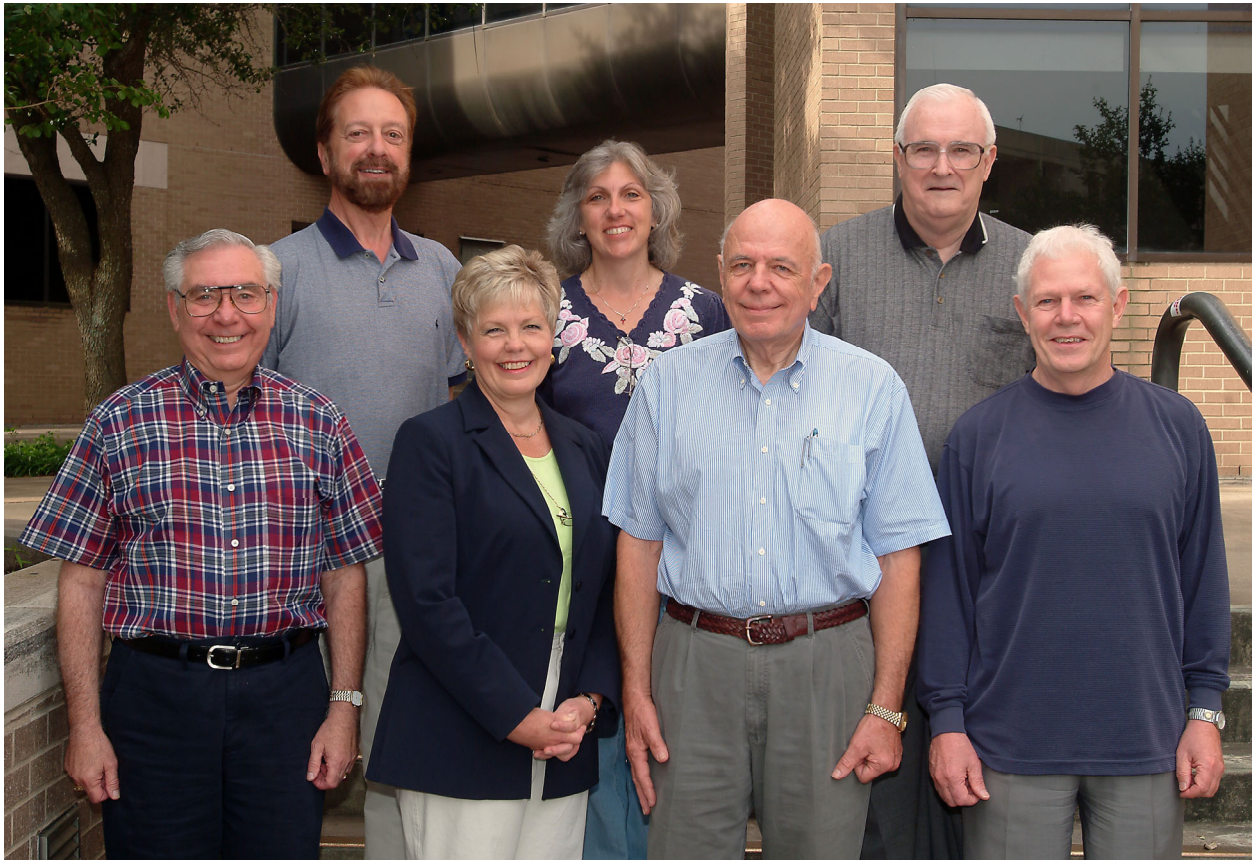


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**COMPENDIUM:
PAPERS ON
ADVANCED SURFACE TRANSPORTATION SYSTEMS
AUGUST 2004**



Class Instructor and Mentors (front row, from left) Conrad Dudek, Christine Johnson, Thomas Hicks, James Wright, (back row) Walter Dunn, Marsha Anderson Bomar, Wayne Shackelford

PREFACE

This document is the culmination of the fourteenth offering of a Mentors Program at Texas A&M University on Advanced Surface Transportation Systems that was presented in 2004 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.

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 the 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.

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.

Marsha Anderson Bomar, Walter Dunn, Thomas Hicks, Christine Johnson, Wayne Shackelford, and James Wright devoted considerable time and energy to this Program. We are extremely grateful for their valuable contributions in making the 2004 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.

Colleen Dau, Lead Office Assistant 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 by the participants since 1991 is shown in Appendix D.

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2004 MENTORS**MARSHA ANDERSON BOMAR**

In 1990, Marsha Anderson Bomar formed *Street Smarts*, a transportation planning and engineering consulting firm based in Atlanta, Georgia. She had the honor of being the first woman to serve as International President of the Institute of Transportation Engineers. Ms. Bomar has received the Gwinnett County Chamber of Commerce Athena Award. This is given to the Outstanding Businesswoman who has made a significant contribution in business, community service and her profession. In 2003, Marsha was the recipient of the Institute of Transportation Engineers Burton Marsh Award, given to a person who has made outstanding contributions to the advancement of ITE throughout a period of several years.

In addition to her position with Street Smarts, Marsha is now a Senior Research Associate with the Texas Transportation Institute (TTI). She is involved in a variety of projects in the Traffic Operations group, as well as freight planning and work in the security area.



Ms. Bomar has been responsible for a wide range of technical projects. In the past several years, she has led the effort on the application of handheld computer technology for data collection applications, as well as designing a transit system to serve the cultural and historic sights of Atlanta using Electric Vehicle technology, and assisted in the planning for the Advantage I-75 corridor and the I-95 Corridor Coalition. Currently, she is the Project Manager for a major study for the DOT investigating and implementing strategies for managing Truck Traffic in the Atlanta metro area.

Ms. Bomar is past Chair of the Institute of Transportation Engineers' Technical Council Design Department, Policy Committee, Transportation Planners Council and Goods Movement Council. She was a Director of the New Jersey Motor Truck Association, as well as the American Trucking Associations' Scholar-In-Residence. Other affiliations include the numerous Transportation Research Board committees, NCHRP Panels, Women's Transportation Seminar Boards in New York and Atlanta, Council for Quality Growth, and Society of Women Engineers.

Ms. Bomar holds Bachelor and Masters Degrees from the Polytechnic Institute of Brooklyn in Mathematics and Transportation Planning and Engineering, respectively. She also holds a Masters of Civil Engineering with a concentration in Transportation from Princeton University. She is the author of more than two hundred publications and studies. Ms. Bomar is listed in numerous Who's Who publications, including "Professional and Executive Women", in the "South and Southwest", "in the East", and "Among Community Leaders". Marsha was also a finalist for the 2003 Metro Atlanta and Gwinnett County Chamber of Commerce Small Business Person of the Year Awards. Street Smarts was selected in 2002 and in 2003 as an Atlanta Business Chronicle Pacesetter Company (one of only 50 for the whole Metro Atlanta region).

WALTER M. DUNN, JR.

Mr. Walt Dunn is recognized for his expertise in freeway corridor traffic management, freeway incident management, and intelligent transportation systems (ITS). He is the founder and principal partner of Dunn Engineering Associates, a firm he started in 1982, which specializes in traffic management for both the private and public sectors.

Currently, he provides consulting engineering services on ITS projects for the Federal Highway Administration as well as the states of New York, New Jersey, Massachusetts, Rhode Island, Connecticut, Pennsylvania, Michigan, Wisconsin, and Tennessee.

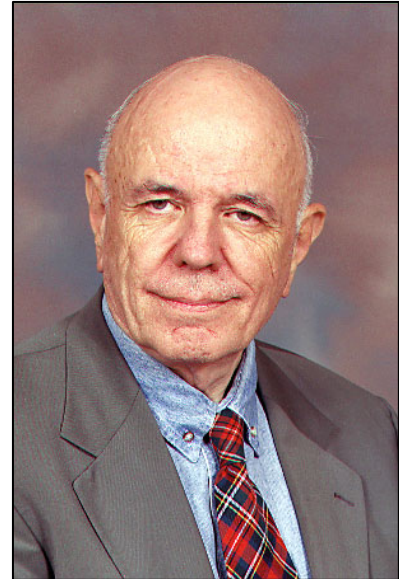
Prior to starting Dunn Engineering Associates, Mr. Dunn worked for the New York State Department of Transportation for 16 years where he was director of the INFORM (Information For Motorists) project from inception through final design. INFORM is a corridor traffic management system designed to obtain better utilization of existing highway facilities. INFORM has been implemented in a 40-mile long highway corridor on Long Island, N.Y. as an operational demonstration.

Mr. Dunn successfully handled the traffic management of the 1995 and 1986 U.S. Golf Open special events in Shinnecock Hills, New York. He is a co-author of the Freeway Incident Management Handbook and Communications Handbook for Traffic Control Systems for FHWA, Freeway Operations Project for the Transportation Research Board and "Freeway Management Systems for Transportation Efficiency and Energy Conservation" for Transport Canada.

On the national level, he is a member of the Freeway Operations Committee of the Transportation Research Board (TRB). He served as 1990 President of the Institute of Transportation Engineers (ITE) Met Section of New York and New Jersey, is a member of the American Society of Civil Engineers and Chi Epsilon and a licensed Professional Engineer in New York and New Jersey. Mr. Dunn is a Graduate of New Jersey Institute of Technology (B.S. in Civil Engineering) and Polytechnic University (M.S. Transportation Planning and Engineering).

THOMAS HICKS

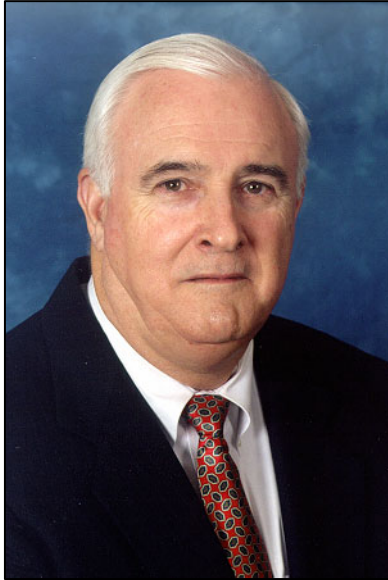
Thomas Hicks is presently the Director of the Office of Traffic & Safety for the Maryland State Highway Administration, one of six engineering offices reporting to the Chief Engineer. He is responsible for coordinating the work of six Divisions - Traffic Safety Analysis, Traffic Engineering/Design, Traffic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



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

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

Mr. Hicks has served in leadership rolls with several professional organizations including ITE, AASHTO, NCUTCD, TRB, ATSSA, and the Safety Council of Maryland. He is currently Vice-Chairman of the AASHTO Committee on Traffic Engineering, a member of the AASHTO Special Committee for Transportation Security and a Member of the NCUTCD where he serves as Vice Chair for Programs. He is a member of the Washington DC ITS; served as a member of various TRB committees; and was a Co-Founder and first President of the Oklahoma Traffic Engineers Association. Mr. Hicks is the recipient of the 1990 National Safety Award from ATSSA; the 1991 Highway Safety Award from AASHTO; and the 1992 Community Transportation Award from the Washington DC Section of ITE. Mr. Hicks is the recipient of the 1999 Theodore M. Matson Award. He is a registered Professional Engineer in Maryland.

WAYNE SHACKELFORD

Wayne Shackelford is Senior Vice President of Gresham Smith and Partners, an architectural, engineering and planning firm with offices in eleven cities in nine states. The firm has major planning, design, and construction activities in intelligent transportation systems at this time. Prior to this current position, he served as the Commissioner of the Georgia Department of Transportation from 1991 until his retirement in 2000. As Commissioner, he administered an annual budget of \$1.4 billion and managed the department's approximately 5,900 employees statewide. With those resources, he successfully provided the mobility that gave the world the opportunity to travel in Georgia during and after the 1996 Summer Olympic Games.

He brought a keen interest in customer service with him to the Georgia DOT. He nurtured the incident management and transportation management programs existing in the Department to bring them to a world-class level in time for the Centennial Olympics. The Department's Advanced Transportation Management System, NAVIGATOR, is a complete model of an urban transportation management system and is being studied by transportation leaders worldwide.

Mr. Shackelford has been active in both regional and national transportation policy development since he became Commissioner of the Georgia DOT. In 1993 he served as President of the Southeastern Association of State Highway and Transportation Officials (SASHTO), and in 1995 he was President of the American Association of State Highway and Transportation Officials (AASHTO). He served as Chairman of the Board of Directors of the Intelligent Transportation Society of America (ITSA) from May 1998 through April 1999 and was a member of the Board from 1996 to 2000.

Mr. Shackelford was Chairman of the Executive Committee of the Transportation Research Board (TRB), National Research Council in 1999 and has served on the Executive Committee since 1995. He served on the President's Council on Year 2000 Conversion as one of 21 professionals nationwide, from both the public and private sectors, invited to participate in this historical committee, where he represented surface transportation. He became Chairman of the Board of Georgians for Better Transportation in August 2003.

He has earned many national and state awards, including the Key Citizen of 1996 Award from the Georgia Municipal Association. In September 1997, the State Transportation Board bestowed their highest honor and dedicated the Transportation Management Center on Confederate Avenue as the Wayne Shackelford Building. In 2000 the Association of County Commissioners of Georgia created the perpetual Wayne Shackelford Excellence in Public Leadership Award and Mr. Shackelford was named the first recipient of this award. Also, the American society of Highway Engineers has chosen Mr. Shackelford to receive the Robert E. Pearson, Person of the Year Award, in June 2001. The George S. Bartlett Award was presented by AASHTO, TRB, and ARTBA to Shackelford in December 2001. This award is conferred annually to an official who has made an outstanding contribution to highway progress.

Following military service, Mr. Shackelford joined the University of Georgia Cooperative Extension Service, serving from 1959 through 1973. He was appointed Executive Assistant to the Gwinnett County Commission on January 1, 1973 where he managed the nation's fastest growing county for the next eleven years. From 1984 to 1991 he held executive positions with two major development companies.

CHRISTINE M. JOHNSON, PH.D.

In August of 2002, Christine Johnson was appointed Director of Field Services for the West, Federal Highway Administration (FHWA). In this role, she functions as an extension of the Executive Director's Office in providing oversight to the Western Division Offices, Midwestern Resource Center, and Western Resource Center and taking a leadership role in promoting innovation and technological change.

Prior to receiving this appointment, Christine served as both Program Manager of the Operations Core Business Unit and the Director of the Department's multimodal Intelligent Transportation Systems (ITS) Joint Program Office, a position she had held since 1994 when that organization was established. In these positions, she provided leadership for establishing highway operations as a core mission within the FHWA and among State and local partners. She has been instrumental in shaping Federal ITS program strategies to bring ITS to the forefront of modern-day transportation in the United States. Under her leadership, national attention has been focused on the value of maximizing performance of existing surface transportation resources via a "National Dialogue on Operations." She had responsibility within FHWA for ITS deployment, freight and logistics policy, work zone operations, value pricing, the Manual on Uniform Traffic Control Devices, and travel management.



Prior to joining the FHWA, Christine Johnson was Vice President of Parsons-Brinkerhoff where she was responsible for ISTEA programs, including statewide planning activities, management systems, and major investment analysis. From 1990-1993, Christine served as Assistant Commissioner for Policy and Planning with the New Jersey Department of Transportation. From 1984 through 1990, she held managerial and executive positions with the Port Authority of New York and New Jersey (PANYNJ). She was Director of Transportation Planning when she left PANYNJ. She has also held management positions with the American Public Works Association, the Checker Taxi Corporation, and the Chicago Area Transportation Study. She was an Assistant Professor of the School of Urban Sciences at the University of Illinois at Chicago and was a visiting lecturer at the University of Tennessee.

Christine received her B.A. and M.A. from the University of Illinois. She received her Ph.D. in Public Policy Analysis from that University in 1976.

Her service on professional boards and associations include ITS America, the Transportation Research Board, the American Association of State Highway and Transportation Officials, the Institute of Traffic Engineers, and the White House Conference on Global Climate Change.

JAMES WRIGHT



James Wright is currently an on-loan executive from the Minnesota Department of Transportation to the American Association of State Highway and Transportation Officials (AASHTO) in Washington, DC. He is providing executive leadership for the national 511 Coalition, the ITS Standards program, the Integrated Network of Transportation Information, and ITS America initiatives. Immediately prior to this assignment he served in the role of Division Intelligent Transportation Systems (ITS) Engineer for the Minnesota Department of Transportation's Metropolitan Division. His responsibilities were ITS planning, regional deployments—delivering a \$40 million regional deployment—and national and international liaison.

From 1991 to 1996 he directed the Minnesota Guidestar Program which is a statewide ITS effort. From 1996 to the present he has directed the Orion “Model Deployment” program. During these years he has delivered \$50 million in ITS work.

Key achievements include: 1) development of creative procurement processes for public/private partnerships resulting in \$10 million in private investments, 2) development and completion of 12 ITS field trials, 3) development of over 15 ITS project managers who are continuously being recruited throughout the nation, 4) establishment and management of the statewide ITS organizational structure, 5) presentation at every ITS America Annual meeting and the ITS World Congresses, 6) conducting some of the first statewide customer surveys for ITS, and 7) introduction of ITS into rural areas.

National and international liaison is a key role of Mr. Wright's responsibilities. Specific activities include US Congressional liaison, USDOT liaison, and international liaison. The US Congressional liaison was instrumental in bringing \$40 million into MnDOT's ITS program. An additional \$10 million in private investments were brought into the program through strategic alliances.

Mr. Wright served as Chair of ENTERPRISE (consortium of states with emerging ITS initiatives) and as an at-large member of ITS America Coordinating Council. He is currently serving as Chair of the 511 Working Committee, Chair of the AASHTO/ITE Traffic Management Data Dictionary; Chair of ITS America Advanced Traffic Management Systems Committee; Vice Chair of the ITS America Coordinating Council; and is the English-speaking secretary for the Network Operations Committee of the World Road Congress. Prior to his ITS activities Mr. Wright spent five years developing the department's computer aided design

Mr. Wright completed his BSCE at the University of Minnesota and his ME at the University of California at Berkeley. He also completed one year of advanced coursework towards a Ph.D. in molecular biology and environmental engineering.

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APPLYING ACCELERATED CONSTRUCTION TECHNIQUES TO NON-EMERGENCY PROJECTS

by

Michael P. Pratt

Professional Mentor
Wayne Shackelford
Gresham Smith and Partners

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Prepared for
Mentor Program
Advanced Surface Transportation Systems

Department of Civil Engineering
Texas A&M University
College Station, TX

August 2004

SUMMARY

Increasing traffic volumes are making it more difficult for state departments of transportation (DOTs) to identify times when highway reconstruction and rehabilitation projects can be implemented without significant disruption to the traveling public. Because many urban highways are near the end of their service lives, there will be a greater number of reconstruction/rehabilitation projects on the horizon, and state DOTs need to identify methods to complete construction work for the needed projects more quickly.

State DOTs have already demonstrated the ability to build highway structures rapidly and safely in emergency situations, like when highways are damaged in natural disasters or bridges are destroyed in large crashes. When regulatory red tape is reduced, highways can be built at a remarkable pace.

A literature review of current and innovative regulatory and contracting techniques was done, and telephone interviews were conducted with state DOT officials to gather information about specific emergency repair projects. Specifically, the procedural changes implemented for emergency projects were identified by comparing the various project development steps (planning, design, approval, contracting, etc.) to the development steps for non-emergency projects.

The contracting and regulatory changes were then evaluated for possible application to typical (non-emergency) projects by determining the situations in which accelerated construction is needed and justified. Construction cost, road user costs, traffic impacts, and work zone safety were the criteria used to determine when accelerated construction is warranted. As construction time decreases, construction cost increases, but road user costs decrease. Road user costs, which are comprised mainly of traffic congestion delays, increase when traffic volumes are high, more lanes are closed for construction work, or lanes are closed for longer periods of time. Work zone safety is influenced by drivers' perceptions of the work zone and the visibility of construction workers.

An alternate construction process was recommended based on the literature review and the telephone surveys. This revised procedure was the implementation of design sequencing contracting, combined with streamlined environmental review processes.

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INTRODUCTION

As traffic volumes continue to increase in urban areas, it is becoming more difficult for state departments of transportation (DOTs) to identify times when highway work can be completed without creating major delays to traffic. Highway construction projects usually require lanes to be closed temporarily, resulting in a partial loss of capacity and increased delays for the traveling public. In addition, because typical highway reconstruction and rehabilitation projects take months or even years to complete, motorists have to endure the resulting congestion for long periods of time.

Partial losses in highway capacity also occur when structures are damaged in natural disasters or major incidents. However, in these cases, state DOTs are able to employ accelerated construction techniques to repair the lost highway capacity with remarkable speed. The state DOTs are able to accomplish this by having environmental regulations waived, receiving emergency funding from the federal government, and paying construction contractors incentives to complete the work rapidly. The contractors can also implement special procedures, including paying workers overtime, having workers at the site 24 hours per day, and keeping material plants and other facilities open beyond normal operating hours. These accelerated regulatory, contracting, and construction procedures allow lost highway capacity to be restored faster with minimal impacts to motorists, resulting in savings in travel time and travel cost. However, accelerated work is also more expensive than typical highway construction work.

If typical highway reconstruction and rehabilitation projects could be completed with the same speed and urgency as is seen in emergency situations, the traveling public could potentially see tremendous benefits in reduced construction delay and improved mobility.

Problem Statement

At a pavement renewal workshop, Charles Nemmers (L) of the Federal Highway Administration (FHWA) summarized the challenge of innovating highway construction as follows:

We estimated it would take about two years to rebuild a 10-mile highway. Do you know what that means? It means that for the rest of our lives, every 38 miles we travel the national highway system, we will come across a construction work zone. Now, if we can get that project built in one year instead of two, there will be at least a 76-mile gap before we come to another work zone.

Highway construction work can cause significant delay for motorists. The impact on traffic flow can be minimized by reducing the amount of time it takes to complete the work. In cases where highway capacity is lost during natural disasters or major incidents, state DOTs have proven to be able to replace the lost capacity in short periods of time by implementing special regulatory and contracting procedures.

With traffic volumes increasing to the point that it can be impossible to complete routine reconstruction and rehabilitation projects without generating excessive delay, the problem facing state DOTs is to complete projects in a minimal amount of time. To accomplish this goal, regulatory and contracting procedures need to be revised to allow accelerated construction techniques to be used more often, and for a larger range of situations. State legislatures need to amend contracting laws to empower state DOTs to use the newest and most efficient contracting methods. State DOTs, in turn, need to prioritize carefully the urgency of upcoming reconstruction and rehabilitation projects, based on traffic volumes, potential delay created by work zone lane closures, and the resulting road user cost increases due the resulting congestion. The most urgently needed projects need to be built using accelerated construction methods, both to reduce road user costs and impacts, and to improve work zone safety by reducing construction workers' exposure time to traffic.

Objectives

The goal of this research was to determine the need and the feasibility of increasing the use of accelerated construction methods for highway projects. The specific objectives were as follows:

- Review the current state of the practice for contracting and regulatory procedures in both typical and emergency construction projects;
- Identify sources of delay in existing highway project development, and areas needing improvement;
- Determine which methods are most effective in reducing project development time;
- Suggest legislative and regulatory reforms that would enable increased use of accelerated construction methods; and
- Specify the need for the increased use of accelerated construction methods.

Scope

Case studies were performed on emergency projects where a traffic incident or natural disaster caused partial loss of capacity on a highway. The regulatory and contracting procedures used in each case were compared with standard procedures used in routine reconstruction and rehabilitation projects. No reviews were conducted for new construction projects or projects where capacity is added to existing highways.

BACKGROUND

Two goals in highway construction management are to minimize construction time and to minimize the amount of highway capacity reduction during the project. These goals have been addressed through innovative contracting techniques like A+B bidding, incentive/disincentive clauses, and lane rental fees. The loss of capacity during significant construction projects has often been mitigated through various measures like improving surface arterial signal timing and re-striping shoulders as temporary lanes.

Contracting Techniques

A+B Bidding

To implement a typical highway project, a DOT prepares a plan for the project, makes the plan available to the public, and solicits bids from contractors who wish to build the project. The DOT then grants the contract to the bidder with the lowest cost. With A+B bidding, the DOT considers not only the construction cost, but also the construction time, as follows (2):

$$\text{Bid price} = A + B \times RUC \quad (\text{Equation 1})$$

where A = construction cost (\$)

B = construction time (days)

RUC = road user costs (\$/day)

The purpose of A+B bidding is to give contractors an incentive to use construction procedures that minimize construction time. The contractor is not paid the total bid price, but only the 'A' component, the cost of the actual work performed (3).

Incentive/Disincentive Clauses

Contracts can include incentive/disincentive clauses that allow a contractor to be paid a premium price for delivering a project ahead of schedule. The incentive is a fixed amount to be paid for each day that the project is completed ahead of schedule, and the disincentive is a fixed amount to be charged to the contractor for each day that the project is completed behind schedule. When incentive/disincentive clauses are used, there is usually a cap on the maximum total incentive the contractor can earn. The incentive and disincentive are the same amount, and determined by the state DOT (2). Most state DOTs use incentive/disincentive rates of between \$2,500 and \$10,000 per day (4). Note that incentive/disincentive clauses can be used both in conventional contracts and in A+B bid contracts.

Lane Rental Fees

When lanes are closed or narrowed to accommodate construction work, traffic congestion will usually increase, resulting in increased road user costs. Some state DOTs account for this by charging contractors fees to “rent” the road space closed for construction. The contractor can be charged daily rental fees or hourly fees that vary depending on hourly traffic volumes (2, 5). Table 1 shows an example of daily and hourly lane rental fees.

