip reliability. Also, surveys for determination of motorists' information needs show that drivers mostly rate travel times as the most meaningful information.

- State DOTs running travel time estimation and prediction system (TTEPS) are satisfied with its performance and are looking at more innovative applications and improvements. Public perception is very good. They want more reliability, coverage, and predictability.

- State DOTs are using different detection methods (AVI, VID, ILD) for TTEPS and are satisfied with the system performance. In case of point-based detection, the use of ILDs is most common among transportation agencies. In case of probe-based methods, cellular geo-location is being evaluated currently by State DOTs (MD and VA). If the evaluation indicates good results, this technology may provide a cost effective detection alternative.

- IDOT does not show travel time estimates on DMSs and limit it to other modes such as Internet and dial-up phone systems. A major concern is loss of credibility in case of inaccurate information. However, studies have shown that motorists do not interpret travel time displays to be 100 percent accurate. Evaluations of TTEPS of State DOTs which display travel times on DMSs indicate that public perception is positive and there are no major reliability issues. The DMS message content can be designed to let motorists know that travel time being displayed is an approximate estimation and not a prediction.

- State DOTs with no TTEPS site two major reasons: 1). Absence of extensive detection infrastructure, and 2). Reliability of information. Both these reasons are basically related to the ability to accurately estimate/predict travel times.

- Some State DOTs (e.g., WiDOT) are interested in prediction capabilities. Research is being conducted in this area. Traffic models such as dynamic traffic assignment may provide predictions with reasonable accuracy.

SUGGESTED GUIDELINES

Based on the information gathered through literature search, survey of State DOTs, and discussion with human factors consultant, following guidelines were developed for successful implementation of TTEPS.

Step 1: Clearly establish the objectives of Travel Time Estimation/Prediction System

The first step is to determine and/or develop the objectives of TTEPS. This step is necessary as it will influence level of accuracy, information dissemination mode, message content, detection technology, coverage area, completely vs. partially automated system, and its role in the overall ATMS and/or ATIS. Both short term and long term objectives should be examined. Also primary as well as secondary applications should be identified.

Step 2: Identify/determine possible information dissemination modes and level of accuracy

Based on the objectives defined in Step 1, possible information dissemination modes are identified. These modes may include DMSs, Internet, HAR, dial-up phone systems, personalized pager systems, in-vehicle information, and local media outlets. At the same time, it will be important to determine the acceptable level of accuracy. The level of accuracy needed for DMS application might be more than that needed for the Internet.

Step 3: Develop message content

The message content is very important as it effects driver behavior directly, and thus effecting the overall system efficiency. The message content should be based on desired objective, and should be short, simple, easy to understand, and effective. The message can be provided in a number of formats/combinations which may include travel time between two point, travel time to key destination, travel time on alternate routes, travel times on current route and recommended diversion route, travel time and congestion limits, etc. Message formats should include the use of words such as estimated, approx, and/or predicted; range of travel times; and time of day at which estimation/prediction was done (whenever possible). It is suggested that when travel times are provided in a range format; use 2-minute range up to maximum travel time of 15 minutes, and 5-minute range for travel times greater than 15 minutes. For travel times less than 5 minutes, either do not display travel time or use “LESS THAN 5 MIN” type message. This is also true for travel times greater than a maximum threshold time (e.g., 2 hours). In this case, the travel time information should be provided as “MORE THAN 2 HRS”. Travel times on alternate routes should be displayed only when the alternate route is obvious, and the travel times are significantly different depending on length of the segment for which travel times have been estimated/predicted.

Travel times less than minimum travel times, calculated by using maximum speed limits, should never be displayed. In such cases, it is suggested that information be given as “TRAFFIC MOVING WELL”, “NO CONGESTION” or a blank sign.

For travel times on Internet, following options should also be considered.

- Common travel times for most traveled sections, between key points, and for key destinations to provide a quick overview of traffic conditions.
- Personal route selector, which allows to select different routes, which can be bookmarked for future use of real-time travel time information.
- Dynamic route builder, which allows to select two points on the map and provides real-time travel time information.
- Individual major route (freeways, expressways, arterials, etc) pages with link specific information.
- Current DMS messages displays.
- Historical travel time information for various routes to provide quick comparison of existing and normal traffic conditions.

Step 4a: Identify/evaluate existing detection technologies and existing/planned ITS infrastructure

There is no national standard or common practice on the use of detection technology for TTEPS. A thorough evaluation of the technical specifications and cost comparison of competing technologies should be performed. The determination of most appropriate technology will also depend on the desired level of accuracy, current/planned detection infrastructure of the agency, and available financial resources. If the agency has an extensive point-based or probe-based detection system in place, the first step should be to evaluate the effectiveness of this system for travel time estimation and/or prediction. Other steps may include the narrowing of devices based on type of data required, integration of devices with current system, secondary data provided by detectors, operational and maintenance costs, training costs for maintenance personnel, environmental conditions, and required detector density and sample size for accurate travel time estimation and/or prediction. A possible outcome of this step might be a combination of number of detection technologies.

Other ITS devices and components such as video surveillance capabilities to verify road conditions such as congestion and incidents; information dissemination capabilities (DMSs, Internet, HARs, etc) should also be evaluated in this step.

Step 4b: Estimation of missing data

This step will be needed only if the agency is unable to install an extensive detection system, which can provide an accurate estimation/prediction of travel times. Such cases may include absence of enough probe vehicles, and greater spacing/absence of detectors. In such cases, certain traffic estimation/ prediction models can be used to estimate travel times more accurately.

Step 5: System design and integration

In this step, the information dissemination modes and technology(s) selected in Steps 2 and 4 will be designed to meet the objectives. The system design may include strategic locations of DMSs, development of an Internet site, archiving of data collected to build a database which can be used by other models for traffic estimation and/or prediction, detection system details (detector spacing/location, antennas, probes, communication method), data screening system, incident detection system, etc. Different components of the TTEPS are, then, integrated to ensure smooth and reliable operations. Systems integration is the key to processing the data collected from field devices and turning it into usable information for effective ATIS/ATMS. The system should be automated as much as possible, as it ensures smooth operations and lowers operating costs.

Step 6: Implementation and evaluation

Once this real-time TTEPS is designed and implemented, there should be a thorough off-line evaluation of the system. All components of TTEPS should be checked for data accuracy and system reliability. Once the off-line evaluation is successful, then the system can be brought on-line for real time applications. Due to the sensitivity of the information and its accuracy, there should be a continuous or periodic (at minimum) evaluation of the system to ensure its reliability. These evaluations would also provide an opportunity to get information on driver behavior, system effectiveness, and possible future improvements.

Public education is also important so that the motorists know what does the information mean. This not only improves public acceptance of the program but also increases system efficiency as motorists use this information.

APPLICATION OF GUIDELINES: A CASE STUDY

Maryland's CHART System

CHART (Coordinated Highways Action Response Team) is the Maryland State Highway Administration's application of ITS to improve the efficiency and effectiveness of state highway management in the State. It is unique among other ITS deployments nationally as it is the first and still the only Statewide ITS program in the United States; it has a Statewide Operations Center which is fully integrated with regional Traffic Operations and Traffic Management Centers; and it is the first program to integrate the efforts of a state highway agency, state toll authority, and state police.

As CHART is a statewide ITS program, it is suggested that individual objective-oriented travel time applications should be designed with the long-term goal of integrating these applications to provide a Statewide TTEPS. In this report, the author tried to maximize benefit out of the existing/planned ITS capabilities and not suggest new devices/technologies that would require major investment. A schematic of the Balitmore/Washington Metropolitan Study Area is shown in Figure 5.

The guidelines were applied to two TTEPS scenarios. The different factors studied and final recommendations as a result of application of above guidelines will be mostly common to the two scenarios. However, there are some differences, which will be pointed out.

The two scenarios studied are:

1. I-95 corridor in the Washington D.C./Baltimore metropolitan area; and

2. I-270.

I-95 is a major freeway running North/South along the East Coast of the United States. I-95 between Baltimore Beltway (I-695) and Capital Beltway (I-495) is a 22-mile freeway segment. I-695, I-495, and I-95 experience major congestion during AM and PM peak hours. The traffic volumes at other times are also significantly high. Increased construction/maintenance activities and incidents result in congestion during the non-peak hours too. However, there are a number of alternate North/South routes between I-695 and I-495 such as US-29 (planned to be an expressway for most of the section between the two beltways), Baltimore-Washington Parkway (MD-295), US-1 (major arterial), and I-97/US-50. For the purpose of this study, we will consider the two most obvious alternates, i.e., I-95 and MD-295.

I-270 is a major freeway with mainly commuter directional traffic in Washington D.C. metro area. I-270 has HOV and collector-distributor lanes, in Montgomery County, leading to Capital Beltway (I-495). This corridor is considered to be the major technology corridor in Maryland and experiences severe directional congestion during peak hours.

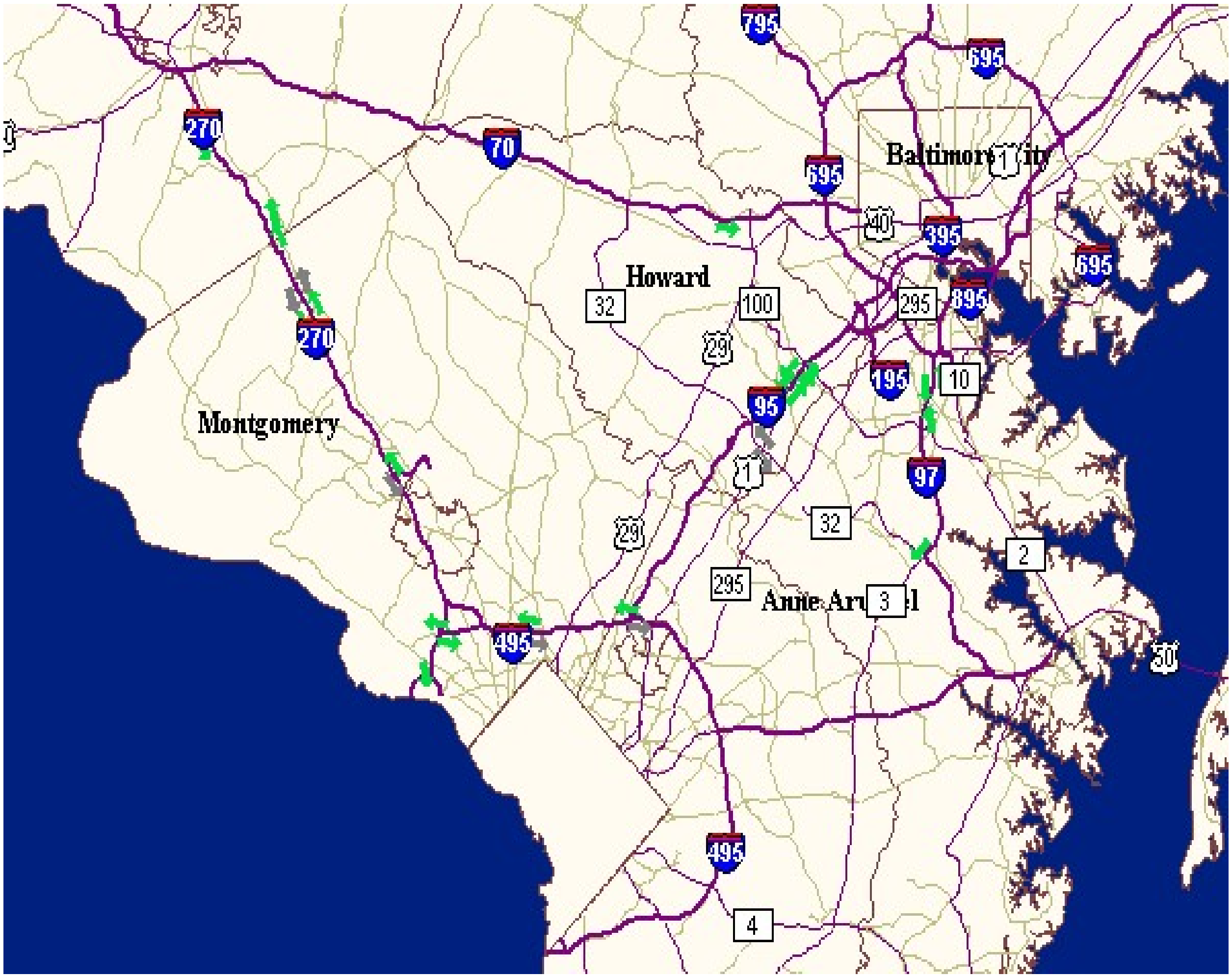


Figure 5. Baltimore/Washington Metropolitan Study Area

Step 1: Clearly establish the objectives of Travel Time Estimation/Prediction System

Based on the understanding of the CHART system, it is recommended that individual objective-oriented travel time applications should be designed with the long-term goal of integrating these applications to provide a statewide TTEPS. The overall objective would be to provide a real-time TTEPS for an effective Statewide ATIS and/or ATMS. The primary individual objectives can be any of the applications discussed earlier in this report. In general, the initial focus should be on major routes, which experience congestion and variations in travel time during different times of the day.

The scenarios being discussed here would have two common objectives. 1). Travel time estimates to key points/destinations along the route, and 2). Identifying the congestion limits and providing travel time information.

Other separate objectives are the following.

1. I-95 corridor in the Washington D.C./Baltimore metropolitan area . Alternate route travel time information to improve travel times to a given destination, develop diversion strategies, and maximize network efficiency.

2. I-270. Travel time information for HOV and general-purpose lanes to encourage use of HOV lanes and improve network productivity.

Step 2: Identify/determine possible information dissemination modes and level of accuracy

Initial information dissemination modes would include DMSs, HAR, Internet, local media, and dial-up phone systems for the two scenarios. Once the system is successfully implemented and proves its effectiveness, then other high-tech options such as personalized pagers and in-vehicle route guidance system should be considered. If the agency determines that it would not show travel times on DMSs, then such information should be provided to motorists through other information dissemination modes, until the agency feels comfortable to use DMSs for this purpose.

The level of accuracy should be as high as possible. However, as suggested earlier in the report that accuracy greater than 71 percent is considered acceptable. The target accuracy should be approximately 85 percent.

Step 3: Develop message content

Some common principles between different modes of communication are listed below.

- It is suggested that the travel time information on alternate routes should be provided first on the Internet. Once the agency feels comfortable, then this information can be displayed on the DMSs.

- Travel times should be provided in range format (as suggested in guidelines).

- Whenever possible, words such as estimated or approx, and/or time-of-the-day information should be displayed on DMSs.

- Messages should be displayed from 6 A.M to 10 P.M. unless other important/emergency messages have to be displayed. Messages should be updated continuously after short interval (e.g., after every 1 minute).

- Travel times for alternate and/or special purpose lanes should not be displayed if the difference is not significant.

Dynamic Message Signs:

The message content is most important when information is displayed on DMSs. It is suggested that descriptive information should be provided unless prescriptive information is required. Typical suggested messages are shown below.

TRAVEL TIME TO I-495		
I-95	X-Y	MIN
D 295	X-Y	MIN

DMS message displayed on I-695 East before I-95 Exit

TRAVEL TIME TO I-495	
MD 295	X-Y MIN
I-95	X-Y MIN

DMS message displayed on I-695 West before MD-295 Exit

TRAVEL TIME TO	
MD 32	X-Y MIN
I-495	X-Y MIN

DMS message along I-95 SB between I-195 and MD-175

TRAVEL TIME TO	
I-195	X-Y MIN
AT 10:00 A.M.	

DMS message along I-95 NB before MD 32

CONGESTION		
FROM	MD-100	EXIT-43
TO	MD-198	EXIT-33

TRAVEL TIME TO	
I-495	X-Y MIN
AT 4:00 P.M.	

DMS along I-95 SB between I-195 and MD-175

TRAVEL TIME TO I-495	
HOV LANE	X-Y MIN
OTHER	X-Y MIN

DMS message along I-270 before Montgomery Village Ave

TRAVEL TIME TO		
XXXX	EVENT	EXIT-5
APPROX	Y-Z MIN	

DMS along I-270 after MD 118

Internet

Based on the guidelines suggested earlier, the information on Internet related to the two scenarios being studied should include one page summary of travel times for most traveled sections and for key points/destinations providing a quick overview of traffic conditions, separate route (I-95, I-270, MD-295) pages with link specific information, and current DMS displays. The overall route with and/or without link specific information should, also, include travel times on HOV lane(s) and alternate routes (wherever available).

Step 4a: Identify/evaluate existing detection technologies and existing/planned ITS infrastructure

For the purpose of this study, both existing and planned (CHART's Business Plan, 2000) detection devices/technologies are considered to be available. CHART's system capabilities are discussed in general while focussing on the corridors being studied in this report.

CHART's current goal is to install side-fire microwave radar detectors (RTMS) on major freeways at 1-mile spacing (*57*). These detectors are capable of providing speed, volume, and occupancy data. The accuracy for speed estimation is approximately 92 percent of ILDs. Current 89 overhead speed detectors, primarily on two beltways and I-95, are also being upgraded and moved to roadside. CHART is also installing loop-based traffic monitoring stations on the National Park Service controlled portions of the Baltimore-Washington Parkway (MD-295). CHART also has some more sparsely located loop detector stations on I-95, I-495, I-695, and I-270. CHART currently has 76 CCTV cameras and plans to add 61 more cameras along I-95, I-495, I-695, I-270 and I-70 in the Washington and Baltimore regions. There will be 9 cameras on I-95 between the two beltways. There will be additional cameras along beltways providing surveillance coverage for I-95 and MD-295 interchanges. CHART has 4 cameras along I-270 near I-495 and plans to add 2 more near I-270/I-70 interchange. Montgomery County's TMC also provides significant video surveillance on I-270. CHART currently has 76 DMSs and plans to add 12 more to its freeway network. These DMSs are primarily located before major interchanges and junctions. There are DMSs along I-495 and I-695 leading to I-95 and MD-295, along I-495 leading to I-270, along I-95 leading to and within the two beltways, and along I-270. SHA has 32 HARs and plans to add 13 more to its freeway network. SHA also plans to install display units to provide traffic and transportation information at location such as rest area, airports, MVA facilities, and Mass Transit Administration transfer points.

The side-fire microwave detector's speed accuracy is acceptable. However, for accurate estimation of travel time, experts suggest that the detector spacing should be ¼- to ½-mile. 1-mile spacing of side-fire detectors may not provide very accurate estimates of travel time (needs to be studied as no current evaluations available). It is suggested that this data should be combined with data from USWC's "RadioCamera" technology and traffic modeling estimates to improve reliability of travel time estimates. A secondary advantage of using a traffic model is to have predictive capabilities for proactive ATIS/ATMS strategies. An obvious alternative to the use of suggested combination of technologies would be to install more microwave detectors to reduce spacing (preferably 1/3 mile apart).

Other probe-based technologies were not considered due to the low probe density in the study region.

Step 4b: Estimation of missing data

It is proposed that TrEPS (Traffic Estimation and Prediction System) be used to estimate travel times based on real-time information and historical data. TrEPS is a dynamic assignment tool designed to work in a TMC environment, and provide good estimates of current conditions, reasonably accurate predictions, and provide guidance for proactive ATIS/ATMS strategies in real time. The two prototypes of TrEPS are DYNAMIT and DYNASMART developed by Massachusetts Institute of Technology (MIT) and University of Texas at Austin respectively (*58*). These prototypes are being evaluated. The historical and surveillance data needed includes speed, volume, occupancy, detector locations, origin-destination data, and roadway geometry. In order to improve the quality of historic data, it is suggested that data should be collected for short time intervals (e.g., every 15 minutes) and individual days.

The travel times estimated and predicted by TrEPS should be thoroughly evaluated for accuracy. Since the system learns with time, the accuracy of the travel time estimates and predictions are also expected to improve with time. Since TrEPS does not recognize an incident itself, it is suggested that an incident detection algorithm be put in place to detect and inform TrEPS that an incident has occurred so that TrEPS can provide estimation, prediction, and guidance for the changed traffic conditions.

Step 5: System design, development and integration

The initial evaluation of the system in step 4 shows that CHART has majority of the capabilities needed to have a good travel time estimation system for the two scenarios being studied. The DMSs, CCTVs, and HARs are available at strategic locations, i.e., before major junctions, key destinations, change in traffic characteristics such as start/end of HOV lanes, etc. In this step, the required number of cellular tracking towers for use of USWC's cellular technology will be determined. Generally, one cellular tracking station can cover at least a mile of roadways. CHART's web site will be redesigned to incorporate travel time features. A dial-up phone system with automated travel time options for different routes/destinations will be designed. A sophisticated database will be designed to add real-time data to historical data. This database will provide necessary data for different ATMS/ATIS applications in addition to TrEPS. The database will update historical data by time of day for different days of each month. An incident detection algorithm will be developed based on current traffic monitoring

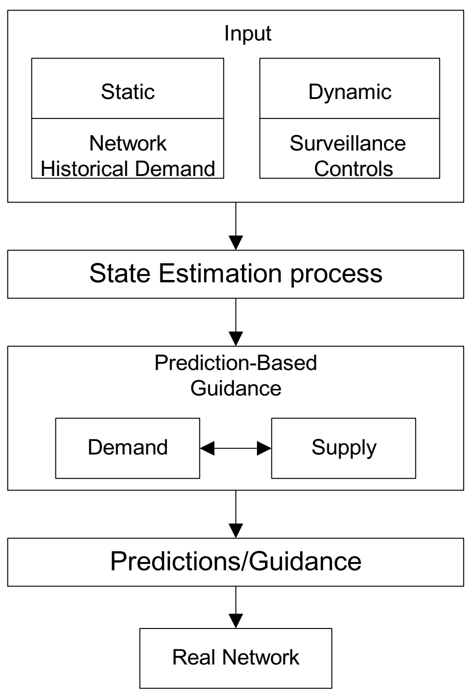


Figure 6. Generalized TrEPS Framework

capabilities. After design/development, the different components of the system, including TrEPS, will be integrated to have one "automated" system for data collection/archiving, traffic (travel time) estimation/prediction, and ATMS/ATIS strategies in real-time. This will include automated use of real-time travel times by different information dissemination modes. The Generalized TrEPS framework is shown in Figure 6.

Step 6: Implementation and evaluation

The system should be evaluated for real-time travel time information accuracy for 6 months. The evaluation should also include proper functioning and reliability of all components of the TTEPS. If the system is reliable and reasonably accurate, then this information should be provided for public use and traffic management applications. Initially travel time information should be provided to public under relatively normal traffic and weather conditions. It is expected that under such conditions the travel time estimates will be more reliable and accurate. This will help in achieving a higher level of user trust. At this time, a public awareness campaign should be started so that motorists can use this information intelligently. The process of evaluation should be continuous to ensure reliability/accuracy, determine its impact on traffic conditions for optimum network performance and safety, and make improvements in its performance. The process of evaluation should include public feedback also. This can be accomplished through mail/web site/phone surveys, interviews at rest areas and Park-and-Ride lots, and monitoring of information on local media.

CONCLUSIONS

As the highway network continues to become increasingly congested it has become very important to find intelligent solutions to improve mobility, productivity and safety. Intelligent Transportation Systems (ITS) uses advanced technologies and concepts to provide solutions for achieving significant improvements in mobility, productivity, and safety. Real-time traffic surveillance is essential for effective management of traffic, especially in urban areas. This real-time data can be used for several applications such as traveler information services, adaptive traffic control systems, congestion management, incident detection, etc. In this paper, real-time freeway travel time estimation and application is explored. Many agencies in United States and worldwide are estimating real-time travel times. Experts have found it to be more meaningful information for motorists as compared to delay, queue length, etc. This information can be provided to public for reducing stress and anxiety due to travel time uncertainty as our network travel times become increasingly unpredictable due to congestion and incidents. It also provides an opportunity to better plan trips and change departure times. Some agencies are using this information for providing alternate route information to maximize the productivity of the network. This information can also be used in incident detection algorithms or as a performance measure for network productivity. This information is provided to motorists using different dissemination modes such as DMSs, Internet, HARs, dial-up phone systems, and personalized pager systems. The survey of the agencies using travel time information shows that motorist like this information and would like to have more reliability, coverage, and predictability. Some agencies provide travel time information using Internet or other modes except DMSs. However, agencies that have been using DMSs for this purpose are satisfied and happy with the system. This shows that motorists do not expect travel time information to be 100percent accurate. Such information should be reasonably accurate, and provided in such a format that motorists can interpret it as an estimated or approximate value. Also such a system should be automated. Guidelines were developed to help agencies looking for implementing a freeway travel time estimation/prediction system based on literature search and the survey results. The findings were also applied to Maryland's CHART system to illustrate the process. The scenarios included travel time information for alternate routes and HOV lanes.