Table 1. Lane Rental Fees (2)

Lane Type	Daily Fees (\$/day)	Hourly Fees (\$/h) 6:30-9:00 AM	Hourly Fees (\$/h) 9:00 AM-3:00 PM
One lane	20,000	2,000	500
One shoulder	5,000	500	125
One lane and shoulder	25,500	2,500	625
Two lanes	45,000	4,500	1,250
Two lanes and shoulder	50,000	5,000	1,375

Effectiveness of Contracting Procedures

A recent survey of 40 state DOTs showed that 94 percent of the agencies use incentive/disincentive clauses, 76 percent use A+B bidding, and 52 percent use lane rental fees (2). Table 2 shows the degree of impact cited by the state DOTs of the procedures on reducing lane occupancy. A+B bidding and incentive/disincentive clauses have proven to be particularly effective. Incentive/disincentive clauses were found by 82.5 percent of the state DOTs surveyed to have a high or medium impact on reducing lane closure time, while A+B bid contracts were found by 65 percent of the state DOTs to have a high or medium impact (2). These innovative contracting techniques have reduced lane occupancy by encouraging contractors to restrict lane closures to low-volume periods and reduce overall construction time.

Table 2. Impact of Contract Methods on Reducing Lane Closure Time (2)

Contract Method	High Impact (% of agencies)	Medium Impact (% of agencies)	Low Impact (% of agencies)
Lane rental	32.5	12.5	7.5
A+B bidding	37.5	27.5	10
Incentive/disincentive	45	37.5	12.5

Factors Affecting Construction Time

Figure 1 shows the results of a National Cooperative Highway Research Program (NCHRP) survey of state DOT practitioners on the factors affecting construction time (4). The most commonly-cited factor is weather and seasonal effects, which was mentioned by 98 percent of the respondents. States that experience severe winters often have to restrict construction activity to only 6-8 months of the year, and many construction tasks are hampered by weather conditions like rain, sleet, snow, and frozen ground. Project location was cited by 88 percent of the respondents, partly because projects in urban areas tend to take longer due to factors like traffic impacts, utility relocation, contract letting time, and night and weekend work. The state of Nevada estimates that production rates are about 75-80 percent of normal in high-volume areas (4). Utility relocation can add as much as 40 percent to contract time. Letting time becomes a factor if a large number of projects are under construction at the same time in a region, causing constraints on the availability of materials and labor. Night and weekend work tends to progress more slowly than daytime work because of lower production rates and more time needed for safety procedures. As a result of these constraints, the window of time available for highway construction in urban areas is only a small portion of the year.

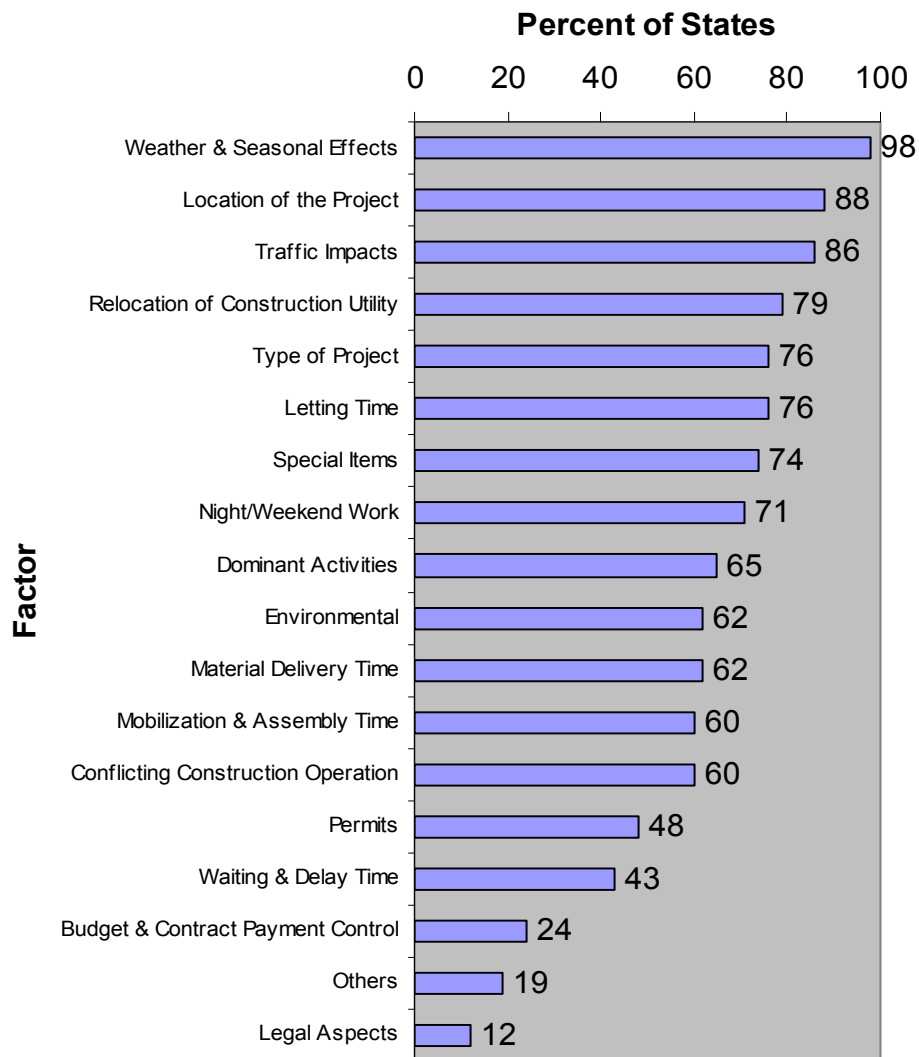


Figure 1. Factors Affecting Contract Time (4)

In addition to these factors, Georgia DOT Construction Engineer James McGee states that special events reduce the amount of time available for construction projects in the Atlanta area (6). According to McGee, it is becoming increasingly difficult to find time to do routine rehabilitation and reconstruction because of the various constraints in urban areas.

Mitigation of Traffic Impacts

Though state DOTs try to restrict lane closures to nights and weekends as much as possible, reconstruction and rehabilitation projects always require some lane closures, resulting in traffic impacts to the motoring public. Some drivers stay on the highway and experience increased congestion through the work zone, while others change their routes to avoid the delay, resulting in an increase in traffic on local roads. In addition to traditional mitigation measures like widening alternate routes, improving traffic signal progression, and adding turn lanes at key intersections, state DOTs have found public outreach—and public cooperation—to be crucial to the smooth delivery of highway reconstruction projects (7).

Improvements to Alternate Routes

Significant changes were made to the surface streets of Indianapolis, Indiana in advance of “Hyperfix 65/70”, the reconstruction of the two-mile multiplex of I-65 and I-70 (7). Hyperfix 65/70 entailed closing the highway completely for almost two months so 33 bridges and 35 lane-miles of concrete pavement could be rehabilitated. Mixed-flow and auxiliary lanes were also added to provide new capacity. To prepare for the closure of the freeway, a parallel alternate surface street was widened by narrowing lanes and cutting into landscaped medians. Traffic signal timing throughout downtown Indianapolis was also improved, parking restrictions were implemented during peak periods, turn bays were added to various intersections, and one traffic signal was removed to allow free flow.

In construction projects where the highway is only partially closed, shoulders are often re-striped and used as temporary lanes. When three eastbound lanes and one westbound lane were destroyed in a tanker truck fire on a bridge at the I-285/SR-400 interchange in Atlanta, Georgia, the intact eastbound shoulder was used temporarily as a travel lane, so three lanes would still be available to traffic (8). The temporary use of shoulders as lanes was also suggested in a symposium on a rehab project for I-710 in Los Angeles, California (9). This practice is common for both typical and emergency highway construction projects.

Demand Management

Because highway closures for reconstruction projects are temporary, permanent improvements like widening alternate routes and removing traffic signals are less common for the traffic mitigation than demand management strategies. Some of the demand management strategies used for Hyperfix 65/70 included installing signal priority systems for buses, increasing bus and shuttle service, and implementing employer rideshare incentives (7). Similar strategies were used for the emergency repair project at I-285/SR-400 in Atlanta (8). When the only bridge connecting Florida’s Sanibel Island to the mainland was closed for 26 hours for emergency repair, ferry boat services were provided for deliveries and essential trips (9).

Public Information Campaigns

As mentioned in the NCHRP survey (see Figure 1), 86 percent of DOT practitioners found traffic impacts to be a major factor in determining contract time for highway projects. Thus, highway projects can be delivered more easily if traffic volumes can be reduced during construction. Various state DOTs have used public outreach and education campaigns successfully to encourage motorists to avoid major work zones. For example, the Georgia DOT obtained significant media coverage for a reconstruction project on I-285 between I-675 and I-20 in Atlanta. The project required one side of the freeway to be closed at a time during weekend work shifts, but the public was made aware of the closures through media coverage

and changeable message signs, and no major traffic jams occurred after the first weekend (10). Indiana DOT informed the public of the full closure for the Hyperfix project by giving it a unique name and logo, making it easily identifiable on the 600 new signs posted throughout the city, using changeable message signs to warn motorists of congestion, and directing regional traffic around the city on the I-465 beltway (7). Florida DOT also employed an extensive public information program during the closure of the Sanibel Island bridge (9). In all of these cases, traffic demand was temporarily reduced, allowing the repair projects to proceed more smoothly and with minimal impacts on the traveling public.

CONSTRUCTION AND ROAD USER COST CONSIDERATIONS

The underlying principle of innovative contracting methods like A+B bidding and incentive/disincentive clauses is to provide a framework for road user costs (RUCs) to be considered along with the construction cost of a project. RUCs increase as project duration increases, due to increased congestion from work zone lane closures. Work for typical construction projects is scheduled during weekends and evenings as much as possible to reduce RUCs. However, as long as traffic volumes in urban areas continue to increase without commensurate increases in highway capacity, it will become more difficult to identify time frames when road work can occur without significant disruption and cost increases for motorists.

Figure 2 demonstrates the principle of overall contract cost minimization. If construction costs alone are considered, there is an optimal contract duration time determined by the cost components (labor, materials, etc.). Decreasing construction time beyond the optimal point results in cost increases because of the need for larger work forces (possibly with overtime pay), more sophisticated equipment, and more expensive materials like fast-setting concrete. When contract administration and RUC components are considered alone, cost increases linearly with time. When all three of these cost components are considered together, there is an optimal point where it is beneficial to incur greater construction costs in exchange for a greater decrease in RUCs (11).

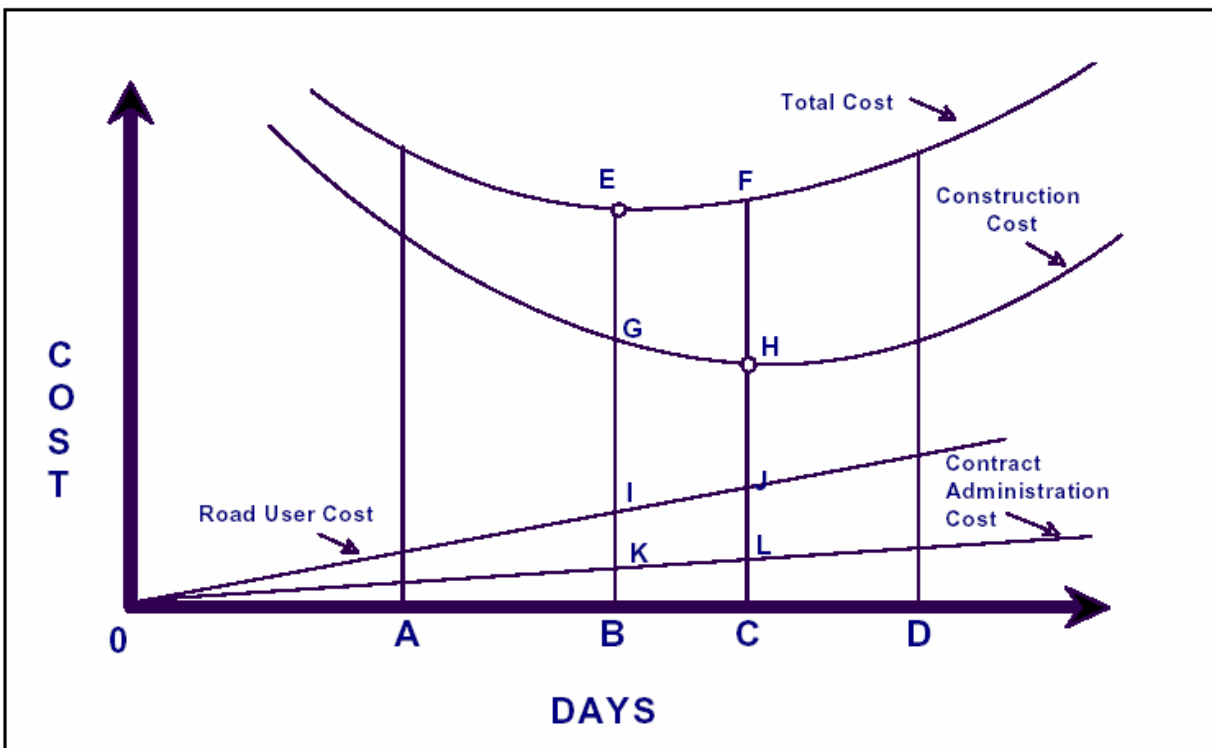


Figure 2. Cost Components (11)

On Figure 2, coordinates B and C on the x-axis represent two different project time durations. The minimum construction cost occurs at point H, with the corresponding road user cost J, contract administration cost L, and total cost (the sum of the three components) F. If the construction project is completed in B days instead of C days, the construction cost increases (point G), but the road user and contract administration costs decrease (points I and K, respectively). The overall result is a decrease in the total cost, which is represented by the difference between points F and E. The minimum total cost occurs at point E, if the project is completed in B days. Further reduction in construction time is possible, but the resulting increase in construction cost will surpass the combined reductions in road user and contract administration costs.

Several noteworthy reconstruction projects were built on accelerated schedules with significant lane closures because of RUC considerations. Two such projects include the Hyperfix 65/70 project and the reconstruction of the Pierce Elevated segment of I-45 in Houston (7, 12). For the latter project, TxDOT considered three options:

- Keep four lanes in each direction open at all times (base strategy);
- Close the freeway in one direction at a time, which was estimated to reduce the project duration by five months; or
- Close both directions of the freeway entirely, which would have reduced project duration by another six weeks.

TxDOT chose the second option because it minimized overall cost. The first option probably had the lowest construction costs (point H on Figure 2), but when RUCs were included in the analysis, an expedited construction pace was a more cost-effective option overall (point E on Figure 2). The third option would have approximately doubled RUCs, and might have increased construction cost as well.

When determining the amount of incentives to be provided for early project completion, state DOTs should consider carefully the potential for RUC reduction (3). Appendix A shows a sample RUC calculation table for reconstruction/rehabilitation (no capacity added) projects on six-lane urban freeways. As annual daily traffic (ADT) volumes increase to 150,000 and greater (values typically seen on busy urban freeways), the need for accelerated construction techniques becomes more apparent.

For the Pierce Elevated I-45 and Hyperfix 65/70 projects, the incentives paid were actually less than the RUCs calculated based on Table 3. The specific values for each project are as follows (7, 12):

Pierce Elevated I-45

ADT = 187,000 veh/day

3 lanes closed

RUC > 3 (\$31,900/day)

RUC > \$95,700/day

Incentives paid: \$53,000/day, \$1.6 million total

Total project cost: \$27.7 million

Percentage of cost comprised of incentives: 6%

Hyperfix 65/70

ADT = 175,000 veh/day

8 lanes closed

RUC > 8 (\$31,900/day)

RUC > \$255,200/day

Incentives paid: \$100,000/day, \$3 million total

Total project cost: \$30 million

Percentage of cost comprised of incentives: 10%

Thus, it is in the best interests of the motoring public to pay as large an incentive as possible. Because of funding constraints, it would be unlikely for a state DOT to pay in incentives the entire value of RUCs for

a particular reconstruction/rehabilitation project. However, the purpose of paying the incentive is only to cover the contractor's increased costs incurred due to the accelerated construction pace, while also providing an opportunity for greater profit by delivering the project ahead of schedule.

CURRENT PROCEDURES FOR PLANNING HIGHWAY PROJECTS

The planning process for a highway project begins with the general task of identifying transportation needs and issues in a region. A number of feasible alternative projects are then devised, and the list is narrowed down until the preferred alternative is identified. These early steps are taken by the state DOT in coordination with the metropolitan planning organization (MPO), with opportunities provided for public input at each step. The California Department of Transportation (CalTrans) summarized this process with the flow chart (13) shown in Figure 3.

The final step on the CalTrans flow chart is project initiation, which involves design and the bidding process. Environmental review occurs along with predesign, and is part of selecting the preferred alternative. Adding these steps to the flow chart, the highway design process is as shown in Figure 4.

The two most time-consuming parts in this process are environmental review, which can take 18 months or longer, even for simple projects, and the first three steps, which all involve extensive public input.

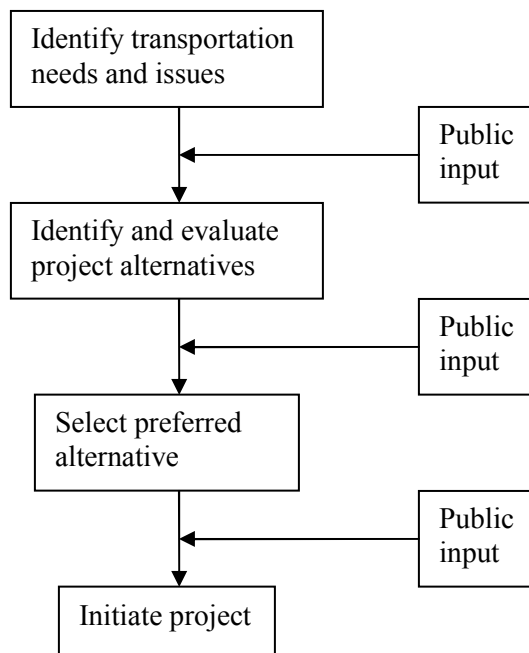


Figure 3. Project Identification and Planning (13)

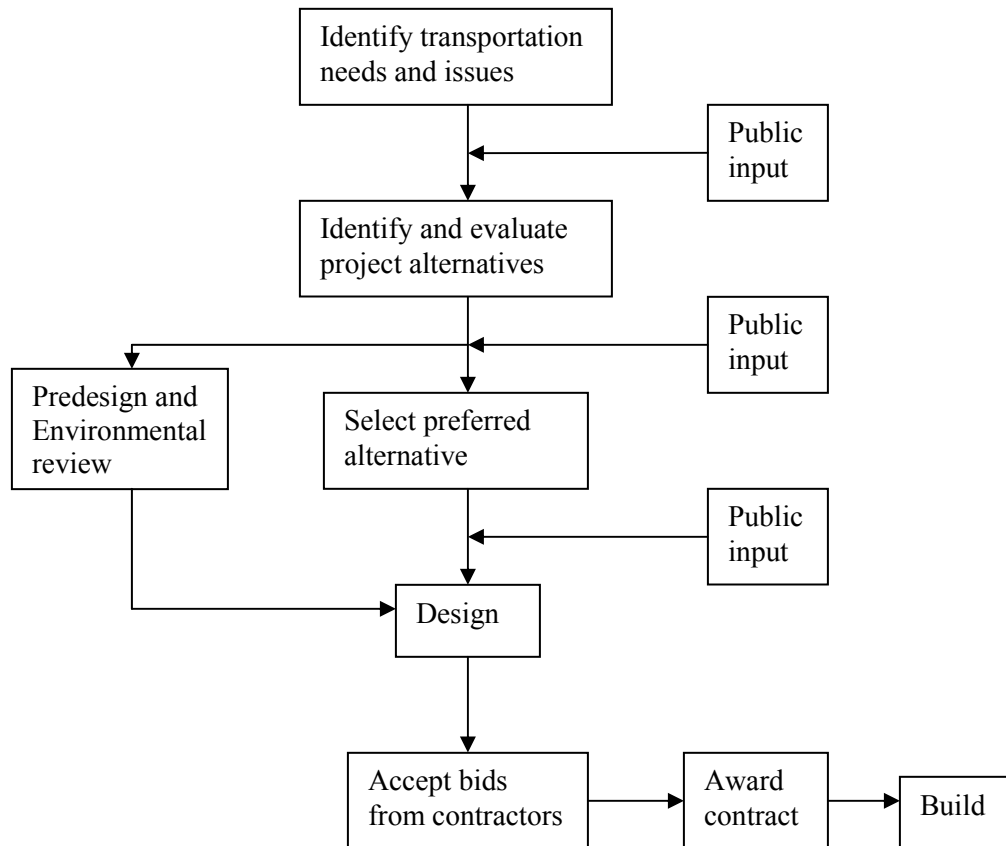


Figure 4. Highway Project Construction Process

LEGISLATIVE REFORM MEASURES

There have been several innovative attempts to reduce the duration of the project construction process through legislative reforms in the states of California and Georgia. Two recently-implemented measures include design-sequencing contracting and public-private partnerships. A third measure, revising emergency powers to include provisions for gridlock, has been introduced several times in the California legislature.

AB 405 (California): Design-Sequencing Contracts (14)

Design-sequencing contracting is the practice of breaking a construction project down into smaller phases and allowing construction to begin on early phases while design for later phases is still in progress. Design-sequencing is a variation on design-build contracting, where the contractor is allowed to do the design in addition to the construction. The purpose of design-sequencing contracting is to reduce the amount of time between design and construction. AB 405 defines “design” as a plan completed to a level of 30 percent. Thus, it allows a project plan to be implemented in as many as four sequences, instead of the traditional method of completing 100 percent of the plan before construction proceeds.

SB 957 (California): Gridlock Emergencies (14)

Arguing that there is no difference between a highway rendered impassible by “an act of God” and a highway rendered impassible by gridlock caused by decades of underinvestment in new highway capacity, state senator Tom McClintock introduced a bill that would add gridlock to the list of situations

where the Governor is allowed to declare a state of emergency, which in turn streamlines the approval process for a highway project by eliminating environmental review and allowing the state DOT commissioner to negotiate contracts without going through the bidding process. The bill defines gridlock as an average of 3,000 or more vehicle-hours of delay on any highway segment, excluding weekends. McClintock has introduced the bill three times during his legislative career, but has never managed to get it out of committee. The bill's critics have argued that the bill amounts to a de facto elimination of the environmental review process for any project adding capacity, and also introduces drastic changes to typical labor regulations. The critics have also noted the difference between emergency projects, which replace existing structures, and congestion relief projects, which add capacity (14).

One principle of SB 957 that deserves further consideration is the streamlining of the environmental review process. With reconstruction and rehabilitation projects, 18 months of environmental review might not be warranted, especially if the project is replace-in-kind of existing structures, whose plans had already gone through environmental review when they were originally created.

SB 257 (Georgia): Public-Private Partnerships (10)

Public-private partnerships involve the development of a highway project to be funded, designed, and built by the private sector. One such proposal currently being evaluated is a tollway between Atlanta and Athens, Georgia. A team including Washington Infrastructure Group and three major Georgia contractors created the plan and submitted it to GDOT for consideration. GDOT then has the responsibility of reviewing the plan to determine if it meets design standards, and then making parts of the plan public to solicit competing bids from any other interested contractors. GDOT has the option of contributing public funds to the project if it determines that the project serves the public good (10).

Public-private partnerships can reduce the amount of time needed to deliver a highway project. First, if the project is built without public funds, fewer of the time-consuming steps like environmental review and solicitation of public input would apply to the project. Second, allowing a contractor to take the lead in developing and designing a project enables the consideration of more projects. When state DOTs and MPOs develop transportation improvement plans (TIPs), they are limited by the amount of available funds and are often left with a long wish list of unfunded projects. Many needed highway projects languish not directly because of regulatory and contracting procedures, but because the funds needed to build the projects take years to materialize.

EMERGENCY CONSTRUCTION PROCEDURES

There are several fundamental differences between routine reconstruction/rehabilitation highway projects and emergency construction projects. In the former case, extensive planning is done to account for the impacts of the project, the state DOT has ample time to warn the public of the inconveniences resulting from work zone lane closures, and work is typically restricted to low-volume periods as much as possible. In the latter case, there is no advance warning, so it is necessary to accelerate the process of replacing the lost highway capacity as much as possible. The required expedience is achieved by bypassing typical regulatory procedures like contract bidding and environmental review, using accelerated construction techniques, and employing large numbers of workers so construction can take place around the clock. Contractors and state DOTs have demonstrated a remarkable ability to build highways quickly when structures and pavement are destroyed by incidents or natural disasters.

To gain insight into the contracting and regulatory processes behind emergency repair projects, two such projects were identified for review. One project was in Atlanta, Georgia, and the other was in Birmingham, Alabama. State DOT officials who had been involved with these projects were given telephone interviews. See Appendix B for a list of the interview questions. The following sections summarize the project details and issues explained by the state DOT officials.

Project Description: I-285/SR-400, Atlanta, GA

Four of the ten lanes on the I-285 mainline bridge at the I-285/SR-400 interchange were destroyed by a tanker truck explosion at 2:00 AM on June 9, 2001 (8). A contractor was notified and on site within a few hours of the incident (15). GDOT also sent a maintenance engineer and a bridge engineer to the site to supervise construction. The repair work began a few hours before formal approval from the deputy commissioner, because approval was anticipated. Removal of the destroyed bridge began at noon on June 9, and planning for the replacement construction was done on-the-fly during the removal (16). Because the repair project was replace-in-kind, the same plans that had already been approved for the old bridge were used for the new bridge, and only a cursory review was required before approval by the chief engineer and the deputy commissioner. In addition, no environmental review was required; the project was given a categorical exclusion (15, 16).

Project Description: I-65/I-59, Birmingham, AL

A similar incident occurred at the I-65/I-59 interchange in Birmingham, Alabama on January 5, 2002. A tanker truck exploded in a traffic accident, and the fire destroyed a three-lane bridge. The bridge was slated to be widened, so approved plans were already in place when the bridge was destroyed in the incident (17). However, some further design was required, as the original plan was to widen the existing bridge instead of replacing it entirely with a new structure. Alabama DOT (ALDOT) engineers worked overtime for seven days to prepare designs for the replacement bridge while the destroyed structure was removed (17, 18). Approval of the new plans occurred quickly. Three of the bridge engineers who had been working on the designs approved the plan, and one more day was required for upper-management review before formal approval (18). Environmental approval was not required, as the project was replace-in-kind except for bridge widening to accommodate future lanes (17).

Challenges Associated with Accelerated Construction

Accelerated construction techniques present their own set of challenges that need to be addressed. The interviewed state DOT officials identified the following issues that needed to be addressed for the emergency repair projects.

Early Response Actions and Planning

When a highway structure is damaged or destroyed in a major incident, the state DOT begins taking action immediately to protect the motoring public and prepare for the emergency repair work (16). First, the damaged lanes and structures are closed to traffic. This can involve the use of temporary barriers or re-striping the intact pavement to realign the travel lanes. Second, engineers are sent out to inspect the damage. In the case of a partially destroyed bridge, it is especially important to determine whether the intact portion is strong enough to continue carrying traffic. Third, crews begin demolishing the portions of the highway structure that need to be replaced. Fourth, the state DOT contacts a contractor to repair the damage. The approval process is streamlined by the declaration of a state of emergency. Because emergency repair projects are often replace-in-kind (exact replacement of the damaged structure, with no deviations from previous designs), minimal review is required, and environmental regulations are waived.

Cost and Contracting Issues

Extra costs are incurred whenever accelerated construction methods are used. For the two emergency repair projects discussed above, the sources of increased costs included overtime pay for laborers, who worked around the clock to replace the destroyed structures; premiums on getting structural steel members fabricated quickly; and costs associated with providing extra equipment needed for accelerated work (6, 15, 16, 18). Contract values also increase because of the use of incentive/disincentive clauses to encourage the contractor to work quickly. According to ALDOT Construction Engineer David Hand, the

I-65/I-59 emergency repair project cost \$2.1 million, while a non-emergency project of similar scale would cost \$1.5-\$1.8 million. Emergency funding from the FHWA was made available for the project (17). The emergency repair project at I-285/SR-400 in Atlanta cost \$1.2 million, while a similar project under typical conditions would cost \$500,000-\$750,000. The project was funded from a critical-needs maintenance lump sum of about \$70 million per year available to GDOT, and the cost is to be recouped from the tanker truck's insurance carrier (16).

Quality Control

Proper supervision and inspection are crucial to the success of any construction project. It is important to ensure that workers adhere to the designs and any appropriate building codes, and it is also necessary to have engineers on hand to make decisions based on unexpected challenges encountered during construction. During an accelerated construction project, quality control becomes a greater challenge because construction often occurs around the clock, and supervisors are required for each work shift.

INDOT addressed this problem during the Hyperfix project by pulling in additional oversight staff from outlying areas (7). In addition, unexpected challenges need to be resolved quickly before they snowball into major issues and possible work stoppages (3). During the reconstruction of a segment of I-45 in Houston, the Texas DOT (TxDOT) kept four engineers on call at all hours specifically for this purpose (12).

Access to the Construction Site

The contractor must have access to the construction site so materials and equipment can be brought in when needed. In the case of bridge structures, care must be taken during both demolition of the old structure and the setting of beams and girders for the new structure if traffic is allowed to flow on the roadway below the bridge. Demolition was expedited for the I-285/SR-400 project by closing both roadways during demolition, so debris from the damaged I-285 bridge was allowed to fall onto the SR-400 mainline (15, 16).

Approval Process

Streamlined approval procedures allow emergency repair projects to begin almost immediately after incident cleanup is finished. Perhaps the most significant exception granted in emergency situations is the waiving of the environmental review process, which is often the most time-consuming part of planning a highway project. According to GDOT Chief Engineer Paul Mullins, environmental review can take up to 18 months for a project the scale of the I-285/GA-400 bridge reconstruction, even if the bridge needed to be replaced because of structural deficiency (15). Another reason approval is simple for emergency repair projects is the nature of the construction work; when the required task is replace-in-kind, previously-approved plans already exist. If formal approval has not yet been provided, work on an emergency repair often begins in anticipation of approval.

According to the state DOT officials interviewed for the emergency repair projects in Atlanta and Birmingham, the use of accelerated construction procedures increased the project costs by 38 percent and 14 percent, respectively, when compared to the expected costs of a typical project of similar scale (16, 17). Using accelerated construction procedures in all projects would thus result in significant cost increases and a commensurate decrease in the amount of road capacity built.

To address this problem, state DOTs must perform two tasks. First, the needs of the state must be prioritized carefully. In addition to RUCs, there are other costs, like annual maintenance costs on highway segments nearing the end of their service lives, that directly impact the state DOT and need to be considered. Second, projects need to be scaled appropriately so the use of incentives for accelerated construction does not comprise too large a portion of the total project cost. Emergency projects are small

in scale, but the urgency of the situation necessitates the use of incentives to get the damaged highway facility repaired, even if the incentives paid to the contractor are a large percentage of the total cost. Contracts for projects of larger scale (like the Pierce Elevated reconstruction and Hyperfix) can have generous incentives without causing too large a cost increase.

PROPOSED ALTERNATE PROCEDURE FOR HIGHWAY PROJECT DEVELOPMENT

Based on information gathered from the telephone interviews, the following alternate procedure is recommended for the implementation of reconstruction and rehabilitation projects that do not involve adding capacity. The process could also be used for capacity-increasing projects if approved by the various government agencies (Environmental Protection Agency, historic preservation groups, local government councils, etc.).

Proposal

Based on the design-sequencing concept described in California’s AB 405, this alternate process allows the design and contract solicitation steps to occur simultaneously. The design and contract solicitation steps are implemented as a feedback loop instead of linearly.

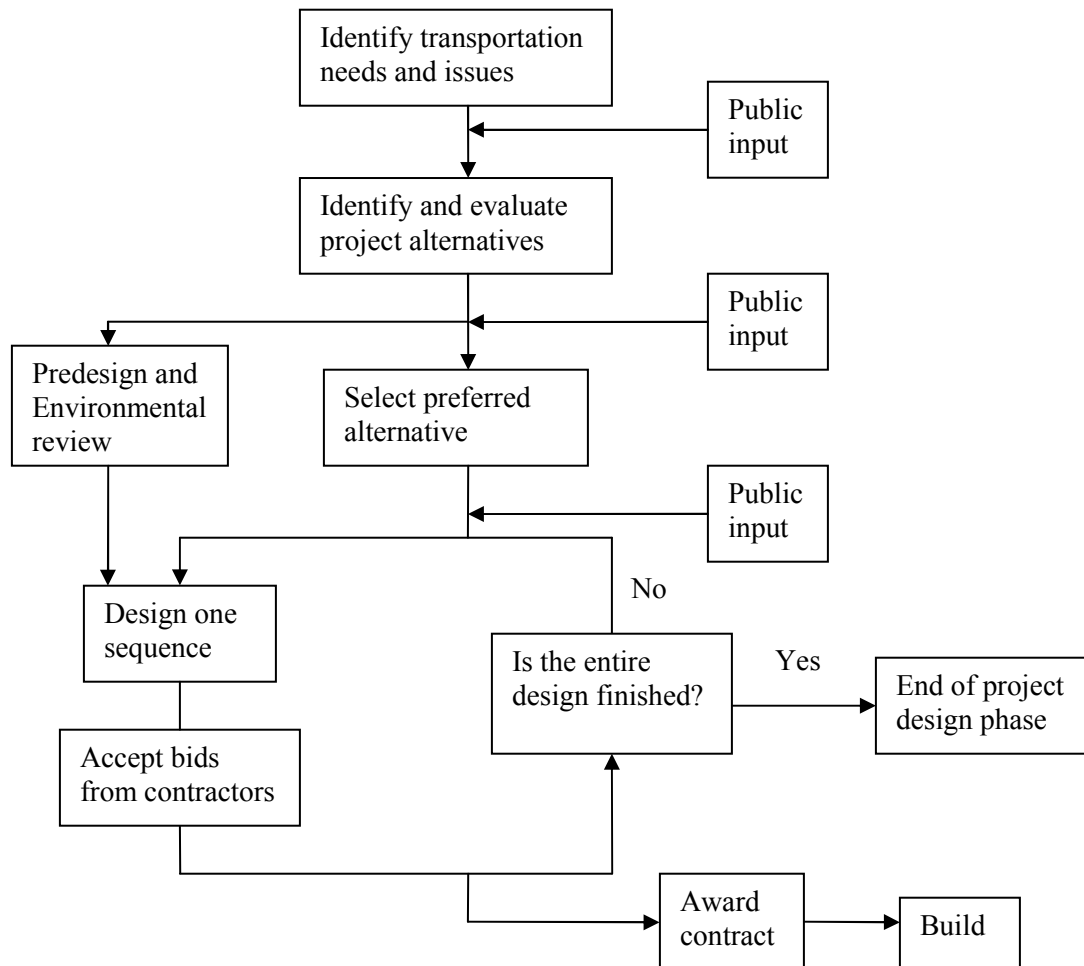


Figure 5. Alternate Process

Evaluation

This process changes the relationship between the state DOT and the contractor by bringing the contractor into the loop before a project has been completely designed. Communication between the contractor and the government agencies would thus be important to the smooth implementation of the process. In addition, this process is much more effective if the duration of the environmental review and predesign step can be shortened, and the process of gathering public input can be streamlined.

Justification

The three main reasons to implement the proposed alternate process for accelerated highway construction projects are the large number of anticipated reconstruction/rehabilitation projects in the coming decades, the high traffic volumes existing in most urban areas, and the need to improve work zone safety.

Amount of Upcoming Reconstruction/Rehabilitation Projects

As explained by Charles Nemmers during the “Get in, Get out, Stay out” symposium, there is a large amount of highway capacity in America that is nearing the end of its service life, and will need to be rebuilt in the coming decades (1). Nemmers’ description of encountering a work zone every 38 miles illustrates the need to minimize highway construction time.

High Urban Traffic Volumes

Accelerated construction was selected for the large projects of rebuilding I-65/I-70 in Indianapolis (Hyperfix) and the Pierce Elevated I-45 segment in Houston. These projects were near urban cores, where traffic volumes are high even at night and on weekends. In both of these cases, the state DOT and other government agencies concluded that rehabilitating the roadways through the typical construction method of closing lanes only during nights and weekends would not be feasible because there were no time periods available where traffic volumes were sufficiently low to avoid impacts to the traveling public. Traffic volumes are increasing steadily in urban areas, so it will likely become increasingly difficult to identify time windows when lane closures will not create major traffic congestion. Thus, state DOTs will have to employ the strategy of closing lanes for construction projects whenever it is necessary to do so, but complete the project on an accelerated schedule to minimize the amount of construction closure time.

Work Zone Safety

The more often drivers pass through idle work zones and see no construction activity, the less likely they are to drive more slowly and carefully through the work zones. If construction occurs only during weekends and evenings, the work zone will appear idle during most times of the day, and during the times when the largest numbers of drivers are exposed to the zone. If construction activity is visible and apparent to drivers, they will be more likely to heed the safety warnings by driving more slowly through work zones, resulting in a safer situation for both drivers and construction workers.

CONCLUSIONS AND RECOMMENDATIONS

As traffic volumes continue to increase in urban areas, and many urban highways are nearing the end of their service lives, state DOTs will soon be challenged with the need for more reconstruction/rehabilitation projects and fewer opportunities to implement the needed projects without creating major disruptions to traffic flow. One solution to this problem is to implement accelerated construction procedures more often. Innovative contracting techniques like A+B bidding and incentive/disincentive clauses are already available and have proven to be effective in reducing contract

time for construction projects. Contractors have also proven themselves to be capable of delivering accelerated highway construction projects through the use of new procedures, more sophisticated equipment, and the use of larger construction crews.

Two main areas of the highway planning process that still need to be improved are the initial planning process, where alternatives are identified and public input is solicited, and environmental review, which is often the most time-consuming step in highway planning but might not be warranted for most reconstruction/rehabilitation projects, particularly replace-in-kind projects. Other issues that need further study include the challenges associated with quality control in accelerated highway construction projects and the ability to establish and maintain good communication both between government agencies and between agencies and contractors during the planning and implementation of projects.

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- James McGee, Georgia Department of Transportation District Construction Engineer
- Paul Mullins, Georgia Department of Transportation Chief Engineer
- Ray M. Webb, Kansas City SCOUT Traffic Operations Center Manager
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APPENDIX A

**Table 3. RUCs for Reconstruction/Rehabilitation Projects on Six-Lane Urban Freeways
(\$/day/mile) (11)**

One Lane in One Direction		All Lanes Open with Reduced Capacity	
ADT	Road User Costs	ADT	Road User Costs
25,000	0	25,000	0
30,000	100	30,000	0
35,000	100	35,000	100
40,000	100	40,000	100
45,000	200	45,000	100
50,000	200	50,000	100
55,000	300	55,000	100
60,000	400	60,000	200
65,000	900	65,000	200
70,000	1,400	70,000	300
75,000	1,800	75,000	400
80,000	2,500	80,000	500
85,000	3,700	85,000	600
90,000	5,200	90,000	1,400
95,000	6,700	95,000	2,200
100,000	8,300	100,000	3,300
105,000	10,600	105,000	4,300
110,000	13,400	110,000	4,900
115,000	15,700	115,000	4,900
120,000	17,500	120,000	5,400
125,000	19,000	125,000	6,300
130,000	21,100	130,000	7,700
135,000	23,100	135,000	9,100
140,000	25,100	140,000	10,900
145,000	27,100	145,000	13,300
150,000	28,800	150,000	15,500
155,000	30,300	155,000	17,800
160,000	31,900	160,000	20,400
		165,000	23,000
		170,000	22,500
		175,000	27,200
		180,000	29,000
		185,000	30,100
		190,000	30,900
		195,000	31,100
		200,000	30,700

APPENDIX B

DOT Employee Interview

Date:
Time:
Person:
Area of expertise:

Information from newspaper:
Project:
Incident:
Number of lanes destroyed:
Date and time of incident:
Date and time of reopening:

1. How long would a project of comparable scale take under typical (non-emergency) conditions?
2. How many lanes were available during the construction? In other words, were any of the intact lanes closed?
3. How much did the repair work cost, and how much would a project of comparable scale cost if done under typical (non-emergency) conditions?
4. Was the repair work done entirely in-house, or was it contracted out?
5. How long did it take to plan and coordinate the construction tasks?
6. How many different people within the state DOT needed to sign off on the repair construction plan before it was implemented, and how much time did each person require to review the plan?
7. Did you have to secure environmental approval for the project? If so, how long did that take?
8. What were the most important challenges related to your area of expertise?
9. What, in your opinion, is the biggest regulatory hurdle that makes typical highway projects take so long to build?

MICHAEL P. PRATT

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**AN EXAMINATION OF TECHNOLOGY ALTERNATIVES
FOR A ROAD USER FEE SYSTEM**

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SUMMARY

The future of transportation finance is not a certain one. The fuel tax is likely to become a less viable source of revenue due to numerous factors. As new technology has developed, automobiles have become more fuel efficient. If this trend continues, less gas will be purchased and revenue will drop. A road user fee system can be used as a replacement for the motor fuel tax.

However, along with providing the needed replacement for the motor fuel tax, a road user fee system can also be used to accomplish other transportation goals, such as relieving traffic congestion. With the addition of value pricing, the road user fee can be used to manage travel demand and reduce congestion on our nation's roadways.

The objectives of this research were to identify the technological requirements of a road user fee system, identify feasible technologies and their capabilities and strengths and weaknesses, and examine the long-term implementation process for wide-scale application. This was accomplished in three steps. First, a literature review was performed to learn about current research and available technologies. Second, the available technologies were compared for a number of possible fee scenarios. Finally, with the help of expert feedback, a series of steps were developed that will be necessary for the successful implementation of a technology on a large scale.

There are a numerous types of technology available to monitor road use. This research focuses on a set of technologies most likely to be used in a road user fee system. Each type of technology has different capabilities. The best choice of technology will depend on the requirements of the road user fee, which could vary greatly from one application to another. Four primary technologies which could be used to assess a road user fee were examined:

- Odometers/Hubodometers
- Automatic Vehicle Identification (AVI)
- Video
- Global Positioning System (GPS) Units

The long-term application of a road user fee system on a wide scale will require a phase-in process of the necessary technology. It will likely take many years to phase in a road user fee system, and it is important that certain steps are followed to ensure that the conversion is successful. A series of five steps that must be undertaken to accomplish a complete technology phase-in are outlined:

- Step 1: Choose Most Feasible Technology
- Step 2: Enact Legislation to Require In-Vehicle Technology
- Step 3: Develop Alternative Fee Collection System
- Step 4: Offer Incentives for Drivers to Retrofit Their Vehicles
- Step 5: Develop Enforcement System

In this research, the technology alternatives for use in a road user fee system were outlined. The abilities of each type of technology were outlined and compared. The technologies were compared using a series of possible fee scenarios to determine which technologies would be most feasible in certain situations. Additionally, the technological requirements of implementing a road user fee on a very large scale were examined. A series of steps were outlined that should be used to ensure the successful implementation of technology for a road user fee system. The results of this research provide a summary of the available technologies that can be used in a road user fee system and a series of guidelines for their implementation.

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INTRODUCTION

For years, the transportation infrastructure has relied upon the motor fuel tax as a major source of revenue. However, technological improvements in the field of auto manufacturing are causing the motor fuel tax to become a less viable source of revenue. Over the years, automobiles have greatly increased in fuel efficiency, and hybrid-electric vehicles are becoming more popular. If these trends continue, less fuel will be used, resulting in a reduction in fuel tax dollars (1). This makes it imperative that an additional funding source be established. One likely solution to this is the implementation of a road user fee (1, 2, 3).

A road user fee would allow drivers to be charged based on their driving habits. Prices can be determined by not only how many miles are traveled, but also when and where they were traveled. For example, in London a special fee is charged when entering the city center during the business day. This method of charging is known as congestion pricing. By charging drivers for use of the roadway system, the shortfalls of the motor fuel tax can be overcome. However, the implementation of this type of system raises many questions, particularly in the area of technological requirements.

PROBLEM STATEMENT

As the motor fuel tax becomes a less viable source of revenue, alternative funding sources must be considered. There is a need to find alternatives to the motor tax, and one likely alternative is a road user fee. When considering the implementation of a road user fee, there are many technological requirements to consider. The task of recording the travel of a large number of drivers is a daunting one. It is important that adequate technology be used to ensure the success of the system while minimizing agency cost. The technology used must be able to effectively measure the number of miles traveled, and, in the case of a congestion pricing scenario, where and when they were traveled.

SCOPE

In this research, the available technologies for a road user fee system were evaluated, and the abilities of each were examined. The application of technologies on a small-scale and large scale implementation was considered. The long-term implementation process was also evaluated. This research was limited to only road user fee technology. Other aspects of road user fee implementation (such as enforcement or privacy issues) were not examined.

RESEARCH OBJECTIVES

The objectives of this research were to:

1. Identify the technological requirements of a road user fee system;
2. Identify feasible technologies available for a road user fee system;
3. Identify the capabilities of each type of technology to collect road user fees;
4. Choose the most feasible technology for various implementation scenarios; and
5. Examine the long-term implementation process for wide-scale application.

STUDY APPROACH

The assessment of technology implementation for a road user fee was accomplished in three primary steps. The steps are outlined in this section.

Literature Review

A literature review was performed to identify the available technologies that could be used. The most feasible technologies were identified based on previous research. Additionally, this task served to familiarize the author with current research that has been performed in the area of road user fees.

Apply Technologies to Fee Scenarios

The available technologies were analyzed for their feasibility under a series of fee scenarios. This task served to identify the strengths and weaknesses of the different technologies. It also provided useful information about what types of technologies are more useful under certain conditions.

Develop Steps for Wide-Scale Long-Term Implementation

A series of steps was developed that would be necessary if a road user fee system technology were to be implemented on a large scale. This was accomplished in two steps. First, a preliminary set of steps was created by the author. Next, a panel of experts in the field of road pricing were consulted about their opinions of the steps. Using the experts' feedback, a modified set of steps was created.

THE NEED FOR A ROAD USER FEE SYSTEM

The future of transportation finance is not a certain one. The fuel tax is likely to become a less viable source of revenue due to numerous factors. As new technology has developed, automobiles have become more fuel efficient. Additionally, environmental concerns have prompted the exploration of alternative fuel sources. If this trend continues, less gas will be purchased and revenue will drop. A road user fee system can be used as a replacement for the motor fuel tax. In its simplest form, this would involve charging travelers on a per-mile basis. Research has been conducted in Iowa, Minnesota, and Oregon to determine the method of implementing this type of system (2, 3, 4).

However, along with providing the needed replacement for the motor fuel tax, a road user fee system can also be used to accomplish other transportation goals, such as relieving traffic congestion. With the addition of value pricing, the road user fee can be used to manage travel demand and reduce congestion on our nation's roadways. Value pricing is defined as the use of fees or tolls that vary according to travel demand (5). The implementation of value pricing along with a road user fee system allows transportation engineers to effectively control travel demand by charging based on when and where trips are made.

AVAILABLE TECHNOLOGIES

There are a numerous types of technology available to monitor road use. This research focuses on a set of technologies most likely to be used in a road user fee system. Each type of technology has different capabilities. The best choice of technology will depend on the requirements of the road user fee, which could vary greatly from one application to another. This section examines four primary technologies which could be used to assess a road user fee: odometers/hubodometers, automatic vehicle identification, video, and GPS units.

Odometer/Hubodometer

The simplest technology that could be used in a road user fee system is the odometers on the vehicles. Odometers can be used to measure the total number of miles traveled over a period of time. Additionally, they are standard on all vehicles, so the cost of technology implementation is very low. A hubodometer (see Figure 1) is a mechanical device that is attached to the axle of a vehicle. It measures miles traveled in the same way that an odometer does. However, they are not standard on vehicles and would have to be installed.



Figure 1. Hubodometer (6)

The use of odometers or hubodometers is also limited by the type of road pricing that is to be implemented. Odometers can only track the number of miles traveled over a given period of time. They cannot track when or where a vehicle travels. This limits their application to only the most basic road pricing scenario, a flat-rate road use fee. Under a flat-rate system, drivers would be charged based on the number of miles traveled over a period of time.

Automatic Vehicle Identification (AVI)

AVI has been used for almost 15 years in the United States and is typically used for toll applications. One of the first applications was on the Dallas North Tollway in 1989 (7). The use of AVI allows vehicles to be charged for road use via a transponder (see Figure 2) located on board the vehicle. These transponders (also called tags) are typically affixed to the inside of the windshield of a vehicle. The tags are radio frequency (RF) transponders and are read by antennas (see Figure 3) that are located on the roadway. In toll applications, the antennas are placed where toll booths previously would have been. Figure 4 shows an example of a toll application of AVI. The unique transponder identification number (ID) and time are recorded by the antenna and sent to a host computer. The host computer will typically relay the information to the toll authority via an internet connection (8).

There are three types of tags available: Type I, Type II, and Type III. Type I tags are read-only and contain a unique identification number. Type II tags can also be written to, and Type III tags offer the ability to communicate information to the driver as well as being read/write (8). On toll roads, the unique transponder ID is read at a toll plaza and the driver's prepaid account is deducted the amount of the toll. The free flow conditions of AVI lanes at toll plazas open the door to violators. However, violators are monitored using a video enforcement system (VES). Presence detectors in the roadway sense when a

vehicle passes through the AVI lane. If no valid transponder ID is read, a camera snaps picture of the vehicle's license plate. This information is then used to issue citations (8).



Figure 2. AVI Transponder (9)



Figure 3. AVI Antennas (10)

For use in a road user fee system, antennas would have to be installed at every location where travel would need to be monitored. This may present an economic obstacle if the number of antennas to be installed becomes too high.

Video

Some toll applications have used video to charge for road use. These systems work in the same manner as a VES, but instead of issuing citations, bills are sent to road users. Toronto's Highway 407 utilizes this type of system. Tolls are collected on Highway 407 by both AVI and by video. If a vehicle does not have a valid transponder, a picture is taken of its license plate when it enters and exits the highway. A bill for the toll is then sent to the driver based on the license plate information (11).