A need exists for future research in the area of improving travel time estimates with less than desirable traffic monitoring capabilities. Also, further evaluation of the use of cellular technology for providing real-time travel time information will show if this provides agencies with a cost-effective alternate to expensive detection infrastructure. The combination of different detection devices and use of traffic prediction models also needs to be studied. Also, more real-world field evaluations are needed to get a better understanding of the effect of real-time travel time information on driver behavior and network productivity.

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This paper was developed for Advanced Surface Transportation Systems, a graduate course in Civil Engineering at Texas A&M University. The author would like to express his gratitude to his professional mentor Mr. Joseph McDermott for his assistance and guidance in conducting this research and preparing the report. A sincere thanks goes to all the other mentors Mr. Jack Kay, Mr. David Roper, Mr. Patrick Irwin, Mr. William Spreitzer, and Mr. Wayne Kittleson for their time and efforts in sharing their expertise and supporting this course. The author would like to extend special appreciation to Dr. Conrad Dudek for the opportunity to participate in this unique program and for the opportunity to work with a diverse group of transportation professionals. An extra special thanks goes to Michael Fontaine, Barry Heard, Sean Merrell, Grant Shultz, and Jaime Helmuth for making visits to Texas A&M University beneficial and

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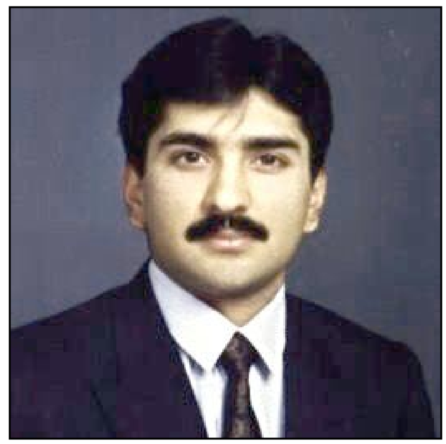

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Mr. Paracha's transportation interests include traffic engineering analysis, work zone traffic safety and operations, traffic control systems, and ITS operations.

ADVANCED TECHNOLOGY WARNING DEVICES TO IMPROVE MOTORIST RESPONSE TO UNEXPECTED CONDITIONS

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SUMMARY

Everyday, motorists are faced with unexpected conditions in which they must make split second decisions in order to avoid a collision. Oftentimes decisions are made in error leading to crashes, injuries, and in some cases death. There is a need to warn motorists of these unexpected conditions, thereby increasing reaction time and allowing them to make more informed decisions. Several different infrastructure based warning devices such as freeway and intersection warning devices, as well as advanced traffic management systems are currently in use throughout the United States to warn motorists of these unexpected conditions. In addition, more advanced technology devices are currently being researched, developed, and tested for implementation.

To determine the extent of warning device usage in the United States, the author conducted a state Department of Transportation (DOT) survey. The results of the survey indicated that infrastructure based devices are the most widely used today, while more advanced technology in-vehicle warning devices hold the key to the future. The survey results also indicated that these in-vehicle devices have technical and in some cases political concerns that must be addressed before they will be widely utilized and accepted.

Based on the research, five techniques were determined to be applicable to address the problem of crash reduction outlined in this report. The five techniques include the following:

- Freeway warning devices;
- Intersection warning devices;
- Advanced traffic management systems;
- Rear-end collision avoidance systems; and
- Intersection collision avoidance systems.

To determine the effectiveness of each of the techniques, several merits or measures of performance were developed for consideration in ranking the warning techniques. The merits chosen for ranking the techniques were:

- Ease of implementation;
- Cost of implementation;
- Addresses the crash reduction problem;
- Cost of operation/maintenance; and
- Adaptable/non-discriminating.

Each of the techniques were ranked independently according to the level in which they addressed the merits. The intelligent vehicle components (rear-end and intersection collision avoidance systems) were determined to be the most effective in addressing the crash problem, followed closely by the advanced traffic management systems, which were found to effectively reduce crashes within their influence areas.

The five techniques were applied to a theoretical case study location to determine effectiveness and to make recommendations on how best to implement the technologies. The results indicated that rear-end and intersection collision avoidance techniques would be most applicable to provide warning to motorists of unexpected conditions leading to crash reduction potential. Advanced traffic management systems were also recommended for the case study location as an effective technique to improve motorist response to unexpected conditions.

TABLE OF CONTENTS

INTRODUCTION

Everyday, motorists are faced with situations in which they must react to unexpected conditions along the roadway corridor in which they are traveling. These unexpected conditions include adverse weather, queue backup, sight distance limitations, incidents on the roadway, and others. These conditions affect safety and can lead to added congestion through secondary collisions that in many cases can prove fatal.

The technology of warning devices in the United States had its beginnings in the 1960s and has continued to evolve over the years. Today the field of intelligent transportation systems (ITS) is being utilized to help aid motorists in overcoming the unexpected conditions outlined. Several research programs and test sites have been developed over the past several years to analyze the impacts of different warning systems on motorist behavior and traffic safety. These programs continue to help agencies document the safety benefits that can be achieved through the implementation of advanced technology warning devices, while at the same time provide the research, development, and testing necessary to achieve safer roadways.

Problem Statement

The problem facing transportation professionals today is providing information to motorists to warn them of unexpected conditions in time to allow them to react to the conditions, thus avoiding potential collisions and increasing roadway safety. Both the United States and Japanese researchers have been developing and testing advanced technologies to provide warning to motorists of unexpected conditions that includes vehicle to roadway, vehicle to vehicle, and roadway to vehicle communication to aid in motorist response to such conditions (*1*). There is a need today to utilize these advanced technologies to warn motorists of unexpected conditions in an attempt to reduce crashes and increase safety.

Research Objectives

The primary objectives of this research were to:

1. Identify the state-of-the-practice for providing warning to motorists of unexpected conditions through the use of active warning devices including rear-end and intersection collision avoidance techniques;
2. Identify the use of advanced technology warning devices in the United States through literature review and confirm these results through a survey of state DOT agencies;
3. Project the future of warning devices in the United States (including rear-end and intersection collision avoidance techniques) based on international practice and testing;
4. Develop a summary of techniques for advanced technology warning devices;
5. Identify the benefits of each technique;
6. Determine the merits of the techniques and rank the techniques according to these merits; and
7. Apply the results of the research to a theoretical case study location.

THE NEED FOR WARNING DEVICES

In each of the last five years, the National Highway Traffic Safety Administration (NHTSA) *Traffic Safety Facts* (*2*, *3*) has recorded more than 6.2 million police-reported traffic crashes, leading to more than 3.2 million injuries and over 41,000 fatalities. These crash statistics translate to injury rates that range from 140 injuries per 100 million vehicle miles traveled (VMT) in 1996 to 120 injuries per 100 million VMT in 2000, and fatality rates that range between 1.5 fatalities per 100 million VMT and 1.7 fatalities per 100 million VMT during this same time period, as shown in Table 1. These crashes continue to cost Americans an estimated $150 billion every year. Since the 1960s, government and industry leaders have researched crashes to improve the crash worthiness of motor vehicles and roadway facilities. Even with this research, total crashes and persons injured or killed as a result of these crashes has remained relatively unchanged.

Table 1. Traffic Safety Facts (2, 3)

Year	Traffic Crashes	Persons Injured	Injury Rate per 100 Million VMT	Persons Killed	Fatality Rate per 100 Million VMT
1996	6,842,000	3,465,000	140	42,065	1.7
1997	6,764,000	3,348,000	131	42,013	1.6
1998	6,334,000	3,192,000	121	41,501	1.6
1999	6,279,000	3,236,000	120	41,611	1.5
2000	6,303,000	3,219,000	120	41,800	1.6

The distribution of crash types for all highway vehicles (based on 1998 General Estimates System (GES) data) is shown in Figure 1 (4). This distribution provides researchers an opportunity to target safety improvement efforts through the introduction of effective collision avoidance systems and products. The three largest subsets of crash types identified in Figure 1 are rear-end, intersection, and road departure collisions, which together account for 70 percent of all crashes.

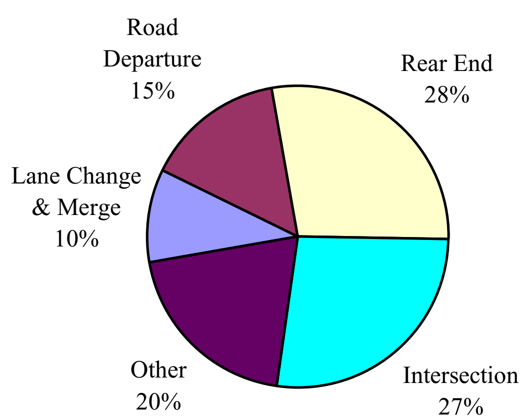

Figure 1. Distribution of Crash Types (4)

In addition to the breakdown of crash types, the causal factors for crashes are also important in determining appropriate countermeasures to increase safety. NHTSA has provided a summary of causal factors for crash research and found that driving task errors were the leading cause of crashes in the United States, contributing in 75.4 percent of all reported crashes. The secondary causes were found to be driver state (14 percent), road surface (8 percent), vehicle defects (2.5 percent) and visibility (0.1 percent).

By further breaking down the driving task errors, researchers found that recognition errors (43.6 percent), decision errors (23.3 percent) and erratic actions (8.5 percent) are the leading causes of driving task errors and crashes (*5*, *6*).

In reviewing these statistics, the need to reduce driving task error appears to be an important factor in increasing roadway safety. To aid in reducing the crash statistics, there is a need to warn motorists of unexpected conditions, thereby increasing reaction time and allowing motorists to make more informed decisions. It is anticipated that providing added warning to motorists may help in improving roadway safety by reducing the total number of crashes caused by driving task error.

BACKGROUND OF WARNING DEVICES

Warning devices on freeway and arterial roadway systems had their beginnings in the 1960s and have continued to evolve over the years. The types of warning devices that have been installed have included freeway warning devices, intersection warning devices, advanced traffic management systems and intelligent vehicle safety advisory and warning devices. A brief background and history for each of these devices is presented in this section.

Freeway Warning Devices

Some of the early research efforts for providing warning to motorists of unexpected conditions on urban freeways occurred in the late 1960s and early 1970s at the Texas Transportation Institute (TTI). Several studies underway at that time indicated a need to reduce congestion and improve the safety and level of service when freeway incidents occur. Messer *et al.* (*7*) showed that the reduction in capacity caused by the occurrence of freeway incidents was the cause of significant delay and congestion. Further studies by Dudek and Biggs (*8*) indicated that one of the biggest causes of these incidents was the restricted sight distance often created by overpasses along freeways that did not allow sufficient time to warn motorists of unexpected conditions. These unexpected conditions combined with sight distance limitations did not allow motorists an opportunity to adjust to the conditions, and rear-end collisions or near misses became prevalent.

In order to provide information to motorists faced with these conditions, a safety warning system was developed. The system consisted of a traffic-actuated warning device located upstream of the overpass crest in which sight distance was a concern. The warning device was designed to be activated when conditions warranted through a series of traffic detectors located on both sides of the overpass. Each warning device consisted of a six foot by twelve foot sign panel containing ten inch black letters with the message “CAUTION SLOW TRAFFIC WHEN FLASHING” displayed on a yellow non-reflectorized panel. In addition, a twelve-inch flashing beacon was attached on the right and left sides of the panel as shown in Figure 2. Operation of this pilot system was initiated on the Gulf Freeway in Houston, Texas on March 13, 1972 (*8*).

Following the installation of the Gulf Freeway safety warning system, Dudek *et al*. (*9*) conducted an evaluation of its effectiveness. As the objectives of the warning system were to alert motorists of unexpected conditions including stoppages downstream of an overpass crest, and allow them to reduce speed to avoid potential rear-end collisions, crashes were selected as the primary measure of the system’s effectiveness. The results of the evaluation suggested that the warning system was cost-effective for alerting approaching motorists to stoppages on the freeway. The warning system resulted in a 49 percent crash reduction for sections of the inbound Gulf Freeway influenced by the warning system, with comparable outbound sections reduced by only 5 percent. In addition, secondary crashes were eliminated during the 9-month reporting period. A survey of motorists observing the sign found that the majority of motorists believed that the sign was useful and that the message was generally understandable.

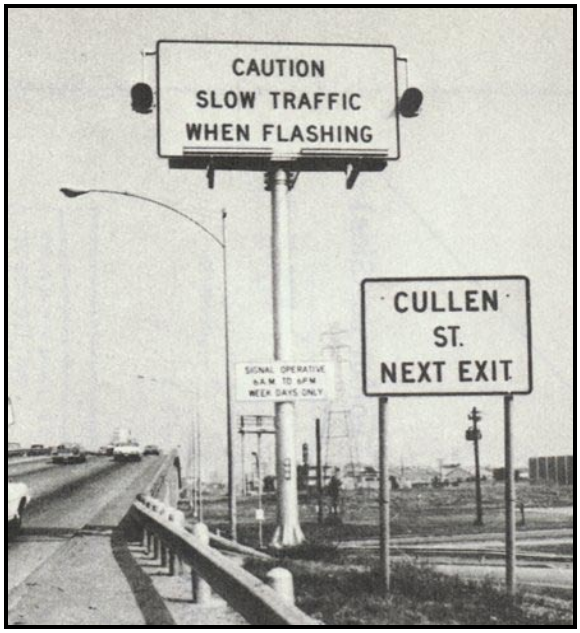

Figure 2. Freeway Warning Sign With Flashers (*8*)

Intersection Warning Devices

While warning devices were being developed for freeway operations, similar designs were being installed to warn motorists of unexpected conditions at signalized intersections. These intersection warning devices were implemented as a result of increased crash potential at intersections, particularly those in which either high-speed, limited sight distance, isolated, or unexpected (first signal in an otherwise unsignalized area) signalized intersections were prevalent.

The installation of warning devices at signalized intersections can be traced back to the 1960s, with early installations that date back to 1968 in Calgary, Alberta, Canada (*10*). Installations of this type have increased over the years to the point where the City of Calgary now has more than 30 installations within the City limits, similar to the one illustrated in Figure 3.

Throughout the United States, intersection warning devices have been documented to take on a number of different designs and practices. Bowman (*11*) prepared a *Synthesis of Highway Practice* outlining the different warning devices that were not specifically identified in the Manual on Uniform Traffic Control Devices (MUTCD). A wide variety of warning devices have been developed by transportation agencies to address unusual safety, operational, or environmental conditions that cannot be adequately addressed using standard warning devices found in the MUTCD. Both active and passive devices intended for long-term use were included in this analysis. Later research conducted by Sayed *et al.* (*12*) summarized the different warning devices into three general categories:

- Prepare To Stop When Flashing (PTSWF): The PTSWF sign is essentially a warning sign with the text Prepare To Stop When Flashing that is complemented by two amber flashers that begin to flash a few seconds before the onset of the yellow interval (at a downstream signalized intersection) and that continue to flash until the end of the red interval.

- Flashing Symbolic Signal Ahead (FSSA): This device is similar to the PTSWF sign except that the words Prepare To Stop When Flashing are replaced by a schematic traffic signal composed of a rectangle with solid red, yellow, and green circles. The flashers operate in the same manner as the PTSWF sign.

- Continuous Flashing Symbolic Signal Ahead (CFSSA): As the name suggest, this device is identical to the FSSA sign but it has flashers that flash all the time – the flashers are not connected to a traffic signal controller" (*12*).

Figure 3. Advance Warning Flasher, Calgary, Alberta (*13*)

The main purpose for the consideration of intersection warning devices is to improve safety at high-speed signalized intersections. Several research projects have been undertaken over the years outlining the effects of these installations on safety. The main criterion used in making a determination on safety has been crash reduction before and after installation. Several researchers have found that intersections with warning devices appear to have lower left-turn, right angle and in some instances, rear-end crashes. In addition, a summary of the research indicates that intersections with warning devices have consistently provided lower overall crash rates and fewer severe crashes than intersections without the devices. These reductions, however, have not been shown to be statistically significant (*12*, *14*, *15*, *16*, *17*).

Advanced Traffic Management Systems

Advanced traffic management systems (ATMS) primarily consist of permanent infrastructure and installation to provide real-time information to motorists of roadway and infrastructure conditions. In recent years, portable traffic management systems (PTMS) have also emerged to warn motorists of unexpected conditions in temporary work zone environments. Permanent ATMS installations as well as portable ATMS installations will be presented in this section.

Permanent ATMS Installations

One of the more recent advancements in the history of using advanced technology to provide warning to motorists of unexpected conditions has come about as a result of the emergence of advanced traffic management systems (ATMS). The strategic plan for intelligent vehicle highway systems (IVHS) (now referred to as intelligent transportation systems (ITS)) in 1992 indicated, "ATMS is the foundation upon which all other IVHS [ITS] technologies rely" (*18*). In 1993, Loral AeroSys ATMS Consortium (*19*) completed a study on the state-of-the-practice of traffic management centers for the United States Department of Transportation (U.S. DOT) Federal Highway Administration (FHWA). The results of this study indicated that ATMS would employ innovative technologies and integrate existing and new traffic management and control systems that would be responsive to dynamic traffic conditions.

At the center of the ATMS system is the traffic management center (TMC) or traffic operations center (TOC) where information is collected and processed. In the event of an incident or other unexpected condition, warning is provided to motorists through the use of dynamic message signs (DMS), lane control signals (LCS), and highway advisory radio (HAR). These devices provide real-time information to motorists, alerting them of the conditions ahead, and providing them with an opportunity to respond to these conditions. In some cases, these devices also provide motorists with alternate routes to avoid the unexpected conditions altogether.

The purpose of the ATMS program is to reduce congestion and improve highway safety; two of the key elements outlined in the goals of the ITS program. As a result of these goals, FHWA has developed a series of ITS Operational Tests that are being conducted across the country. These tests are designed to implement and evaluate advanced systems in real-world situations. One such test is currently being deployed in San Antonio, Texas where the Texas Department of Transportation (TxDOT) has installed an ATMS that is being utilized to bridge the gap between research and development, and full-scale deployment of ITS services. The Transportation Guidance System (TransGuide System) was designed to be the most advanced ATMS system in the United States. The first phase of the TransGuide System began in July 1995 and included coverage on 26 miles of San Antonio's freeway system. The last phase is scheduled for completion in January 2002 and will bring the total freeway monitoring to over 90 miles. Currently the system has been expanded to approximately 73 miles of total coverage through a digital communication network shown in Figure 4, with field equipment consisting of DMS, LCS, loop detectors, and surveillance cameras (20, 21, 22).

Figure 4. TransGuide System Control Center (23)

Research prepared at TTI by Henk *et al.* (21) on the before-and-after analysis of the first phase of the TransGuide system demonstrated an injury crash rate reduction of 15 percent and an overall projected crash rate reduction of 21 percent as a result of the combined impact of all components of the TransGuide System. The report further indicated that freeways not covered by the TransGuide System for this same time period recorded a 7.8 percent increase in total crashes and a 4.3 percent increase in overall crash rate. The TransGuide System utilizes visual information displayed to motorists via DMS and LCS to warn motorists of incidents and traffic congestion and/or to provide guidance to motorists on alternate routes based on these incidents as shown in Figure 5. The TransGuide System is demonstrating quantifiable benefits in the areas of safety, incident management, and motorist understanding and utilization (21).

Figure 5. TransGuide System Dynamic Message Sign (<u>*23*</u>)

Portable ATMS Installations

In addition to the permanent ATMS systems outlined in the previous section, portable traffic management systems (PTMS) have also been implemented in several locations to provide real-time information to motorists when no permanent ATMS infrastructure is in place. PTMS installations use portable speed and lane sensors, portable dynamic message signs (PDMS), HAR, and other portable dynamic warning devices to warn motorists of unexpected conditions, and to provide information to motorists on how to react to these conditions. Several different algorithms are currently available to analyze incoming sensor data and determine if a warning message should be displayed. Three typical applications used in making this determination include (<u>*24*</u>):

- Speed advisory;
- Travel time or delay advisory; and
- Diversion guidance.

Speed advisory systems communicate average speeds from portable sensor locations to the central control system at regular intervals. If the average speeds vary by a predetermined amount, upstream PDMS or other portable dynamic warning devices are used to warn motorists of the conditions ahead. Travel time or delay advisory systems use this same speed data to calculate travel time and delay through the application zone. These calculations are compared to ideal travel times to generate delay through the zone. If the delays are determined to be excessive, upstream PDMS or other portable dynamic warning devices provide information to motorists warning them of these conditions. Finally, diversion guidance systems can be used in conjunction with the speed advisory or travel time and delay advisory systems to provide alternate routes to motorists via the PDMS in an attempt to help motorists avoid congestion (<u>*24*</u>).

One of the more common applications of PTMS systems is the use of condition-responsive, reduced-speed-ahead messages in advance of work zones on rural interstate highways. These systems detect the presence of slow moving or stopped vehicles on the approach to work zones and provide warning to upstream motorists of these unexpected conditions via PDMS, HAR, and/or flashing beacons on fixed-message signs. McCoy and Pesti (<u>*25*</u>) evaluated the effectiveness of one of these systems and found that the reduced-speed-ahead messages were not very effective in reducing speeds, unless traffic flow was approaching congestion levels and motorists were aware of the work zone and therefore more likely to perceive the need to reduce their speeds. The most likely reason for the ineffectiveness of the devices was attributed to the location of the portable devices, which were too far in advance of the slow conditions and therefore motorists did not perceive the need to slow down (*25*). These conditions can be avoided through proper sign installation procedures and work zone management. Fontaine (*24*) has developed a series of guidelines to help overcome these types of problems and to aid in proper installation of PTMS systems in temporary applications.

Intelligent Vehicle Safety Advisory and Warning Devices

At the ITS America Tenth Annual Meeting and Exposition, David L. Smith, Light Vehicle Platform Technical Director for the Intelligent Vehicle Initiative indicated that the "…intelligent vehicle era is upon us. If one defines an 'intelligent vehicle' as a vehicle that senses the environment and produces some corresponding automatic action or driver advisory, then this era actually started some time ago. Such intelligent features as anti-lock brakes, traction control, air bags, and adaptive transmission control have been features in light vehicles for several years, at least. More recent developments include backing warning systems, adaptive cruise control, and infrared-based vision enhancement, all of which were announced as features in light vehicles in the U.S. market in the last year of the millennium. While these features promise improvements in safety, the steady and high level of crashes in light vehicles each year shows that the problem of safety remains critical" (*5*). The history of intelligent vehicle safety advisory and warning devices and how these devices can be used to warn motorists of unexpected conditions is presented in this section.

In 1963, William B. Roeca, Jr. and Adam C. Thomas of the Department of Electrical Engineering at Ohio State University published a paper entitled "An Anti-Rear-End Collision System" in the *Highway Research Record*. Roeca and Thomas (*26*) indicated that within the study of electronic aids to highway safety, one of the more exciting subjects has been the application of electronics to longitudinal control of individual vehicles. Two of the desired gains that would occur as a result of this application are a reduction in the number of rear-end collisions and an increase in safe traffic density. This research formed some of the early beginnings of what is now know as in-vehicle warning devices, or more recently intelligent vehicle or collision avoidance technology.

Since these early beginnings, researchers have continued to improve the technology of warning devices and to develop "smart" vehicles that use advanced technology to sense unexpected conditions and provide warning to motorists of these conditions. This warning is provided through a combination of audible (chimes, voice, radio), visual (heads up display, in-vehicle monitor), and/or tactile (seat vibration, brake pulse) devices that allow the technology to improve safety while maintaining freedom of choice and control for the motorist. The technology also has the capability to interface with the driving task, if the motorist does not respond appropriately to the warning provided (*5*). This intelligent vehicle safety advisory and warning device research and development effectively moves toward improved safety and innovative solutions to transportation needs.

With the passage of the Intermodal Surface Transportation Act (ISTEA) in 1991, the United States Secretary of Transportation was provided a directive to "…develop an automated highway and vehicle prototype from which fully automated intelligent vehicle highway systems can be developed" (*27*). This legislation led to the formation of the Automated Highway System (AHS) program. The research conducted under the AHS program established an extensive knowledge of collision avoidance, while aiding in the development of the Variable Dynamics Test Vehicle (VDTV) and the National Advanced Driving Simulator (NADS). Operational tests were also conducted to determine the benefits of the Intelligent Cruise Control (ICC) and the Automated Collision Notification (ACN) systems. One of the great milestones reached as part of the project was the AHS Demonstration in 1997 on I-15 near San

Diego, California (4). The demonstration successfully tested integrated vehicle control and warning devices.

Legislation passed as part of the Transportation Equity Act for the 21st Century (TEA-21), authorized the U.S. DOT in 1998 to coordinate research efforts related to safety and collision avoidance systems including the AHS research program and research efforts being conducted by NHTSA into one joint research effort, the Intelligent Vehicle Initiative (IVI).

Intelligent Vehicle Initiative (IVI)

The focus of the IVI program is to take roadway safety to the next level by improving vehicle design and incorporating new technologies that will aid in warning motorists of unexpected conditions, recommending actions to help respond better to these conditions, and in extreme cases assuming partial control of vehicles in order to avoid collisions. The bottom line with the IVI program is crash avoidance. As former Deputy Secretary of Transportation Mortimer L. Downey indicated in the *First Intelligent Vehicle Initiative National Showcase and Meeting*, "One of our [U.S. DOTs] favorite mottos is that 'The crash that doesn't happen is the best kind!'" (28).

The IVI program focuses on the following safety related areas (4):

- Rear-end collisions;
- Roadway departure collisions;
- Lane change and merge collisions;
- Intersection collisions;
- Driver impairment monitoring;
- Vision enhancement;
- Vehicle stability; and
- Safety impacting systems.

Early studies by the NHTSA indicate that with full deployment of three of the eight IVI safety related areas (rear-end collisions, roadway departure collisions, and lane change and merge collisions), one in six crashes would be eliminated annually (4). Of the eight safety related areas, two are most susceptible to aiding motorists in avoiding collisions due to unexpected conditions along the roadway corridor in which they are traveling. These two areas are rear-end collision avoidance and intersection collision avoidance. The other six safety related areas are also helpful in overall collision avoidance technology, however, the two outlined are the primary IVI program areas that relate to advanced technology warning devices as defined in this report. A summary of each of these two technologies is contained in the following sections.

<u>Rear-end Collision Avoidance.</u> Rear-end collisions account for one in four of all crashes in the United States (over 1.7 million in 1998) and have become a major focus area in the research and development of safe transportation systems. Since 1993, rear-end collision avoidance has been actively researched by the U.S. DOT and has included detailed analysis of the causal factors for the crash problems, operational tests of ICC, development of preliminary performance specifications, and the development of an extensive human factors database for rear-end collision avoidance. One of the greatest products of this research is the development and implementation of the adaptive cruise control (ACC) system, an option on several vehicles manufactured today (4).

Early versions of the rear-end collision avoidance research used extensions of the ACC capabilities to detect and classify stationary objects and to determine the level of threat from vehicles in front. More advanced versions of the technology include increased longitudinal control through vehicle braking, and ultimately the capability to perform coordinated lateral control and braking actions (4). Great strides have been made in the last few years in the area of rear-end crash countermeasures including the development of forward looking radar, forward looking vision systems, and a global positioning system (GPS) based map used in conjunction with other in-vehicle sensors. The program is currently headed in the direction of developing sensor data to adequately identify in-path collision threats and to incorporate this sensor data with ACC and active braking technologies (5). These new technologies will be used to sense the presence and speed of vehicles ahead and to provide warning to avoid collisions with these vehicles as illustrated in Figure 6.

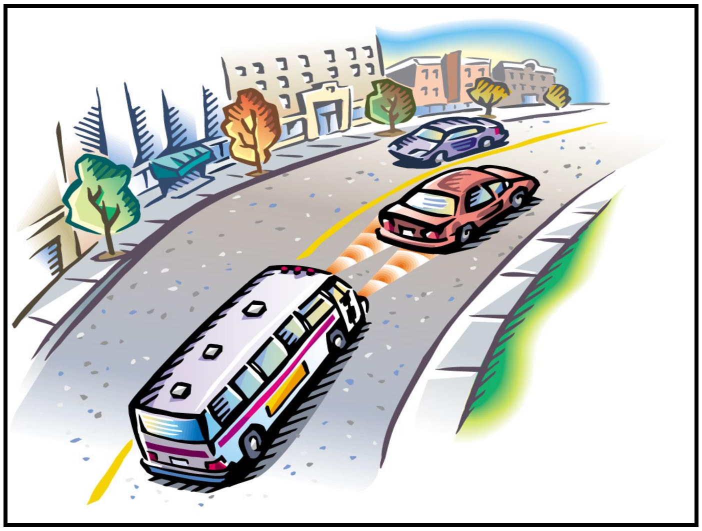

Figure 6. Rear-End Collision Avoidance (29)

Intersection Collision Avoidance. As outlined in Figure 1, 27 percent of all crashes in the United States are intersection related. Intersection collision avoidance is a complex problem that requires systems to warn motorists when the potential for collisions could occur. Intersection collision avoidance systems monitor vehicle speed and position relative to the intersection, while simultaneously monitoring the speed and position of other vehicles approaching the intersection. If this monitoring determines that there are potential right-of-way violations or other conditions that could warrant a collision, the system is activated to warn the motorist of this unexpected condition. Complexities of this system include first of all the sensing of vehicles on intersection roadways, and secondly determining the intent of these vehicles in terms of slowing, turning, or potential for violation of traffic control devices once they have been sensed (4).

In the area of intersection collision avoidance, vehicle-based countermeasure concepts using side-looking radar to detect cross flow conflicts in connection with GPS mapping to locate the junction and determine traffic control devices is currently being developed. Two difficulties that have been encountered in the current research are the signal phase, which introduces a confusing variable in terms of understanding cross flow intent, as well as prediction of violations of the traffic control devices (5). As this technology is developed, it is anticipated to be especially helpful for emergency vehicles approaching busy intersections (Figure 7) by providing warning to both cross traffic and the emergency vehicle of unexpected and unsafe conditions.

System Deployment. The U.S. DOTs strategic safety goal is to “promote the public health and safety by working toward the elimination of transportation-related deaths, injuries, and property damage” (4). The challenge in meeting this goal through the use of rear-end collision avoidance, intersection collision

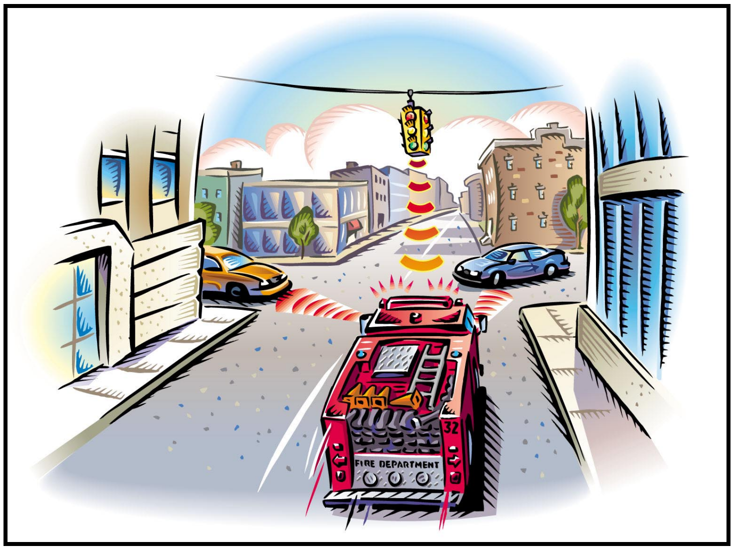

Figure 7. Intersection Collision Avoidance (*29*)

avoidance or any of the other six safety focus areas is the challenge of providing information to the motorist in such a manner that it will reduce or eliminate deaths, injuries, and property damage, rather than add to these statistics. Motorist or driver error is cited as the primary cause in approximately 90 percent of all police-reported crashes. The challenge with the implementation of the IVI program is to present information to the motorist without increasing the level of distraction and further compounding the problem. Currently this is being done through the use of: "route guidance and navigation systems, adaptive cruise control, automatic collision notification, cellular telephone, in-vehicle computing, and commercial vehicles diagnostics/prognostics" (*29*). These devices are used to provide warning to motorists of unexpected conditions and to aid them in responding to these conditions.

SURVEY OF THE USE OF WARNING DEVICES IN THE UNITED STATES

The literature review and background analysis of warning devices indicates that the types of devices currently in use in the United States are freeway and signalized intersection warning systems as well as a variety of ATMS operations. A state Department of Transportation (DOT) survey was conducted by the author to verify the extent of usage of these types of devices, to confirm the research findings, and to identify additional techniques being utilized within the United States. The DOT survey was conducted in the states of Illinois (IL), Maryland (MD), Missouri (MO), New York (NY), South Carolina (SC), Texas (TX), Utah (UT), Virginia (VA) and Washington (WA) as highlighted in Figure 8. In addition, the San Antonio office of the Texas Transportation Institute (TTI) was also contacted to provide input on recent research efforts and implementation in the state of Texas.

DOT Survey Development

The state DOT survey included a brief introduction of the proposed research along with a definition of the warning devices being considered as part of this research. Following the introduction, a series of questions were presented to obtain information on current technologies in practice. The desired outcome of the survey was to obtain information on the following:

- State-of-the-practice warning device technology being used in each state surveyed;
- Perceived benefits of this technology;
- Concerns with implementation;

- Guidelines for implementation; and
- General thoughts on the future of the technology.

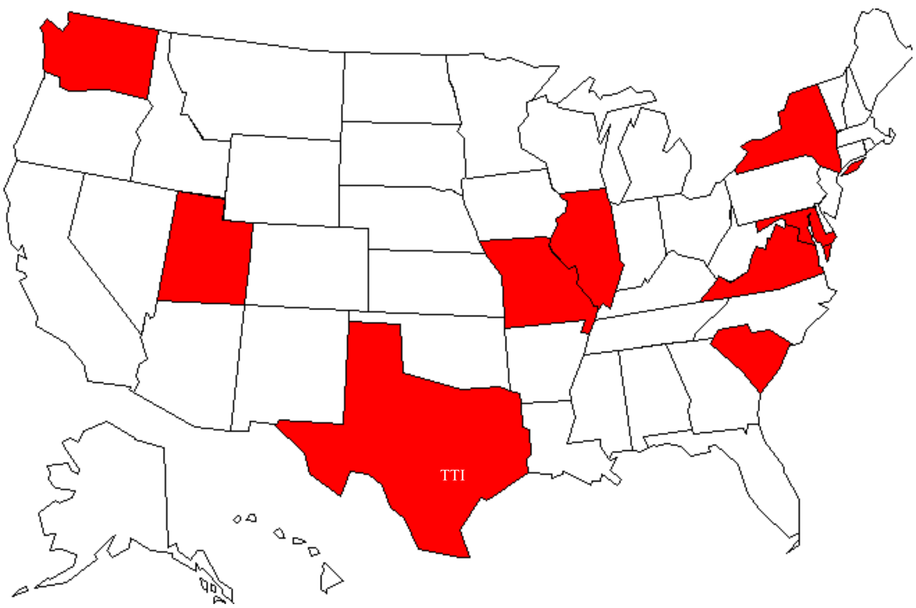

Figure 8. State DOT Survey Locations

The survey was e-mailed to representatives in each of the agencies outlined for a total of ten surveys. Following the initial e-mailing of the survey, follow-up e-mail and telephone calls were placed to the respondents in order to solicit input or to receive clarification on initial responses. Completed surveys were received from nine of the ten respondents contacted and the information was compiled for use in this study. A copy of the e-mail survey can be found in the Appendix with a summary of the survey results provided in the following section.

DOT Survey Results

A summary of the state DOT survey responses is provided in Table 2, with more detailed survey results summarized in this section.

The survey indicated that the majority of warning devices currently in use in the United States are being implemented through an ATMS and include such devices as DMS, LCS, HAR, and static and dynamic advanced signal warning devices.

All of the respondents indicated that there are benefits received from the warning devices currently in use. These benefits include most importantly the ability to provide reliable information to motorists, alerting them of adverse roadway conditions (i.e., incidents, inclement weather) and encouraging them to use alternate routes in order to reduce congestion and decrease the number of crashes on the roadway. All respondents indicated that the systems they are currently using appear to be effective, however, they were not aware of any documented benefits, with the exception of the Texas respondents. Mr. Patrick Irwin, Director of Transportation Operations, San Antonio District indicated that TxDOT and TTI had completed a joint study in San Antonio that analyzed the reduction in secondary collisions as a result of the ATMS system (*30*). The results of this study on the effectiveness of the TransGuide System were outlined previously in this report.

Table 2. State DOT Advanced Technology Warning Devices Survey Summary of Results

Question	Response
Types of warning devices:	DMS, LCS, HAR, and advanced traffic signal warning devices.
Benefits of technology:	Ability to provide reliable information to motorists, and potential decrease in the number of secondary crashes on the roadway.
Shortcomings of implementation:	Budgetary constraints, limitations in messages communicated with DMS, and limitations with HAR technology.
Additional technology to implement:	Radar and/or video imaging, automated HAR, fiber optics, FM radio communication, and permanent message sign implementation.
Guidelines for implementation:	In the absence of a detailed area wide plan, engineering judgment (perceived need) is typically used.
"Collision avoidance" technology:	Potential problems identified including liability, privacy, public acceptance, availability, and potential "over-reliance".

Even with the effectiveness of the current technology, several shortcomings were also identified through the survey. The first of these shortcomings was the limitations placed on system expansion due to budgetary constraints. The second shortcoming identified was the limited time and space for DMS messages. Oftentimes it is difficult to display the proper message with the limited number of characters to use on the message boards. Other times the message may not be interpreted correctly due to message constraints. Mr. David Kinnecom, Traffic Management Engineer for the Utah Department of Transportation (UDOT) indicated that this is especially true for surface street DMSs, where the size of the signs severely limits the message (*31*). The final shortcoming that was identified through the survey was related to the HAR. Several respondents indicated that the HAR had limitations on the range of listeners being serviced; others commented on the awkwardness of recording messages; while others expressed concern over the inability for real-time messages using their existing systems.

Some of the additional technology that is not currently being used but that was identified as technology that the states would like to deploy includes incident detection via radar and/or video imaging (no human monitoring), automated HAR (scenario driven system that would recognize a given condition and provide a real-time message related to the scenario detected), fiber optic communications, FM radio frequency with real-time traffic reporting rather than HAR, permanent rather than portable message signs, and voice-based notification of critical traffic information in the vehicle.

The guidelines for implementation of ATMS warning devices (DMS, LCS) were generally found to follow one common theme; engineering judgment, or perceived need. Several of the ATMS systems that have been installed by the survey respondents included detailed initial studies that identified target locations for warning devices and then provided a plan for deployment of the system. In the absence of a detailed plan, however, the general consensus was that engineering judgment or the perceived need for the device should be used in order to provide information at critical locations on the highway system. The typical factors identified in determining critical locations included crash statistics, major route diversion locations and areas of recurrent congestion.

When asked about the future of advanced technology for "collision avoidance," most respondents agreed that collision avoidance appears to be the next big leap in roadway safety. The respondents identified several problems with this new technology, however, including issues about liability, privacy, public acceptance, availability of the technology for all users, schedule for implementation, and the potential for "over-reliance" on the technology.

INTERNATIONAL PRACTICE

Japan has played an important part in the international development of ITS and the advancement of intelligent transportation and vehicle technology. The Japanese systems appear to be slightly ahead of the U.S. deployment for several reasons. First of all, the Japanese government has provided a strong commitment to work with the manufacturers and other research agencies to develop intelligent vehicle products. This public-private partnership and cooperation has been very helpful in the success of the Japanese research. Secondly, Japan has historically been known for its innovative technologies, particularly in the areas of automobiles and electronics, the two critical elements of the ITS system. Finally, Japan is a geographically small nation with over 120 million people and more than 70 million vehicles. Congestion has increased considerably in Japan, while the geography has limited the potential for growth and development, much more than in the United States. As a result of the geographic constraints, Japan has been forced to look at alternatives to the traditional roadway capacity improvements and has done so through ITS (*32*).

Background on ITS in Japan

In 1989 the Japan Ministry of Construction (MOC) launched the research and development phase for the Advanced Cruise-Assist Highway Systems (AHS) program. The goals of AHS were to promote safer driving, reduce crashes, enhance transportation efficiency, improve environmental conditions, and reduce burdens on motorists by enhancing their convenience and comfort. In June 1991, a public-private research program was started by the national government that included the MOC along with 24 private companies. The focus of the research effort was the field of automated cruise that included warning against road danger ahead, position recognition of other vehicles, and the prevention of rear-end collisions (*33*).

In November 1995 a demonstration of the AHS research vehicles was conducted at the Public Work Research Institute (PWRI) of MOC in Tsukuba Research Center, Ibaraki Prefecture, Japan. The goal of the demonstration was the development of a vehicle control system for longitudinal and lateral behavior. This demonstration was one of many demonstration projects at the Tsukuba Research Center that have effectively demonstrated the application of advanced technology warning device research and implementation in Japan.

Since September 1996, intelligent vehicle research and development has been promoted jointly with the AHS Research Association along with a consortium of leading-edge technology companies that have joined to form the Advanced Cruise-Assist Highway System Research Association (AHSRA) (*33*). AHSRA has provided the leadership that has enabled the Japanese program to move forward by providing that important public-private partnership and cooperation.

Smart Cruise Systems

Based on the results of the early research and development, the Smart Cruise Systems were jointly developed by the Ministry of Transport (MOT), which has been promoting research and development of the Advanced Safety Vehicle (ASV), and the MOC, which has been promoting research and development of AHS. The Smart Cruise Systems provide the following information to motorists concerning obstacles in front of the vehicle, vehicle conflicts in an intersection, location of vehicles on the road, and general road surface conditions (33):

- Information provision to make up for the delay in the motorists detection;
- Warnings to alert misjudgment; and
- Cruise assistance to correct erroneous operation.

Seven different services have been identified as focus areas for the Smart Cruise Systems based on their effectiveness to reduce crashes. Each of these systems is set to be launched sequentially starting in 2003. A listing of each of the services along with a description for each is provided in Table 3, while a graphical representation of each of the systems and how they would perform is provided in Figure 9 (33).

Table 3. Smart Cruise Systems Service and Description (33)

Service	Description
1. Support for prevention of collisions with forward obstacles	Notification to vehicle: detects vehicles, headway objects, etc. in poor visibility. Vehicle gives motorist information, warning and operational support.
2. Support for prevention of over shooting on curve	Notification to vehicle: detects the distance and shape of curves ahead before approaching. Vehicle gives motorist information, warning and operational support.
3. Support for prevention of lane departure	Supplementation to vehicle: lateral direction information from lane markers which were installed in the road. Vehicle gives motorist information, warning and operational support.
4. Support for prevention of crossing collisions	Notification to vehicle: detects the approaching vehicle with a right of way at intersection. Vehicle gives motorist information and warning.
5. Support for prevention of right turn collisions	Notification to vehicle: informs vehicle of intersections where right turns are possible and detect on coming vehicles. Vehicle gives motorist information.
6. Support for prevention of collisions with pedestrians crossing streets	Notification to vehicle: detects pedestrian crossing. Information service from vehicle to motorist. Vehicle gives motorist information.
7. Support for road surface condition information for maintaining headway etc.	Notification to vehicle: follows up on information such as road surface conditions. Vehicle utilizes this data on maintenance of headway and other services.

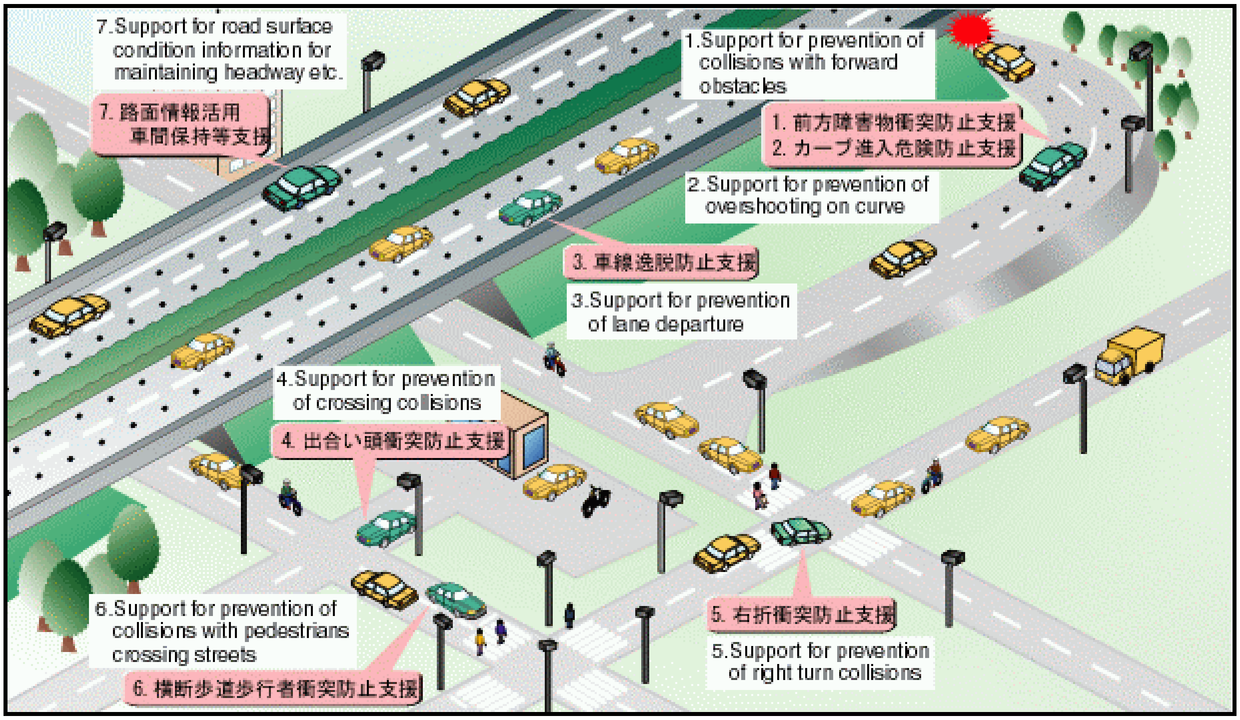

Figure 9. Smart Cruise Systems (33)

Smart Cruise 21 - Demo 2000

To test the technology and implementation of the Smart Cruise Systems, the MOT and MOC began a proving test program called "Smart Cruise 21" in October 2000 at the PWRI Tsukuba City driving course. In addition to the "Smart Cruise 21" proving tests, a public demonstration "Smart Cruise 21 – Demo 2000" was also held from November 28 through December 1, 2000. During the demonstration visitors to the Demo were given an opportunity to ride in a vehicle equipped with the state-of-the-art technologies developed through the Smart Cruise Systems and "Smart Cruise 21" performance testing. Several lectures and technical sessions were also held to present the technologies used in the Smart Cruise Systems and to exchange ideas between researchers and developers (33).

Demo 2000 was an important milestone in the development of the ASV program and in the development of intelligent vehicle technology. In a survey of visitors and participants at the event, more than 90 percent indicated that they would like to use the systems demonstrated. In addition, many commented on the level of sophistication in vehicle technology, suggesting great interest among the respondents (34). Richard Bishop, an independent consultant focusing on intelligent road-vehicle systems commented that the "…Smart Cruise systems offered in Demo 2000 provided a vivid experience of the potential of true 'intelligent vehicle-highway systems' to maximize safety on our roads" (35).

SUMMARY OF TECHNIQUES

Several techniques for the application of advanced technology warning devices have been identified through the literature review, state DOT survey, and international practice. These techniques include not only those currently being implemented in the United States, but also include future techniques and implementation, currently in the research and development stages. A summary of the techniques both within the United States and internationally is provided in the following sections.

United States

The warning devices currently in use, or under development in the United States include the following:

Freeway Warning Devices

Freeway warning devices have been used since the 1960s, particularly to warn motorists of unexpected conditions in areas were sight distance limitations are prevalent. The early installations of freeway warning devices occurred on the Gulf Freeway in south Texas where loop detectors were used to monitor traffic upstream of the warning signs and flashing lights were triggered when speeds downstream indicated possible congestion.

Intersection Warning Devices

Intersection warning devices have also been used in the United States since the 1960s at signalized intersection locations. These devices include three basic configurations that provide warning to motorists at signalized intersections; Prepare to Stop When Flashing (PTSWF); Flashing Symbolic Signal Ahead (FSSA); and Continuous Flashing Symbolic Signal Ahead (CFSSA). The majority of the installations in use in the United States are the CFSSA, a passive warning device. A more effective operation is the PTSWF or FSSA (active warning devices) in which the device is set to flash prior to the onset of the yellow interval and continue to flash until the end of red, warning motorists of the red traffic signal ahead.

Advanced Traffic Management Systems

ATMS installations have been in use in the United States for decades. ATMS combine TMC/TOC real-time data and area-wide surveillance and detection with a series of DMS, LCS, and other devices to provide warning to motorists of unexpected conditions. HAR is also used independently, or as part of the ATMS to provide information to travelers in the event of congestion, adverse weather conditions, or other incidents. In addition to permanent ATMS installations, portable traffic management systems (PTMS) are also being used, particularly in work zone applications.