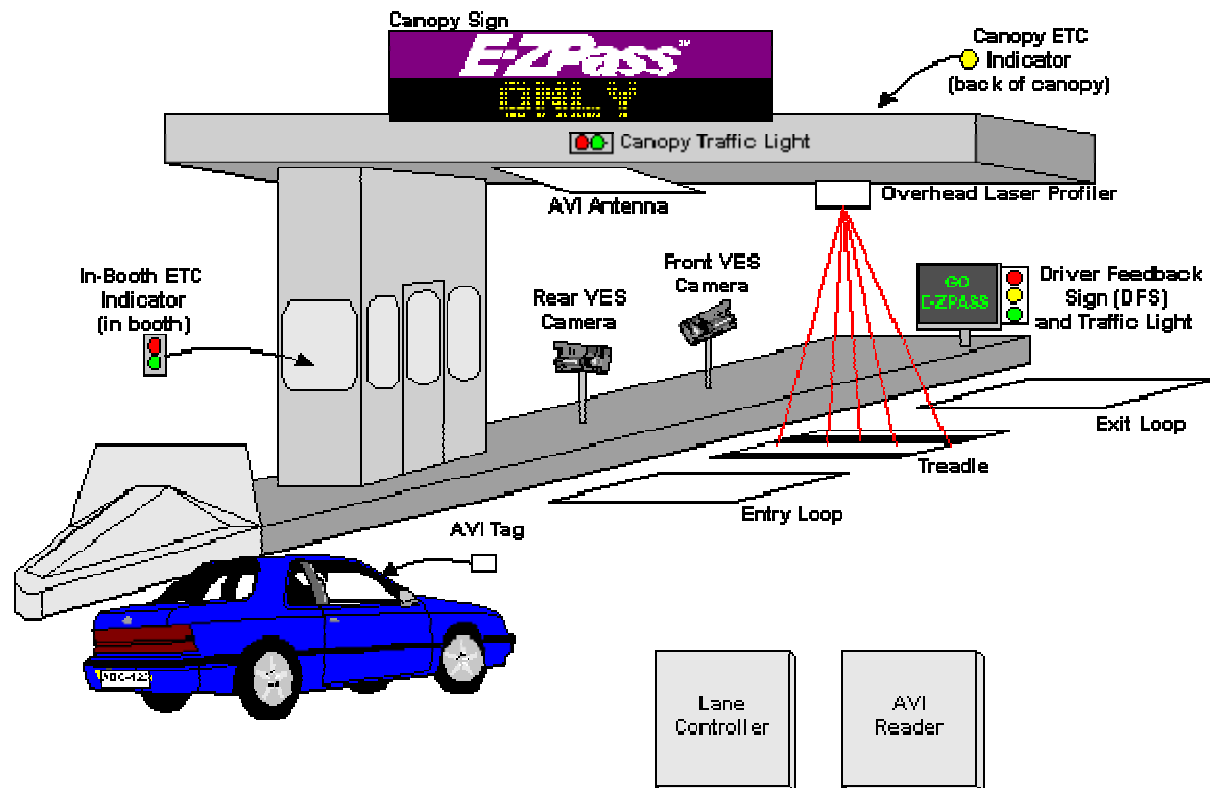


Figure 4. The AVI Toll Collection Process (12)

Modern license plate recognition systems use computer programs to analyze the photographic data and read the license plate numbers (13). Computer software utilizes complex algorithms to analyze the photos pixel by pixel to extrapolate the license plate number. This is very beneficial for a road user fee system because it eliminates the need for tedious manual video analysis.

This type of technology has also been used to detect violators on toll roads and to catch drivers running red lights. The major benefit of using video to assess a road user fee is that it does not require any in-vehicle installation. This eases the phase-in process significantly because modifications would only be made to the infrastructure and not to individual vehicles. Figure 5 shows an example of a red light enforcement camera, which utilizes license plate capture technology.

Global Positioning System (GPS) Units

The Global Positioning System is a series of 24 satellites that orbit the earth (see Figure 6). The satellites are consistently broadcasting signals that can be used by a GPS receiver to accurately identify its location on the earth's surface. The position of the satellites ensures that a GPS receiver is in contact with at least four satellites no matter where it is. However, some areas, such as urban areas with tall buildings can cause signal interference problems. However, interpolation and extrapolation can be used to fill in missing information if the signal loss is short (2).

GPS units have become increasingly popular over the years, and are now standard on many vehicles. They are currently used primarily as navigational tools. GPS units complete with graphic interfaces are available for drivers to install in their vehicles. Other units are available that can be connected to personal digital assistants (PDAs) to monitor travel (see Figure 7).



Figure 5. Red Light Camera (14)

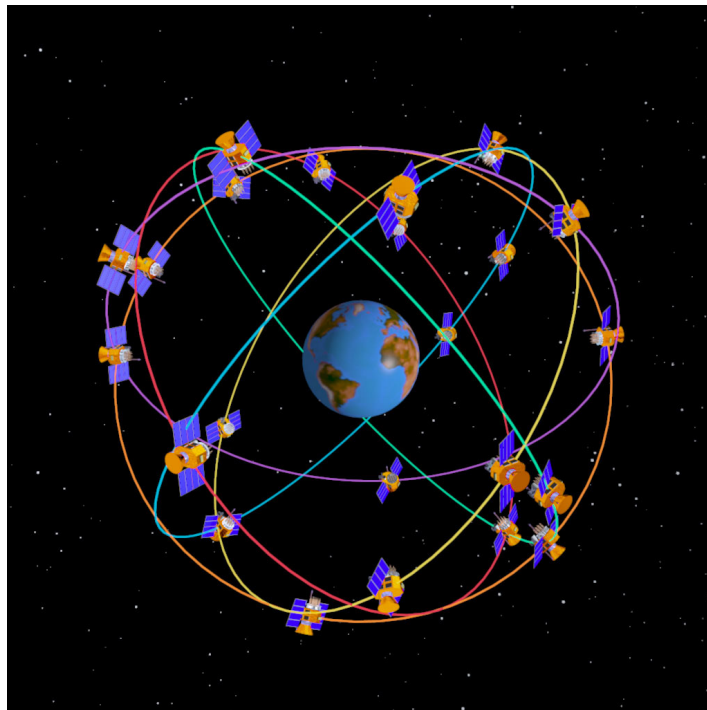


Figure 6. The GPS Constellation (15)



Figure 7. GPS Receiver and PDA (16)

For a road user fee system, a GPS receiver would monitor travel and store the travel data locally within the vehicle. The information would then have to be transmitted to a centralized collection center. There are two primary methods of accomplishing this: smart cards and wireless communications. Smart cards are about the size of a credit card, but they are embedded with a microchip that is used to store information. The smart card would be connected to the GPS receiver at all times and travel data would be written to it continuously. The smart card would have to be removed from the GPS receiver to transfer the information to the collection center (2).

The travel data could also be transmitted using wireless communication. A wireless communication device would be connected to the GPS receiver and would transmit the data to intermediate receivers located in public places that are frequently traveled. The data would then be transferred by the intermediate receiver to the collection center.

Once travel data has been collected, however, it must be analyzed using a geographic information system (GIS) database. GPS data is recorded as latitude and longitude values. A GIS database is used to determine what roadways correspond to those latitude and longitude values. This process is very important if a value pricing system is to be implemented.

APPLICATION OF TECHNOLOGY TO FEE SCENARIOS

The application of a road user fee system could be completed in many different ways. For example, the fee could be applied as a charge for the number of vehicle-miles traveled or as a charge to enter certain designated areas. Depending on the type of fee scenario, the technological requirements may differ. Four road user fee scenarios were examined, with special attention being paid to the technological requirements of each, and are presented in this section of the paper. The four scenarios examined were a flat-rate vehicle-miles-traveled fee, a cordon fee scenario, a corridor fee, and a small network fee. With the exception of the vehicle-miles-traveled fee, each scenario included fees that vary depending on route and time of day.

Flat-Rate Vehicle-Miles-Traveled Fee

Under this type of fee scenario, travelers would be charged based on the number of miles they traveled over a given period of time. For a flat-rate fee, the cost would be per mile. Therefore, the number of

miles traveled for a given period of time would have to be measured for each vehicle. This can be accomplished by all of the discussed technologies.

Odometer/Hubodometer

Odometers could easily accomplish the technological requirements of a flat-rate vehicle-miles traveled fee. The benefit of using odometers would be the low cost of equipping vehicles with the technology. Odometers are standard on all vehicles, but using them would require manual readings to determine the fees to charge the user.

AVI

The vehicle-miles-traveled fee could be achieved through the use of AVI, but it may be economically infeasible. AVI antennas would have to be placed along every roadway where travel would be recorded, which is likely not an option for a larger area. It would be impossible to track all miles traveled through the use of AVI.

Video

The use of video technology presents the same problems presented by AVI. Video cameras would have to be placed along all roadways in the system, which would likely be quite expensive. Video camera technology is probably not a feasible technology for a flat-rate vehicle-miles-traveled application.

GPS

The capabilities of GPS allow it to be used for a flat-rate vehicle-miles-traveled fee. Travel can be monitored at all times at all locations on Earth. Additionally, the use of GPS allows for more efficient data transfer than odometer readings.

Cordon Fee

Under a cordon fee system, drivers would be charged for entrance into a particular area. This type of road pricing was recently implemented in London, England (*17*). In London, drivers are charged a toll during a certain part of the day to drive into the city center. A cordon fee can be applied with or without variable pricing. One option would be to charge a flat toll for entrance into a designated area regardless of the day or time. It may also be beneficial to change the fee depending on the time of day. Figure 8 shows an example of a cordon fee area. The technology used in this type of system must be able to automatically detect when vehicles enter the fee area. It must also be able to accommodate a variable fee. Because odometers/hubodometers are only capable of recording the number of miles traveled and not time or location, they will be ignored in this fee scenario and the following two scenarios.

AVI

AVI can easily accomplish the technological requirements of a cordon fee scenario. Antennas would need to be placed at all entrance points to the fee area. All drivers entering the cordon area would be required to have a transponder in their vehicle. The transponders would be connected to accounts that would be charged for entrance to the area. AVI also allows for variable charging, however signs would be needed to inform drivers of the current fee being imposed.

Video

The cordon fee scenario requirements can also be met by video technology. In a similar fashion to the application of AVI, video cameras would be placed at all entrance points to the cordon area. The license

plates read as vehicles enter the cordon area would be used to assess the fee. Additionally, no in-vehicle installations would be necessary.

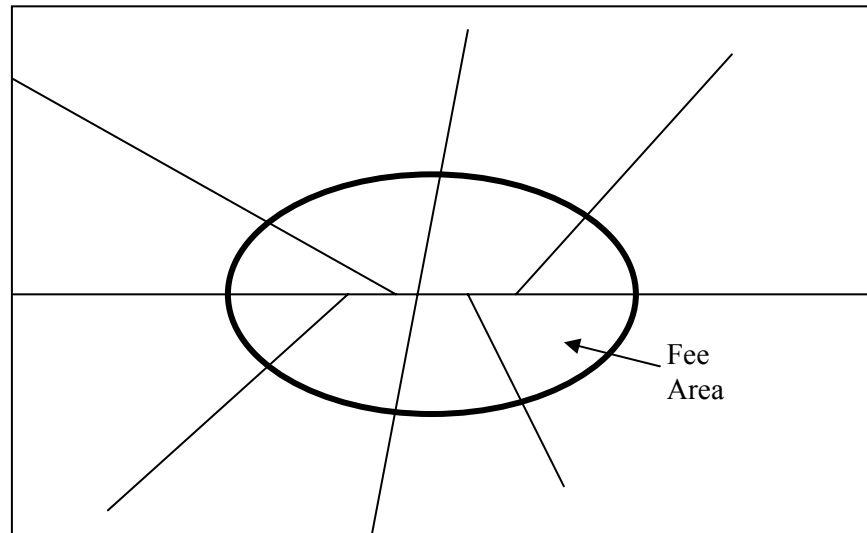


Figure 8. Example of a Cordon Fee Scenario

GPS

GPS units would also be able to accomplish the requirements of a cordon, but the technology is more advanced than is necessary. All vehicles would need to be outfitted with GPS units, and a GIS database incorporating the cordon area would need to be created. GPS would likely only be feasible if a cordon fee was used as a stepping stone to a more wide-scale application.

Corridor Fee

Under a corridor fee system, drivers would be charged for the use of a single corridor. In many ways, this is similar a toll road application. Drivers would be charged for use of a single roadway, on which the fee could be either a flat rate, or it could vary by time of day or congestion level. This type of fee would require technology that could record when drivers were using the designated corridor.

AVI

A corridor fee is very similar to a toll road scenario, and AVI is the most commonly used technology on toll roads. Antennas would need to be installed at all entrances and exits along the corridor. Additionally, all vehicles using the corridor would need to be equipped with transponders.

Video

Video could also be used in a corridor fee scenario. Like the use of AVI, video units would need to be placed at all entrance and exit points along the corridor. The license plate numbers would be used to send bills to drivers using the road. Additionally, this type of system could be used in conjunction with AVI, giving drivers a choice of payment method.

GPS

GPS units would also be able to accomplish the requirements of a corridor fee, but the technology is more advanced than is necessary. All vehicles would need to be outfitted with GPS units. This would likely be economically infeasible for such a small-scale application

Small Network System

A small network system would consist of a network of roads in which only some charged a fee for use. Figure 9 shows an example of a small network system. In the figure, the roads designated with bold lines would charge fees, while the others would not. Additionally, certain roads could charge a higher or lower fee than other roads. This type of scenario would likely occur during the process of achieving a full-scale implementation of a road user fee. The technology used in this fee scenario would have to be able to determine when vehicles were using any of the roads charging fees.

AVI

The use of AVI becomes much more complex than in the previous two scenarios. Depending on the size of the network, the installation of AVI antennas could become quite costly. Antennas would need to be located at all entry and exit points of all roadways included in the network. Additionally, all vehicles would need to be equipped with transponders.

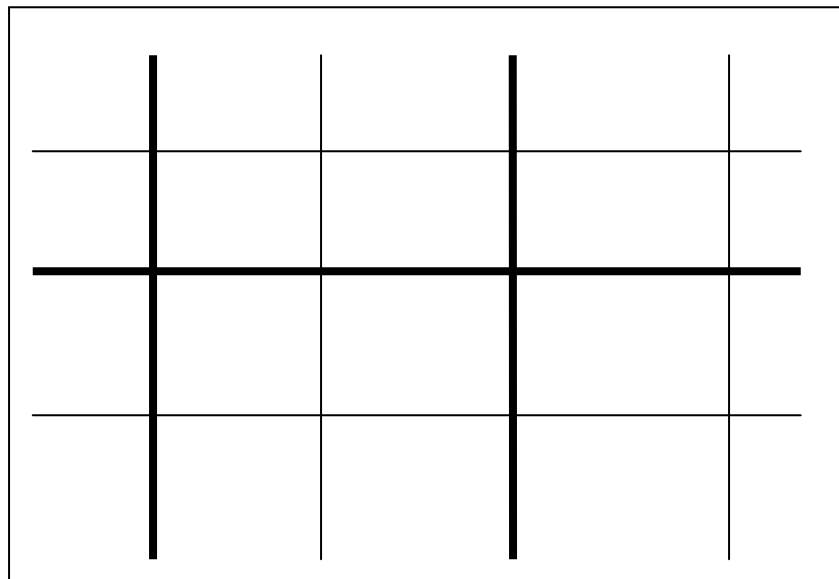


Figure 9. Example of Small Network System

Video

The use of video would have the same cost issues as AVI. Cameras would need to be installed at all entry and exit points of all roadways in the network. The license plate numbers would be used to send bills to drivers. This could get quite complex, however, with the large number of roads being monitored.

GPS

GPS technology could easily accomplish the requirements of the small network system scenario. All vehicles would need to be outfitted with GPS receivers. By using either smart card or wireless communication, travel data can be used with a GIS database to determine when and where trips were made. This also makes the addition of roads to the system much simpler than it would be if using video or AVI technology.

Summary

Table 1 shows the most feasible technologies for the four fee scenarios examined. For a flat-rate vehicle-miles-traveled fee, odometer readings or GPS could be used to track vehicle miles traveled, while AVI or video would not be able to track all miles that were traveled. The cordon fee and corridor fee scenarios are best accomplished through the use of video or AVI. GPS would likely be unnecessary for these smaller scale applications. However, GPS would likely be the best choice for a small network system because the installation of numerous video units and antennas would be difficult.

Table 1. Most Feasible Technologies for Fee Scenarios

Fee Scenario	Most Feasible Technology
Flat-Rate Vehicle-Miles-Traveled Fee	Odometer or GPS
Cordon Fee	AVI or Video
Corridor Fee	AVI or Video
Small Network System	GPS

LARGE-SCALE IMPLEMENTATION

In the previous section, available technologies were examined for a number of road user fee scenarios to demonstrate their abilities and strengths and weaknesses. However, if a road user fee system is to be used to permanently replace the motor fuel tax, then it must be applied on a large scale. The small-scale applications could be used as a supplement to motor fuel tax revenue loss, but any permanent solution would have to cover a very large area. Undertaking the conversion from fuel tax to a road user fee system will be no easy task, and a number of steps must be undertaken to ensure a successful implementation. In this section, the steps that are necessary to implement a technology on a large scale are examined.

Expert Feedback

A number of experts in the field of transportation finance were consulted during the analysis of road user fee implementation on a large scale. Table 2 shows the panel of experts consulted along with their respective affiliations. Their feedback, along with the author's research, was used to develop a series of recommendations for the long-term implementation of a road user fee system on a wide scale.

Table 2. Panel of Experts

Expert	Affiliation
Patrick DeCorla-Souza	Federal Highway Administration
Dr. Christine Johnson	Federal Highway Administration
Dr. David Levinson	University of Minnesota
Todd Litman	Victoria Transport Policy Institute
Dr. Anthony M. Rufolo	Portland State University

Table 3. Expert Feedback

Expert	Feedback
Patrick DeCorla-Souza	Provided additional information on current research
Dr. Christine Johnson	Suggested additional step to account for infrastructure development.
Dr. David Levinson	Provided suggestions for in-vehicle technology installation.
Todd Litman	Provided additional information on current research.
Dr. Anthony M. Rufolo	Suggested modifications to steps 1,2,4,5, and 6.

Recommendations for Long-Term Implementation

The long-term application of a road user fee system on a wide scale will require a phase-in process of the necessary technology. It will likely take many years to phase in a road user fee system, and it is important that certain steps are followed to ensure that the conversion is successful. A series of six steps that must be undertaken to accomplish a complete technology phase-in are outlined in this section.

Step 1: Choose Most Feasible Technology

The first step in technology implementation is the selection of adequate technology for the application. Based on previous research, the most likely choice is GPS for a wide scale application. However, other technologies may also be possible for use. For instance, if only major highways were to be charged road use fees, AVI could be used by installing antennas at each entrance and exit. Additionally, implementation costs must be examined. The in-vehicle cost of AVI is likely much cheaper than GPS, but on a larger scale, the cost of antennas and other infrastructure costs could make AVI an infeasible choice. All costs must be examined when choosing a most feasible technology. Along with being the most cost-effective, the chosen technology must also be able to perform all of the necessary functions of the road user fee system.

Step 2: Enact Legislation to Require In-Vehicle Technology

The next step is to pass legislation that would require all vehicles to be equipped with in-vehicle technology. This can be pursued simultaneously in two ways. For example, if GPS was to be used to assess the road user fee, one method would be to require auto manufacturers to install GPS units into all vehicles. A deadline would be set after which all vehicles coming off the assembly line must have the units installed. Over a period of time, this would result in all vehicles being equipped with the technology. However, this would likely take decades to achieve. Another method would be requiring all older cars to be retrofitted by a certain date. One way would be to restrict the distribution of license plates or registration until a retrofit was complete. This would help to accelerate the phase-in process.

Step 3: Implement Fee Collection Infrastructure

The implementation of a road user fee system will require a significant amount of infrastructure to collect fees from users. Once the road use technology has been installed, a collection center will need to be developed to handle the logistics of actually billing users for their travel. This will likely be a very costly undertaking, requiring a significant amount of personnel training and hardware procurement. This step is crucial because the assessment of a road user fee is impossible without a system for using the collected travel data to bill users.

Step 4: Develop Alternative Fee Collection System

The use of a standard in-vehicle technology to collect road use fees creates a problem for out-of-system vehicles and those that have not yet been retrofitted. An alternative collection method must be developed to collect fees from these vehicles. This could be done with video license plate capture technology, although it would likely prove to be too expensive. One option would be to charge out-of-system a flat fee upon entrance or exit from the system. For example, if the road user fee was charged on a statewide level, video technology could be implemented at all entrances to the state. Video could also be used to charge vehicles that have not been retrofitted, but it would likely be too expensive. One possible solution would be to continue to charge non-retrofitted vehicles with a fuel tax.

Step 5: Offer Incentives for Drivers to Retrofit Their Vehicles

An effort must be made to encourage drivers to retrofit their vehicles with GPS units. This could be done by offering tax incentives such as fuel tax rebates. These incentives could greatly accelerate the phase-in process. It is also important to market the new system to make it appealing to drivers. If drivers can see a benefit to using the new technology, they will be more likely to retrofit their vehicle.

Step 6: Develop Enforcement System

Finally, the use of in-vehicle technology to collect fees creates an enforcement problem. A system must be put in place that can ensure that all drivers comply with the road user fee and are not sabotaging the in-vehicle technology to avoid payment. Some technologies are more susceptible than others to this type of behavior. One possible method to combat violation would be to install the technology so that drivers do not have access to it. Another necessary method to discourage violation is auditing. These audits would be performed in the same manner as income tax audits. The use of enforcement is crucial to the success of a road user fee system.

SUMMARY AND CONCLUSION

The goals of this paper were to look at various technologies that could deliver information required for a road user fee systems, to compare their attributes to different pricing scenarios, and to lay out an implementation strategy. The results of this research provide a summary of the available technologies that can be used in a road user fee system and a series of guidelines for their implementation. There are many factors to consider when choosing a most feasible technology, and it is important that any agency implementing a road user fee chooses the best technology and follows the adequate steps to ensure successful implementation. There are also numerous considerations that can have an impact on implementation beyond what is discussed in this paper. All of these issues will need to be addressed for the implementation of a road user fee system to be successful.

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SIGNALIZATION AND METERING OF ROUNDABOUTS

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SUMMARY

With the emergence of the modern roundabout as an effective form of traffic control in the United States, more and more information is needed when situations arise where added traffic control is required. The signalization and metering of roundabouts can relieve congestion during peak hours of the day as well as possibly provide safer access for pedestrians and cyclists.

Although the signalization or metering of a roundabout may prove to be effective in solving access and congestion issues, it is not common in the United States and few have been installed. Of the roundabouts where signals or meters have been installed they were done with little or no formal guidance. With that in mind a need exists for a set of guidelines to aide engineers, planners and government officials in implementing a signal or meter.

Several tasks were accomplished to generate a set of guidelines for the signalization and metering of roundabouts including;

- Literature review
- State of Practice Survey
- Review of literature and survey responses to develop a compilation of site information
- Developing a rough set of guidelines for review
- Obtaining comments on the guidelines from experts in the field of roundabout operation and design
- Finalizing a set of guidelines

Upon completing the above tasks several options for the signalization and metering of roundabouts were found including options for means of control, time of operation, and approach control. Unbalanced flow and high circulatory speeds are also discussed having been found to be the main reasons for signalization. Several existing signalized and metered roundabouts are detailed from current literature and survey responses and compiled in a table as part of the guidelines. Using all of the information from survey responses and literature seven guidelines were established;

- Observe and Obtain Data
- Review Data
- Identify Main Concerns
- Choose Means of Control
- Choose Time of Operation
- Choose Approaches to Control

Developing the guidelines for the signalization and metering of roundabouts and receiving comments on them lead the author to believe that more investigation is needed to solidify the guidelines and presents an excellent opportunity for future research.

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INTRODUCTION

With the emergence of the modern roundabout as an effective form of traffic control in the United States, more and more information is needed when situations arise where added traffic control is required. The signalization and metering of roundabouts can relieve congestion during peak hours of the day as well as possibly provide safer access for pedestrians and cyclists. (1)

Signalizing and metering traffic at a roundabout can be considered reverse thinking. Roundabouts are installed to gain greater capacity and lower delays and an added signal defeats this purpose. It should also be made clear that a signalized or metered roundabout is still far better than a regular signalized intersection. Even with some loss of capacity and greater delays, they still offer the benefits of improved safety over signalized intersections. (2)

There have been several reported cases of roundabout signalization in the United States. In Florida and Utah, pedestrian actuated traffic signals have been installed. While in Maryland, a metering device is being considered to help ease congestion during certain periods of peak traffic flow. (3) Although the Florida and Utah locations have worked well, they were installed without a set of general roundabout signalization and metering guidelines. If a set of guidelines was developed, it would help professionals make decisions when considering signalization or metering at a roundabout while still providing the flexibility of good intersection design engineering.

PROBLEM STATEMENT

The signalization or metering of roundabouts may prove to be effective in solving access and congestion issues at roundabouts. Although several roundabouts in the United States have used traffic control signals, and metering is being seriously considered at one site, there still is a need for a set of guidelines to aide in the decision for implementation. Such signalization and metering appears to have fairly widespread use in Europe and Australia.

RESEARCH OBJECTIVES

In order to develop a set of guidelines applicable to the installation of traffic control signals and meters at a roundabout, several objectives were established. The primary research objectives were to:

- Obtain general information and methods on the signalization and metering of roundabouts;
- Determine locations and features of roundabouts that have traffic signals and meters in the United States, Europe, and Australia;
- Determine the reasons for signalization and metering;
- Determine locations where signalization and metering have been planned or could help operations;
- Highlight the results of traffic signalization and metering and discuss their effectiveness;
- Develop a set of guidelines for traffic control signals and meters at a roundabout;
- Gain feedback on the developed set of guidelines from known roundabout experts in roundabout design and operations relative to the applicability of the guidelines;
- Finalize a set of guidelines applicable to the signalization and metering of roundabouts.

SCOPE

The finalized set of guidelines on signalization and metering of roundabout is only applicable to what is known as the modern roundabout and does not consider rotaries or traffic circles. Cases involving

roundabout interchanges signal coordination and signaling for pedestrians were also not considered. Guidelines were based on information from individual case studies, literature, and recommendations from known authorities on the subject.