Intelligent Vehicle Safety Advisory and Warning Devices

Several intelligent vehicle safety advisory and warning devices are currently in use throughout the United States. These devices include features such as anti-lock brakes, traction control, air bags, adaptive transmission control, backing warning systems, ACC, and infrared-based vision enhancement. Although these devices do not all provide a "warning" to motorists of unexpected conditions, they do help the motorist overcome unexpected conditions, control his/her vehicle after an unexpected condition is encountered, or withstand the impact of a crash, if such an occurrence were to arise.

Several new technologies are currently being researched and developed as part of the U.S. DOT IVI program, which includes the following initiatives:

- Rear-end collision avoidance;
- Road departure collision avoidance;
- Lane change and merge collision avoidance;
- Intersection collision avoidance;
- Driver condition monitoring;
- Vision enhancement;
- Vehicle stability; and
- Safety impacting services.

Each of these technologies is geared toward increased safety through in-vehicle technology. Two of the programs; rear-end collision avoidance, and intersection collision avoidance; are designed to provide warning to motorists of unexpected conditions, allowing them to respond to these conditions, and in extreme cases, allowing the vehicle to respond for the motorist. These technologies operate as an "in-vehicle ATMS" and hold the key to the future in warning motorist of unexpected conditions in the United States.

International

The international research has focused on the technology currently being developed in Japan. The Japanese have been actively researching, developing and testing intelligent transportation solutions since the 1980s. The results of this research have led to the consortium of leading-edge technology companies and government agencies that have joined to form the Advanced Cruise-Assist Highway System Research Association (AHSRA). AHSRA has provided critical leadership that has enabled the Japanese program to move forward, as well as providing the much needed public-private partnership and cooperation that has led to several demonstrations and continued research in the areas of warning against road danger ahead, collision prevention, lane keeping, and automated cruise-assist.

The Japanese have developed a series of programs aimed at providing vehicle to vehicle, vehicle to roadside, and roadside to vehicle communications. The Smart Cruise Systems have been developed to provide services for the following conditions:

1. Support for prevention of collisions with forward obstacles;
2. Support for prevention of overshooting on curve;
3. Support for prevention of lane departure;
4. Support for prevention of crossing collisions;
5. Support for prevention of right turn collisions;
6. Support for prevention of collisions with pedestrians crossing streets; and
7. Support for road surface condition information for maintaining headway etc.

Once fully implemented, these seven services are expected to reduce the risk of driver-induced crashes by as much as two-thirds (*33*). The Japanese have tested these systems and expect to launch the systems sequentially beginning in 2003.

Techniques to Analyze

A summary of the application of advanced technology warning devices including problems that need to be addressed by advanced technology warning devices, the general locations where these problems exist, advanced technology warning devices currently in use in the United States, and those currently being developed and tested in the United States as identified in the research is outlined in Table 4.

Based on the United States summary of techniques, the need for these techniques and the general locations in which the techniques are effective, the following five techniques have been determined to be most applicable to warning motorists of unexpected conditions as outlined in this report. These five techniques include the following:

- Freeway warning devices;
- Intersection warning devices;
- Advanced traffic management systems;
- Rear-end collision avoidance systems; and
- Intersection collision avoidance systems.

These five techniques will be analyzed in the following sections to summarize the benefits of each technique, determine the merits of each technique, and apply the techniques to a theoretical case study location.

Table 4. Summary of Advanced Technology Warning Devices

Description	Summary of Application
Problems to address with advanced technology warning devices:	• Safety improvement; • Motorist task error reduction; and • Crash reduction.
Locations where problems exist:	• Intersections (signalized and unsignalized); • Limited sight distance locations (freeway and arterial); • High speed locations (freeway and arterial); • Crest vertical curves; and • Inadequate roadway design.
Advanced technology warning devices currently in use in the United States:	• Freeway warning devices; • Intersection warning devices; and • Advanced traffic management systems.
Advanced technology warning devices currently being developed and tested in the United States:	• IVI safety related research (rear-end collisions, roadway departure collisions, lane change and merge collisions, intersection collisions, driver impairment monitoring, vision enhancement, vehicle stability, and safety impacting systems).

BENEFITS OF ADVANCED TECHNOLOGY WARNING DEVICES

The most important benefit that has been identified for the implementation of advanced technology warning devices is the improvement of roadway safety, and the subsequent crash reduction, by providing needed information to motorists regarding their environment. Secondary benefits have also been identified as a result of increased safety and crash reduction; first, a reduction in delay time; second, financial savings as a direct result of crash reduction, and indirectly through potential insurance premium reductions; and third, increased capacity for mobility at a lower cost than new construction.

Each of the secondary benefits of warning devices comes about as a direct result of the primary benefit; crash reduction. The U.S. DOT IVI Business Plan indicates that the "…U.S. DOT's strategic safety goal is to 'promote the public health and safety by working toward the elimination of transportation-related deaths, injuries, and property damage.' Success in achieving the safety strategic goal will be measured by realizing an improvement in the outcome goals" (4).

Several studies have been identified in previous sections of this report that outline the crash reduction potential of the five warning device techniques outlined. A summary of these devices and the crash reduction potential of each are provided in Table 5. Advanced technology warning devices are an important ITS tool that can save lives by preventing crashes. Through this crash prevention, delay times can be reduced and the capacity for mobility that is needed can be provided at less cost than construction of new roadways. In addition, this technology can save money by reducing the costs of crashes across the nation and by making transportation more efficient.

Table 5. Crash Reduction Potential of Advanced Technology Warning Devices

Technique	Crash Reduction
Freeway Warning Devices	• 49 percent reduction in primary crashes (*9*) [1] • 100 percent reduction in secondary crashes (*9*) [1]
Intersection Warning Devices	• 10 percent reduction in total crashes (*12*) [1] • 12 percent reduction in severe crashes (*12*) [1]
Advanced Traffic Management Systems	• 21 percent reduction in total crashes (*21*) [1] • 15 percent reduction in injury crashes (*21*) [1]
Intelligent Vehicle Safety Advisory and Warning Devices (IVI)	• Projected 17 percent crash reduction rate (*4*) [2] (partial deployment)
Smart Cruise Systems (Japan)	• Projected to reduce motorist-induced crashes by 67 percent (*33*) [2] (full deployment)

[1] Site specific reduction rates.
[2] System wide reduction rates.

MERITS OF TECHNIQUES

Webster defines merit as: "a praiseworthy quality" or, "character or conduct deserving reward, honor, or esteem" (*36*). Each of the techniques outlined in the previous section has specific qualities or measures of performance that are praiseworthy, or that deserve reward over another. Several merits could be discussed in this section, but these have been narrowed to five distinct qualities that should be considered in determining the measures of performance. These merits include the following:

- Ease of implementation;
- Cost of implementation;
- Addresses the crash reduction problem;
- Cost of operation/maintenance; and
- Adaptable/non-discriminating.

Merits Defined

A brief definition of each of these merits is provided in the following sections.

Ease of Implementation

The first merit is ease of implementation, or simply; how easy is it to implement the proposed technique. Several techniques are relatively easy to implement, while others require a considerable amount of effort. For example, freeway warning systems can be implemented with relative ease; the freeway infrastructure is already in place, the roadside is available for sign installation, and in many instances, loop or video detection systems may be in place to monitor conditions upstream of the device. Other installations, such as the ATMS installation are not as easy to implement, as overhead message boards, detection systems, and monitoring centers must be installed prior to implementation.

Cost of Implementation

The next merit to consider is the cost of implementation. Cost of implementation varies greatly between the different techniques from relatively low cost ("best" merit ranking), to high cost techniques ("good" merit ranking). Intersection warning devices, for example can generally be installed for less than $50,000 depending on the details of the structure, base, sign, lighting, and wiring of the system. ATMS systems, on the other hand, include installation costs that may range from hundreds of thousands of dollars to millions of dollars, depending on the size of the system.

Addresses the Crash Reduction Problem

Probably one of the most important merits for consideration in ranking warning devices is its ability to meet the objectives outlined in the research by effectively addressing the problem of safety through crash reduction. Several studies have been identified in this report that have summarized the benefits of crash reduction by the different systems. These benefits are generally limited to site-specific locations or influence areas, with the exception of the rear-end and intersection collision avoidance systems. Assuming that in-vehicle communication technology is available in all vehicles, these systems (when performing in a vehicle to vehicle communication mode) can be successful regardless of the infrastructure technology in place. Additional infrastructure is needed for roadside communication systems to work effectively, and when in place the crash reduction potential increases substantially as was noted in Table 4.

Cost of Operation/Maintenance

Once the system is in place, the cost of operation and maintenance as well as identification of the funding source for these costs must also be considered for each technique. As with costs of implementation, cost of operation/maintenance varies greatly between the different techniques from relatively low cost ("best" merit ranking), to high cost techniques ("good" merit ranking). Intersection warning devices typically include operation/maintenance costs of less than $1,000 per year, depending on the complexity of the installation. ATMS systems, however, include operations costs that include salary for the operators of the TMC/TOC, maintenance of a large inventory of signs and other traffic control devices, as well as overhead, management, and other operation costs. These costs could range from tens of thousands of dollars per year to hundreds of thousands of dollars per year depending on the size of the system.

Adaptable/Non-Discriminating

The final measure of performance to consider in determining the merits of each system is its ability to be adaptable to a wide-variety of users, while at the same time not discriminating against user groups. For example, freeway warning devices, intersection warning devices, and ATMS systems can be used by all motorists, regardless of the age, model, make and year of the vehicle they are driving. The rear-end and intersection collision avoidance systems, however, require in-vehicle communication devices that are not currently available to all users. This lack of technology for some motorists reduces the effectiveness of the system, even for those who have this technology. This is especially critical for government agencies that are considering the best way to spend taxpayer dollars, as all users should be able to benefit from the systems implemented, particularly when tax dollars are involved.

Analysis of Merits by Technique

A delphi approach has been used by the author to rank each of the five techniques outlined in the previous section as “good”, “better”, or “best” according to the criteria outlined as merits of a successful system. The results of this ranking are provided in the matrix of merits by technique, summarized in Table 6. Although each system may rank higher in one merit over another, different merits carry heavier weighting, depending on their application. For example, in Table 6 the author has ranked rear-end and intersection collision avoidance systems as “best” in terms of addressing the problem of reducing crashes, but they only rank “good” in terms of ease of implementation and cost of implementation. What is not included in this matrix is a cost/benefit analysis to determine if the benefits of crash reduction outweigh the increased costs of implementation. The author’s interpretation of the research summarized in this report is that the benefits of the intelligent vehicle systems are anticipated to outweigh the costs of research and development after full deployment. It was reported that crashes today cost Americans approximately $150 billion every year. If the number of crashes system wide on our nations highways can be substantially reduced as current projections show through the use of intelligent vehicle solutions, these costs can also be reduced substantially, offsetting the costs of implementation of the warning device.

Table 6. Matrix of Merits by Technique

Technique	Merit [a]				
	1.	**2.**	**3.**	**4.**	**5.**
Freeway Warning Devices	○	○	●	○	○
Intersection Warning Devices	○	○	●	○	○
Advanced Traffic Management Systems	◗	◗	◗	◗	○
Rear-End Collision Avoidance Systems	●	◗	○	◗	●
Intersection Collision Avoidance Systems	●	◗	○	◗	●

○ Best **◗ Better** **● Good**

[a] Merits are defined as follows:

1. Ease of implementation
2. Cost of implementation
3. Addresses the crash reduction problem
4. Cost of operation/maintenance
5. Adaptable/non-discriminating

To rank the techniques according to their merits, the author has proposed that a base ranking of fifteen (15) points be used for “best” criteria, a base ranking of ten (10) points be applied to “better” criteria and a base ranking of five (5) points be applied to the “good” criteria.

To capture the variability in the merits of the different warning devices, cost/benefit and merit ranking adjustments are proposed by the author to address the ability of the technique to respond to the problem of crash reduction. Crash statistics over the past five years have shown little reduction in overall numbers of crashes and crash rates, but rather have remained somewhat steady during this time period. This steady state condition would indicate that although the technology being implemented today appears to be providing site specific benefits in terms of crash reduction, particularly secondary collisions, it is not providing the types of reductions in crash rates that are necessary to dramatically improve safety system wide. U.S. DOT researchers have indicated that full deployment of the rear-end collision avoidance, road-departure collision avoidance and lane change and merge collision avoidance systems would eliminate one in six, or approximately 17 to 20 percent of all crashes (*4*). Based on this statistic and the estimated $150 billion per year that crashes cost Americans, deployment of these three systems has the potential to cut costs of crashes by an estimated $25 billion. Since the cost savings of crash reduction are so substantial for the rear-end collision avoidance and intersection collision avoidance systems, the author has proposed that a cost/benefit ratio of ten (10) be applied to the crash reduction merit in the matrix based on the 20 percent crash reduction potential (10 percent for each system). To account for the high cost/benefit ratio for the crash reduction merits as outlined, it is proposed that the factor will be multiplied by the base ranking in the applicable situations. A similar cost/benefit ratio can be applied to the ATMS deployment due to the crash reductions provided in an ATMS system. The overall ratio for this technique is not as high since the ATMS crash reduction is not applied system wide. Therefore, a cost/benefit ratio of five (5) is proposed for the ATMS technique. As with the collision avoidance techniques, the factor for this technique will be multiplied by the base ranking in applicable situations.

In addition to the crash reduction factor, it is proposed that a technique factor be applied to the ATMS, rear-end collision avoidance, and intersection collision avoidance systems. The purpose for this factor is to account for the variability in coverage area for the different techniques. Freeway and intersection warning devices are generally applied to spot locations or individual intersections. ATMS installations, however, include multiple locations, with coverage as high as 90 miles of a freeway network as is illustrated with San Antonio's TransGuide System. The author anticipates that an ATMS application would cover at least ten spot locations, and typically many more. Since the coverage area for an ATMS application covers a larger area than a single application device, a coverage factor of ten (10) is to be applied to all ATMS merits in the matrix. In the case of the crash reduction merit, multiplicative ratios shall be added prior to being multiplied by the base ranking. For example, rather than applying a factor of five (5) for the cost/benefit ratio and multiplying this factor by ten (10) for the coverage factor, the cost/benefit ratio and coverage factors shall be added making a total multiplicative factor of fifteen (15) for this merit.

As with the ATMS extended coverage area, the rear-end and intersection collision avoidance systems also include a larger coverage area than single installations. With full deployment of these systems and 100 percent in-vehicle installation, the coverage area for collision avoidance techniques is virtually limitless. This would lead to some justification for an infinite coverage factor for these systems. However, an infinite factor would not provide for adequate comparison between techniques, and the costs of implementation are notably higher in this situation. To provide for a more comparable analysis between techniques, a coverage factor of fifteen (15) is recommended for the rear-end and intersection collision avoidance techniques in the matrix. This is only slightly higher than the ATMS coverage factor and shall be applied in the same manner. The result of the complete ranking for each of the merits and warning device techniques is shown in Table 7.

After applying the cost/benefit factors to the merit criteria ranking, and the coverage factors to the applicable techniques, the rear-end and intersection collision avoidance systems provide the best benefit, assuming that the crash reduction and coverage projections can be met. In reviewing the ranking identified in Table 7, the advanced traffic management systems appear to outweigh the freeway and intersection warning devices by a factor of ten. This is as expected based on the ranking factors applied by the author and the basic premise that the advanced traffic management systems cover an area ten times (as a minimum) that of a single freeway and intersection warning device. The rear-end and intersection collision avoidance systems are approximately thirteen times as effective according to the merit ranking criteria. This may actually be low, given the projected effectiveness of these devices after full deployment. Based on this analysis, research and development of collision avoidance systems like those outlined should continue forward in an attempt to equip our highways with the technology to allow these systems to warn motorists of unexpected conditions.

Table 7. Ranking of Merits by Technique

Technique	Merits [a] /Ranking [b]					
	1.	**2.**	**3.** [c]	**4.**	**5.**	**Total**
Freeway Warning Devices	15	15	5	15	15	**65**
Intersection Warning Devices	15	15	5	15	15	**65**
Advanced Traffic Management Systems [d]	100	100	150	100	150	**600**
Rear-End Collision Avoidance Systems [e]	75	150	375	150	75	**825**
Intersection Collision Avoidance Systems [e]	75	150	375	150	75	**825**

[a] Merits are defined as follows:
1. Ease of implementation
2. Cost of implementation
3. Addresses the crash reduction problem
4. Cost of operation/maintenance
5. Adaptable/non-discriminating

[b] A base ranking of 15 has been applied to “best” criteria, a base ranking of 10 has been applied to “better” criteria, and a base ranking of 5 has been applied to “good” criteria.
[c] A cost/benefit factor of 5 has been applied to advanced traffic management systems and a cost/benefit factor of 10 has been applied to rear-end and intersection collision avoidance systems.
[d] A coverage factor of 10 has been applied to this technique.
[e] A coverage factor of 15 has been applied to this technique.

CASE STUDY

The summary of techniques developed has been applied to a theoretical case study to demonstrate the need and applicability of such devices. The theoretical site is an arterial corridor with several curves, restricted sight distance locations and heavy traffic at signalized intersections. The application of the research to consider includes queue spillback at signalized intersections in limited sight distance locations that has led to high crash rates, as well as right angle crashes at driveways in which limited sight distance conditions exist. The next section outlines the existing conditions for the theoretical case study location along with discussion and recommendations for warning device installation.

Arterial Road

The theoretical Arterial Road is a five lane arterial along a mostly commercial corridor in “Anywhere, USA”. Traffic volumes along the corridor are assumed to be approximately 30,000 vehicles per day with several moderate to high volume cross streets located along the arterial. Land use along the corridor includes office, restaurants, convenience stores and some residential properties. The cross section of Arterial Road includes two travel lanes in each direction, a center two-way left-turn lane, sidewalks and curb and gutter on both sides of the roadway. The posted speed limit is assumed to be 35 mph on curves and limited sight distance locations and 40 mph to 45 mph on straight sections of the corridor.

The design of Arterial Road includes several sections in which sight distance is a concern on both the major street (Arterial Road) and the minor cross street locations. One location on the theoretical section combines both a residential cross street (Cross Street) in which limited sight distance conditions exist with sight distance restrictions on Arterial Road to the downstream intersection. Crash rates at this intersection are assumed to be above the expected rates at both the Cross Street and the downstream intersection location.

Several different techniques would be applicable in this situation to warn motorists of unexpected conditions and to address the Cross Street right angle crashes and the high number of rear-end crashes at the downstream intersection. Of the five techniques outlined and analyzed in this report, it is recommended that an advanced traffic management system, rear-end collision avoidance system, and intersection collision avoidance system be implemented. A summary of each of the five techniques and their potential for application is provided in the following sections.

Freeway Warning Devices

Since the corridor in question is an arterial street corridor, freeway warning devices would not be applicable in this situation.

Intersection Warning Devices

Intersection warning devices do not appear to have application in this location. These devices have been proven to be more effective at high-speed locations. While this application may be effective in warning motorists of the signal ahead, and possibly of being utilized to dynamically indicate when the signal is red, they are not anticipated to be effective in warning motorists of long queues at the intersection immediately following green signal indication change, and are therefore not recommended for installation in this situation.

Advanced Traffic Management Systems

Advanced traffic management systems would have application in this case. The system that is recommended would include ATMS with inductive loop detectors or video imaging vehicle detection system on both Arterial Road and Cross Street. Through the use of vehicle detection, DMS systems could be used to warn motorists of approaching vehicles. On Cross Street, detectors would sense vehicles along Arterial Road and provide notice to motorists attempting to turn onto Arterial Road through the use of a DMS. If vehicles are detected approaching the intersection, the proposed messages in Figure 10 could be displayed for vehicles approaching Arterial Road on Cross Street. In the event that no vehicles are approaching the intersection, no message would be displayed and vehicles would proceed based on standard practice at a stop-controlled intersection.

The ATMS scenario should also be applied to the arterial street traffic using the same detection in combination with a DMS system. The detection devices would monitor traffic and display messages such as “CONGESTION AHEAD”, or “USE CAUTION” in the event of an incident on the roadway or excessive queue detection at the upstream signalized intersections. The monitoring of incidents ahead is anticipated to lead to fewer secondary collisions, while queue detection would reduce the number of rear-end collisions at the intersection.

VEHICLES **APPROACHING**
USE **CAUTION**

Figure 10. Proposed ATMS Message

Rear-End Collision Avoidance

Rear-end collision avoidance technology has the capability of providing one of the best solutions to overcoming potential rear-end collisions at arterial intersection locations. Some of the systems to be utilized in this location include forward looking radar and forward looking vision systems combined with a GPS based map that could be used in conjunction with other in-vehicle sensors. The information processed by these systems would then be used to identify in-path collision threats and to incorporate this sensor data with the ACC and active braking technologies. The advantage of this system over the ATMS system described previously for this or any other location is the ability of the rear-end collision avoidance system to play an active role in reducing the potential for a collision. The ATMS system provides needed information to the motorist that can be used to make better decisions and potentially react at a more efficient rate. The rear-end collision avoidance system not only provides information, but can apply the information that is provided to automatically respond to the conditions.

Intersection Collision Avoidance

Intersection collision avoidance technology also has the capability of greatly improving conditions on arterial streets by aiding motorists in overcoming potential intersection collisions. Intersection collision avoidance systems monitor vehicle speed and position relative to the intersection, while simultaneously monitoring the speed and position of other vehicles approaching the intersection. If this monitoring determines that there are potential right-of-way violations or other conditions that could warrant a collision, the system is activated to provide warning to the motorist of this unexpected condition. As with rear-end collision avoidance systems, intersection collision avoidance systems have an advantage over the ATMS system by allowing the vehicle to play an active role in avoiding the potential collision. The ATMS system provides needed information to the motorist that can be used to make better decisions and react at a more efficient rate, while the intersection collision avoidance system applies the information that it receives and responds to the conditions. This would be very effective in the arterial environment for both signalized and unsignalized intersections.

Other Technologies

One additional technology that was not identified in the research that is recommended in this situation is that of in-vehicle speed enforcement. Posted speed limits along the theoretical Arterial Road vary from 45 mph on straight sections in which sight distance restrictions are not a problem to 35 mph in locations where sight distance limitations, sharp curves or other unexpected conditions exist. It is proposed that a speed enforcement system be implemented in this situation to warn motorists of potential speed violations through audible warning in the vehicle. It is recommended that sensors be placed on speed limit signs that would transmit the posted speed limit to the vehicle. This transmitted speed would then be compared electronically to the speed of the vehicle and if necessary, an audible message relayed to the motorist encouraging him/her to slow to the posted speed. If the motorist does not respond to the warning, the system would then assess the surrounding environment and determine if the brakes should be applied through ACC and active braking technologies. The assessment of the surrounding environment would be necessary to determine if there are other influences in the area that may require a higher speed to avoid a crash, or to respond to an emergency situation. If this assessment indicates a need to safely slow the vehicle, the brakes would be applied. The author believes that in most cases, if recommended speeds were followed on roadways such as those outlined in the theoretical case study, potential collisions could be avoided, as speeds would be better controlled allowing motorists more time to react to conditions.

A second technology that was not identified in the research that is also recommended in this case study location is an in-vehicle signal warning device. This device could be integrated into the intersection collision avoidance technology and would include an in-vehicle warning that provides information to the motorist of the signal indication at the approaching intersection. This device would receive information from the signal controller that would warn the motorist of impending "gap out" at the signal and could provide an audible and/or visual warning to the motorist of the end of green, and of red signal indications. The system would alert the motorist of the signal indication and encourage slowing prior to the signal. Once the warning has been provided, the additional technology of the intersection collision avoidance system would then take effect by identifying potential conflicts and providing additional warning as necessary.

A summary of the theoretical case study application is provided in Table 8.

Table 8. Theoretical Case Study Application

<table>
<tr><th colspan="2">Technique</th><th>Arterial Road Application</th></tr>
<tr><td colspan="2">Freeway Warning Device</td><td>✖</td></tr>
<tr><td colspan="2">Intersection Warning Device</td><td>✖</td></tr>
<tr><td colspan="2">Advanced Traffic Management System</td><td>✔</td></tr>
<tr><td colspan="2">Rear-End Collision Avoidance System</td><td>✔</td></tr>
<tr><td colspan="2">Intersection Collision Avoidance System</td><td>✔</td></tr>
<tr><td colspan="2">In-vehicle Speed Warning Device</td><td>❋</td></tr>
<tr><td colspan="2">In-vehicle Signal Warning Device</td><td>❋</td></tr>
<tr><td>Not Applicable ✖</td><td>Applicable ✔</td><td>Recommended "New" Technique ❋</td></tr>
</table>

CONCLUSIONS

The need for warning devices to provide advance notification of unexpected conditions has been realized since the 1960s. In an attempt to address this need, several infrastructure based warning devices have been developed and tested, including freeway warning devices, intersection warning devices and advanced traffic management systems (ATMS) that provide real-time information to motorists within their influence area. In addition to the infrastructure based warning devices, in-vehicle devices have also been researched and developed and are currently being implemented in a limited number of vehicles throughout the United States.

The goal of advanced technology warning devices is to improve safety on our nations highways through crash reduction. Even with the recent technological advances and safer highways that have evolved over the last decade, total numbers of traffic crashes and fatalities as well as traffic crash and fatality rates have remained relatively steady. This steady crash rate leads researchers and developers toward more advanced technology solutions to solve the safety concerns on our highways today. New technology such as rear-end collision avoidance, intersection collision avoidance and other intelligent vehicle solutions are now being used to address the crash problem. As these systems develop they have the potential to reduce crash rates nationwide by an estimated 17 to 20 percent with partial deployment, while the benefits that can be received through full implementation of these in-vehicle devices is estimated to eliminate 2 out of every 3 crashes on our nations highways. The potential for vehicle to vehicle, vehicle to roadside and roadside to vehicle communications will allow our infrastructure and vehicles to work together, eliminating a portion of the motorist error that we experience today and providing a safer environment for everyone to enjoy.

The cost of implementing these systems must be addressed early on in order to determine the feasibility of the systems, while the standardization of these systems must also be addressed in order to ensure that they are compatible throughout not only individual states, but throughout the nation, and possibly internationally through cooperation with international agencies.

The research contained in this report has summarized the basic warning devices and presented the advanced technology that is currently being implemented to warn motorists of unexpected conditions. The technology that is being developed is constantly changing, providing continuous opportunity for additional research.

In addition to outlining the basic warning devices and presenting future technology and application, the author has also presented a delphi approach to ranking the merits of each of these techniques. This approach provides the basis for many opportunities for future research to compare the different warning devices and to analyze them based on their merits. The author's approach indicates that the intelligent vehicle safety advisory and warning devices (i.e., rear-end and intersection collision avoidance systems) provide the best benefit in terms of warning motorists of unexpected conditions. Based on this analysis, the author recommends research and development should continue to move forward in an attempt to equip our highways with the technology to allow these systems to be effective.

While the author has provided this analysis and has made recommendations to continue to research, develop and implement these techniques, the analysis opens the door for further research and refinement of the merit analysis methodology. A more detailed sensitivity analysis and application to a more theoretical choice or preference model is recommended to further evaluate the different warning device techniques. In addition, the new technologies identified in the case study (in-vehicle speed enforcement and in-vehicle signal warning devices) should also be considered in future research efforts.

The future of roadway safety rests in making the entire system safer by moving beyond injuries and death to prevention of the crash. In order to experience this goal, public agencies and private vehicle manufacturers should continue to work together to develop the technology that is key to the success of warning devices, while minimizing motorist distraction caused by these devices. Researchers should continue their efforts to make the entire system of roadways and vehicles smarter and safer for everyone to enjoy.

ACKNOWLEDGEMENTS

This paper was prepared for *Advanced Surface Transportation Systems*, a graduate course in Civil Engineering at Texas A&M University. The author would like to express his gratitude to Dr. Conrad Dudek for the opportunity to participate in this unique and rewarding program. The author would also like to thank his professional mentors, Mr. William M. Spreitzer and Mr. Wayne Kittelson, for their insightful input and suggestions provided throughout the course as well as their assistance and guidance in conducting this research and preparing this report. A thank you is also extended to each of the other mentors, Mr. Patrick Irwin, Mr. Jack Kay, Mr. Joseph McDermott, and Mr. David Roper who shared of their time and talents to make this program a success for the participants.

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APPENDIX

STATE DOT ADVANCED TECHNOLOGY WARNING DEVICES SURVEY

Name: ____________________

Agency: ____________________

Address: ____________________

City: ____________________

State: ____________________

Phone: ____________________

e-mail: ____________________

Everyday, drivers are faced with situations in which they must react to unexpected conditions along the roadway corridor in which they are traveling. These unexpected conditions include adverse weather, queue backup, sight distance limitations, incidents and other dynamic roadway conditions. The field of intelligent transportation systems (ITS) is currently being utilized to help warn drivers of the unexpected conditions outlined in an effort to increase safety through the use of incident warning systems (IWSs), changeable messages signs (CMS), variable speed limit signs (VMS) and in some cases more advanced "collision-avoidance" technology.

The purpose of this survey is to gather information on the state-of-the-practice throughout the United States for warning devices aimed at increasing safety. This information will be incorporated into a research paper being prepared for the summer graduate course *Advanced Surface Transportation Systems* at Texas A&M University. This paper will be used to provide information on current implementation of such devices as well as providing recommendations on the future of advanced technology warning devices.

Please respond to the following questions as they relate to your State and return your survey results to Grant Schultz via e-mail: grant-schultz@tamu.edu or by fax at (979) 845-6254 by **Friday June 22, 2001**. If you have questions about the survey please contact me via the e-mail address above or by telephone at (979) 862-2673. The survey can also be conducted by telephone. If you would prefer this method, please let me know and we can set a time to discuss the survey.

I appreciate your willingness to participate in this survey and look forward to receiving your input!

1. What types of advanced warning devices are currently being implemented in your State (i.e. DMS, CMS, HAR, etc.)?
2. What do you perceive as the benefits of this technology? Are you aware of any documented benefits, and if so, would it be possible to get a copy of this documentation?
3. What shortcomings have been identified with advanced warning devices that you have implemented (i.e. inadequate warning time, limited text of messages, too few warning devices, etc.)?
4. What additional technology are you aware of that you are not currently using, but would like to deploy within your system? Why?
5. Do you have guidelines for implementation of advanced warning devices within your organization and if so, would it be possible to get copies of these guidelines (i.e. accident history, ADT thresholds, sight distance limitations, etc.)?
6. It appears as though the future of advanced warning technology for "collision-avoidance" will be found within the vehicle itself through intelligent vehicle (i.e. vehicle to vehicle, vehicle to roadway and roadway to vehicle) communication. What are your thoughts on the future of this "collision-avoidance" technology?

GRANT G. SCHULTZ

Grant Schultz received a Bachelor of Science degree in Civil Engineering in April 1994 from Brigham Young University and a Master of Science degree in Civil Engineering in April 1995, also from Brigham Young University. Grant is currently pursuing his Ph.D. degree in Civil Engineering from Texas A&M University. While enrolled at Texas A&M, Grant is employed as a Graduate Research Assistant at the Texas Transportation Institute (TTI) where he is working on "Techniques for Managing Access On Arterials", a project sponsored by the Texas Department of Transportation (TxDOT).

Prior to attending Texas A&M University to pursue a Ph.D. degree he was employed as a practicing engineer in the Salt Lake City office of the consulting firm Sear-Brown. In his role at Sear-Brown, Grant was a Transportation Project Manager and head of the Traffic Studies Group for the Salt Lake City office. Grant was employed with Sear-Brown in Salt Lake City for 4½ years during which time he completed more than 50 traffic impact studies, was involved in several transportation master planning projects, completed environmental assessments for the Salt Lake City Intermodal Center and I-15 Viaduct Shortening projects and was project manager for the I-15 milepost 4 modern roundabout interchange project. Prior to employment with Sear-Brown, Grant worked in Boise, Idaho with the firm of Keller Associates, Inc. for 1½ years. In his role at Keller Associates Grant worked on several roadway, site/civil and rest area design projects. He was also employed for 4 months with the Utah Department of Transportation Urban Planning Division prior to beginning his Master of Science degree.

Grant is a registered Professional Engineer in the state of Utah and a Professional Traffic Operations Engineer under the Transportation Professional Certification Board, Inc. Throughout his academic and professional career, Grant has been actively involved in the Institute of Transportation Engineers where he is an Associate Member and has prepared papers for presentation at the National, District, Section and Local Chapter levels. Most recently he presented at the ITE Annual Conferences held in Chicago, Illinois in August 2001, Nashville, Tennessee in August 2000, and Las Vegas, Nevada in August 1999. Grant has also been involved in and is currently an Associate Member of the American Society of Civil Engineers, is a member of the Golden Key National Honor Society and member of Tau Beta Pi, Utah Beta Chapter. Grant's areas of interest include traffic operations, transportation planning and traffic safety.

DEVELOPMENT OF A PLAN TO EVALUATE THE EFFECTIVENESS OF BUS PRIORITY SYSTEMS

by

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SUMMARY

The author presents a conceptual plan to evaluate a bus priority system. An overview of bus priority systems is presented, followed by an introduction to the "Best Bus" project. The Best Bus project addresses the transportation needs of the NY Route 5 corridor linking the cities of Albany and Schenectady in upstate New York. The Best Bus project proposes signal coordination for the traffic signals on Route 5 and includes a bus priority system as a part of an advanced communications system to be purchased by the local transit agency.

The conceptual plan developed here for the evaluation of a bus priority system emphasizes that evaluation be included as an on-going feedback mechanism that leads to improvements and greater efficiency. The team approach to evaluation is emphasized whereby all stakeholders are represented and priorities defined by the team.

The evaluation plan developed is applied to the Best Bus project in a limited way because the Best Bus project will be implemented in late 2001. Nevertheless, some issues and concerns about evaluation and data collection are highlighted. Recommendations for future research include developing general conceptual models for evaluations, and reporting on evaluations. Also, the author points out the need to develop better software for simulation analysis of bus priority systems.

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INTRODUCTION

Bus priority systems for transit operation are considered an effective tool for improving the efficiency and the attractiveness of a transit system. Some transit agencies are hoping to increase ridership by making their service more reliable by better schedule adherence. Other transit agencies hope to increase ridership by improving (reducing) the trip time; they believe that doing so would make people consider riding the bus instead of driving their car.

The evaluation of the bus priority system will enable the transit agency to verify that the objectives for implementing the bus priority system were achieved. More importantly, it will provide them valuable feedback which could lead to improvements and greater efficiency.

The traffic operations at an intersection involve not only the bus but also private vehicles—both on the bus route (main street) and the side streets. Thus, the stakeholders include not only the transit agency and its customers (current and potential) and the motorists on the bus route (main street) but also the motorists on the side street(s).

The NY Route 5 corridor links the City of Albany and the City of Schenectady in New York State and is a significant component of the region's transportation system. This corridor carries both the highest arterial traffic volumes and the greatest number of transit riders in the region. The signal systems on this corridor are mostly uncoordinated and old. The project proposed for this corridor is named the "Best Bus" project and includes improved transfer points, passenger waiting areas, scheduling, signal coordination, and bus priority.

A plan to evaluate a bus priority system will be developed; the plan will be applied to evaluate the bus priority system proposed for the NY Route 5 corridor.

OBJECTIVES

The overall goal of this research is to develop an evaluation plan for a bus priority system. This objective would be accomplished by:

- Providing an overview of bus priority systems;
- Developing an evaluation plan for a bus priority system; and
- Applying the plan to a bus priority project in New York State.

BUS PRIORITY SYSTEMS: AN OVERVIEW

What is Bus Priority?

Signal priority for transit vehicles involves manipulating the phasing and timing of traffic signals to ensure that transit vehicles receive green indications as quickly as possible upon arriving at the signalized intersections (*1*). Traffic signal priority for buses reduces delays in bus service resulting from waiting at signalized intersections.

Why Bus Priority?

Bus priority systems contribute to objectives set for the operation of a transportation system. Some objectives, such as improved schedule adherence and reduced trip time, appeal to both the transit agency and its customers even if for different reasons. Other objectives, such as reduced operating costs and need for fewer buses, are the concern of the transit agency alone.

Motorists, too, want to reduce their trip time. In other words, they want to reach their destinations quickly and safely. One way to accomplish this is by avoiding congestion and delays at signals. Providing bus priority may adversely impact the side-street traffic but may increase ridership. Theoretically, this could result in decreased congestion.

Providing priority benefits the traffic on the corridor because the entire platoon of traffic benefits from the "green" granted to the bus by the bus priority system. Thus, the effects on the motorists can be two-sided and the tradeoffs should be considered. This has significance to the evaluation of bus priority systems because it helps the evaluation team establish objectives.

Types of Bus Priority Systems

In general bus priority systems can be classified into two types. In the first type, a bus approaching a signal extends the "green" time or advances the signal cycle to "green," through transponders or other electronic communications devices, to proceed through the intersection (*2*). A typical value for the extension of the "green" is 10 seconds. The bus driver determines whether signal priority is needed.

In the second type of bus priority system, the bus is equipped with an automatic vehicle location (AVL) system and advanced radio communications. The bus may seek signal priority from the operations center or the bus may be outfitted to seek priority directly from the signal controller. The bus may be granted signal priority based on considerations such as its schedule adherence and distance from the intersection

CURRENT BUS PRIORITY SYSTEMS

Bus priority systems have been installed in several different locations throughout North America and Europe. Most of the systems installed in the 1970s and 1980s used preemption to provide priority to buses, which resulted in significant reduction in travel times for buses (see Table 1). However, these systems caused significant delays to traffic on the side-street(s) and a loss of coordination on the main street. Balke (*1*) reports that most of these systems have, therefore, been discontinued. Balke (*1*) has summarized the discontinued and operational bus priority systems in the US (see Tables 1 and 2). These systems have improved bus operations marginally; evaluation studies have shown that these bus priority systems reduced bus travel times between 4 and 25 percent (*1*).

Limitations of Current Bus Priority Systems

Balke (*1*) believes that one of the reasons for the marginal performance of the current bus priority systems in the US is that they disrupt the normal operations of the signal at the intersection. Several of the bus priority systems operating today preempt the normal operation of the signal to grant priority to buses. Preempting the normal operation causes the signal to drop from coordination. As a result, traffic progression between traffic signals on the main street is lost (*1*).

FUTURE OF BUS PRIORITY SYSTEMS

Advancing communications technology will enable prediction of when in the signal cycle the buses will arrive at the intersection. A bus priority algorithm is considered to be "intelligent" when it utilizes such technology to adjust the timing of the signal to ensure that the bus receives a green indication when it arrives at the intersection. By granting priority only to those buses that truly need it and by doing so in an "intelligent" manner many of the limitations of the current bus priority systems can be eliminated (*1*).

Table 1. Summary of Discontinued Bus Priority Systems in the US

Location	Year Documented	No. of Signals	Evaluation Results
Washington, DC	1972-1976	34	3 to 10 percent reduction in bus travel times
Louisville, KY	1972	8	15 to 19 percent reduction in p.m. travel time
Miami, FL	1977	37	23 percent reduction in travel time
Concord, CA	1978	12	10 percent reduction in bus travel time
Santa Clara, CA	1978	60	System worked well but abuse and high maintenance costs degraded benefits
Dallas, TX	1982	N/A	5 percent reduction in bus travel time, peak direction

Adapted from Reference (1)

Table 2. Summary of Recent Bus Priority Systems in the US and Their Status

Location	Year Documented	No. of Signals	Evaluation Results	Current Status
Los Angeles, CA	1986	49	4.2 percent reduction in bus travel time; 21.6 percent reduction in bus delay at intersections	Unknown
Maryland	1993	14	N/A	Operational
Bremerton, WA	1993	43	5 to 16 percent reduction in bus travel time; 3.9 percent reduction in total system delay	Operational
Minneapolis, MN	1989	20	N/A	Unknown
Portland, OR	1995	4	Bus travel times reduced slightly in peaks and significantly in off-peaks	Operational
San Francisco, CA	1997	34	10 to 50 percent reduction in bus signal delay	Operational

Adapted from Reference (1)

The Best Bus project poised for implementation on NY Route 5 (Figure 1) will accomplish bus priority "intelligently" because it will utilize advanced communications technology. This technology will ensure that the signals stay coordinated.

THE "BEST BUS" PROJECT IN NEW YORK STATE

What is the "Best Bus" project?

The "Best Bus" project is a project that addresses the needs of the NY Route 5 corridor linking the City of Albany and the City of Schenectady in upstate New York, (Figure 1). This corridor is 14 miles long. One part of the Best Bus project involves coordination of the traffic signal systems on this corridor, which are mostly uncoordinated and old. Many of these signals lack the features necessary for coordination.

The traffic signal systems are operated by the respective cities in their jurisdictions and by the New York State Department of Transportation (NYSDOT) in the portion between the two cities. The City of Albany and the City of Schenectady use NEMA TS-2 signal controllers and New York State uses Model 179 controllers. As a part of the signal coordination project software will be installed which will allow these two types of controllers to communicate with one another and with the master controller (in the Traffic Management Center). NYSDOT will award a contract to upgrade and coordinate the traffic signals (approx. seventy-seven signals). The bids for this work were opened on July 19, 2001 and the lowest bid was $7.3 million (*3*).

The other part of the Best Bus project involves purchase of an advanced radio communications system by Capital District Transportation Authority (CDTA); CDTA is the local transit agency. A bus priority system will be a component of the new advanced communications system. Thirty-four out of seventy seven traffic signals on NY Route 5 will have bus priority capabilities. CDTA has budgeted $6 million for a base system, and up to $4 million for options. CDTA is evaluating proposals from four different vendors for procuring the advanced communications system.

CDTA hopes to increase transit ridership on the NY Route 5 corridor by (a) improving the reliability (punctuality) of Bus Route 55 on this corridor and (b) by reducing the running time for Bus Route 55 on this corridor (*4*).

FINDINGS FROM REVIEW OF LITERATURE AND INTERVIEWS

A review of literature and interviews with researchers and others were used as a means to formulate the evaluation plan. The findings that emerged from the literature search are listed below.

1. Very little reported in literature on evaluations. While bus priority systems are not new the subject of evaluating bus priority systems does not seem to have attracted much attention in recent times. The absence of any significant literature suggests that evaluations are not being done.

2. Reporting is mostly field-specific, not generalized. What is reported in the literature is specific to a particular scenario or software, and not exactly a generalized evaluation. It is, therefore, hard to draw general conclusions from it.

3. Need to do and report evaluations. Based on the previous discussion, this author believes that there exists a need to perform evaluations of bus priority systems and report the evaluations.

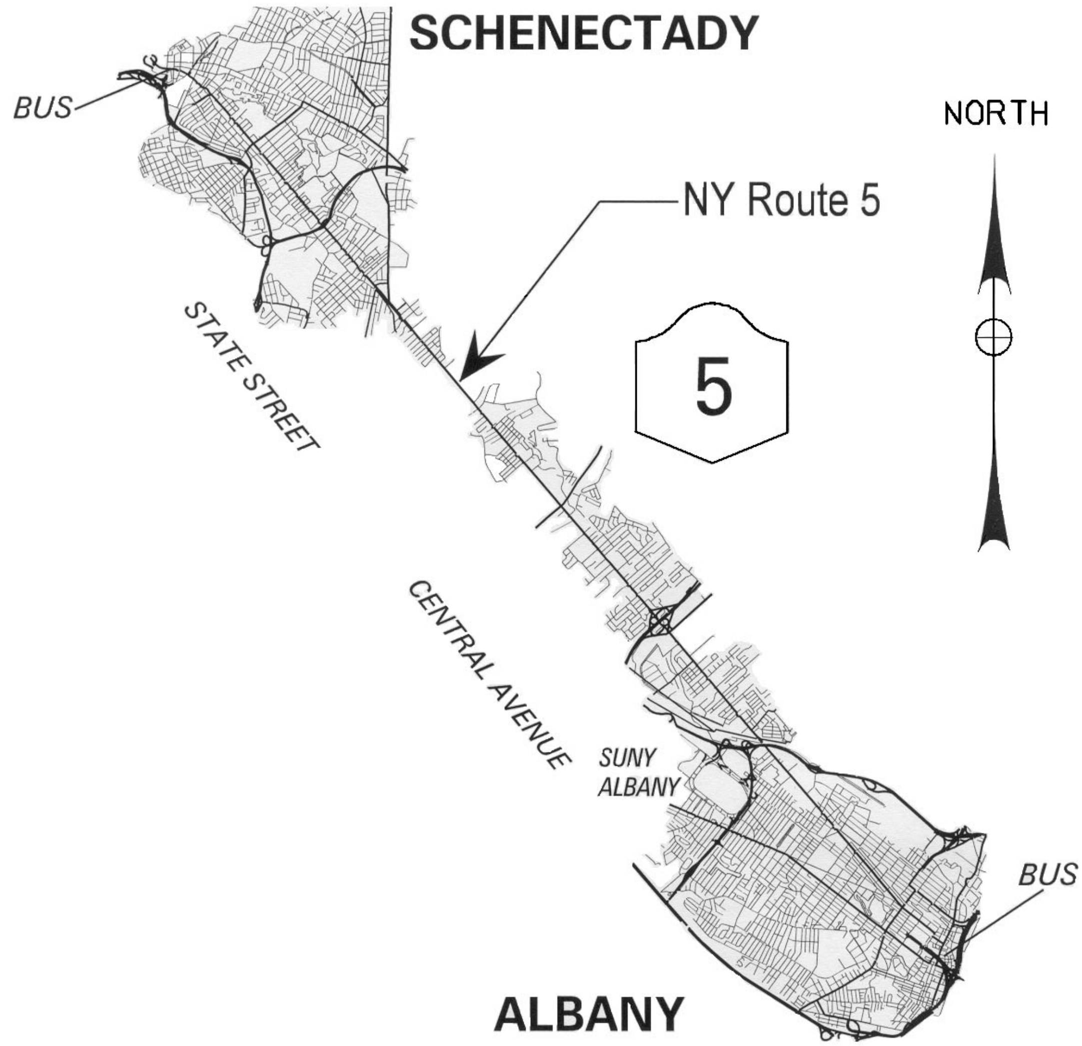

Figure 1. Location of the "Best Bus" project in New York State

The principal stakeholders and their objectives are shown in Table 3.

Table 3. Stakeholders and their Objectives

Transit Agency • Improve Service • Reduce Costs	**Transit Customers** • Reduce Wait Time • Reduce Trip Time
Signal Operators • Safe Operations • Satisfied Motorists	**Motorists** • Reduce Trip Time • Avoid Congestion

Adapted from Reference (5)

4. CORSIM not suitable for simulation analysis. It was noted in (6) that CORSIM did not appear well suited to evaluate the effect of traffic signal system improvements on bus trip performance. This suggests that there is a need for better software for simulation analysis.

The findings from the interviews revealed the reasons, listed below, why evaluations are not done.

1. Changes between before-and-after. It was claimed that a before-and-after comparison might not be a true comparison because changes occur over time. This author believes that not all changes are significant enough to invalidate the data. Further, it makes more sense to look at the data and do a before-and-after comparison while being mindful of the change than not doing a comparison at all because of the change(s). In essence, the occurrence of changes should be viewed as a limitation but not as a reason to not perform an evaluation.

2. Evaluate only for troubleshooting. Sometimes evaluations are done when the system is malfunctioning. For example, researchers from Texas Transportation Institute were invited by Houston Metro to help trouble-shoot their system.

3. Fear of evaluation. While no one specifically cited fear as a reason it became apparent that this could be a reason for not evaluating. The personnel who promoted the project may not favor an evaluation if they believe that the expectations from the project have not been met. Also, the concern that some system deficiencies may be exposed during the evaluation may discourage responsible personnel from viewing any evaluation attempt from a positive perspective. It is, therefore, critical, that there be well-defined objectives and goals to guide any evaluation work.

4. No money to evaluate. The lack of money was mentioned as a constraint. This author believes that agencies should evaluate to a greater or lesser degree keeping in view their resources. In other words, the limited resources can be a constraint with which one must work but not an excuse to not evaluate.

5. No requirement to evaluate. The absence of a requirement to evaluate by the funding agency, say the FHWA (Federal Highway Administration) can be a reason to not evaluate.

EVALUATING A BUS PRIORITY SYSTEM

Performance Evaluation

Performance is defined as the ability of a system or subsystem to perform its functions. Performance evaluation is the technical assessment of a system, subsystem, or component to determine how effectively objectives have been achieved (7).

Why Evaluate?

There can be multiple reasons for evaluating a bus priority system:

- Verify that the system is functioning as designed;
- Compare actual with anticipated system performance;
- Document contribution of system; and
- Justify future investment needs.

Unlike some typical "before-and-after" studies, the role of evaluation should not just be a "snapshot assessment" that yields a report to document the contribution of the implemented system (7). Instead, it should function as a feedback mechanism (Figure 2) that is fully integrated with the operations as well as maintenance of the system (7). The evaluation should be performed by a team that would resolve conflicting priorities and take full advantage of the findings. The evaluation should become a part of the routine operations and be continuously conducted to feed back all performance indicators.