WHO SHOULD REVIEW THIS DOCUMENT?

The main purpose of this document is to provide information that transportation engineers, planners and government agencies can use to make decisions regarding the use of traffic signals and metering signals at a roundabout.

WHY DO WE NEED GUIDELINES FOR SIGNALISING OR METERING A ROUNDABOUT?

With the surge of roundabouts being placed throughout the United States situations where signalization may be necessary are sure to surface and literature on the subject will be of value to individuals unfamiliar with roundabout signalization.

STUDY APPROACH

To meet the objectives established earlier there were five steps that needed to be completed in order to obtain the information needed to complete the research. The five steps included a literature review, developing a state of the practice survey, developing guidelines, obtaining comments from experts on the developed guidelines, and finalizing a set of guidelines.

Literature Review

A literature review of documents relating to the signalization and metering of roundabouts was completed using resources from the library and internet. Approximately 10 documents were used in the review with a vast majority of the documents coming from countries outside of the United States.

State of the Practice Survey

A web survey was created to gain information by asking known experts in the field of roundabout design and operation to provide the information listed below relative to traffic signalization at roundabouts.

- Location of existing signalized roundabouts
- Type of signal system in place
- Location of signal system
- Main cause for signalization
- Affect of volume on the decision to signalize
- Affect of the location on the decision to signalize
- Human factors
- The addition of signs and striping with the installation of the signal
- Literature used to make decisions regarding implementation
- Peak hour considerations
- Software used to analyze the roundabout

The web survey was sent to known experts in the field of roundabout design and operations, as well as the Kansas State roundabout listserv. The survey is still available and can be accessed at

[www.cstevensandcomp.com/roundaboutsurvey.html](http://www.cstevensandcomp.com/roundaboutssurvey.html). Seven surveys were received, including two indicating no experience with signalization or metering, two surveys detailing the same location and one of the surveys providing great information on two pedestrian signals that were not within the scope of the research. Three sites pertinent to the research were detailed with survey responses and will be described in detail in a later section of this document.

Developing Guidelines

After completing the literature review and reviewing all of the survey responses the information was used to establish a set of guidelines. The guidelines are not technical in nature and should be easily understood by someone not familiar with roundabout signalization and metering. The guidelines are mainly based from reoccurring patterns in literature and survey responses.

Experts Review

Another web based form was created to obtain comments on the developed guidelines for the signalization and metering of roundabouts. The website address was sent to the survey respondents as well as other experts in roundabout design and operation and can still be found at www.cstevensandcomp.com/rbguidelines.html. Please feel free to access this page and comment on the guidelines.

Finalize Set of Guidelines

After obtaining comments on the developed set of guidelines the suggestion were used to finalize a set of guidelines for the signalization and metering of roundabouts.

WHAT IS A ROUNDABOUT?

In order to better present information on the signalization and metering of roundabouts it important for the reader to be familiar with what defines a modern roundabout. It is also important to understand the operational and geometric features of a modern roundabout. This is especially true when discussing the benefits provided by roundabout geometry and operation in the areas of safety, capacity and delay. If the reader has experience with roundabouts and knows of the features and benefits a non-signalized roundabout can provide, they should feel free to skip to the next section.

Defining a Roundabout

Roundabouts are often misrepresented as traffic circles or rotaries. In order to separate the modern roundabout from these other forms of intersection arrangements it is important to provide information and definitions for each. The Federal Highway Administration's document, Roundabouts an Informational Guide, provides excellent and precise definitions of each arrangement. (*L*)

Traffic Circles

“Traffic circles are typically built at the intersections of local streets for reasons of traffic calming and/or aesthetics. The intersection approaches may be uncontrolled or stop-controlled. They do not typically include raised channelization to guide the approaching driver onto the circulatory roadway. At some traffic circles, left-turning movements are allowed to occur to the left of (clockwise around) the central island, potentially conflicting with other circulating traffic.”

Rotaries

“Rotaries are old-style circular intersections common to the United States prior to the 1960’s. Rotaries are characterized by a large diameter, often in excess of 100 m (300 ft). This large diameter typically results in travel speeds within the circulatory roadway that exceed 50 km/h (30 mph). They typically provide little or no horizontal deflection of the paths of through traffic and may even operate according to the traditional “yield-to-the-right” rule, i.e., circulating traffic yields to entering traffic.”

Roundabouts

“Roundabouts are circular intersections with specific design and traffic control features. These features include yield control of all entering traffic, channelized approaches, and appropriate geometric curvature to ensure that travel speeds on the circulatory roadway are typically less than 30 mph (50 km/h).”

Roundabout Geometry (I)

The modern roundabout consists of several geometric elements which can be seen in Figure 1 and include;

- Central Island,
- Splitter Island,
- Circulatory Roadway,
- Apron,
- Yield Line,
- Accessible Pedestrian Crossing,
- Bicycle Treatments, and
- Landscaping Buffer.

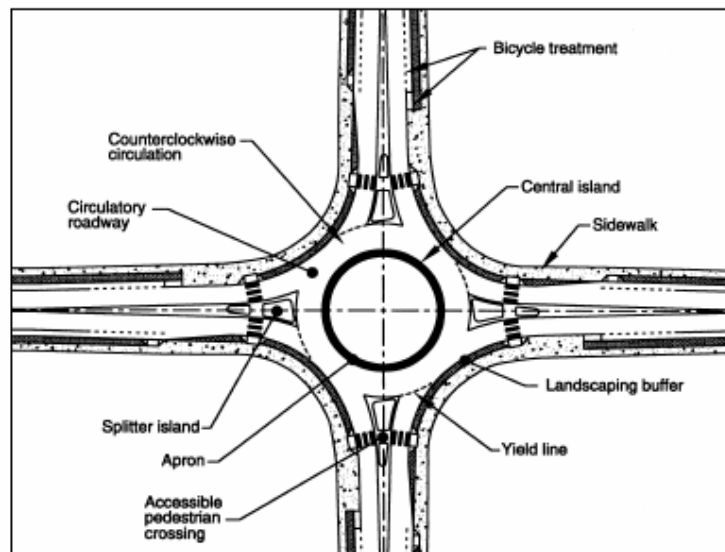


Figure 1. Roundabout Geometry (I)

Central Island – “The central island is the raised area in the center of a roundabout around which traffic circulates.”

Splitter Island -“A splitter island is a raised or painted area on an approach used to separate entering from exiting traffic, deflect and slow entering traffic, and provide storage space for pedestrians crossing the road in two stages.”

Circulatory Roadway – “The circulatory roadway is the curved path used by vehicles to travel in a counterclockwise fashion around the central island.”

Apron – “If required on smaller roundabouts to accommodate the wheel tracking of large vehicles, an apron is the mountable portion of the central island adjacent to the circulatory roadway.”

Yield Line – “A yield line is a pavement marking used to mark the point of entry from an approach into the circulatory roadway and is generally marked along the inscribed circle. Entering vehicles must yield to any circulating traffic coming from the left before crossing this line into the circulatory roadway.”

Accessible Pedestrian Crossings – “Accessible pedestrian crossings should be provided at all roundabouts. The crossing location is set back from the yield line, and the splitter island is cut to allow pedestrians, wheelchairs, strollers, and bicycles to pass through.”

Bicycle Treatments – “Bicycle treatments at roundabouts provide bicyclists the option of traveling through the roundabout either as a vehicle or as a pedestrian, depending on the bicyclist’s level of comfort.”

Landscaping Buffer – “Landscaping buffers are provided at most roundabouts to separate vehicular and pedestrian traffic and to encourage pedestrians to cross only at the designated crossing locations. Landscaping buffers can also significantly improve the aesthetics of the intersection.”

Benefits of a Roundabout (I)

Safety

Results from a roundabout before and after study of average annual crash frequencies at eleven intersections converted to roundabouts showed a 30 percent to 70 percent reduction in injury crashes and a 10 percent to 30 percent reduction in property damage crashes after installation. The roundabout improved safety by providing several of the following:

- Fewer conflicts points
- Eliminating right angle crashes
- Reducing entry speeds due to deflection of vehicle
- Reducing circulating speeds within the intersection

Operating and Maintenance Costs

Operating and maintenance cost are low when compared to that of a signalized intersection. A roundabout only needs to be maintained aesthetically with landscaping, and have signs and markings replaced due to wear or damage.

Capacity

Increase in traffic capacity is due to two things, yield on entry and reduced speeds of circulating traffic. When a driver approaches a roundabout he/she does not need to come to a complete stop, reducing the time lost when compared to a stop controlled or signalized intersection. Reduced entry and circulating speeds allow for a shorter acceptable gap for entering traffic also increasing capacity.

Delay

When operating within capacity, a roundabout can produce lower delays when compared to a stop controlled or signalized intersection. As discussed above approaching drivers need not come to a complete stop upon entering the roundabout. If queues form they will usually dissipate quickly.

GENERAL INFORMATION AND METHODS ON THE SIGNALIZATION AND METERING OF ROUNDABOUTS

Why is a Signalized or Metered Roundabout better than a Signalized Intersection?

Although signalization of a roundabout superficially defeats its intended purpose there are still several underlying benefits that the geometry of a roundabout provides. The deflection of vehicles due to the presence of the central island and splitter island not only reduces entry speeds but also eliminates right angle collisions. The FHWA concludes that reduced speeds within the roundabout gives drivers more time to react to possible incidents, can reduce crash severity, allow for safer merging, and especially makes the intersection safer for drivers who are unfamiliar with the area. (1)

Another key safety element that remains after a roundabout has been signalized is fewer conflict points. A four leg, single lane roundabout has eight conflict points compared to that of an intersection with four two lane entering roadways having 32 possible conflict points. If a roundabout is metered it is important to remember that during non-peak times the roundabout still offers all of the benefits discussed in the previous section. (1)

Some may ask why put in a roundabout if it is likely to be signalized? The reason is that although a signalized roundabout may not provide the same improved capacity and delay values it is still safer than a normal signalized intersection. A signal or meter can extend the “life” of the roundabout while still providing added safety and aesthetic value. (1)

Signalization vs. Metering

In order to apply the developed guidelines it is very important to understand the differences in operation between signalization and metering.

Traffic Signalization

Hallworth (5) defines a signalized roundabout as “any system of one-way traffic circulating around a central island with at least one approach controlled by a traffic signal.” The Manual on Uniform Traffic Control Devices (MUTCD) defines a traffic signal as “any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed.” (4)

Traffic Metering

A traffic meter at a roundabout parallels a freeway ramp meter in many ways. Signal display and signage are identical as well as its intended purpose; to control the flow of entering vehicles into a roadway facility. (4) The following excerpt from the MUTCD Design for Freeway Entrance Ramp Control Signals list the requirements for a ramp meter.

Ramp control signals shall meet all of the standard design specifications for traffic control signals, except as noted herein:

- The signal face for freeway entrance ramp control signals shall be either a two-lens signal face containing red and green signal lenses or a three-lens signal face containing red, yellow and green signal lenses.
- A minimum of two signal faces per ramp shall face entering traffic.
- Ramp control signal faces need not be illuminated when not in use.
- Ramp Control signals shall be located and design to minimize their viewing by mainline freeway traffic.

This design standard can be applied to a metered roundabout approach. (1) A meter is traffic actuated by a queue detector located at a distance away from the stop line. The placement of the detectors varies depending on the geometric properties of the roundabout.

Signalization and Metering Options

Once a decision has been made to signalize or meter a roundabout there are several options. Means of control, time of operation and approach control are the three most important signalization characteristics. Due to the differences between signalization and metering these options vary. The different options for signalization and metering are described below in the form of a flow chart. (See Figures 2 and 3)

Means of Control

The means of control at a signalized or metered roundabout describes how the signal system controls entering and exiting vehicles. There are two main means of control at a signalized or metered roundabout; direct control and indirect control.

Direct

A direct means of control affects both external and internal approaches, influencing traffic entering the roundabout as well as vehicles leaving from within the roundabout. For a metered approach a direct means of control usually only affects vehicles entering the roundabout. (5)

Indirect

Indirect control affects external traffic at a distance away from the entry point of the roundabout. The circulatory traffic within the roundabout is not affected. Indirect control of vehicles is sometime established with the addition of pedestrian signals where crosswalks are at a distance away from the roundabout entry. (5)

Time of Operation

The time of operation at a signalized or metered roundabout focuses on the period of time a signal or meter operates. There are two times of operation common at signalized or metered roundabouts; full-time and part-time control.

Full

The installed signals operate permanently and do not turn off during non-peak times. (5)

Part-Time

The installed signal does not operate at all times. The signal is activated by time of day or by detectors. Detectors are usually placed at a distance away from the controlled approach on a delay setting to determine when a queue has built up. For a metered approach the time of operation varies according to

queue length and dissipation, once a queue is no longer detected metering signals will go blank and normal operation will resume. (5)

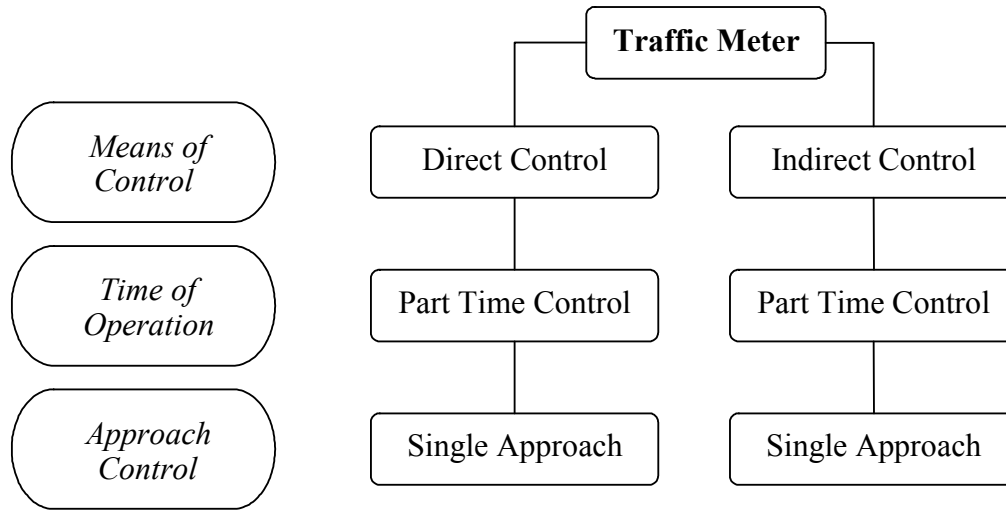


Figure 2. Traffic Metering Options

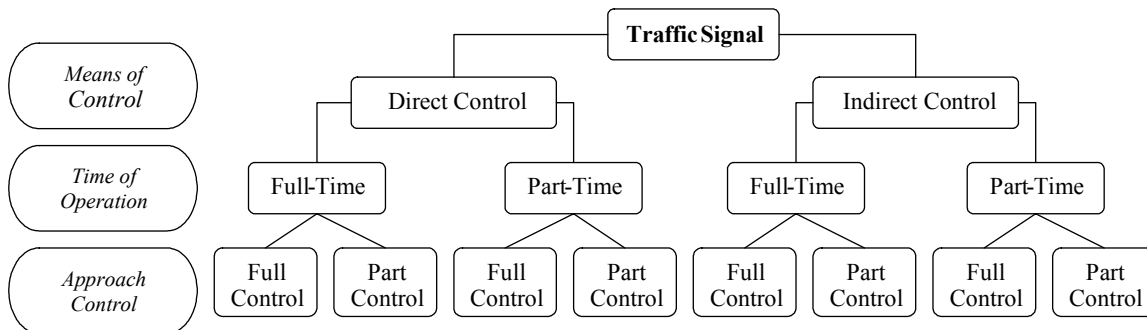


Figure 3. Traffic Signal Options

Approach Control

Approach control describes the number of approaches controlled with a signal or meter. There are two main types of approach control; full control and part control.

Full-Control

This arrangement controls all approaches of the roundabout. (5)

Part-Control

Part approach control at a signalized or metered roundabout is defined as control of one or more, but not all, legs of a roundabout while remaining approaches operate under right-of-way control. Roundabout metering signals usually control a single lane and are considered part-control. (5)

Reasons to Signalize or Meter a Roundabout

A problematic roundabout usually falls into two main areas; unbalanced flow and high circulatory speeds. It should also be mentioned that there are several characteristics that each situation may cause within a roundabout including;

- Loss of capacity,
- Delays,
- Elevated numbers of crashes,
- Excessive queues,
- Gap acceptance problems, and
- Circulatory lockup.

Unbalanced Flow

Hudaart details unbalanced flow by stating; “The capacity of roundabouts is particularly limited if traffic flows are unbalanced. This is particularly the case if one entry has very heavy flow and the entry immediately before it on the roundabout has light flow so that the heavy flow proceeds virtually uninterrupted. This produces continuous circulating traffic which therefore prevents traffic entry on subsequent approaches.” Huddart also states that in such situations “signals can be used to initiate gaps in the traffic flow and hence balance the capacity.” (6)

High Circulatory Speeds

With the need to weave and merge with in a roundabout sometimes higher than desired speeds can occur within the circulating sections, and can make it difficult for entering traffic. Another example of high speeds, brought to my attention by Tom Hicks (7) of the Maryland State Highway Administration, is that of roundabouts with elliptical shaped central islands. The discussion resulted in the conclusion that vehicles tend to increase speed on the longer side of the central island causing incidents as the vehicle meet slower entering traffic on the short sides of the island. Signals can regulate traffic directly if desired by placing signal within the circulating traffic reducing speeds and allow for safer and more efficient movement of traffic. (5)

Benefits of Signal Control

Although signalization and metering is against the nature of a true roundabouts purpose they may provide solution in such situations as discussed earlier with unbalanced flows and high circulatory speeds. There are four main benefits to signalizing or metering a roundabouts including, lower delays, reduced queue lengths, increase in capacity and safety.

Lower Delays

Delays at non-signalized roundabouts increase due to unbalanced flows or interactions with other intersections. Signals and meters can be used to balance delays and can reduce delays among a coordinated network. (5)

Reduced Queue Lengths

With unbalanced flow queues can become excessive sometimes backing up into other intersections or roadways. This situation is most likely to take place on frontage roads off ramps. A signal or meter can reduce queues by allowing queued traffic the right-of-way once a critical queue is detected. (5)

Increase in Capacity

If an excessive amount of traffic due to growth or new developments is entering a roundabout traffic may not be able to circulate freely and can sometimes cause lockup. In situations where traffic is excessive, traffic signals may improve operations. It should also be noted that additional improvements to the roundabout design may be need to supplement the addition of signals. (5)

Safety

With the need for weaving and merging within a roundabout internal circulatory speed can increase, and can hinder the ability for entering traffic to accept a gap. Traffic signals and meters better regulate the entry and sometime exit of the roundabout slowing the speeds of weaving and merging traffic giving more time for drivers to react and increasing the safety at a roundabout. (5)

ROUNABOUT SIGNALIZATION AND METERING IN LITERATURE

There are several examples of signalization and metering in literature and four are summarized in Table 1 below;

Table 1. Signalized and Metered Roundabouts from Literature

Roundabout	Means of Control	Time of Operation	Approach Control	Problem Areas
Park Square, South Yorkshire, UK	Direct	Full	All	Excessive delays and accidents; high circulatory speeds
Newbridge, Scotland	Direct	Full	All	Traffic congestion, poor safety, high circulatory speeds, large queue lengths and delay
Sheaf Square, South Yorkshire, UK	Indirect	Part	All	Delays due to excessive pedestrian traffic
Moore Street	Indirect	Metered	All	Unbalanced flow, excessive turning traffic, and delay

Park Square, South Yorkshire, UK

The Park Square roundabout is 200 meters at its widest point and has a morning and afternoon peak volumes of 6,500 vehicles per hour. Park Square had problems with excessive delays and accidents. “The large diameter and [circulatory roadway] widths contributed to high vehicle speeds, leading to comparatively low circulatory flows at high speed preventing large numbers of vehicles from entering the roundabout. The result was long queues and excessive delays.” (8) The accident rate for the site was approximately 12 personal injury accidents per year. The installed traffic signals operate by creating

alternating streams of traffic for conflicting movements. The signals are operated permanently on all approaches with a 60 sec cycle time during peak periods and a 50 sec cycle length at all other times. After installation travel times were reduced and a 30 percent decrease in accident was recorded. (8)

Newbridge Roundabout, Seven Miles West of Edinburgh, Scotland

The Newbridge roundabout is an at-grade roundabout with heavy volumes, carrying over 60,000 vehicles per day originating from five approaches. It has an inscribed circular diameter of approximately 60 meters with circulatory roadway widths of 16 and 20 m (53 and 66 ft). “During peak periods the roundabout suffers from severe traffic congestion which has had adverse effect on road safety conditions, due mainly to the combination of high circulatory carriageway speeds and motorists’ difficulty in accepting suitable gaps in the circulatory traffic to gain safe entry onto the roundabout. Significant inequalities in queue length and delay were also experienced at the roundabout due to lighter traffic flows gaining priority over much larger movements.” A study was conducted and the installation of traffic control signals was suggested on all approaches as well as the adoption of a queue balancing system. The system installed was direct in nature and is operated by a series of detectors varying in distance from the stop line. The purpose of multiple detectors on each approach is to measure queue lengths by adjusting signal phases to balance queues. The system consists of two fixed time traffic control plans, one for normal traffic and an alternative plan that is activated if an imbalance in queues is detected. Data on delays and crashes was not yet available. (9)

Sheaf Square, South Yorkshire, UK

Pedestrians were a major concern at this roundabout demanding access across three of its five legs. Two of the five signals installed at this site are known as indirect control, where a signal and stop line is placed at a distance away from the entry point of the roundabout. It is important to note that even after the completion of the signal’s cycle, drivers are still required to yield right-of-way upon entering the roundabout. All five legs are signalized and are set to a cycle length of 40 sec during the morning peak and a 60 sec cycle length during the evening peak. The traffic signal switches on when actuated during non-peak periods and operates on a 30 sec cycle length. (8)

Moore Street Roundabout, South Yorkshire, UK

The roundabout at the intersection of Moore Street and Saint Mary’s Gate had problems mainly during peak periods due to unbalanced flow and excessive turning traffic making it difficult for vehicles from the minor approaches to enter the roundabout. The objectives of signalization were to reduce overall delays and redistribute them equally among approaches. To do this an indirect means of control was used on all approaches at a distance of 25 meters back from the entry way of the roundabout. The yield line at the entry of the roundabout was also strengthened or widened for better visibility. The signal scheme installed at this site consists of a traffic meter on all approaches and does not have a set time for operation. After installation an average reduction in delay of 65 seconds during the morning peak and 40 seconds during the evening peak was recorded. It is important to mention that although there was an average reduction in delay on the Moore street approach, due to the redistribution of delay, overall delay increased in the morning peak. (8)

Guideline Development

Literature provided a detailed look into the process of signalization and specific triggers for added traffic control. Several themes resounded through out the literature including data collection and observations and the three categories of signalization options; mean of control, time of operation, and approach control.

STATE OF PRACTICE SURVEY RESULTS

A web survey was created in order to gain information by asking known experts in the field of roundabout design and operations. Four survey responses detailing three roundabout locations are listed below in Table 2.

Table 2. Signalization and Metering from Survey Responses

Roundabout	Means of Control	Time of Operation	Approach Control	Problem Areas
Charles Street, MD, USA	Indirect	Full	All	Unbalanced flow
Clearwater, FL, USA	Indirect	Full	One	Unbalanced flow during spring break
Penn Inn, Abbot, UK	NA	Full	All	Unbalanced flow, and excessive turning movements

Survey Responses

Charles Street at Bellona Avenue, Lutherville, Maryland, USA

A traffic signal was installed at the Charles Street roundabout because “the traffic flow is very unbalanced, with two legs of the roundabout representing over 90 percent of the flow.”⁽¹⁰⁾ The two heavy legs are northbound Charles Street and westbound Bellona Avenue. Charles Street did not have to yield the right-of-way very often due to the absence of conflicting flow, resulting in very few gaps in traffic for the westbound movement. A signal existed approximately 600 feet south of this intersection the timing was changed to add a dummy phase to create artificial gaps for the northbound movement. Roundabout location, human factors, and pedestrians were not really an issue at this site. No new signing or striping was added, and no literature was used to aide in implementation. “We actually just went in the field with the signal technician and played with the timing until we reached the balance we were looking for.”⁽¹⁰⁾ No special software was used to evaluate the signal timing but aaSIDRA was used for evaluating the roundabout.

Causeway at Coronado at Mandalay, Clearwater Beach, Florida, USA

Information on this location was received from two respondents. The first author provided the following;

A metering signal was installed on the main approach of this roundabout to create downstream gaps. The signals were located 150 – 250 ft upstream of entry and are actuated by a queue detector on downstream approach. The author of the survey states; “This is an ambitious topic for which it might be difficult to obtain useful results at this stage. The number of roundabouts that are currently metered directly or with signalized pedestrian crossings is very small. Use of simulation as the sole basis for guidelines, if that is what is being considered, requires accurate modeling of the roundabout itself. Whatever the outcome, these guidelines need to fit in with ongoing operational and accessibility research.”⁽¹⁰⁾

The second author also provides detailed information on the signal system;

“On occasions there is a massive flow onto the island of Clearwater Beach. As a result of a deficiency of parking spaces congestions starts south of the roundabout continues northward through the roundabout and sometimes almost to the mainland. The roundabout was a vast improvement over the signals. This backup limited access to the roundabout from other legs. Installing metering signals on the causeway approach with queue loops on other approaches enabled the automatic stoppage for traffic from the mainland for 90 seconds wherever the queue conditions were met. It has been a great success. It only works late at night and Saturday lunchtime, Saturday late afternoon.” (10)

Penn Inn, Newton Abbot, Devon, UK

Traffic signals were installed to balance complex turning movements on this an overloaded roundabout. The site has recently been improved and updated but traffic lanes are still not perfect. “Many drivers tend to drift laterally across the lanes.” (10) The signals are located on all approaches adjacent to the circulatory roadway. The author was not sure of software or literature used to implement signalization.