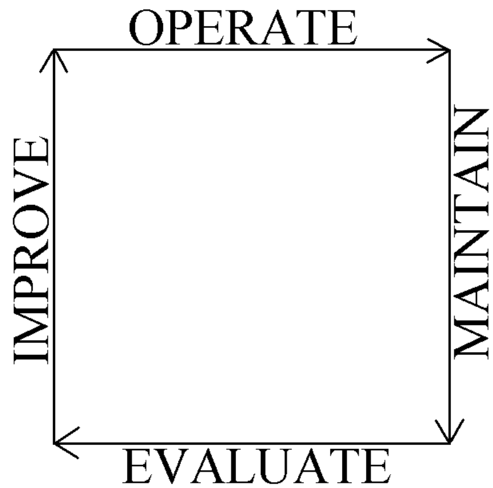

Figure 2. Evaluation Is Integral To the System

A rigorous evaluation not only provides a measure of performance efficiency and resulting cost-benefits but also an opportunity to identify information needed for short-term, long-term, and area-wide improvements and transportation planning (7).

EVALUATION PLAN FOR BUS PRIORITY PERFORMANCE

Before-and-after studies appear to be the primary means to evaluate a bus priority system once it is implemented. These studies involve collecting field data at one or more intersections both before and after the priority system is installed. The advantage of this type of study is that it allows for a direct comparison. The limitation of before-and-after studies is that they require that the system be actually implemented in the field even as it may be difficult to control (or keep intact) all the field conditions (1). For example, the location of a bus stop may have moved as the system was being implemented. Yet another example would be the opening of a new shopping center that changes the ridership at the nearest bus stop.

Step 1: Identify Goals And Objectives

It is important that the transit agency defines its objective(s) and collect the data geared to measuring if those objective(s) are met (8). For example, a bus company may choose to make schedule adherence it's objective while another bus company may choose meeting the headway (e.g. a bus arriving at a major bus stop every 10 minutes during the peak hour) as its objective. Also, note that the primary objective of different systems may not be consistent or compatible. For example, the primary objective for an automatic vehicle location (AVL) system may not be for increasing ridership but for improving the efficiency of fleet operations.

Step 2: Understand Key System Features

It is important to establish the interrelations between the key features of an implemented system and the objectives to be achieved (8). Doing so is essential to develop evaluation criteria and performance indicators. For instance, knowing that NYSDOT uses the Model 179 controller and the City of Albany uses the NEMA TS-2 controller is crucial to establishing performance indicators for the signal coordination system on NY Route 5 because understanding the controllers' features enables you to establish performance measures for the signal coordination system.

Step 3: Establish Measures Of Effectiveness

It is important to establish indicators for measuring performance of a feature before assessing efficiency. Because a large number of transit customers ride the same bus trip every day, day-to-day reliability is an important determinant of waiting time. These customers adapt their arrival pattern to the actual operating characteristics of their buses. Improved schedule adherence can reduce customer wait time and schedule adherence could be measured. Also, reduction in delays at signals by say, providing signal coordination and bus priority, can reduce travel time and this can be measured.

Customers will plan to arrive at the bus stop closer to the scheduled arrival time of their bus if they believe that the service is reliable (punctual). This would reduce customer wait time, which is important to customers.

Several performance indicators are listed here; the relevant ones will have to be chosen (*9*, *10*).

Run Time

- Average Run Time
- Variance in Run Time

Schedule Adherence

- Average Lateness
- Delays at Signals
- Customer Wait Time

Delays At Signals

- Main Street Motorists
- Side-Street Motorists
- Pedestrians
- Buses

Step 4: Measure Direct Impacts

All direct impacts on the users and the environment must be measured (*7*). The impact of the bus priority system on (a) the traffic at the intersection and (b) on the buses themselves must be measured (*8*).

The before-and-after comparison of the traffic at the intersection will indicate if granting priority to the buses has resulted in any significant adverse impact on the other traffic at the intersection—both vehicular and pedestrian. This comparison also will verify if extending the green for say 10 seconds has enabled the platoon of traffic (which includes the bus) to progress along the corridor. (The term "progression" refers to the progressive movement of traffic through several intersections within a control system without stopping.)

Yet another question to ask is "Is the impact of granting signal priority to the bus lasting more than one cycle?" Reviewing the controllers' logs will reveal the answer.

Studying the impact of the bus priority system on the buses themselves is important to answer the following questions:

- Did the bus get "green" faster than it otherwise would have?
- Is the bus waiting less time at the signal for a "green" than before?

Yet another measure would be the run time of the bus (Run time is the total travel time of the bus less the delay at each stop). Where schedule adherence has been made a priority (as for the Best Bus project) the overriding question would be: Is the bus more punctual than before?

Step 5: Collect Data To Capture Every Incremental Change

A true before-and-after study requires that data be collected when any change occurs. A change could be relocation of a bus stop, change in the signal timing at the intersection, a new shopping center on the corridor. Facts such as schools being open or closed, and unusual events such as a large employer having a picnic for its employees are relevant and must be reckoned in the data collection. In other words, a multi-step study is required to compare B against A, C against B, and so on (*8*, *11*).

Step 6: Long Term Measure

A long-term measure of evaluation would be to measure the ridership; increased ridership by guaranteeing a trip time would be a measure of the success of the bus priority system. Increased ridership on a particular route would be reflected in fare box revenues, and also could be measured by passenger counts. Yet another indicator of increased ridership would be the need for more frequent buses to service a particular route. People are more likely to give up their car in favor of the bus when they believe that the bus is a reliable mode of transportation to reach their destination in a timely manner.

APPLICATION OF THE EVALUATION PLAN TO THE BEST BUS PROJECT

Background

Interviews with NYSDOT and CDTA personnel revealed that no evaluation plan exists for the Best Bus project nor is there any requirement that there be one. The absence of an evaluation plan does not mean that no data is being collected. CDTA routinely seeks and receives feedback from its drivers and its customers through drivers and customers calling in, and by periodic customer surveys. Further it has "checkers" that monitor the bus service, and passive transponders mounted on signal poles at some major intersections that record the presence of buses. CDTA updates its bus schedule approximately three times in a year (*12*).

Evaluation Plan for the Best Bus Project

The steps outlined in the evaluation plan developed earlier will be repeated but geared to the Best Bus project. Before beginning the evaluation, the agencies involved must put together an evaluation team that is representative. It should include:

- City of Albany
- City of Schenectady
- New York State Dept. of Transportation (NYSDOT)
- Capital District Transportation Authority (CDTA)
- Capital District Transportation Committee (CDTC)

CDTC is the MPO (Metropolitan Planning Organization) for the area and may be considered to represent the citizens including transit passengers.

Step 1: Identify Goals and Objectives

It is critical for the evaluation team to establish goals and objectives that will reflect tradeoffs between various system impacts. The well-defined and accepted goals and objectives will guide the evaluation work.

Step 2: Understand Key System Features

Knowing the key features of the controllers used in the signal coordination and the features of the advanced communications system (to be purchased by CDTA) are crucial to establishing performance indicators. (The bus priority system will be a component of the advanced communications system.) The features of the controller enable you to answer questions such as why a bus was not granted priority. The answer, from the controller's logs, would reveal that the reason the bus was not granted priority is because an emergency vehicle arrived at the intersection (emergency vehicles deserve the highest priority).

Step 3: Establish Measures Of Effectiveness

Several performance indicators were listed earlier; the relevant ones will have to be chosen (*9*,*10*).

Schedule adherence may be recorded as shown in Table 4 and existing ("before") travel times on NY Route 5 may be recorded as shown in Table 5.

Step 4: Measure Direct Impacts

The evaluation team will have to decide what impacts they wish to measure and how. Before-and-after comparison is one method and comparing simulation results against "after" data is another. It must be pointed out that not every impact is measurable; there may be practical constraints. For example, implementing a bus priority system may result in reduced fuel consumption by traffic on the main street; however, this impact would be difficult to measure.

Table 4. Schedule Adherence Data for Bus Route 55 Westbound

Run	Time Of Run	Colonie Center	State St @ Balltown Rd	State St @ Washington Ave
1	Mon 7:00 a.m.	+2 min.	-1 min.	+2 min.
2	Wed 8:11 a.m.	+2 min.	+1 min.	+2 min.
3	Thu 8:39 a.m.	-7 min.	-6 min.	-6 min.
4	Mon 3:23 pm	-4 min.	+1 min.	+3 min.
5	Tue 2:50 pm	-6 min.	-6 min.	-7 min.

Adapted from reference (*13*)

(+) entries represent buses ahead of schedule; (-) entries represent buses behind schedule.

Results

- Seven data points (47 percent) show buses ahead of schedule;
- Eight data points (53 percent) show buses behind schedule;
- All buses average 2 minutes behind schedule; and
- Late buses average 5.4 minutes behind schedule.

Table 5. Recording "Before" Bus Travel Times On NY Route 5 Corridor Sections

Period	Travel Time	Travel Time	Travel Time	Travel Time
	Albany (minutes)	NYSDOT Section (minutes)	Schenectady (minutes)	Entire Route 5 Corridor (minutes)
AM Eastbound	16.8	20.1	18.3	55.2
Midday Eastbound	17.2	20.8	15.1	53.1
PM Eastbound	17.5	21.3	17.7	56.5
AM Westbound	17.1	19.4	20.5	57.0
Midday Westbound	16.5	19.9	16.9	53.3
PM Westbound	17.4	20.9	19.1	57.4

Adapted from Reference (4)

Step 5: Collect Data To Capture Every Incremental Change

This is especially important to a before-and-after study. One important change here is that the coordination of the signals and the installation of the advanced communications system (of which the bus priority system will be a part) may occur simultaneously or follow one another. It is, therefore, important to measure changes as they occur so that we're comparing B against A, and C against B, and not overlooking changes by comparing C against A.

BEST BUS PROJECT: ISSUES AND OBSERVATIONS

Discussions with CDTA, CDTC, and NYSDOT personnel and a review of the project materials revealed the following:

Simulation Software

Some data was collected and simulation done using CORSIM; the results were used to justify the need for the Best Bus project. However, CORSIM has its limitations and did not appear to be well suited for the application. CDTA personnel did not appear to have much faith in the CORSIM analysis (12).

Data Collection

The data being collected by CDTA is used to make changes but is not necessarily being saved as "before" data. CDTA has some reservations about a "before-and-after" study because they believe that the changes in the field conditions are significant enough that a true comparison is not possible. This author believes that the changes at most locations would not be significant; further, it would be useful to collect data and be mindful of the change when making the comparison.

The task of data collection seems split between the CDTA (transit agency) and the CDTC (*14*) ("the MPO"). However, it is not clearly defined who will collect what data.

Resistance To Evaluation

There appears to be some resistance to doing an evaluation for fear that the changing field conditions may not be adequately reflected in the "after" data which in turn could lead to the conclusion that the project was unsuccessful.

CONCLUSION

A conceptual plan for evaluating a bus priority system is presented. The roles of the stakeholders, such as the transit agency and its customers, and their sometimes-conflicting priorities have been highlighted. The importance of measuring incremental changes as a part of the evaluation has been emphasized.

RECOMMENDATIONS

General Recommendations

It is important that any ITS system such as a bus priority system be evaluated. More importantly, the evaluation activity must be an on going process and viewed as an opportunity to discover inefficiencies and improve, and not as a "snap-shot assessment." The evaluation team must be representative of all the stakeholders.

Recommendations For Future Research

Much of the research reported has been concerned with field-testing at specific locations. Future research should focus on the following:

- developing general conceptual models for various evaluation applications;
- reporting on the evaluation experience; and
- developing better software for simulation analysis of bus priority systems.

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Between October 1994 and August 1999 Mr. Vora served as the Region's Quality Assurance Engineer. In this role he enhanced quality by reviewing design reports and plans and monitoring quality assurance activities. Mr. Vora received an Award of Excellence from NYSDOT in 1998 in recognition of his dedicated efforts to ensure a high level of quality in the reports and plans produced in the Region.

Earlier in his career with NYSDOT Mr. Vora worked on designs for bridge and highway projects. He also worked as a construction inspector in the summer of 1993. Mr. Vora earned his Bachelor's degree in civil engineering from the University of Bombay in India and a Master of Science degree in civil engineering from the University of Texas at Austin. Mr. Vora has a graduate Diploma in Business Management. He is a licensed Professional Engineer in New York State.

IMPROVING INCIDENT RESPONSE FOR A RURAL RECREATIONAL ROUTE

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SUMMARY

Efficient incident response serves both to reduce the impact of incidents to the traveling public and reduce time for emergency services to reach those in need after an incident.

The objective of this research was to identify practical incident response improvements for a specific location, SR525 and SR20 on Whidbey Island in the state of Washington. Data were collected to examine both characteristics of the highway and collisions occurring on it. Telephone interviews were conducted to learn about existing incident response on the island. Literature was reviewed to learn about the character and concerns of providing incident response in a rural setting.

Potential improvement measures were identified and presented in a short and long-range implementation format.

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INTRODUCTION

Whidbey Island, located in the Puget Sound area of Washington State, is a rural area served by a single two-lane state route about 51 miles in length. This roadway is essential for providing mobility for residents and tourists and movement of goods and services. The island is accessed by the Mukilteo/Clinton ferry route at the south end, the Port Townsend/Keystone ferry route on the west side, and a bridge crossing scenic Deception Pass at the north end. Approximately 5 miles farther north of the north end of the island, the 2-lane roadway section becomes a 4-lane section and in another 12 miles connects with I-5, a major north/south freeway in Washington. A schematic map of Whidbey Island is provided as Figure 1.

There are several small communities, many popular with retirees, and four state parks, on the island. Oak Harbor, location of Whidbey Island Naval Air Station, is the largest community. Deception Pass State Park is a popular visitor destination for sight seeing and recreation. The shoulders of Deception Pass Bridge have been converted to sidewalks to provide separation of pedestrians and vehicles on the bridge. There are no emergency stopping areas for vehicles on the bridge. Wildlife hits are a predominant collision type on the southern end of the island. Traffic at the southern end in the vicinity of Clinton is platooned by ferry offloading every 30 minutes. Traffic in the vicinity of the Keystone ferry dock is platooned on a 45 minute schedule.

Incidents, whether large or small and whether there is space to pull out of the traveled lane or not, create traffic backups. These backups hamper the movement of people and goods in a location dependent upon one primary route. Improving incident response provides an opportunity to minimize the disruption of traffic back-ups.

Research Objectives

The objectives of this research were to:

- Examine existing incident response characteristics on Whidbey Island's state highway;
- Examine incident response techniques applicable for rural areas;
- Identify viable incident response improvement techniques; and
- Develop a staged implementation plan broken into a short and long-range format for Whidbey Island's state highway.

Scope

The project was specific to the Whidbey Island Corridor. Incident response improvement alternatives considered and analyzed were limited to those practically implementable.

ROADWAY CHARACTERISTICS

Data Collected

To learn about the Whidbey Island area and incident response in particular the following information was collected and reviewed:

- Washington State Department of Transportation (WSDOT) State Highway Log for location of intersections, pavement width and speed limit by milepost.

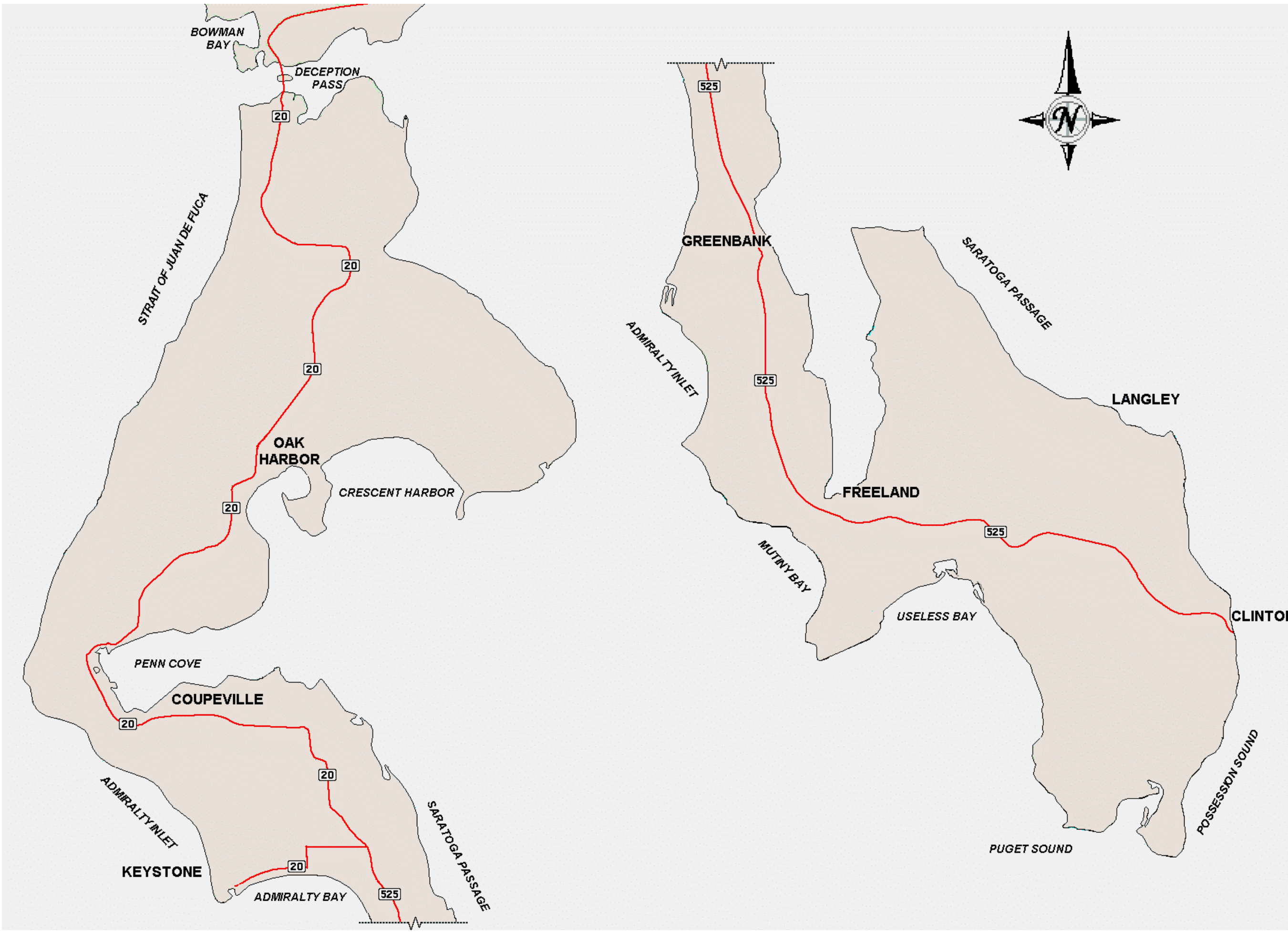

Figure 1. Map of Whidbey Island

- WSDOT Annual Traffic Report for average daily traffic volume data and truck percentages throughout the corridor. There are twenty-six data sites in the twenty-two mile SR525 roadway section and forty-seven data sites in the twenty-nine mile SR20 roadway section.

- Accident Summaries for the period 1994 through 2000. These data are tabulated by year, month, day of week, hour, milepost, collision type, object struck, intersection relationship, most severe injury, contributing cause, and vehicle type.

- Unplanned Roadway Closure Reports prepared by incident response staff. The time elapsed between incident response staff call-out and being in service as well as roadway closure duration is recorded.

Average daily traffic volume depends on location and varies between 1,100 to 25,000 vehicles per day. The average in the southern part of the island is 8,800 and in the northern part 14,000.

SR525 Collision Summary

Review of the collision data for the southern part of the island (SR525 milepost 8.48 to 30.52) indicated the characteristics presented below.

- More collisions occur in the months of October (75) and November (79) than other months, which average 45 crashes per month.

- Collisions are fairly evenly distributed throughout the week with Friday being the highest day.

- There seems to be commuter influence to the time of day collisions occur due to travelers rushing to catch and return from the first and last ferries of the day. Spikes occur at 7am and 9pm. The 11am to 7pm hours also predominate.

- Collision location is highest between milepost 8 and 18. This area is at the southern end of Whidbey Island, which is more heavily populated and likely to be used by commuters traveling to the Clinton ferry dock.

- Predominant collision types are enter at angle, rearend, wildlife hit, and hit fixed object.

SR20 Collision Summary

Review of the accident data for the northern part of the island (SR20 milepost 12.88 to 47.79) indicated the characteristics below.

- Collisions are evenly distributed throughout the months of the year.

- Collisions are fairly evenly distributed throughout the days of the week.

- Time of day of collisions is bell curve shaped with the curve starting at 9am, peaking at 4pm and ending at 10pm.

- Collision location is evenly distributed throughout the corridor length with the exception of the southern city limits of Oak Harbor. This is a recognized High Accident Location, with the cause attributable to poor access control.

- Predominant collision types are enter at angle, rearend, and hit fixed object.

CURRENT INCIDENT RESPONSE PRACTICE

Telephone interviews were conducted to learn about current incident response practice on Whidbey Island. The information collected is described below.

Detection

Incidents are reported to Island Communications (ICOM), the 911 operator, by someone involved or a passersby. ICOM coordinates response with emergency services and the Washington State Patrol (WSP). The incident report can come in the form of a cellular call, a wireline call, or a radio transmission from a local law enforcement jurisdiction or WSDOT maintenance staff. 80 percent of calls are cellular. (*1*) WSP manages the incident scene and requests dispatch of WSDOT's Incident Response (IR) vehicles if needed by contacting WSDOT Seattle Radio. Seattle Radio is WSDOT's central radio communications center. It is operated twenty-four hours per day, seven days per week.

Response

Within minutes of notification, Seattle Radio calls the IR team member on duty for the location of the incident. The IR team member is to be in service within ten minutes of receiving a call. As well as calling out for the IR vehicle, Seattle Radio communicates with the WSDOT maintenance area supervisor who determines if response is better accomplished out of the maintenance yard located in Coupeville, which is approximately mid-island. The four maintenance workers stationed there are trained for incident response and can respond; but do not have the full set of response equipment at their disposal. IR trucks are equipped with high intensity lights, a generator, oil containment equipment, traffic control devices, and other items needed to manage incident scenes. (2) The Coupeville maintenance crew members are not "on call" on their off hours. Response off hours entails driving a personal vehicle to the yard to pick up a standard WSDOT truck, which takes about 15 minutes, and then driving to the incident site, which takes about another 45 minutes. (3)

There is one IR truck to serve an area considerably larger than Whidbey Island. Depending on the location of the incident and IR truck, response time can take up to 1.5 hours. (4)

The IR trucks and WSP vehicles are equipped so that they can communicate directly. This is useful for determining who will arrive first, the best approach route, and preplanning for implementation of response efforts. Once at the site, most emergency responders are equipped so that they can communicate on the "Learn" radio frequency.

The local fire service is usually first to respond. IR team members have worked with the local fire districts to train them in setting up detours with turning radii suitable for most vehicle types. There are detour routes for most of the island with the exception of the Deception Pass area and the community of Greenbank. If a detour route is available, generally 5 to 10 minutes is added to a traveler's trip. (2)

Deception Pass State Park rangers often respond first to incidents occurring in the vicinity of the park. Heavy traffic (14,000 ADT) in this area can back up quickly when a lane blockage occurs. If there is no injury, park rangers clear the incident to the side of the road to allow traffic to pass. (3)

Much of the highway has shoulders or driveways near enough that disabled vehicles, if able, can move out of the way in order to allow traffic to pass. (2) Areas yet to be improved with the addition of shoulders remain.

Removal

Tow service is available from two shops in Oak Harbor and another two in Clinton. Service is dispatched within 5 minutes of receiving the call. Tow trucks on the island are capable of handling up to recreational size vehicles. The nearest location of tow service for larger vehicles is Mount Vernon, which is 22 miles away from the northern end of Whidbey Island. (5)

Tow service is arranged on a rotational basis. WSP administers the rotation program. There are criteria to get on the list and a process to take complaints and enforce standards. (2)

It can take 45 minutes to an hour for the backup caused by an incident to clear. A cause of long clearance time is the lack of left turn refuge, which would allow through traffic to proceed. (3)

Motorist Information

Motorist information exists in the form of detour signs encountered en-route. For incidents of a duration expected to exceed 2 hours, WSDOT's Seattle Radio disseminates information to the Public Affairs office, which in turn prepares press releases. The improbability of the information in a press release, even if prepared and electronically sent to print and radio media in the vicinity of Whidbey Island, reaching travelers makes this of limited benefit.

FINDINGS

Examination of Whidbey Island roadway and crash characteristics and current incident response practice indicated the findings presented below.

- There is no location or time pattern to incidents that provides an opportunity for targeted response.
- There is a traffic volume peak that occurs during work shift changes at the Naval Air Station.
- Due to rocky terrain, there is poor cellular coverage in the four mile roadway section north of Deception Pass State Park. Another area with poor cellular coverage is located in the vicinity of the communities of Greenbank and Freeland.
- Response time is influenced by the communication links between ICOM, WSP, and WSDOT as well as by the location of the IR vehicle.
- Incident queue clearance time is impeded by the lack of left turn storage that would move turning vehicles out of the traffic stream.
- Incident removal capability by tow trucks is adequate.
- Motorist information that would allow travelers the opportunity to plan their trips to avoid incidents is lacking.