No Experience with Signalization

Of the seven survey responses received two of them stated that they had no experience with signalization. Three e-mails outside of the survey were also received expressing their lack of experience with signalized or metered roundabouts.

Guideline Development

The information obtained from survey responses present areas of concern at a roundabout and although detailed information was not received regarding official data collection, observational comments were a standard in all three responses. Information was also given regarding the means of control, time of operation, approach control, and software packages used for analysis.

AN ADDITIONAL LOCATION WHERE SIGNALIZATION AND METERING MAY IMPROVE OPERATIONS

MD 100 at Snowden River, Howard County, Maryland, USA

The roundabout at the intersection of Maryland state highway 100 and Snowden River serves both northbound and southbound lefts. (See Figure 4) There is a traffic signal located just south of the roundabout. When the green releases vehicles travel towards the roundabout arriving in large platoons and take over the roundabout. Since there are no vehicles coming from the left that would cause entering traffic to yield the vehicles proceed uninterrupted through the roundabout. This obviously prevents vehicles coming from the ramp of MD 100 from entering the roundabout and has caused a large queue to form nearing the freeway during the evening peak hour. (11)

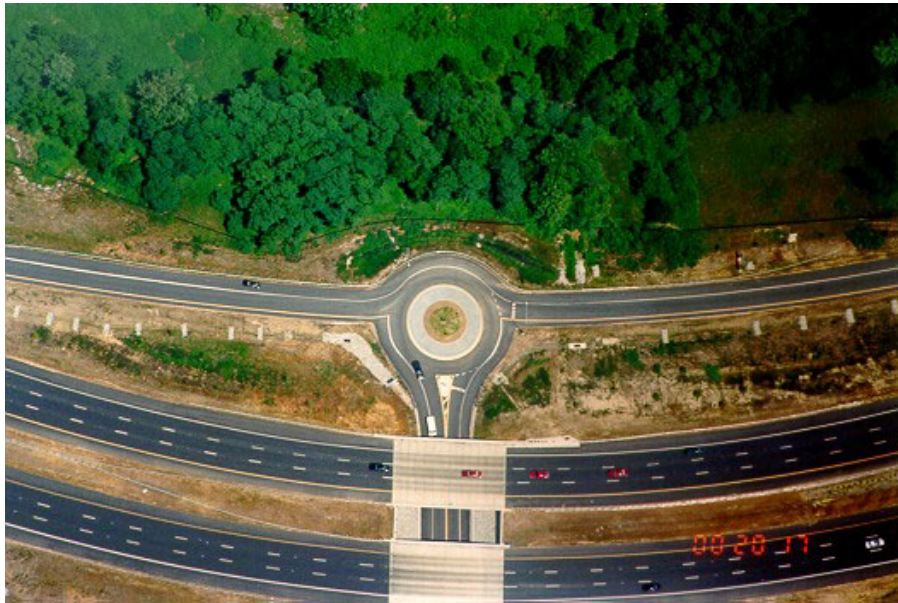


Figure 4. Aerial of MD 100 at Snowden River Roundabout

Guidelines Development

This location and e-mail response helped in completing the guidelines by simply provide the question; what should be done next? This site gives perspective into the decisions that would need to be made regarding the numerous signal options available. Some questions that might come up and would need to be addressed by the guidelines are;

- Should it be controlled directly or indirectly?
- Should the roundabout be metered or signalized?
- Would the signal or meter need to be on at all times?
- Which approach needs the added control?

GUIDELINES FOR THE SIGNALIZATION AND METERING OF A ROUNDABOUT

Before presenting the established guidelines for the signalization and metering of roundabouts, it should be mentioned that lack of detailed information and difficulty in obtaining specific information about signalized and metered roundabouts may limit the utility of the guidelines. Due to this the guidelines are not technical in nature and can only realistically aim to inform engineers of their options and the corresponding process of implementing a signal or meter. Completing this research only leads one to ask; “What is next?” and “How can these guidelines be improved to be of more use?” More detailed and accurate information is required and could be the next step in terms of research for this topic.

Observe and Obtain Data

Observation of a problematic roundabout will most likely provide much information into what is causing the problem. The following data should be obtained for further analysis;

- Entry and Exit Volumes
- Circulatory Volumes
- Circulatory Speeds

- Accident Data
- Queue Lengths
- Delays
- Headways
- Gap Acceptance Data

Review the Data

Upon obtaining data and observing the operation of the roundabout in question it may be appropriate to compare data from previous signalization experiences when facing the decision to implement a signal or meter. Although not every situation is alike the following values obtained from literature can help characterize a problematic roundabout. (See Table 3)

Table 3. Values from Literature and Survey Responses for Review

Roundabout or Guidelines	Signal System	Geometry	Volume Design/Actual (vph)	ADT Design/Actual	Location of Signal	Queue Lengths	Other
Clearwater, FL	Traffic Meter	Oval 150/180 m	3,655/ NA	39,500/58,000 during spring break	150 to 250 from entry		
Park Square, UK	Signal	200 m across	NA/6500		At entry		12 Injury/year, 3:1 ration of approaches during peak hr
Granville Square, UK	Signal	Oval 70/30 m	NA/3500-4000		At entry		
Moore Street, UK	Part-Time Signal		NA/3,300-1800 u-turn		25 m from entry		
Newbridge, Scotland	Signal	60 m diameter		NA/60,000	At entry	1.5 km (max)	30 mph
Vindintine, Finland	Signal	140 m diameter		NA/50,000	At entry		40 per year
Mickleham and Broadmeadows, Australia	Meter	60 m diameter	NA/1440 per lane		At entry	500 to 600 m (Detection at 90 m)	
Australian Traffic Signal Guide					20 m from entry	(Detection at 50 to 120 m)	

Identify Main Concerns

Upon observing the roundabout a list of concerns should be established. The following question can help in identifying those concerns.

- Is the roundabout suffering from unbalanced flow?
- If the roundabout has unbalanced flow which approach has the heaviest volume?
- Do all approaches need to be signalized?
- Are there excessive speeds within the circulatory roadway?
- Are there more than a normal or expected number of crashes at this roundabout?
- Are there any geometric restrictions that will influence the placement of the signals?
- Does the roundabout affect, or is it affected by, other nearby signalized intersections or roadways?
- Is there a need to accommodate for pedestrian traffic?

Choose Means of Control

Once the main concerns for signalization have been identified it is time to choose the means of control for the intersection. Direct control is what the name implies; it directly controls traffic at the entry points of a roundabout. Direct Control is one of the most common forms of control and signals are usually placed at roundabout entries to alter the natural progression of a heavy volume that tends to prevent weaker approaches from entering the roundabout. Indirect control is when the signal is placed a distance away from the entry of the roundabout. Indirect control often utilizes a metering signal, similar to a ramp meter, providing gaps in the traffic stream. In another form of metering control is the presence of an indirect pedestrian signal at a crosswalk. With indirect control literature has shown strengthening or widening the yield line is a common practice; this is because vehicles must still yield the right-of-way after moving through the indirect signal.

Choose Signal Operation

Signal operation can come in many forms including full-time control, part-time control, and metering. Full time control means that the signal will operate permanently and never switch off. There have been several noted cases of full time control. In one case the signal system has set cycle lengths for morning and evening peaks as well as a set cycle length for all other times. Another example of full-time operation is a traffic response control system that operates at different cycle lengths depending on actuated queue measurements. With part-time control the signal usually only operates during peak periods. Part-time operation is usually the combination of a set period of operation or operation for a period of time due to detection of excessive queue lengths. Metering of vehicles can also be an effective for of traffic control at problematic roundabouts. A metering signal is usually placed on the approach carrying high volumes that may prevent other vehicles from entering the roundabout. A traffic metering system can help alleviate this problem by detecting excessive queues and activating the signal, stopping traffic on the high volume approach long enough for some vehicles to escape the impeded approach. Once the queue has dissipated on the impeded approach and is no longer detected the signal will go blank and the roundabout will revert back to normal operation. This is similar to a ramp metering operation.

Choose Approaches to Signalize

Not all approaches need to be signalized, in many case metering one heavily traveled approach can be very effective. When establishing a queue balancing system it is sometimes necessary to signalize all approaches. A queue balancing system monitors all approaches of the roundabout and uses the input to operate the signal or metering system.

COMMENTS AND FEEDBACK FROM EXPERTS

A comment form was crated to facilitate feedback from experts in the field of roundabout operations and design. These comments where used to establish the finalized set of guidelines above. Four general items of interest where presented for response including; the clearness of the guidelines, their usefulness, items that the reviewer would liked to have seen in the guidelines and any additional remarks. Comments from roundabout experts can be found in Appendix A are listed below in Table 4.

Table 4. Developed Guidelines Comments

Reviewer (12)	Clear and Understandable	Usefulness	Item the reviewer would like to see in the guidelines	Additional Comments
1	“These guidelines are very clear and understandable.”	“I believe the guidelines to be very useful and beneficial.”	Situations in urban areas where upstream signals may be close enough where the signalized or metered roundabout might affect it operation	
2	“The guidelines are generally clear”	Limited utility	Reviewer expressed concern for the lack of detailed data within the guidelines	
3				“It is a good start”

CONCLUSIONS

After completing this research one conclusion that can be made is the definite need for more investigation. One problem that seems to be facing engineers, planners and government officials is the absence of a formal set of values to justify signalization or metering. A table similar to the one presented in the finalized guidelines would be an ideal place to begin. Obtaining more detailed information from the before state of the signalized or metered roundabout can give engineers more values from which a decision to signalize or meter a roundabout can be based.

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APPENDIX A

Reviewer One's Comments

ARE_GUIDELINES_CLEAR_UNDRSTANDABLE: These guidelines are very clear and understandable.

USEFUL = I believe the guidelines to be very useful and beneficial. Although, I think that you should discuss in the guidelines situations in urban areas where upstream conventional signalized intersections may be in close proximity of the roundabout (i.e., signals 500' - 1000' upstream of a roundabout). Care should taken so that a signalized or metered roundabout does not affect operations at the upstream signalized conventional intersection. In these situations queue detectors should be placed upstream so that vehicles do not back up thru the upstream intersection.

MISSING: See above

ADDITIONAL: None

Reviewer Two's Comments

ARE_GUIDELINES_CLEAR_UNDRSTANDABLE: The guidelines are generally clear and understandable; although a bit of editorial work is needed.

USEFUL: To be honest, I think these guidelines as currently formulated will have limited utility. My initial reaction after reading them was; ok, now what? I'm no closer to knowing what to do than before. Table 1 is an interesting compilation of sites, but it is missing key information on why the roundabout or a given approach is being metered. First, it is unclear whether the entire roundabout is signalized or whether one or more approaches is signalized/metered. Second, there is no information on the number of lanes, the specific geometry, or the volume pattern that is creating the over-capacity condition. Why is that particular roundabout being signalized? Some narrative for each site would be helpful in at least framing the problem for why signalization was being considered or used. The list of concerns is reasonable. The fourth bullet related to speeds is not likely to be something that signalization can address - it's more of a geometric problem. The last bullet is a hot topic and probably should not be singled out separate from the bullet above it. One could argue that every crosswalk warrants treatments for pedestrians of all abilities, and that may or may not require signalization (upcoming research to study this). The means of control section and types of signal operation are good overviews of the types that have been/can be used, although they should be combined together and combined with the survey of existing sites. As it is written now, one cannot use this information to decide which application is best for a given problem. It is also unclear whether the full-time, part-time, and metering approaches are direct or indirect. I assume the full-time and part-time are direct and the metering is indirect, but correct me if I'm wrong. The simulation options section is thin and misleading. RODEL and aaSIDRA (current version of SIDRA) model roundabouts in isolation and cannot model signalization of a roundabout. TRANSYT can model signalized intersections but cannot model the yield condition of a roundabout. I'm not familiar with TRACSIM, and I doubt most US practitioners are. To my knowledge, only microsimulation models (e.g., VISSIM, Paramics, and AIMSUN) are capable of modeling both roundabouts and signals simultaneously and capture the interactions between them. It would be nice to have an analytical model or planning guidance that captures some of the major effects, but (a) it might not be possible, and (b) it is surely outside your scope for this project.

MISSING: See above

ADDITIONAL: You've tackled a difficult topic which I'm sure you found was thin in terms of available guidance. I hope my comments are helpful to you, rather than unduly discouraging.

Reviewer Three's Comments

It is a good start

CHARLES STEVENS



Charles Stevens received his Bachelor of Science in Civil Engineering from Texas A&M University in December 2003. He has been employed with the Texas Transportation Institute since 2000, and currently holds the position of Graduate Research Assistant. Charles has been active in the American Society of Civil Engineers and recently served as steel bridge chair. He also serves as vice president for the Texas A&M University Student Chapter of the Institute of Transportation Engineers. In April of 2004 Charles received the Allen C. Ludwig, Jr. Award for his outstanding commitment to student organizations and the Civil Engineering Department. Charles is currently pursuing his M.S. in Civil Engineering from Texas A&M University. His professional interests include traffic operations and design, pedestrians, and roundabouts.

USING THE INTERNET TO DISSEMINATE TRAVELER INFORMATION

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SUMMARY

Over the last 10 to 15 years traveler information such as traffic, construction and weather conditions have become increasingly popular with the traveling public. The quality and extent of traveler information has steadily improved over this same timeframe with the growing deployment of intelligent transportation systems (ITS). Likewise, the means of delivering traveler information has grown from occasional spots during drive time radio to “traffic and weather every 10 minutes”, the national 511 telephone system for delivering travel information on demand, and more that 200 websites providing traffic information. The focus of this paper is the use of the Internet to deliver traveler information. Two critical dimensions of traveler information websites: 1) the type and quality of content and 2) the ease of accessing the information on the website design were specifically examined. The examination resulted in the development of a traveler information content quality checklist which can be used by organizations sponsoring traveler information websites as a self assessment and benchmarking tool.

The approach used in this examination included a review of the relevant literature dealing with traveler information, its use, and motorist information preferences. Based on the review, a checklist was developed to objectively evaluate the content quality of traveler information websites. It was subsequently used to score the content quality of a sample of ten typical traveler information websites. Having obtained an objective view of information available on each website, a panel of users was then asked to evaluate the ease of using the websites. Several conclusions were drawn about the state of the practice in traveler information website content quality and user preferences in presenting traveler information in a website design.

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INTRODUCTION

As the deployment of intelligent transportation systems (ITS) have progressed, the quality and quantity of information on travel speeds, traffic incidents, construction, and weather has dramatically improved. This information has enabled better traffic management and spawned a new market in consumer traveler information.

The motorist has found the information valuable in gauging how soon he or she should leave home depending on the weather or traffic conditions – thus reducing the uncertainty of whether he or she will arrive on time. Others have found advanced information on traffic incidents and construction zones valuable in order to plan alternate routes and save otherwise wasted time. Still others have found advanced information on special event routing and parking relieves the stress of attending a major football game or similar large gathering.

While many means are used to disseminate such information including radio and television, dynamic message signs, highway advisory radio, and special telephone numbers, the Internet has become one of the most inexpensive and ubiquitous means of delivering detailed travel information on demand.

Problem Statement

As agencies have experimented with the use of the Internet for travel information dissemination, the quantity, quality, and user friendliness have varied dramatically and have at times risked souring the public with trivial or dated information. However, with over 200 traffic information websites and 1400 transit information websites in the United States alone, the use of the Internet for delivering travel information has reached a level of maturity where it is appropriate to begin establishing benchmarks of quality in usability and content, as well as best practices.

Research Objectives

This paper will further the small but growing body of knowledge in this area by evaluating the content and usability of ten typical traffic information websites, using an objective content quality checklist and a subjective evaluation of website usability by a panel of 10 users. Evaluations will be completed from the user perspective with emphasis on data availability, ease of access, and data updates. Accuracy and reliability of data presented on the Internet will not be compared to actual field travel conditions, but instead taken at face value.

The examination results in tentative conclusions on best practices which should be subjected to verification in a larger study as well as a traveler information content quality check list which could be used by organizations sponsoring travel information checklists as a self assessment and benchmarking tool.

Several research objectives necessary for successful checklist design are listed below.

- Review available literature to determine preferred traveler information.
- Review current practice in traveler information website design.
- Develop a checklist to evaluate traveler information websites.
- Engage an expert panel to review the tested checklist.
- Revise the checklist based on expert comments.
- Utilize the checklist to evaluate ten traveler information websites.
- Conduct a subjective evaluation of the chosen websites by a panel of ten users.
- Draw conclusions on best practices and effective content of traveler information websites available on the Internet.

- Distribute the revised checklist to Federal Highway Administration divisions for use as a self assessment tool for agencies sponsoring traveler information websites.

Research Approach

Literature Review

A literature review was conducted to gather relevant information on the dissemination of traveler information, with an emphasis on the Internet as a medium. This includes a brief review of effective traveler information website design. Additional references on motorist preferences of traveler information were researched, aiding in the creation of the checklist.

Selection of Traveler Information Websites for Evaluation

After review of approximately 25 traveler information websites, ten were selected for further evaluation. The selection incorporated a representative sample of current traffic information websites, including sites reporting rural information and sites reporting traveler information for large metropolitan regions. Although the majority of selected traveler information websites were developed by public agencies, two privately designed websites were included for comparative purposes.

Checklist Creation, Review, and Implementation

A checklist was developed by the author which could be used by transportation agencies to evaluate the content quality of traffic information websites. The checklist was designed such that each website could be scored on both the extent of data available and some aspects of its quality then compared to other websites. The checklist was submitted for review to a panel of four experts selected for their knowledge of current practices in traveler information website design and of motorist preferences of traveler information. The author made revisions to the checklist based on feedback from the experts. The checklist was then used to score the content of the ten selected traveler information websites.

Subjective Evaluation

A study of traveler information websites was developed as a user test of the ten selected websites. The primary objective of the study was to determine user-friendliness of the traveler information sites. This was measured by how easily selected users could access pertinent information on the websites. Ten individuals were selected to participate in the study. Each participant was asked to evaluate each of the ten websites.

LITERATURE REVIEW

Traveler information is an important component of ITS. It is both a service to the customer and a means of managing traffic to achieve improved safety, mobility, and productivity.

Mitretek Systems suggest three primary functions for traveler information: 1) multi-modal trip planning, which is accomplished by providing travelers with static and dynamic information on several regional transportation modes, including private cars, transit, carpooling, air travel, etc. 2) route and 3) temporal guidance including static and dynamic information on route lengths, congestion, incidents, special events, and weather which aid motorists in planning their route and time of travel (*1*).

Benefits of Traveler Information

Motorists share common perceptions of the benefits of traveler information, the largest of which is the reduction of trip uncertainty (2). This reduction in uncertainty helps motorists avoid needlessly early departures (3). Another benefit of traveler information is saved time. This can be achieved through reduced travel time or reduced intermodal delays (1, 4, 5). Additionally, traveler information helps motorists avoid congestion and other traffic problems (4, 5). A qualitative benefit of traveler information is reduced traveler stress, which can result from numerous traffic situations (4, 5). The ability to avoid unsafe conditions is also considered an important benefit of traveler information (5). Traveler information allows motorists to alter their routes or travel times to avoid unnecessary hazards. Furthermore, traveler information can reduce motorist distraction thereby decreasing crash risks (1). Mitretek Systems also expands on this list considering mode choice based on real-time data an essential benefit (1).

Traveler Information Users

Research indicates the desire and use for travel information varies by 1) type of trip (3), 2) the level of congestion in the area (6) and 3) the electronic sophistication of the user (7). Those who regularly use travel information have demonstrated a willingness to change their departure time, change all or part of their route, and adjust their expectations (2). Importantly, Pierce and Lappin have shown that insufficient information quality is the principal impediment to more frequent use of traveler information services (3).

Traveler Information Quality

Because the quality of information is so crucial to the utilization of traveler information services, considerable research has been conducted in this arena. Motorists agree that traveler information services must provide accurate, timely, reliable information that is safe and convenient to use (5). It is also necessary that the available information be relevant to making travel decisions (1). The degree of guidance and personalization also has an important impact on traveler information quality (1, 5). For example, traveler information websites have begun providing personal route selectors where users can customize traveler information to their route. This increased personalization is considered valuable by traveler information website users. Some users of traveler information services are also concerned with the geographic coverage of the traveler information (1, 3). Information should be available throughout the entire region, regardless of jurisdictional boundaries.

The desired quantity of information is directly proportional to the level of congestion and complexity of the regional transportation system. Experienced users of traveler information consider the following to be important features:

Incidents

Travelers look for pre-trip information on incidents to aid in the trip planning (5, 8). Dudek found that motorists give preference to incident information over other measures such as travel speeds, delays, and travel times (9).

Traffic Conditions

However, direct measures of vehicle speeds are desired as well as derived travel times between origins and destinations (5, 6, 8). This information can be used to predict future conditions which motorists also desire, though no traffic management center currently has this capability. Much of the traveler information available today is limited to data collected from highways in the metropolitan region. Motorists would like to see geographical expansion of this coverage to include the surrounding suburbs, as well as extension of these services to major arterials (5, 6, 8, 10).

Weather

Adverse weather conditions impacting travel are important to the pre-trip planning process. More and more, motorists are expecting detailed and timely weather information as part of the traveler information services (5, 11).

Other Traffic Information

Motorists continue to expect more from traveler information providers. In addition to the above incident, traffic, and weather information, users now want additional information on special services, recreational travel, and parking. (5, 8, 11) Finally, traveler information users expect to be provided with information on alternate transportation modes, improving multi-modal capabilities within the region. This will allow motorists to be comfortable with their mode choice decisions (5).

Traveler Information Website Characteristics

The Internet is a popular tool for disseminating traveler information. Several features of the Internet as an information medium have allowed it to develop in the traveler information arena (12):

- The interactive interface draws interest to the websites and permits the dissemination of more in depth traveler information.
- Traveler information on the Internet is available to motorists at any time of the day, at home or in the office.
- The Internet allows fast, convenient reference of traveler information.

Due to the unique capabilities of the Internet, dissemination of traveler information must be approached in a new manner. Best practices in disseminating traveler information via radio, television, telephone, message signs, etc. should be expanded to effectively develop traveler information websites. A primary concern of traveler information dissemination by the Internet is the user-friendliness of the website designs.

Sauer et al. developed four usability criteria for consideration in the development of traveler information websites (11). The first is audience appropriateness. The language and icons on the website should focus on meeting the needs of a variety of audiences. The second criterion is discoverability, or how easy it is to locate the features users are looking for. A third criterion is the consistency of labels and page names throughout the website. Link descriptions on the website should be representative of the information they link to. The final criterion is ease of information gathering. The site should facilitate complex information gathering without requiring users to be subject experts.

Navigation

Navigation throughout the website should be straightforward. In fact, a good rule-of-thumb is that all information should be accessible within “3 clicks” of the mouse (13). This gives users the ability to easily maneuver throughout and retrace their steps in the future. Whether the website is simple or complex, navigational aids should be employed to improve the usability of the site. Several suggested aids are: navigation bars, site maps, table of contents, “bread crumb” trails, search facilities, return to home page capabilities, and usable ‘back’ button (13).

Homepage

It is essential that the homepage of all websites be properly and attractively designed. Too much clutter can hinder usability. Finally, all essential information should be presented on the homepage (13).

Graphics

Graphics can be used to “grab” the user’s attention; however they are often unnecessarily distracting and confusing (13). Map interfaces, common graphics on traveler information websites, are integral to disseminating traveler information. A metropolitan area map is one of the most desired features of traveler information users (8). Maps should provide sufficient detail for trip planning without overwhelming users with information. Motorists desire the maps to have point-and-click and zoom capabilities (6, 8). However, designers should proceed with caution as sophisticated features tend to detract attention (13).

Information Currency

Another essential aspect of traveler information websites is the currency of information provided (5, 8, 13). Information on the websites should be current and updated frequently. Additionally, the last update time should always be noted on the website.

Feedback

Many users want the opportunity to provide feedback to responsible agencies (13). This is especially true when real-time information is available on the website. Email contacts or telephone numbers are both appropriate customer feedback methods (8).

Public and Private Traveler Information Services

Private and public sectors have both played a role in traveler information with varying degrees of success. Noticeable differences in the dissemination of traveler information can be seen between the two sectors for a variety of reasons. Radin stated that most generally, private sectors and public agencies have different traveler information goals. She found that they place importance on disseminating different types of traveler information (14).

The private sector prioritizes traveler information in the following manner (14).

1. Traffic speeds;
2. Incidents;
3. Road conditions;
4. Current and scheduled work zones; and
5. Weather conditions.

The public sector prioritizes traveler information in the following manner (14).

1. Current and scheduled work zones;
2. Incidents;
3. Road conditions;
4. Emergency evacuation procedures; and
5. Weather conditions.

This is primarily a function of the type of data to which the private and public sectors have easy access. Soolman et al. found that public traveler information websites were most commonly equipped with real time camera views and information on alternate transportation modes and programs (8). Conversely, private sites more commonly provided point-and-click capabilities, real-time travel time, special service information, and information on how frequently the site is updated.

Mitretek found that “traveler information systems can be enhanced by public-private partnerships which involve leveraging of the resources from both sides of the partnership to a mutual advantage” (1). Public-private partnerships, such as Partners in Motion, have been established in the past allowing financial, operational, and data resource sharing (15). Although these collaborations provide motorists with improved traveler information systems, there are several obstacles to such collaborations which cannot be discussed within the scope of this paper.

SELECTION OF TRAVELER INFORMATION WEBSITES

Currently, there are over 1600 websites providing traveler information within the United States. Nearly 250 of these sites provide traffic information. Approximately 25 traffic information websites were reviewed by the author before selecting ten for further study. Websites were selected to obtain a representative sample of current traffic websites with respect to traveler information content and dissemination techniques. A wide range of websites, from those in their first months of operation to veteran US Department of Transportation award winners were selected. Five of the chosen websites provide statewide traveler information, while the others provide traveler information germane to a single metropolitan area. Two of the websites are privately operated, with the remaining sites managed by public transportation agencies. The sites selected are listed in Table 1.

Table 1. Selected Traveler Information Websites

Locality	Website	Geographic Region	Operating Agency
Arizona Department of Transportation	http://www.az511.com	Statewide	Public
Colorado Department of Transportation	http://www.cotrip.org	Statewide	Public
Georgia Navigator	http://www.georgia-navigator.com	Statewide	Public
Houston TranStar	http://www.houstontranstar.org	Metropolitan Area	Public
Kansas City Scout	http://www.kcscout.net	Metropolitan Area	Public
Montana Department of Transportation	http://www.mdt.state.mt.us/travinfo	Statewide	Public
San Antonio TransGuide	http://www.transguide.dot.state.tx.us	Metropolitan Area	Public
SmarTraveler (Boston Area)	http://www.smartraveler.com	Metropolitan Area	Private
Traffic.com (Washington D.C. Area)	http://www.traffic.com	Metropolitan Area	Private
Washington State Department of Transportation	http://www.wsdot.wa.gov	Statewide	Public

TRAVELER INFORMATION WEBSITE CHECKLIST

The effectiveness of traveler information websites is dependent not only upon usability, but also on the website content. The amount, type, and quality of traveler information are important to users. A checklist, based on the literature review and a background scan of existing websites was developed to objectively score websites on the amount, type, and quality of the traveler information available to motorists on typical traffic information websites. The checklist, consisting mostly of yes/no questions was designed such that both public and private agencies sponsoring traveler information websites can score their own content and compare it to benchmarks of best practice.

Expert Panel Review

The preliminary checklist was developed then submitted for review to four professionals with expertise in the traveler information field. The experts reviewed the preliminary checklist providing the following significant comments:

- It would be helpful to think about prioritizing the information. It is necessary to distinguish between information that is critical for traffic websites and information that is included for the sake of completeness.
- The types of websites which are evaluated with the checklist should also be considered; whether the checklist is applied to statewide or metropolitan area websites will affect the website score.
- The objective of the traveler information system will affect the information displayed on the websites.
- The checklist should also consider tourism information, emergency alerts, AMBER Alerts, security information, natural hazard alerts, paratransit information, and Highway Advisory Radio information.

Their comments were incorporated and the checklist finalized.

Checklist Design

The final checklist, as seen in Appendix A, poses an extensive amount of questions with the goal of objectively evaluating the content of traveler information websites. As designed, agencies sponsoring traveler information websites can achieve a better sense of the traffic information they are providing in comparison to benchmark websites. Traveler information addressed in the checklist is categorized in the following manner:

- General traveler information content;
- Traffic characteristics;
- Incident information;
- Closures and construction;
- Weather;
- Message signs;
- Cameras;
- Alternative transportation modes; and
- Other traveler information.

Scoring

Scoring of the final checklist played an integral part in providing an unbiased evaluation of the selected sites. Completing the checklist requires answering numerous questions about a traveler information website. Answers to each question are circled by the evaluator. A different numerical value (in parenthesis) is associated with each answer, weighted based on relative importance. The values are then tallied to determine the overall score of the website. A total possible tally of 268 can be achieved.

Reductions to the attainable score must be made in several cases. The most notable case is for rural statewide traveler information websites. Significant congestion seldom occurs in such areas, thus the availability of congestion data would not necessarily be a best practice. Because traffic condition information is worth a total of 38 points in the checklist, it would be subtracted from the possible score of 268 for a more accurate comparison. Other examples include the presences of HOV lanes, mass transportation services, and toll roads, which would require nine, ten, and four point reductions, respectively. Finally, the total score achieved is divided by the attainable score to produce a percentile for use in practical comparisons.

Checklist Application

The checklist was applied to the ten selected traveler information websites. A wide range of available traveler information was presented on the selected sites. The amount, type, and quality of traveler information varied significantly between public and private sector websites, as well as rural and metropolitan area websites. The selected traveler information websites scored between 25% and 65% with the checklist application. Award winning traveler information websites received top scores above the 55th percentile. These websites currently incorporate some of the best practices in traveler information website design and can be established as a benchmark for comparisons.

SUBJECTIVE EVALUATION

User friendliness of traveler information websites is crucial to their success although sometimes difficult to achieve. It is also hard to measure objectively. Typically it is evaluated using a qualitative study. Therefore, a panel of users was recruited to evaluate the user friendliness of the ten selected traveler information websites.

Participants

Ten individuals were asked to participate in the usability study. The participants were chosen based on their familiarity with the Internet as an information source. No prior experience with online travel information was necessary. Six females and four males with an age distribution, shown in Table 2 on the following page, completed the study. While the responses of such a panel are not sufficient to draw definitive conclusions on website usability, their responses are sufficient to suggest usability themes and hypothesis for investigation.

Evaluation Design

The participants were asked to evaluate each of the traveler information websites as if they were a motorist traveling through the area. They were directed access each of the ten traveler information websites during peak travel periods of the day. For each website, panel members were provided with a specific travel scenario, detailing their current location and their proposed travel route.

Given this information, subjects were asked to identify the following information on their prescribed routes:

- Traffic conditions (e.g. travel time, speed, congestion);
- Incident information (e.g. accidents, stalled vehicles);
- Construction information (e.g. road closures, lane closures); and
- Weather conditions.

Table 2. Age Distribution of Participants

Age Range (Years)	Number of Participants
18-24	4
26-39	3
40-54	2
55-64	1
65+	0

These four features were chosen based on previously identified motorist preferences and the availability of the above information on most of the selected traveler information websites.

Most importantly, the participants were asked to rank the difficulty (on a scale of 1 to 5) they experienced in locating the information. A ranking of 1 indicated that the task was easily completed, whereas a ranking of 5 indicated that the task was difficult. Additionally, the participants could mark not applicable (N/A) if the information was not available on the website. This was true in only the following two instances:

- One publicly operated statewide website does not provide information on traffic conditions.
- One privately operated website does not provide weather information on their website.

The evaluation form distributed to participants can be seen in Appendix C.

Subjective Evaluation Results

Significant Findings

Participants in the subjective evaluation were asked to comment on each of the traffic information websites. Some of the most significant findings with regards to user-friendliness of the websites stemmed from these remarks. Important aspects of the traffic information websites not specifically addressed in the evaluation include maps, homepage design, and the quantity of traveler information.

Maps. Nine participants commented on the traveler information maps (90%). Users were drawn to maps as a primary source for locating information. Three participants (30%) complained that the same data provided in lists or tables was not as easily accessed and understood. Figure 1 and Figure 2 present information on the same incidents in table and map formats, respectively. While the table provides more detail on the incidents up front, participants in the subjective evaluation preferred using map formats and clicking on incident icons for further detail.

ID	Type	Location	Time
in00	Major Accident	MARCH AV ROOSEVELT AV	Wed 04-Aug-04 14:32
in01	Minor Accident	08924 ATHENS	Wed 04-Aug-04 19:07
in02	Minor Accident	07700 FLOYD CURL DR	Wed 04-Aug-04 19:35
in03	Minor Accident	LOOP 410 NE MC CULLOUGH AV	Wed 04-Aug-04 19:48
in04	Minor Accident	LOOP 410 NE US 281 N	Wed 04-Aug-04 19:48
in05	Minor Accident	DE ZAVALA RD WB IH 10	Wed 04-Aug-04 19:48
in06	Minor Accident	LOOP 410 SW HWY 151	Wed 04-Aug-04 20:04
in07	Minor Accident	00900 MAIN AV N	Wed 04-Aug-04 20:18

Figure 1. Table of Incident Information

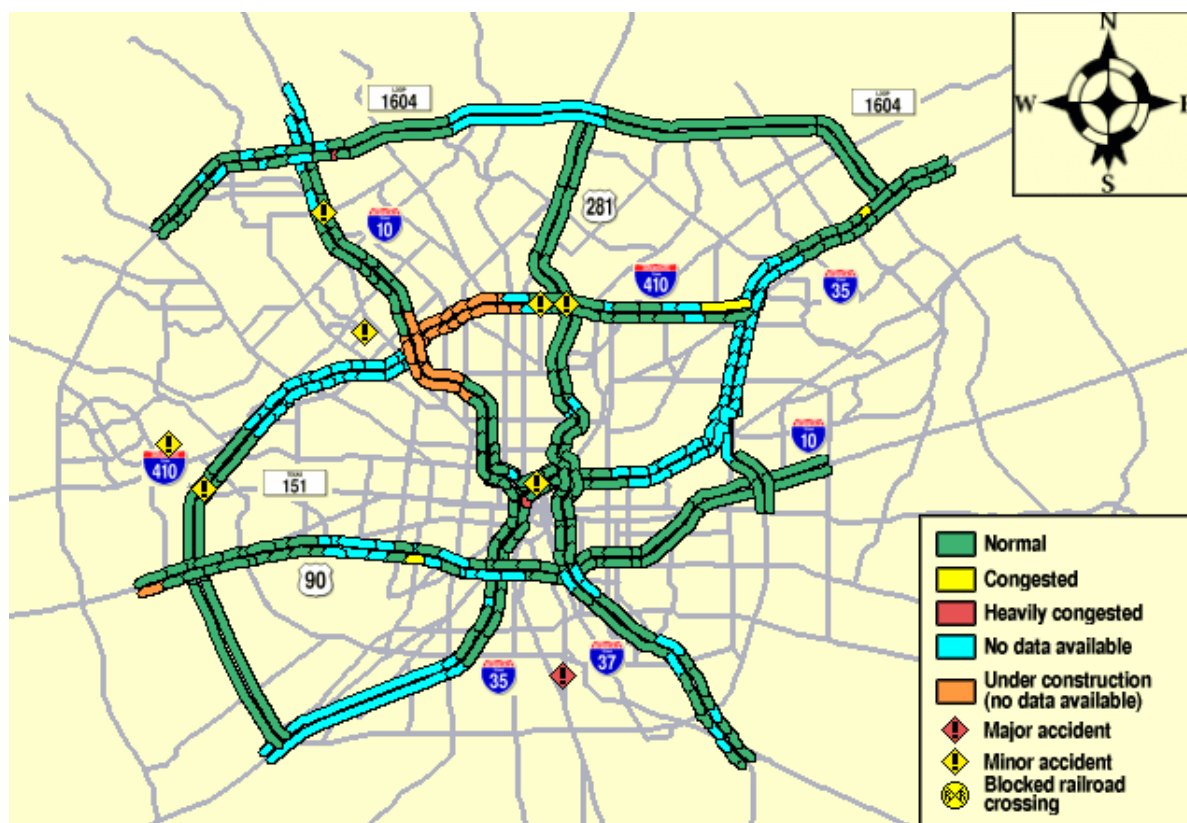


Figure 2. Map of Incidents

Additionally, 30 percent of participants commented that they preferred websites which presented all of the desired information on one map. They did not want to switch between multiple maps for information on traffic, incidents, construction, etc. An example of a multi-use map displaying information on traffic conditions, incidents, and construction can be seen in Figure 3.

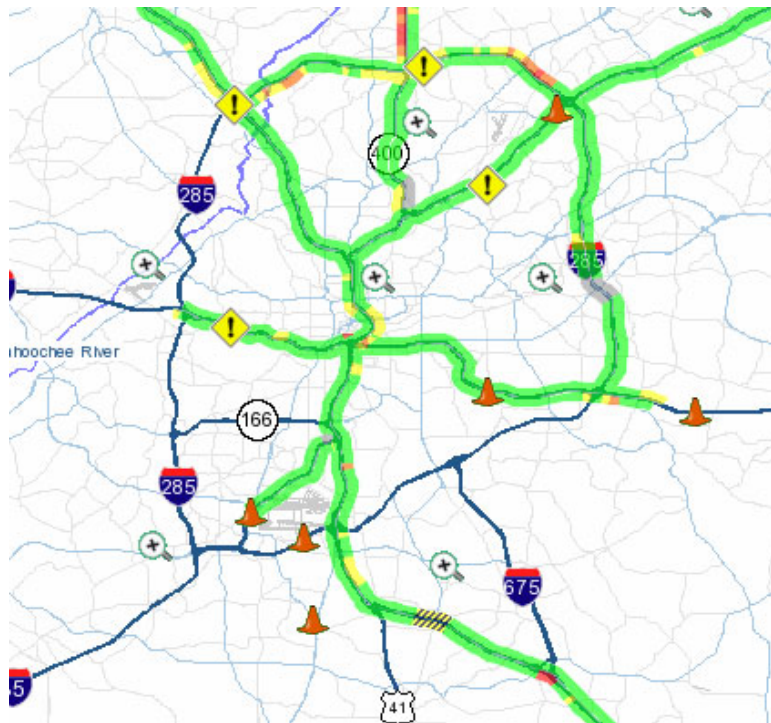


Figure 3. Multi-Use Map

Two respondents (20%) commented positively on the layer control provided with more complex maps. The layer control feature facilitates customization of one map; giving users the capability to choose which information to display on the map. Layer control can be an effective method of managing large quantities of information if presented clearly. Three participants (30%) complained of difficulty in identifying and distinguishing between layer control names and icons. Layer names should clearly describe the information provided in each layer and should be easily understood by all users of the website. Figure 4 illustrates simple layer control, while Figure 5 is an example of more complex layer control. The map associated with the layer control in Figure 5 displays more information to the user and allows greater customization of information, however may be confusing and overwhelming.



Figure 4. Simple Layer Control



Figure 5. Complex Layer Control

General map quality issues were also considered important by five respondents (50%) including: detail of map, size of map, legibility of text, and overlapping of symbols and route numbers.

Homepage Design. Participants in this study were initially directed to the homepage of each traveler information website. The usability of the homepage seemed to have a large impact on opinions of the site, stemming 50 percent of evaluation respondents to comment. Easy access to relevant information from the homepage is important. Four participants (40%) discussed their appreciation of large quantities of information presented up front so it was “one click away”. By contrast, numerous links on the homepage created three complaints (30%) of clutter and confusion. Some agencies are able to effectively organize the abundance of information on their homepage which initiated one positive remark (10%). Figure 6 is an example of a traffic information website with numerous links on the homepage. The links have been well organized to ensure a user-friendly design.

In addition to the layout of the homepage, the contents of the homepage were discussed by the evaluation participants. The display of area maps on the homepage received positive remarks by two participants (20%) in the study. One participant (10%) also commented on the value of displaying important alerts on the homepage. An example of alerts posted on one traveler information website homepage can be seen in Figure 7.

Quantity of Information. Participants in the subjective evaluation appreciated large quantities of traveler information, not only on the homepage, but throughout the website. Four participants (40%) commented negatively about traveler information websites providing too little information. Additionally, 40% of respondents remarked on the level of detail in the traffic information available. They felt much of the information was too general.

Travel Information <ul style="list-style-type: none"> • Road Conditions • Alerts & Restrictions • Lane Closures • Oversize/Overweight Restrictions • Winter Driving • Construction • Rest Areas • Related links <i>Updated!</i> • Frequently Asked Questions • Site help • Disclaimer • Neighboring States <i>New!</i> • Visit [redacted] via your PDA or Cell Phone! 	Variable Message Signs <ul style="list-style-type: none"> • State Wide • I-70 [redacted] • I-25 and I-70 [redacted] • I-25 [redacted] 	Weather <ul style="list-style-type: none"> • National Weather Service Links • Satellite image • More Satellite images • Air Pollution Advisory • Fire and Drought Information
Travel Times and Speed Maps <ul style="list-style-type: none"> • Metro [redacted] Speed Map 	Traffic Cameras <ul style="list-style-type: none"> • State Wide • I-70 [redacted] • I-25 and I-70 [redacted] • I-25 [redacted] 	Weather Stations <ul style="list-style-type: none"> • State Wide • I-70 [redacted] • I-25 and I-70 [redacted] • I-25 [redacted]
Transportation <ul style="list-style-type: none"> • Commuter Choices • Bicycle / Pedestrian • Transit provider 	Highway Advisory Radios <ul style="list-style-type: none"> • State Wide 	Aeronautical Weather Stations <ul style="list-style-type: none"> • State Wide
	Airports <ul style="list-style-type: none"> • [redacted] International • [redacted] • Other Airports (Map) 	ITS Newsletter and Information <ul style="list-style-type: none"> • [redacted] Quarterly • Intelligent Transportation Systems • ITS Technical Information

Figure 6. Traveler Information Website Homepage with Numerous Links



Figure 7. Website Homepage Travel Alert

Other Website Aspects. Some technical aspects of the websites were also commented upon. Participants in the study liked the availability of search engines on the traveler information websites, although two participants (20%) complained of unsuccessful searches. Two participants in the website evaluation (20%) complained about linking to other websites for information. They preferred information available on the traveler information website itself, but were willing to link to other websites if it did not create navigational issues. One participant (10%) also suggested warning users when being forwarded to a new website. For example, one traffic information website would sometimes open external links in new windows, and other times not. This was very annoying to subjects and caused navigational problems. Finally, four participants (40%) complained about the registration requirements of one of the privately operated websites. Although registration was free, they were reluctant to provide personal information.

Website Features Assessed

The subjective evaluation also resulted in a ranking of the selected traveler information websites in the areas of traffic conditions, incidents, construction, and weather. The average score of each website in these four areas was computed. The evaluation panel was asked to rank websites on a scale of 1 to 5, however on many occasions the participants had difficulty locating features on the websites. They mistakenly marked N/A, indicating this information was not available, when in actuality it was merely

difficult to find. For analysis purposes, these responses were given a value of 6. Therefore, the highest possible score for a website was 1.0 while the lowest achievable score was a 6.0.

The resulting ranking of the traveler information websites in each of the four areas is discussed below. Names of the websites are not provided in the rankings. Instead, the websites will be identified by their public or private affiliation, their geographical coverage, and an arbitrary number. For example: "Public/Statewide 1" Each website is assigned a name which remains consistent throughout the comparison of traffic conditions, incidents, construction, and weather.

Traffic Conditions. Participants were asked to identify area traffic conditions at each traveler information website. Little trouble was encountered in this task, except at the one website where this information was not provided. As congestion levels, traffic speeds, and travel times were identified, one participant (10%) expressed a concern about understanding this information. They felt users needed to be able to compare the current conditions with the typical traffic conditions. For example, one website provides users with information on current traffic speeds and historical averages for comparison, as illustrated in Figure 8.

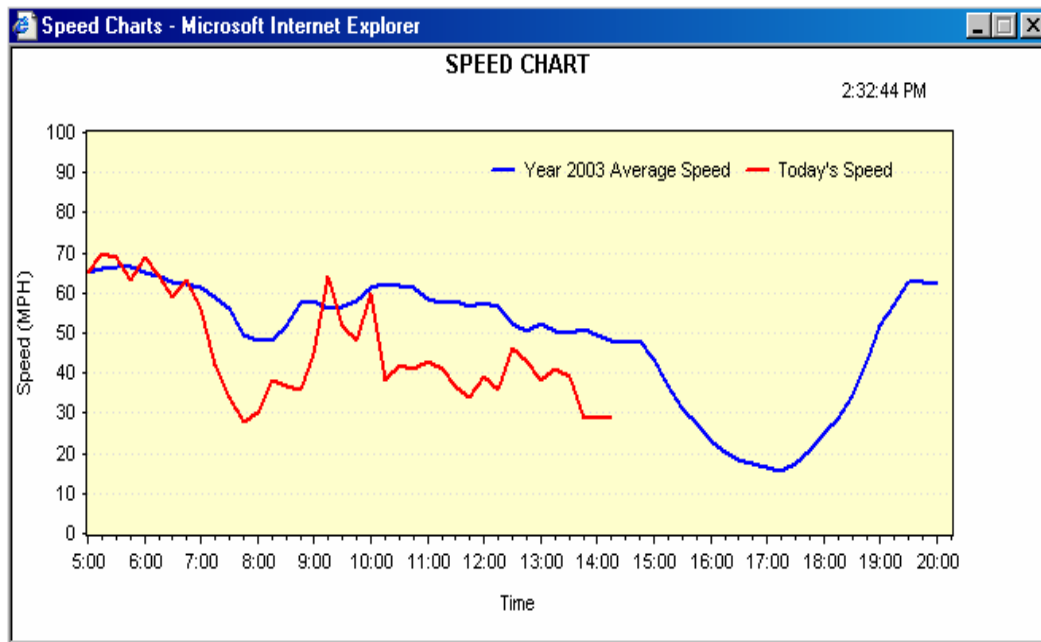


Figure 8. Speed Comparison Chart

The websites receiving the best scores in the traffic conditions had several aspects in common. These websites have prominent links to traffic condition information on the homepage. The traffic condition maps provide traffic speeds in small ranges, generally less than 15 miles per hour. Two of the favored websites provide exact speeds on freeway segments. The resulting ranking of websites with regard to the ease of finding traffic condition information can be seen in Table 3.

Table 3. Traffic Conditions Ranking

Rank	Locality	Score	
		Mean	Standard Deviation
1	Public/Statewide 1	1.10	0.32
1	Public/Metropolitan 1	1.10	0.57
2	Public/Statewide 2	1.33	1.00
3	Public/Metropolitan 2	1.70	0.95
3	Public/Statewide 3	1.70	0.95
4	Private/Metropolitan 1	1.78	1.30
5	Public/Metropolitan 3	2.30	1.25
6	Public/Statewide 4	2.40	1.35
7	Private/Metropolitan 2	3.22	1.56

Incidents. The second task at each website was to locate incident information. One participant (10%) had trouble identifying if incident information was available on the website or if there were no active incidents during their time on the site. Indications should be provided if there are no active incidents at the time, as seen in Figure 9.

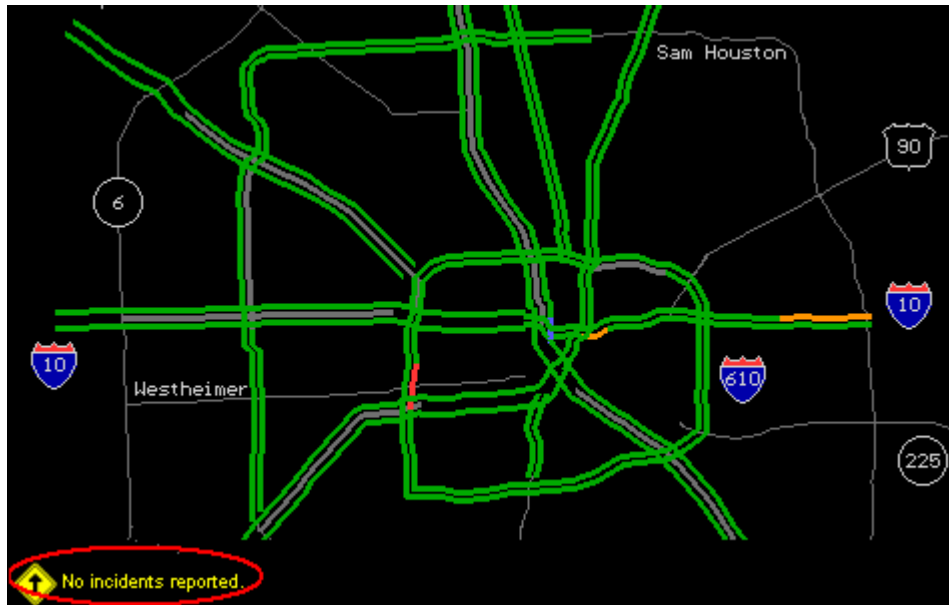


Figure 9. Map with No Active Incidents

Significant problems occurred on one website because incident information is not presented on the homepage, but instead buried under route traffic reports.

Traveler information websites receiving the best score in the incident area have a distinct method of providing incident information. These websites display icons at incident locations on the traffic conditions map. Additional information about the incidents is provided when the icons are clicked. The map of incidents is supplemented with a table detailing all incidents in the area at the current time. Incident details provided include the severity of incident and the number of freeway lanes affected. The resulting ranking of websites with regard to the ease of finding incident information can be seen in Table 4.

Table 4. Incident Ranking

Rank	Locality	Score	
		Mean	Standard Deviation
1	Public/Statewide 1	1.10	0.32
2	Public/Metropolitan 1	1.11	0.33
3	Private/Metropolitan 1	1.33	0.50
4	Public/Metropolitan 2	1.60	0.97
5	Public/Statewide 3	2.00	1.25
6	Public/Statewide 4	2.40	1.17
6	Public/Statewide 5	2.40	1.26
7	Public/Metropolitan 3	2.60	1.78
8	Public/Statewide 2	2.88	2.10
9	Private/Metropolitan 2	3.44	1.88

Construction. The next task at each website was to locate construction information. This task was also fairly straightforward. Two participants (20%) had some trouble associating “closures” on one website with the desired “construction” information. One participant (10%) also showed a desire for further detail on construction, including detour and alternate route information.