RECOMMENDATIONS

Literature was reviewed and suggestions collected for measures that would improve incident response on Whidbey Island. The measures, with discussion, are presented below. They are grouped in two categories: low cost measures that can be implemented in a short amount of time and higher cost measures that require additional funding sources and hence can not be implemented until such funding is secured.

A cost benefit analysis approach using delay cost was considered and rejected. (9) The analysis used average traffic volumes, estimated queue dissipation time, and value of time per person and per commercial vehicle to estimate delay cost incurred by the traveling public per incident. It was evident that in rural areas congestion and motorist delay savings are not likely to be significant, and evaluation based on emergency response time improvement would be more representative. (*6*) The delay based cost benefit analysis attempted confirmed that inclusion of other benefits are necessary to achieve a favorable ratio in a rural setting. Quantifying additional benefits, such as improved emergency response time for injured travelers, is outside the scope of this report.

Short Term Improvement Measures

Improve Communication

Communication is key to efficient incident response. Opportunities for saving time exist between ICOM, WSP, and WSDOT communication links. WSP determines whether IR assistance is needed. The fundamental criteria is that IR is called out when it is thought they are needed to manage traffic at the scene. WSP can and does request IR assistance before a trooper is able to arrive. Occasionally, IR is not requested until some time after the trooper’s arrival. More time goes by while IR travels to the scene, before their services can be implemented. Continued coordination between these groups and a less conservative approach to calling out IR assistance is recommended.

Coordinate IR Truck Location Schedule with Naval Base Shift Change Schedule

Besides the increased traffic volumes associated with summer vacations, traffic volumes also increase when shifts change at the Whidbey Island Naval Air Station. It is suggested this schedule be coordinated with the location of the IR vehicle. The IR truck is driven home by the IR team member on a weekly rotational schedule. Currently, the IR vehicle is on Whidbey Island one week of every four. The truck is in the Burlington area the remaining 3 weeks.

Improve Motorist Information of Incidents

Use the WSP log as a source of data for export to the "Highway Advisory" web site. The log already exists. Once the electronic communication links are established, no additional work effort would be required. While the information would only be available to computer users, it would provide a means of getting travel information before en-route encounter with detour signs.

Long Term Improvement Measures

Improve Communication

At this time, the various emergency responders (ambulance, fire, law enforcement) cannot communicate with each other before arrival at the scene. Once at the scene, all have access to the "Learn" radio frequency. Pre-arrival communication would facilitate planning response activities.

IR Vehicle Dedicated to Whidbey Island

An IR vehicle located mid island would minimize response time. The vehicle would be best located to respond either north or south as opposed to having to travel from as far away as Burlington, which is 17 miles away from the north end of the island. An IR vehicle on the island would also facilitate quick dispatch during off hours because the vehicle would be driven home by the IR team member and would be fully loaded with the needed equipment. Fully equipped IR vehicles cost $70,000.

Vehicle Dedicated to Whidbey Island

This is a down-sized version of the suggestion above. Rather than an IR vehicle, a standard pick-up which could be driven home by off-duty IR team members would be outfitted full-time with incident response gear. The responding employee would save drive time to the shop to pick up a WSDOT truck and the time needed to remove standard work-shift equipment and replace it with incident response equipment.

Install Call Boxes

Cellular coverage on Whidbey Island is lacking in the rocky four mile area north of Deception Pass and the Greenbank and Freeland areas on the south end of the island. While wireline phones are generally within walking distance and passersby will travel into areas of adequate coverage to make a call, call boxes targeted in these areas could be useful. (*78*)

Install Left Turn Channelization

Installation of left turn pockets would improve safety and mobility for both day-to-day highway operations as well as incident situations.

CONCLUSION

Quick incident response has the obvious benefits of providing help to those in need and minimization of disruption to the traveling public. Opportunities exist for improving incident response on Whidbey Island. The options range from simple attention to 9 improving communication among the many entities involved in incident response to investment in incidence response equipment and highway improvements.

ACKNOWLEDGEMENTS

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APPLICATIONS FOR PORTABLE CAMERA SYSTEMS ON SOUTH CAROLINA HIGHWAYS

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SUMMARY

Intelligent transportation systems (ITS) are being implemented in metropolitan areas across the United States as a tool for managing congestion. As these systems grow and attain acceptance, transportation officials and motorists alike begin looking for these technologies during other times of congestion. Events like work zones, incidents and evacuations often cause excessive delays and backups. While these areas have times of critical need, the normal traffic volumes generally do not justify the expense of permanent ITS technologies.

One of the most popular and recognizable elements of ITS is closed circuit television (CCTV) cameras. CCTV cameras provide real-time video to transportation officials managing traffic during peak hours and at incident scenes. The camera images returned to a traffic management center (TMC) are used to determine the additional information and guidance required by motorists, the progress of removing the cause of congestion, as well as personnel and equipment needs in the field. Installing video technology in areas with seasonal traffic volumes may not be economically feasible, but having this tool during peak times offers many benefits to motorists. Using portable camera systems, in conjunction with portable changeable message signs (CMSs) and highway advisory radios (HARs), aids in providing motorists with incident information and route alternatives needed to make informed traveling decisions. The expansion of ITS in these areas has the potential to reduce congestion and driver frustration. These systems also can be used to demonstrate the capabilities of ITS for traffic management and help assess the benefits of permanent installations.

Deploying video systems for special events offers several challenges. Because of deployment times, it will not always be feasible to set up these systems at incidents, but major incidents at unmonitored sections of roadway may be conducive to deployment. For planned activities like sporting events, concerts and hurricane evacuations, there will be adequate notice to mobilize the systems. However, once the systems are deployed the platform for transmitting the data to a traffic management center becomes the next obstacle. Using a wireless phone connection is suitable for some applications, but these systems often get overloaded during mass evacuations.

Using information gathered from a literature review and from interviews with engineers and others responsible for the development and use of mobile cameras, guidelines for deploying portable camera systems in South Carolina were developed. A review panel of South Carolina transportation officials with varying responsibilities for traffic management (traffic engineers, law enforcement and data transmission) critiqued the guidelines. This process, and the subsequent revisions, refined the practicality of the guidelines and helped assure that conclusions were relevant and applicable. These guidelines were then applied to a case study in South Carolina to further assess their applicability.

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INTRODUCTION

As travel on South Carolina's roadways continues to grow, new methods and technologies must be implemented to help manage the number of motorists and the associated congestion. South Carolina, like other states throughout the country, has reached a point where it can no longer build new roads to alleviate congestion. The need for new solutions is further heightened during atypical traffic generators, like special events, coastal evacuations and construction.

Intelligent transportation systems (ITS) have proven to be effective tools for managing traffic. South Carolina has utilized many tools under the ITS umbrella-technologies that include changeable message signs (CMSs), highway advisory radios (HARs), motorists assistance patrols (State Highway Emergency Program or SHEP) and closed circuit television (CCTV) cameras. South Carolina's initial deployment of CMSs and HARs were all portable trailer mounted applications, but the CCTV cameras were post mounted with data transfer by leased or state owned hardwire connections. CMSs and HARs have been useful in areas with seasonal or sporadic traffic demands, but CCTV camera installations have not been feasible. However, as technologies have developed, portable camera systems now present themselves as a viable option in these areas. They may also prove effective in new areas and as temporary replacements for damaged or malfunctioning permanent installations.

Research Objectives

The primary objective of this research was to develop a deployment guide for portable cameras useful to the South Carolina Department of Transportation (SCDOT). The specific objectives for this research were to:

- Determine the relative impact of additional video surveillance;
- Review the available platforms and determine the best method for transmitting video data to a traffic management center (TMC);
- Evaluate past experiences with portable camera systems;
- Analyze current mobile surveillance systems;
- Determine site requirements;
- Establish mobilization and setup times;
- Develop guidelines for deploying portable camera systems;
- Facilitate a panel discussion of South Carolina transportation officials to determine methods of improving guidelines; and
- Apply the guidelines to a case study in South Carolina.

Scope

The primary goal of this research was to produce guidelines for deploying portable camera systems that would be practical and useful to SCDOT. To meet this goal, interviews were conducted with state and local transportation officials who have experience in utilizing portable camera systems. Also included were a literature review of the data transmission platforms available and an interview with a television industry professional with extensive experience in remote video transfer. The scope also took into consideration existing equipment in South Carolina as well as decisions made by SCDOT that will effect future deployments.

METHODOLOGY

To develop guidelines for deploying portable camera systems, the primary sources for research were literature reviews, telephone interviews, field observations of camera installations and guideline reviews by transportation officials.

Literature Review

A literature review was conducted to locate previous research and identify possible challenges associated with portable camera systems. Because of obstacles South Carolina had faced with mobile communications, a lot of the research was dedicated to the video transmission platform. Spread spectrum radio was identified as a technology used in a growing number of traffic engineering applications and was selected for detailed review in this study. Additionally, because the applications for portable cameras are still developing, literature from system manufacturers was also reviewed.

Telephone Interviews

To gain a better understanding of how transportation professionals are utilizing portable cameras, telephone interviews were conducted with representatives from California, Georgia, Kansas, Minnesota and Rhode Island. In addition to officials from other states, interviews were expanded to include the chief engineer of a television station with vast experience in wireless video transfer and SCDOT employees involved in portable camera deployments.

Each interview consisted of a series of scripted questions, but the interviews evolved based on each person's expertise. The complete telephone survey is included in Appendix A.

Field Observations

During the time of this research South Carolina purchased two portable camera systems for use in a construction zone. After, conducting a paper review and telephone interviews, it was beneficial to visit one of the South Carolina locations. This allowed interviews with employees responsible for deployment, a chance to see changes incorporated in current models, and an opportunity to identify improvements for future deployments.

Additionally, the Kansas Department of Transportation (KDOT) and the Kansas Highway Patrol hosted an open house to demonstrate the aspects of their race day traffic control plan. Their system utilized wireless communications with portable cameras, CMSs and HARs, with all information coordinated at a temporary TMC in KDOT's Bonner Springs office. This demonstration allowed interviews with engineers, law enforcement and vendors who each played a vital role in managing traffic generated by a stock car race at the Kansas Speedway and were experienced in utilizing portable cameras during a special event.

Guidelines Review

The goal of this research was to produce a guideline that will be utilized by SCDOT. The literature review, interviews and field observations were used to draft the guideline. After the initial draft, the guideline will be reviewed by a diverse group of South Carolina transportation officials in hopes of utilizing their expertise to finalize a practical guideline.

BACKGROUND

The history and development of portable camera systems and how these systems have been utilized is described below. Additionally, SCDOT's needs were reviewed to see how these cameras could aid South Carolina's motorists.

In the mid-1990s several states conducted operational tests of portable traffic management systems (PTMS). These PTMS were natural extensions of existing TMCs and, in addition to cameras, included technologies like changeable message signs, signal heads and ramp metering devices. These portable systems offer cost-effective alternatives to traditional inductive loop detectors and landline communications used at special events or remote locations (1).

Early Operational Tests

Early operational tests had similar goals and challenges that South Carolina faces today. Tests conducted in both California and Minnesota utilized portable cameras, as a part of a PTMS at areas where traditional traffic detectors and communication systems did not exist (such as pre-planned events and construction zones).

Anaheim Special Event Test (1)

In the Anaheim Special Event Test, one of the primary objectives was to determine the relative impact of additional video surveillance with respect to special event traffic management. Only camera imagery was of interest in this test, and spread spectrum radios were used for video transmission. This evaluation recognized that video surveillance produces benefits to traffic management only when operations personnel use the information appropriately and focused on features such as transportability, self-contained power and wireless communications.

As this test progressed, many of the challenges it faced have been addressed in current equipment, yet several obstacles seem to persist for portable cameras. Aside from institutional coordination issues, the list below recaps the primary challenges in the Anaheim test.

- The trailer size limits the places it can be deployed, and the trailers are subject to frequent moves that are exacerbated by their size. Additionally, the size and weight of the trailers necessitated larger tires.
- Additional relay sites needed to be deployed to assure the integrity of wireless data transmissions. Site development required multiple steps including negotiating access to space, securing liability coverage and providing reasonable upkeep to the site and the equipment.
- Trailer design should incorporate trailer hitches compatible to those used on other trailers. Ball hitches had to be replaced with the Caltrans hook-and-pintel hitch, further highlighting the need for coordination among all of the project partners.
- The trailers' analog control system functioned poorly and did not charge the primary batteries. This required a complete redesign of the power distribution architecture, but the new system was not evaluated in this test.

The Anaheim Special Event Test showed that there was value in deploying the video surveillance trailers to a special event location. The trailers performed well when positioned to produce imagery valuable to event traffic managers. The data suggested that the additional video might reduce the traffic egress time from a special event but that expenditures of resources may not be commensurate with the benefits.

Minnesota's Smart Work Zone Application (2)

Minnesota originally deployed portable cameras as a part of their PTMS concept to handle traffic at major sporting events. Their intent was to provide a means to control periodic traffic congestion problems resulting from major events where the traffic problems were not frequent enough to justify major facility upgrades. This portable system was developed to be easily moved and adapted to various event locations. The next phase was to apply the basic concept to work zone applications. The intent was to improve the safety of workers and motorists while maintaining adequate traffic flow. Minnesota also sought to develop a cost-effective system.

A key issue identified in Minnesota's test was again communications. As with previous tests, they faced problems in finding a suitable platform for sending data, but they did conclude that spread spectrum radio could successfully transmit video and data to a TMC. Other conclusions from the Minnesota report that are pertinent to this paper are listed below.

- PTMS could be successfully deployed in a variety of work zones with relative ease.
- Traffic volumes increased and speed variability decreased in work zones where PTMS were deployed.
- A survey of motorists showed 66 percent remembered seeing the PTMS and the message displayed on the changeable message sign. Additionally, focus groups indicated that the PTMS was successful.

Spread Spectrum Radio

Several communications platforms were used in these tests, but spread spectrum radios (SSR) were given the best reviews. In general, there are three categories of network topologies used for data transmission. The first category utilizes wireless radio waves as described above. Second, traditional ITS technologies have used a landline wired connection directly to a CCTV camera, CMS or HAR. Finally, and most common, a hybrid network is created that utilizes both wireless and wired mediums to provide connectivity to a portable camera. Because SCDOT plans to utilize SSR (both stand alone and as a part of a hybrid network for its data transfer) research focused on the requirements and flexibility of this platform (*3*).

SSR can be traced to Hedy Lamarr, the Hollywood actress of the 1930s and 40s. Lamarr, along with her second husband George Antheil, received a patent for "A Secret Communications System" that employed a unique radio hopping technology (*4*).

The principle behind the process of spread spectrum communications is to distribute a radio signal over a range of frequencies. This spreading or synchronized hopping was initially developed as a means for the military to transmit data without the possibility of interception or jamming. Today this hopping offers a means to prevent a signal from being jammed by commercial noise interference. Additionally, the lower transmitted power density gives spread spectrum the advantage of occupying the same frequency as narrow bands with little or no interference. This provides the commercial user with a military tested system that is virtually immune to noise.

The two most popular modulation techniques for SSR are frequency hopping and direct sequence. Frequency hopping causes the transmitter to periodically "hop" to a new frequency, transmit information on the frequency for a defined period of time, then hop to the next frequency and repeat the process. This hopping occurs several times each second. Direct sequence SSR code is used to cause a fixed frequency transmitter to spread its power more or less evenly across a wide band of RF spectrum. These techniques are compared graphically in Figure 1 (*5*).

Frequency hopping is the optimum technique for long-range communications in a shared radio spectrum, while direct sequence enables high data rates over shorter path lengths.

A critical issue for SSR is that the transmitter and receiver must operate on line-of-sight and obstructions between the sending and receiving stations will affect system performance. These signals are prone to attenuation from obstructions like terrain, foliage and buildings. However, if the system is to cover only a limited geographic area (1 to 3 miles) some obstructions in the transmission path can usually be tolerated with minimal impact.

CURRENT PRACTICE

Telephone interviews and field observations were used to gain further understanding of the current practices and technologies that could be useful in deploying portable camera systems.

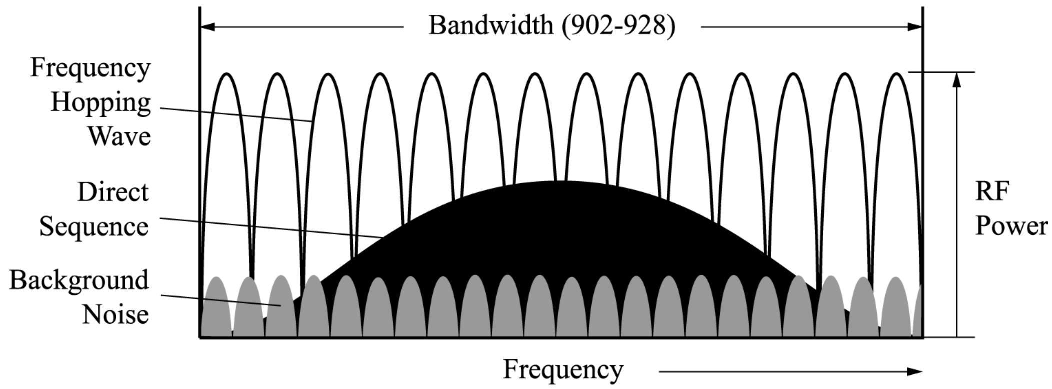

Figure 1. Direct Sequence Versus Frequency Hopping (5)

Table 1. Summary of Current Practices

	Applications	Communications Platform	Number of Cameras	Deployment Guideline Developed
Anaheim	Special Events	SSR, Hybrid	2	
Georgia	Evacuations, Special Events	Hardwire, SSR, Hybrid	5	No
Kansas	Special Events	SSR	3	No
Minnesota	Work Zones, Special Events		Varies by District	No
Rhode Island	Work Zones		Deployment Incomplete	No

Telephone Interviews

One of the most common uses of wireless video transfer is for remote television broadcasts. In South Carolina, most television images from remote locations utilize microwave transmissions. Establishing line-of-site from the remote site to one of the receiving antennas is the primary limitation. The transmission unit is generally housed in a van which has a mast antenna that extends 45 – 50 feet. Establishing the line-of-site is the most time consuming step in the broadcast set-up.

Satellite is another technology applied in television broadcasts but is often cost prohibitive. In utilizing satellites, stations typically purchase time from a satellite company, usually in 15-minute blocks. When the broadcast is ready, the satellite is called from the remote site and the data transmitted to the satellite and then retrieved by the station. Television stations have experimented with SSR, but found the bandwidth to be insufficient (*6*).

The Anaheim Special Event Test did not determine if portable camera systems offered a sufficient return on the investment of human and fiscal resources. However, the portable cameras have been replaced permanent installations at the event venue (*7*). While this does not prove the traffic management benefits of portable cameras, it does show that they can be helpful in demonstrating the need for permanent ITS installations and acquiring the required funding.

The Georgia Department of Transportation is using 5 portable cameras to aid hurricane evacuation traffic. Each of these portable cameras is equipped with a CMS. Camera locations have been predetermined and have asphalt pads with electrical power and telephone service for communications. Telephone connections were deemed necessary because of the rural locations and device spacing of up to 10 miles. Their deployments call for the cameras to be positioned at the beginning of hurricane season and relocated at the end. The off-season deployments have not been finalized, but the cameras are equipped with SSRs for use at special events like The Masters, St. Patrick's Day celebrations and the state fair (*8*).

The Kansas Department of Transportation is utilizing 3 portable cameras, each equipped with a CMS. The portable cameras are a part of the traffic management system implemented in coordination with the Kansas Highway Patrol for the Kansas Speedway. Because portable cameras are only being used for speedway events, the equipment is leased for each race. KDOT uses SSR to transmit traffic images to a TMC located approximately 2 miles away (*9*).

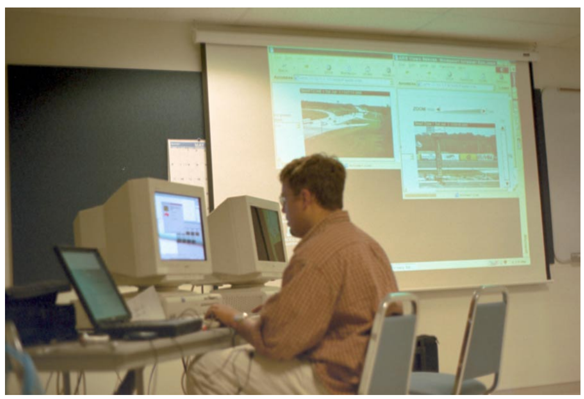

Figure 2. KDOT TMC Utilized During Events at the Kansas Speedway.

The Minnesota Department of Transportation continues to operate PTMS, primarily in work zones. They utilize SSR for data transmission and plan to use PTMS for pre-planned special events like the opening of hunting and fishing seasons and marathons. They have not established criteria for when to deploy PTMS to a special event and will rely on the experience of local transportation officials. They are also deploying PTMS as part of their ITS initiatives for TMCs in each of their nine districts (*10*)(*11*).

The Rhode Island Department of Transportation has included portable cameras in their traffic management plan, but they are currently concentrating on permanent camera installations. They still plan to utilize portable cameras and believe their primary applications will be in work zones (*12*).

Field Observations

Kansas's use of portable cameras demonstrates the value of cameras as part of a traffic control plan for a pre-planned special event. The cameras systems leased by KDOT are identical to the systems purchased by SCDOT as part of a current construction project on I-85 in Anderson County. The primary conclusions from Kansas' plan are listed below.

- Camera images can be effectively transmitted using SSR over a short distance (around 2 miles).

- The effectiveness of camera images relies on the ability of TMC personnel to utilize the images to make changes to existing traffic control.
- The success of the traffic control plan is largely controlled by the strength of the relationship and communications between TMC personnel and law enforcement. Kansas exemplifies the ideal relationship.
- Cameras are part of a total traffic management plan and the Kansas Speedway's location and excellent system of connecting roads aids their plan's effectiveness.

Field observations of South Carolina's portable camera systems show that several of the problems identified in early operational tests have been addressed. The portable camera systems purchased by SCDOT are trailer mounted and include a CCTV color camera mounted on a 33-foot high retractable tower and a full matrix changeable message sign. Data transmission for these units is by a hybrid network, utilizing both wireless and wired mediums. In the current setup, images are transferred by SSR to a cabinet where the images are then transmitted to a TMC by T-1 landlines.

Trailers

The portable camera trailers are just over 20 feet long by 7 feet wide, with a maximum height of 10 feet. The trailers utilize larger tires and hitches compatible with SCDOT's other portable ITS components (CMSs, and HARs). Because of the variety of vehicles that may be used to move a portable camera, CMS, or HAR, SCDOT vehicles use a sleeve connection that allows ball and hook-and-pintel hitches to be easily interchanged.

Site Selection

Trailer size, while improved, still introduces limitations on site selection. Also, because the camera needs to be level, keeping the camera trailer level is more critical than with the trailer of a CMS or HAR. SCDOT is also considering some type of hydraulic system or outrigger to offer additional stability. Currently, the sites being used by SCDOT are in urban work zones and supplement existing permanent installations.

Power Supply

The South Carolina portable camera units are solar powered, using a 32 battery array that has posed few maintenance or operational problems. This system overcomes many of the obstacles faced in the Anaheim Special Event Test.

Communications Platform

As stated earlier, SCDOT is utilizing direct sequence SSR for data transmission. However, as with the previous operational tests, data transfer has been one of the primary obstacles. SSR has proved reliable in transferring data back to the cabinet of a permanently installed camera. The images are then transferred to a shared T-1 landline. Problems, however, are encountered with the share. The manufacturer of the portable camera system is currently reviewing ways to split the bandwidth between two cameras. Other hybrid platforms, utilizing cellular and fiber-optic cable, are being considered for future applications (*13*, *14*).

GUIDELINES

The goal of this paper is to develop guidelines that are practical for South Carolina applications. The primary issue to be addressed will be site selection, as affected by the communications platform and accessibility. Other guidelines will address the need for traffic video, establishing mobilization and setup times for each possible site, and choosing a data transmission platform.

Figure 3. Portable Camera System Used By SCDOT.

Need for Real-Time Traffic Video

Of the interviewed states utilizing portable cameras, none has established deployment guidelines for special events or work zones based on traffic counts, anticipated attendance, or project costs. Deployment decisions are based on the experience of the local transportation officials. This process has been effective in identifying locations, and it does not limit deployments to large events or projects. For example, Kansas identified the potential for congestion at the Kansas Speedway prior to the first race. Their traffic control plan was implemented at several smaller track events (attendance 45,000) prior to the track's largest event, a NASCAR Winston Cup race with attendance expected to be near 120,000. Again, because this was a first-time event, the foresight of law enforcement and engineers is credited with establishing a traffic control plan based on their experience with other special events.

Based on the congestion created by the coastal evacuations during Hurricane Floyd, South Carolina will concentrate on locating camera's at strategic points where traditional cameras have not been installed. The areas of primary concern are Beaufort, Hilton Head Island and Myrtle Beach. Each of these areas experiences tremendous amounts of local and visitor traffic and does not have direct interstate access. Currently, South Carolina's ITS technologies are located along urban interstates, but there is a growing need for ITS solutions along rural roads. These rural areas experience seasonal volumes and coastal evacuations, but they do not maintain the traffic volumes to support funding for permanent CCTV camera installations.

To help justify the costs of providing portable video cameras, uses beyond hurricane season need to be identified. Darlington Raceway in South Carolina hosts several special events that could benefit from video. Darlington Raceway is located in a rural area that has not demonstrated a daily need for traffic video, but congestion surrounding speedway events occurs several weekends each year. Using the Kansas Speedway plan as a model, deploying portable cameras purchased for coastal evacuations can help optimize the use of portable video.

Site Selection

Site selection will be affected by several factors, most predominate being trailer size and communications platform. Because of the limitations in data transmission, sites will need to be identified for any deployment area.

An acceptable site must be easily accessible by pick-up truck and provide a level surface at least 10 ft. x 25 ft. In addition to space for the trailer and space for the truck to enter and exit, there will be vertical clearance requirements for the camera mast and line-of-site considerations for the SSR and CCTV camera.

Anaheim faced issues with attaining permission and space for their trailers, but since SCDOT will be deploying its units on roadways it maintains, this will not be a major factor. Additionally, since the communications platform may vary, the location of existing control cabinets may also factor into site selection.

Mobilization and Setup Times

Once sites are selected, mobilization and setup times can be established. Currently, SCDOT staff expect that setup, after arriving at a previously selected location, will take about 30 minutes (*13*). Mobilization will depend on the number of cameras purchased and whether a camera will come from storage or will have to be removed from one site and taken to another. The source for a portable camera should be identified for each of the selected locations to assure minimal transport times and that the proper hardware for data transmission is included with each camera.

Data Transmission Platform

SCDOT is utilizing a hybrid topology for its current deployments but anticipates that other solutions or combinations may be needed as cameras are deployed to other parts of South Carolina. The current systems are in an urban construction project where data can be effectively relayed to nearby control cabinets of permanent camera installations. From the cabinets, data will be transferred to the TMCs via T-1 landlines.

As future sites are selected, the nearest cabinets may be for traffic signals that contain traditional phone drops. Another possibility for data transmission is cellular, but this has proven inaccessible during times of critical needs.

PANEL REVIEW OF GUIDELINES

To assure that the guidelines developed by this research are comprehensive, a review panel was established to review each of the facets. The review panel was a group of diverse professionals, having backgrounds in traffic engineering, law enforcement and network services. The members are listed below.

- Jimmy Bolton, South Carolina Department of Transportation (Traffic Engineering, district TMC)
- Richard F. Jenkins, Jr., South Carolina Department of Transportation (Traffic Engineering, State ITS Engineer)
- Richard Spangler, South Carolina Department of Transportation (Traffic Engineering, state TMC)
- Capt. Harry Stubblefield, South Carolina Department of Public Safety (state traffic coordination)

Need for Real-Time Traffic Video

South Carolina's ITS programs were initiated along urban stretches of interstates in Charleston, Columbia, Greenville, Rock Hill and Spartanburg, and SCDOT utilizes real-time video in each of these areas to monitor daily traffic. With these urban areas having demonstrated the value of video to traffic operations, SCDOT is purchasing portable cameras for deployment in off-interstate areas like Myrtle Beach.

Myrtle Beach is located along the northeastern coast of South Carolina and is a popular tourist destination. Tourist volumes reach their peaks during hurricane season, thus highlighting the need for video traffic monitoring during weekend movements and especially during coastal evacuations. Video offers the best way to observe traffic movements and convey information to motorists via other ITS technologies. Again, because many of the motorists are visitors to the area, the need for communications is heightened.

While coastal deployments will continue to be the focus for portable cameras, SCDOT will look for deployments in construction zones and at special events. Construction zones have unique traffic characteristics and were one of the original applications for portable video as shown in the Minnesota field test. Constructions zones are also appealing because the can provide the necessary funding to purchase portable cameras that can be deployed in other areas after the project's completion. Other special events (football games, golf tournaments, etc.) have been identified, but there are no current plans for these deployments. South Carolina's focus will continue to be on coastal evacuations, but as their ITS program grows, alternative deployments can be part of the traffic control plan.

Site Selection

The primary factor for site selection will be the need for video and locating the camera where it can effectively capture the needed images. SCDOT is deploying two portable cameras in the Myrtle Beach area, see Figure 4, and accessibility by a pick-up truck was not deemed to be critical. At the intersection of US 17 and US 501, the location that provides the best camera location is on a hill and enclosed with guardrail. This camera was positioned by crane. While the guardrail limited pick-up access, it provides additional protection to the camera unit and which be lowered and left in place during a hurricane.

Mobilization and Setup Times

Based on field observations and discussions with deployment personnel, setup time will take about 30 minutes after the camera is in position. Because camera locations have been determined for the initial deployments, mobilization will not be a factor. The cameras will remain at the selected sites and will only have to be raised and activated when needed.

Data Transmission Platform

The initial deployments will be at pre-selected locations and the data transmission platforms have already been determined. For the camera located at the intersection of US 501 and US 17 (See Figure 4), images

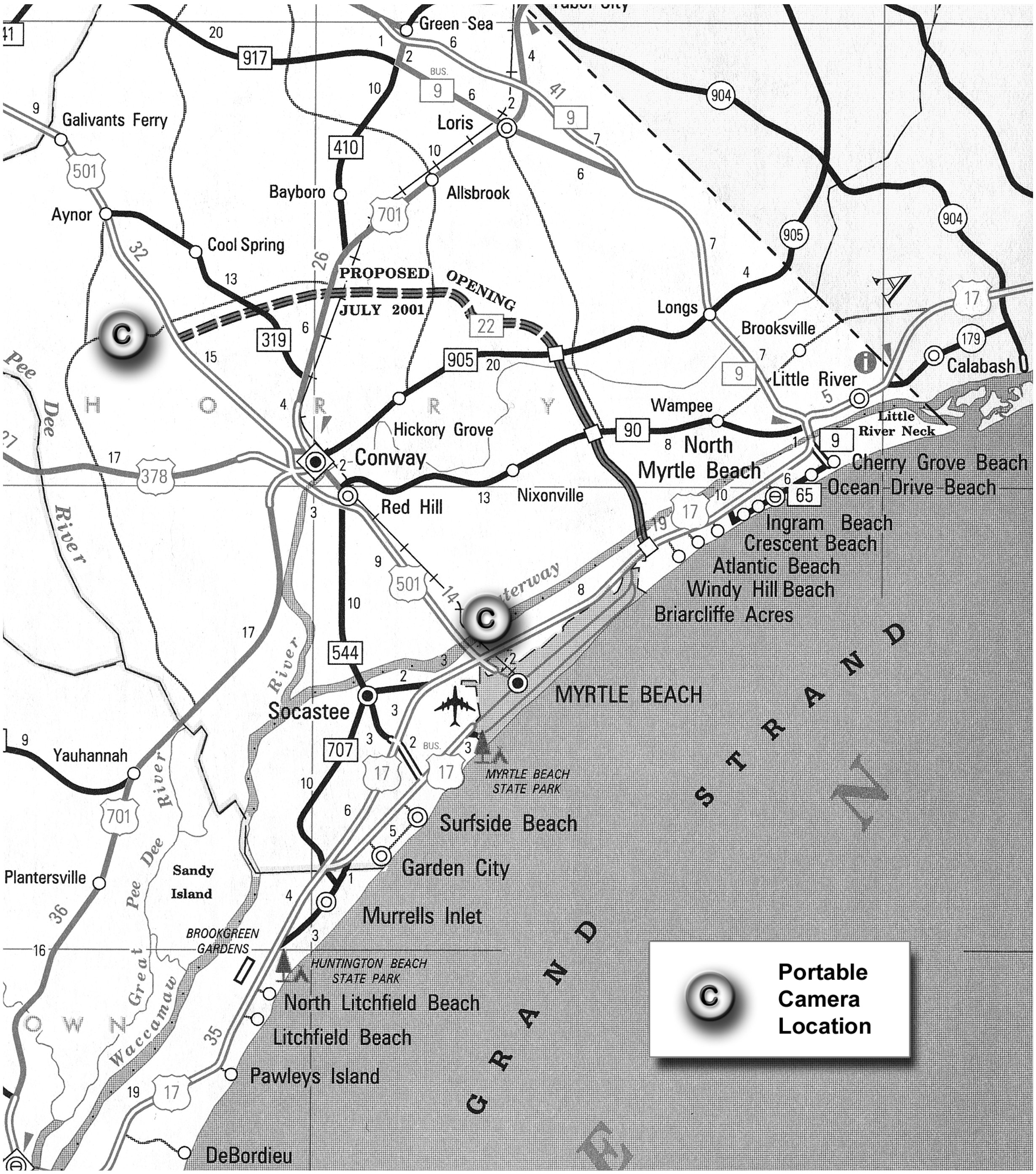

Figure 4. Sites Selected for Portable Cameras in Myrtle Beach, South Carolina.

will be transferred by SSR to a regional TMC. For the second camera, located at the intersection of US 501 and the recently completed SC 22, images are being sent over a permanently installed T-1 line back to the regional TMC. The review panel also indicated that each portable camera cabinet should be fittedwith the necessary equipment to transfer data by traditional phone line and cellular or 3rd generation wireless, in addition to the existing SSR and T-1 capabilities.

CASE STUDY

The two cameras evaluated for this case study were purchased for use during a construction project along I-85 in the northwestern part of South Carolina. These cameras will remain in the construction zone for the duration of the project, but could be moved to a coastal region in the event of a hurricane. At the conclusion of the project, both cameras will be available for deployment in other areas of South Carolina.

In seeking to establish a deployment plan for portable cameras, this case study is identifying a use for these cameras during costal evacuations and for a special event. Though neither of the deployments has been tested, engineers and law enforcement officials in South Carolina were consulted to determine the optimal locations.

Coastal Evacuations

South Carolina's ITS efforts received tremendous financial and public support after hurricane Floyd in October 1999. The anticipated destruction associated with hurricane Floyd caused evacuations from much of the southeastern coast of the United States and the resulting congestion caused several states to revaluate their evacuation plans. For South Carolina, this included interstate reversals, increased public awareness, route designations and increased ITS funding.

Need for Real-Time Traffic Video

The need for traffic video was highlighted during the congestion that occurred during the Floyd evacuation in 1999. Motorists reported spending over 26 hours to make inland trips that typically take around 2 hours. Reports of travel conditions were often inaccurate, leaving transportation officials with the real-time information required to make appropriate decisions.

Site Selection

Based on the lessons learned during hurricane Floyd and the deployment of South Carolina's current evacuation plans, the most critical areas of I-26 between Charleston and Columbia now have permanent CCTV camera installations. However, as discussed in the panel reviews, many of the coastal evacuation areas are not located along urban interstates and do not have video coverage.

As shown in Figure 4, two locations have been identified for portable camera deployments in the Myrtle Beach area. For this case study, two additional sites have been selected. The first site is located at the intersection of SC 375 and US 521 in Greeleyville (see Figure 5), and the second deployment will be to at I-95 near the Georgia state line. The second deployment is in the Hilton Head Island area and is shown in Figure 6.

Mobilization and Setup Times

SCDOT field personnel have estimated setup times to be 30 minutes. For each of these installations, mobilization times have been established at 6½ hours.

Data Transmission Platform

Each of these cameras will be in remote areas where SSR will not be feasible because of the data transfer distance and cellular communications were shown during hurricane Floyd to be unreliable. Because each of these cameras will be located at signalized intersections, sites were selected where data transfer could be accomplished by using existing telephone drops.

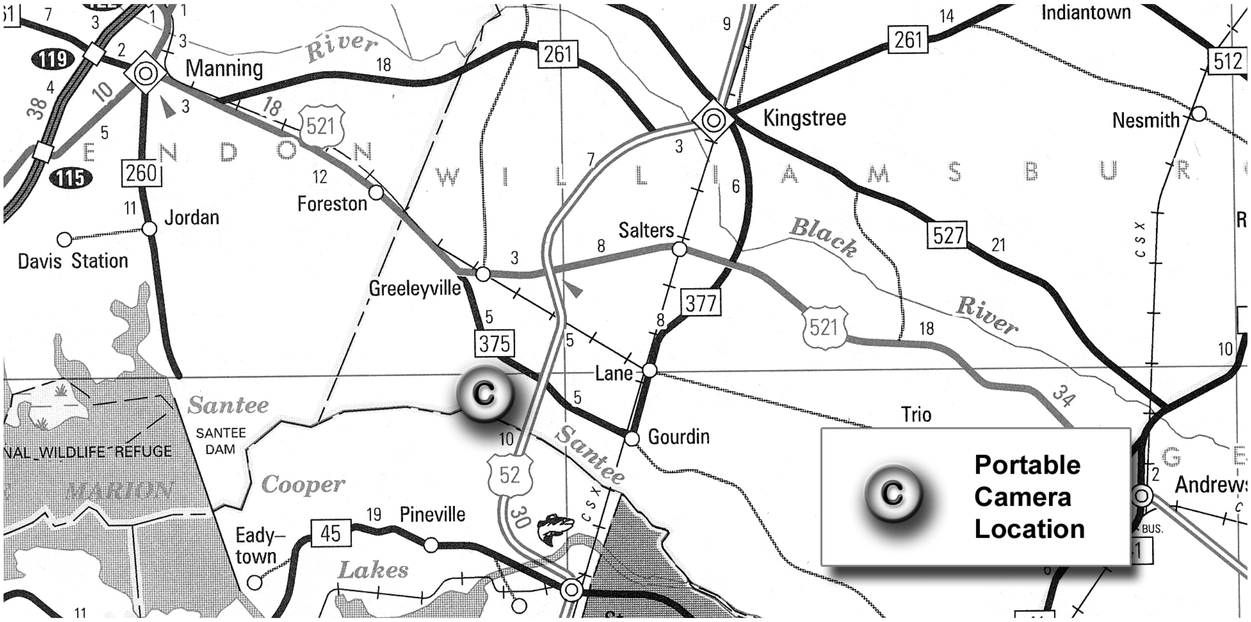

Figure 5. Case Study Portable Camera Deployment in Greeleyville, SC.

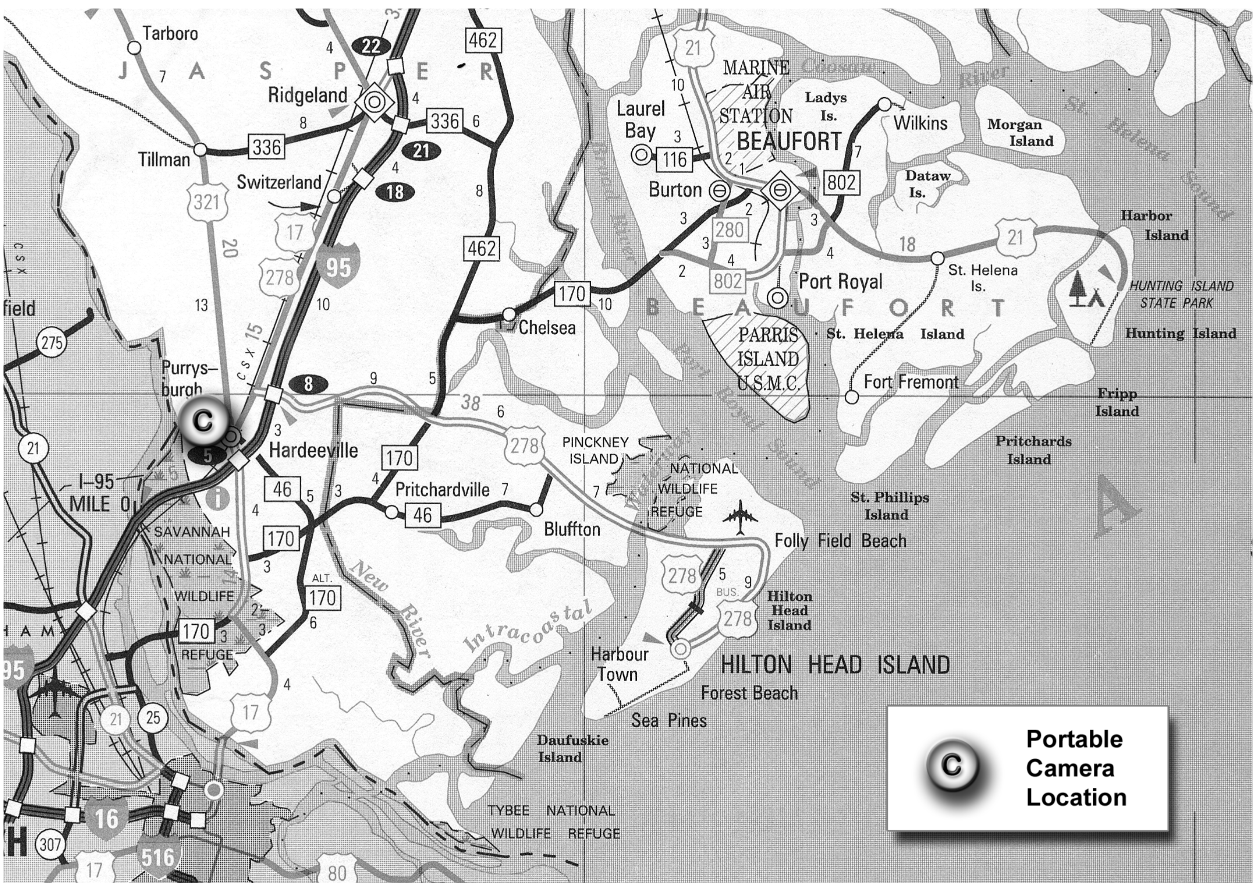

Figure 6. Case Study Portable Camera Deployment Near Hilton Head Island, SC.

Special Event

As South Carolina increases the number of portable cameras available for it's ITS efforts, uses outside of hurricane season need to be identified. Darlington Raceway hosts multiple events each year, but the normal traffic volumes do not warrant permanent camera installations. The deployments witnessed at the Kansas Speedway indicate that a similar traffic control plan could aid flow at Darlington Raceway events.

Need for Real-Time Traffic Video

Law enforcement personnel responsible for traffic control surrounding events in Darlington have expressed an interest in using video to aid their efforts. During the most recent NASCAR Winston Cup race, troopers used aerial photography to analyze movements around the Darlington Raceway. Using real-time video to augment existing efforts will enable better flow to and from the raceway. Again, the Kansas Speedway will serve as a model for deployment and to justify the increased effort.

Site Selection

Two sites have been selected as shown in Figure 7. The first will be located along I-20 at Exit 131. This exit is used by most eastbound travelers and the raceway is signed prior to this interchange with traditional guide signs. The second camera will be located at the interchange of US 52 and SC 34/151, since US 52 is a primary route of north-south race attendees.

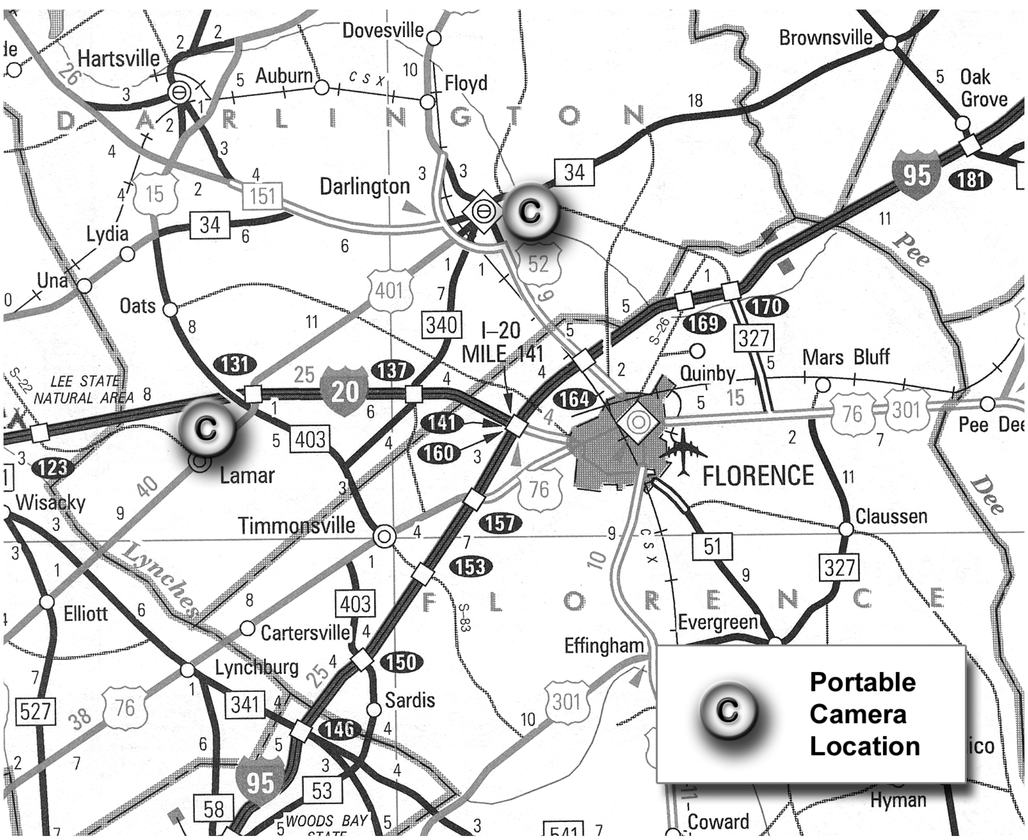

Figure 7. Case Study Portable Camera Deployment Near Darlington Raceway.

Mobilization and Setup Times

While setup times remain constant at 30 minutes, mobilization will be less of a consideration for pre-planned special events like races in Darlington.

Data Transmission Platform

Data will be transferred by a hybrid platform. The first camera will utilize a SSR to communicate with the camera located at the intersection of US 52 and SC 34/151. This second camera will utilize a cellular modem to send images back to a TMC.

CONCLUSIONS

CCTV cameras provide an integral part of intelligent transportation systems, and portable cameras add increased flexibility and solutions for aiding traffic flow. The primary objective of this paper was to establish guidelines for deploying portable cameras on South Carolina's highways. Establishing objective guidelines proved challenging. Many traffic engineering guidelines and practices rely on education and experience as well as objective data, and establishing deployment guidelines proves no different. In determining installations for portable cameras, experience was key in selecting locations and determining when to deploy.

While the guidelines did not develop as originally intended, the steps outlined in this research did prove valuable in establishing a dialogue for deployments outside of hurricane season. Portable cameras are an emerging technology. Their benefits can be utilized in a variety of situations, and expanded use will continue to showcase their flexibility.

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The author would like to thank Dr. Conrad Dudek for his vision in establishing and leading this research course. He invests lots of time and patience to assure the successful blending of graduate students, state transportation engineers and professional mentors to achieve the annual success this compendium has become. The author would also like to recognize the contributions of all of the mentors including William Speitzer, Wayne Kittleson, Patrick Irwin, David Roper, Joseph McDermott and Jack Kay. Jack provided the constructive input, technical knowledge and professional contacts that made this research an invaluable learning tool. Finally, the author recognizes that none of this would be possible without the support given by friends at the South Carolina Department of Transportation and his family who sacrificed time for this effort.

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APPENDIX A

1. Can you describe the portable camera systems currently used by your agency or company? (truck or trailer mounted, manufacturer, transmission platform, etc.);
2. What is the standard mobilization and setup time for your operation?
3. What elements determine when to use portable video? (Time, anticipated congestion, etc.);
4. How is the video relayed back to the traffic management center or home office?
5. What constraints or limitations have you encountered with your relay systems? Have you experienced interrupted service, poor quality, etc.?
6. What experiences have you had in deploying portable camera in high wind conditions? Is "wobble" a significant problem with image quality?
7. What platform consistently offers the best video transmission?
8. When have portable cameras proven to be most helpful? When has their success been limited?
9. What maintenance has been required with your portable camera systems?
10. Were deployment guidelines developed for your system? If so, is it possible to obtain a copy?
11. Are there other documents that you found useful in developing and/or operating your system?
12. Are you aware of other municipalities that have portable camera systems?
13. Are there figures and pictures describing the portable camera system in your city and if so, is it possible to obtain a copy?
14. Would you be willing to review and comment upon a set of operational guidelines that are being developed as part of this research effort?

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