Construction information is presented on the best websites in a manner similar to incident information. Construction zones are noted on a map, which can be clicked for additional construction details including dates and times of active construction as well as freeway lanes affected. The top website also provides construction information for different time periods in the future. For example, different maps are available for construction in the next 24 hours, 72 hours, week, and weekend. The resulting ranking of websites with regard to the ease of finding construction information can be seen in Table 5.

Table 5. Construction Ranking

Rank	Locality	Score	
		Mean	Standard Deviation
1	Public/Metropolitan 1	1.11	0.33
2	Public/Statewide 1	1.30	0.48
3	Public/Metropolitan 2	1.80	0.92
4	Public/Statewide 2	1.89	1.27
5	Private/Metropolitan 1	2.13	1.64
6	Public/Statewide 4	2.30	1.16
6	Public/Statewide 3	2.30	1.34
7	Public/Statewide 5	2.60	1.17
8	Public/Metropolitan 3	3.11	2.03
9	Private/Metropolitan 2	3.67	2.18

Weather. The final task was to identify weather conditions at each traveler information website. This task provided significantly more confusion than others; nine participants in the evaluation (90%) commented on difficulties locating weather information. In all, participants had trouble identifying weather information on four of the nine sites in which it was available. Weather was not provided on one of the privately operated websites.

Weather information is presented on the selected traveler information websites in several formats. Some sites have detailed weather stations throughout the region, while others provide general forecasts. Still, others link users to news or weather websites to obtain weather forecasts. The numerous methods of disseminating weather information were the primary cause of confusion. Links to external websites for weather information were not easily found. Three participants (30%) who found the weather links did not like obtaining weather data through external websites.

Additionally, the websites which ranked highest in the weather category have sensors throughout the region which provide weather data at multiple locations. Specifically, these sensors provide information on pavement conditions which directly impact the traveler's trip. Citywide forecasts provide area temperatures and precipitation, which have a lesser impact on trips. Therefore, websites providing general forecasts were not scored as highly in the subjective evaluation. The resulting ranking of websites with regard to the ease of finding weather information can be seen in Table 6.

Table 6. Weather Ranking

Rank	Locality	Score	
		Mean	Standard Deviation
1	Public/Statewide 1	1.10	0.32
2	Public/Statewide 2	1.33	1.00
3	Public/Metropolitan 1	1.67	1.12
4	Public/Metropolitan 3	2.60	1.65
5	Public/Statewide 5	2.80	1.48
6	Public/Metropolitan 2	3.63	1.69
7	Public/Statewide 3	3.78	2.05
8	Public/Statewide 4	4.40	2.01
9	Private/Metropolitan 2	4.44	1.74

Summary

The overall usability ranking of these sites can be established by combining the scores for traffic condition, incident, construction, and weather information. When examining the final usability rank of the selected websites, the limited inputs must be considered. The usability of each site is dependant upon the dissemination of only four types of information. The resulting ranking of websites considering traffic conditions, incidents, construction, and weather can be seen in Table 7 on the following page.

An examination of results from the subjective evaluation provides an insight into effective traveler information website design. Several themes are consistent throughout the websites which the evaluation panel determined have the best usability. These traveler information websites provide links to traffic conditions, incidents, construction, and weather on the homepage. The best websites have a tendency toward more basic homepages without numerous links. Much of the traveler information is displayed on interactive regional maps with zoom capabilities and clickable icons. A great deal of desired traveler information is provided on these websites without requiring users to link to external sources. The top websites also provide more details on the available traveler information.

Traveler information providers that performed well in the subjective evaluation have greater technical capabilities and greater quantities of traveler information on the websites. Both of these sites are relatively mature and in their 2nd or 3rd generation of development and can probably be considered benchmarks for good practice at this point in time. However, one privately operated website presents an interesting anomaly. While it does not have outstanding content, users, nevertheless rated it relatively highly. This perhaps is an important recommendation to those agencies or companies initiating travel information websites. Good, user friendly website design can overcome thin content; at least initially and apparently keep customers satisfied. In contrast, another website provides a great deal of traveler information yet the evaluation panel found that this website was confusing and hard to maneuver; therefore it is ranked lower on the usability scale, further confirming the importance of a user friendly

web site design. While admittedly a sample of 10 sites and a panel of 10 people are not sufficient to draw a definitive conclusion, it does represent a strong hypothesis for a wider investigation.

Table 7. Overall Usability Ranking

Rank	Locality	Score	
		Mean	Standard Deviation
1	Public/Statewide 1	1.15	0.10
2	Public/Metropolitan 1	1.28	0.26
3	Private/Metropolitan 1	1.75	0.40
4	Public/Statewide 2	1.86	0.73
5	Public/Metropolitan 2	2.18	0.97
6	Public/Statewide 3	2.44	0.92
7	Public/Statewide 5	2.60	0.20
8	Public/Metropolitan 3	2.65	0.34
9	Public/Statewide 4	2.88	1.02
10	Private/Metropolitan 2	3.69	0.53

RECOMMENDATIONS

Website design is critical. Traveler information service providers can create an effective website without extensive content by considering the usability of the site. More specifically, traveler information must be easy to locate in a timely manner, and must be easily understood by all website users. The author recommends the following steps be taken in designing a traveler information website:

- Critical information (real-time alerts) should be provided on the homepage.
- Direct links to important travel information should be available on the homepage.
- All traveler information should be no more than “3 clicks” away.
- Homepages with more than ten links should group links into sections.
- Traveler information should be provided on regional maps.
- Maps should be interactive, allowing users to click for further details.
- Several types of traveler information should be combined into one map.
- Layer control can be utilized to effectively organize map content.
- Layer control maps should not contain more than ten layers.
- Map quality should not be overlooked (detail, legibility of text and icons).
- Websites should indicate the currency of traveler information provided.
- A site map, navigation bar, or table of contents should be used to improve navigation.

- Websites should designate between equipment failures and a lack of travel activity.
- Traveler information should be provided internal to the website when possible.
- If users are linked to external sites, links should open in new window.

The author has stressed the importance of effective traveler information website design, but website content must also be considered. Traveler information content does matter, especially if it is presented well on the website. The type, quality, and quantity of traveler information on websites should be compared to the benchmarks of best practice. The author recommends the developed checklist be used by traveler information providers as a self assessment of their website content.

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APPENDIX A: TRAVELER INFORMATION WEBSITE CHECKLIST

Please circle the appropriate response in the right hand column with respect to the information available on the traveler information website being evaluated. The number in parenthesis indicates the score received for each answer. Tally the total score at the end of each section. Account for possible reductions while tallying the score in each section. For example, if the locality evaluating the website does not have HOV lanes, mass transit, or toll roads, reduce the possible section score by the associated amount. Rural areas may also wish to skip the traffic condition section if this information is not critical to satisfy traffic management objectives. Transfer the section scores from the evaluation to the Scoring Guide located at the end of the checklist. Total the section scores and the possible points in the Scoring Guide. Calculate the final percentage achieved by the website by dividing the total score by the total possible points.

General Traveler Information Content	
<i>Possible Score – 17 points</i>	
Real time travel news and alerts available on home page	(0) – no (1) – yes
Regional map available on homepage	(0) – no (5) – yes
Relevant information provided as layers on one map	(0) – no (5) – yes
Site map available	(0) – no (1) – yes
Website search engine available	(0) – no (1) – yes
Frequently asked questions available	(0) – no (1) – yes
Webmaster contact information available	(0) – no (1) – yes
Traffic agency contact information	(0) – no (1) – yes
Website updated 24 hours a day	(0) – no (1) – yes
<i>General Website Content Score</i>	<i>/ 17 points</i>

Traffic Conditions	
<i>Possible Score – 38 points</i>	
Traffic condition information available	(0) – no (4) – yes
Link to traffic condition information available from homepage	(0) – no (5) – yes
Link to homepage available from traffic condition page	(0) – no (1) – yes
Traffic condition information available for freeways	(0) – no (1) – yes
Traffic condition information available for major arterials	(0) – no (1) – yes
Traffic condition information provided in list format	(0) – no (1) – yes
Traffic condition information provided on a map	(0) – no (4) – yes
Zoom capabilities available on map	(0) – no (1) – yes
Clickable or float cursor over map for further information	(0) – no (1) – yes
Legend located on map	(0) – no (1) – yes
Color coded map	(0) – no (1) – yes
Time / date stamp of traffic condition data provided	(0) – no (1) – yes
Update frequency of traffic condition data	(0) – unknown (1) – 20 minutes + (2) – 10-19 minutes (3) – 3-9 minutes (4) – 2 minutes or less
Greatest traffic condition dissemination capability	(0) – none (1) – congestion levels (2) – travel speeds (3) – travel times

<i>Traffic condition information provided as congestion levels:</i>	
Number of congestion levels provided	(0) – none (1) – 2 levels (2) – 3 levels (3) – 4+ levels
<i>Traffic condition information provided through travel speeds:</i>	
Numerical range of speed data provided	(0) – no speed data (1) – 21+ mph speed range (2) – 11 – 20 mph speed range (3) – 1-10 mph speed range (4) – exact speeds provided
<i>Traffic condition information provided through travel times:</i>	
Travel time origins and destinations are	(0) – no travel times (1) – predefined (2) – user defined
Traffic condition information provided through the use of a personal route selector	(0) – no (1) – yes
Historical data on traffic conditions is available	(0) – no (1) – yes
Predictive traffic condition information is available	(0) – no (1) – yes
<i>Traffic Conditions Content Score</i>	<i>/ 38 points</i>

Incident Information	
<i>Possible Score -41 points</i>	
Incident information available	(0) – no (12) – yes
Link to incident information available from homepage	(0) – no (5) – yes
Link to homepage available from incident page	(0) – no (1) – yes
Incident information available for freeways	(0) – no (1) – yes

Incident information available for major arterials	(0) – no (1) – yes
Incident information provided in list format	(0) – no (1) – yes
Incident information provided on a map	(0) – no (4) – yes
Zoom capabilities available on map	(0) – no (1) – yes
Clickable or float cursor over map for further information	(0) – no (1) – yes
Legend located on map	(0) – no (1) – yes
Description / nature of incident available	(0) – no (1) – yes
Location of incident provided	(0) – no (1) – yes
Information on the severity or number of vehicles involved in the incident provided	(0) – no (1) – yes
Time of incident report or verification provided	(0) – no (1) – yes
Indicates number of lanes affected by the incident	(0) – no (1) – yes
Estimated clearance time of incident provided	(0) – no (1) – yes
Recently cleared incident information available	(0) – no (1) – yes
Time / date stamp of incident data provided	(0) – no (1) – yes
Update frequency of incident data	(0) – unknown (1) – 20 minutes + (2) – 10-19 minutes (3) – 3-9 minutes (4) – 2 minutes or less
Real time updates to posted incidents available	(0) – no (1) – yes
<i>Incident Information Content Score</i>	<i>/ 41 points</i>

Closures and Construction	
<i>Possible Score - 38 points</i>	
Information on closures and construction available	(0) – no (4) – yes
Link to closures and construction information available from homepage	(0) – no (5) – yes
Link to homepage available from closures and construction page	(0) – no (1) – yes
Closure and construction information available for freeways	(0) – no (1) – yes
Closure and construction information available for major arterials	(0) – no (1) – yes
Closure and construction information provided in list format	(0) – no (1) – yes
Closure and construction information provided on a map	(0) – no (4) – yes
Zoom capabilities available on map	(0) – no (1) – yes
Clickable or float cursor over map for further information	(0) – no (1) – yes
Legend located on map	(0) – no (1) – yes
Description / nature of closure and construction available	(0) – no (1) – yes
Indicates emergency versus scheduled closures	(0) – no (1) – yes
Location of closure and construction provided	(0) – no (1) – yes
Date and times of closure and construction provided	(0) – no (1) – yes
Durations of closures and construction provided	(0) – no (1) – yes

Indicates traffic direction affected by closures and construction	(0) – no (1) – yes
Indicates number of lanes affected by the closures and construction	(0) – no (1) – yes
Time / date stamp of closure and construction data provided	(0) – no (1) – yes
Update frequency of closure and construction data	(0) – unknown (1) – monthly + (2) – weekly - monthly (3) – daily (4) – hourly - daily (5) – less than hourly
Information available on future closure and construction	(0) – none (1) – future closure and construction information available for next 24 hour period (2) – future closure and construction information available for next 72 hour period (3) – future closure and construction information for next 1 week period (4) – future closure and construction information for next 2 week period
Detour information provided for closures and construction	(0) – no (1) – yes
<i>Closures and Construction Content Score</i>	<i>/ 38 points</i>

Weather	
<i>Possible Score -34 points</i>	
Weather information available	(0) – no (4) – yes
Link to weather information available from homepage	(0) – no (5) – yes
Link to homepage available from weather page	(0) – no (1) – yes
Location of information	(0) – no information (1) – information externally linked through other websites (2) – website internal information (3) – both internal and external
Weather information provided in list format	(0) – no (1) – yes
Weather information provided on a map	(0) – no (4) – yes
Zoom capabilities available on map	(0) – no (1) – yes
Clickable or float cursor over map for further information	(0) – no (1) – yes
Legend located on map	(0) – no (1) – yes
Weather data available	(0) – none (1) – area wide (2) – at multiple locations throughout region
Sensor locations provided	(0) – no (1) – yes
Type of weather information available	(0) – none (1) – forecasts (4) – real-time conditions
Temperature data available	(0) – no (1) – yes

Precipitation information available	(0) – no (1) – yes
Wind data available	(0) – no (1) – yes
Road weather (e.g. temperatures, water level) available	(0) – no (1) – yes
Local emergency weather conditions provided	(0) – no (1) – yes
Satellite or radar imagery provided	(0) – no (1) – yes
<i>Weather Content Score</i>	<i>/ 34 points</i>

Message Signs	
<i>Possible Score -21 points</i>	
Message sign information available	(0) – no (1) – yes
Link to message signs information available from homepage	(0) – no (5) – yes
Link to homepage available from message sign page	(0) – no (1) – yes
Message sign information provided in list format	(0) – no (1) – yes
Message sign information provided on a map	(0) – no (4) – yes
Zoom capabilities available on map	(0) – no (1) – yes
Clickable or float cursor over map for further information	(0) – no (1) – yes
Legend located on map	(0) – no (1) – yes
Location of message signs provided	(0) – no (1) – yes

Indicates whether message signs are currently functioning	(0) – no (1) – yes
Indicates message signs currently in use	(0) – no (1) – yes
Messages displayed on signs available	(0) – no (1) – yes
Time / date stamp of message sign data provided	(0) – no (1) – yes
Update frequency of message sign data provided	(0) – no (1) – yes
<i>Message Sign Content Score</i>	<i>/ 21 points</i>

Cameras	
<i>Possible Score -22 points</i>	
Camera information available	(0) – no (1) – yes
Link to camera data available from homepage	(0) – no (5) – yes
Link to homepage available from camera data page	(0) – no (1) – yes
Available cameras provided in list format	(0) – no (1) – yes
Camera locations provided on a map	(0) – no (4) – yes
Zoom capabilities available on map	(0) – no (1) – yes
Clickable or float cursor over map for further information	(0) – no (1) – yes
Legend located on map	(0) – no (1) – yes
Indicates whether cameras are currently functioning	(0) – no (1) – yes

Greatest camera capability available	(0) – none (1) – still images (2) – looped still images (3) – live video feed
Orientation of camera denoted	(0) – no (1) – yes
Time / date stamp of camera images provided	(0) – no (1) – yes
Update frequency of camera images provided	(0) – no (1) – yes
<i>Camera Content Score</i>	<i>/ 22 points</i>

Alternate Transportation Modes	
<i>Possible Score –Varies</i>	
Pedestrian information available	(0) – no (1) – yes
Location of information	(0) – no information (1) – information externally linked through other websites (2) – website internal information (3) – both internal and external
Bicycle information available	(0) – no (1) – yes
Location of information	(0) – no information (1) – information externally linked through other websites (2) – website internal information (3) – both internal and external
Airport information provided	(0) – no (1) – yes

Location of information	(0) – no information (1) – information externally linked through other websites (2) – website internal information (3) – both internal and external
Carpool or vanpool information available	(0) – no (1) – yes
Location of information	(0) – no information (1) – information externally linked through other websites (2) – website internal information (3) – both internal and external
Time / date stamp of real-time information provided	(0) – no (1) – yes
Update frequency of real-time information provided	(0) – no (1) – yes
Paratransit information available	(0) – no (1) – yes
Links available to relevant transportation agencies	(0) – no (1) – yes
<i>High Occupancy Vehicle (HOV) lanes: (9 points)</i>	
High Occupancy Vehicle (HOV) information available	(0) – no (1) – yes
Location of information	(0) – no information (1) – information externally linked through other websites (2) – website internal information (3) – both internal and external
Locations of HOV lanes provided	(0) – no (1) – yes
HOV entrances and exits denoted	(0) – no (1) – yes
HOV regulations provided	(0) – no (1) – yes
HOV hours provided	(0) – no (1) – yes

Real-time information on HOV lanes available (e.g. current status or conditions)	(0) – no (1) – yes
<i>Mass Transit (10 points):</i>	
Mass transit information available	(0) – no (1) – yes
Location of information	(0) – no information (1) – information externally linked through other websites (2) – website internal information (3) – both internal and external
Schedules available	(0) – no (1) – yes
Routes available	(0) – no (1) – yes
Fares available	(0) – no (1) – yes
Real time information available	(0) – no (1) – yes
Delays provided	(0) – no information on delays (1) – general delay notification (2) – quantitative delay times
<i>Alternate Transportation Mode Content Score:</i>	
Without HOV lanes and mass transit-	/ 20 points
Without HOV lanes-	/ 30 points
Without mass transit-	/ 29 points
With HOV lanes and mass transit-	/ 39 points

Other Traveler Information	
<i>Possible Score –Varies</i>	
Special event information available	(0) – no (1) – yes

Environmental information available	(0) – no (1) – yes
Natural hazard information available	(0) – no (1) – yes
Amber Alert information available	(0) – no (1) – yes
Security information available	(0) – no (1) – yes
Travel restriction information available	(0) – no (1) – yes
Tourist information available	(0) – no (1) – yes
Parking information available	(0) – no (1) – yes
Highway rest area locations available	(0) – no (1) – yes
Real-time data on highway–railroad grade crossing available	(0) – no (1) – yes
Personalized traffic alerts available	(0) – no (1) – yes
Highway Advisory Radio (HAR) messages available	(0) – no (1) – yes
511 information available	(0) – no (1) – yes
Capability to download information to PDAs or cellular telephones	(0) – no (1) – yes
<i>Toll Roads: (4 points)</i>	
Toll road information available	(0) – no (1) – yes
Information locality	(0) – no information (1) – information externally linked through other websites (2) – website internal information (3) – both internal and external

<i>Other Traveler Information Content Score</i>	
Without toll roads -	/ 14 points
With toll roads -	/ 18 points

Scoring Guide			
	Score	Possible Points	
General Traveler Information Content			17
Traffic Conditions			38
Incident Information			41
Closures and Construction			38
Weather			34
Message Signs			21
Cameras			22
Alternate Transportation Modes		<i>Please Choose Only One</i>	
		Without HOV lanes and mass transit –	20
		Without HOV lanes –	30
		Without mass transit –	29
		With HOV lanes and mass transit –	39
Other Traveler Information		<i>Please Choose Only One</i>	
		Without toll roads –	14
		With toll roads –	18
Total			
Final Percentage (Total Score / Total Possible Points)			

APPENDIX B: SUBJECT STUDY

Dear Sir or Madam:

Thank you for your participation in this research study. The intent of this survey is to evaluate the user friendliness of traveler information websites. Traveler information websites are designed to provide a variety of transportation information to travelers prior to their trip. The intent is to provide travelers a warning of construction, weather or accident delays. The study will include an evaluation of ten different traveler information websites.

This survey is divided into ten sections, one for each traveler information website. Use the provided address to proceed to each traveler information website. At each site, you will be presented with a scenario. The scenario will identify you as a motorist in the area and describe the route in which you are traveling. You will be asked to accomplish four tasks at the traveler information website regarding the specified route. These tasks will include identifying traffic conditions, incidents, construction, and weather on the route. **After you have completed each task, please rank the ease of completing the task. A ranking of 1 indicates that the task was easily completed. A ranking of 5 indicates that the task was difficult.** If insufficient information is provided on the website to complete the desired task, please mark Not Applicable (N/A). If there are no incidents, construction, etc. on your assigned route due to a lack of activity, evaluate the ability of the site to convey such information. For example, if there is an entire section dedicated to construction with maps and tables for detailed information, evaluate its accessibility. Please gather relevant information only from the specified traveler information website. **After you have completed the four tasks at each website** provide additional comments concerning your experience at that site, and **proceed to the next site.** Any final comments on your experience at the ten traveler information websites can also be provided at the end of the survey. If possible try to visit each site during the morning or evening peak hours (i.e. 6:30 a.m. to 9:00 a.m. or 4:00 p.m. to 6:00 p.m.). For each visit note the time and date of your visit

Please return completed surveys in the preaddressed, stamped envelope. It is appreciated if envelopes are postmarked **no later than July 3rd**. Thank you again for your time.

Sincerely,

Leslie Stengele
Graduate Student
Department of Civil Engineering
Texas A&M University

Arizona Department of Transportation							
http://www.az511.com							
Name:		Logon Time:					
Logon date:		Difficulty Level in Locating Information					
Scenario: You are traveling east on I-10 within the Maricopa Region into the Phoenix city center. Can you determine the following information about your trip?		Easy → Hard				N/A	
Traffic conditions (e.g. travel time, speed, congestion) along the route		1	2	3	4	5	N/A
Incidents (e.g. accidents, stalled vehicles) along the route		1	2	3	4	5	N/A
Construction (e.g. road closures, lane closures) along the route		1	2	3	4	5	N/A
Weather conditions on your trip		1	2	3	4	5	N/A
Please provide further comments on your experience with the Arizona DOT website. (e.g. How do you feel the travel information was presented? What do you like and dislike about the website? What other information would you like to see?)							

Colorado Department of Transportation							
http://cotrip.org							
Name:		Logon Time:					
Logon date:		Difficulty Level in Locating Information					
Scenario: You are in the Metro Denver area traveling south on I-25. Can you determine the following information about your trip?		Easy → Hard				N/A	
Traffic conditions (e.g. travel time, speed, congestion) along the route		1	2	3	4	5	N/A
Incidents (e.g. accidents, stalled vehicles) along the route		1	2	3	4	5	N/A
Construction (e.g. road closures, lane closures) along the route		1	2	3	4	5	N/A
Weather conditions on your trip		1	2	3	4	5	N/A
Please provide further comments on your experience with the Colorado DOT website. (e.g. How do you feel the travel information was presented? What do you like and dislike about the website? What other information would you like to see?)							

Georgia Navigator							
http://www.georgia-navigator.com							
Name:							
Logon date:		Logon Time:					
		Difficulty Level in Locating Information					
Scenario: You are in the Atlanta city center traveling south on I-75. Can you determine the following information about your trip?		Easy → Hard				N/A	
Traffic conditions (e.g. travel time, speed, congestion) along the route		1	2	3	4	5	N/A
Incidents (e.g. accidents, stalled vehicles) along the route		1	2	3	4	5	N/A
Construction (e.g. road closures, lane closures) along the route		1	2	3	4	5	N/A
Weather conditions on your trip		1	2	3	4	5	N/A
Please provide further comments on your experience with the Georgia Navigator website. (e.g. How do you feel the travel information was presented? What do you like and dislike about the website? What other information would you like to see?)							

Houston TranStar							
http://www.houstontranstar.org							
Name:							
Logon date:		Logon Time:					
		Difficulty Level in Locating Information					
Scenario: You in the Houston city center traveling east on I-10. Can you determine the following information about your trip?		Easy → Hard				N/A	
Traffic conditions (e.g. travel time, speed, congestion) along the route		1	2	3	4	5	N/A
Incidents (e.g. accidents, stalled vehicles) along the route		1	2	3	4	5	N/A
Construction (e.g. road closures, lane closures) along the route		1	2	3	4	5	N/A
Weather conditions on your trip		1	2	3	4	5	N/A
Please provide further comments on your experience with the Houston TranStar website. (e.g. How do you feel the travel information was presented? What do you like and dislike about the website? What other information would you like to see?)							

Kansas City Scout						
http://www.kcscout.net						
Name:					Logon Time:	
Logon date:						
						Difficulty Level in Locating Information
Scenario: You in the Kansas City center traveling east on I-70. Can you determine the following information about your trip?						Easy → Hard N/A
Traffic conditions (e.g. travel time, speed, congestion) along the route						1 2 3 4 5 N/A
Incidents (e.g. accidents, stalled vehicles) along the route						1 2 3 4 5 N/A
Construction (e.g. road closures, lane closures) along the route						1 2 3 4 5 N/A
Weather conditions on your trip						1 2 3 4 5 N/A
Please provide further comments on your experience with the Kansas City Scout website. (e.g. How do you feel the travel information was presented? What do you like and dislike about the website? What other information would you like to see?)						

Montana Department of Transportation						
http://www.mdt.state.mt.us/travinfo						
Name:					Logon Time:	
Logon date:						
						Difficulty Level in Locating Information
Scenario: You are traveling east on I-90 from Bozeman. Can you determine the following information about your trip?						Easy → Hard N/A
Traffic conditions (e.g. travel time, speed, congestion) along the route						1 2 3 4 5 N/A
Incidents (e.g. accidents, stalled vehicles) along the route						1 2 3 4 5 N/A
Construction (e.g. road closures, lane closures) along the route						1 2 3 4 5 N/A
Weather conditions on your trip						1 2 3 4 5 N/A
Please provide further comments on your experience with the Montana DOT website. (e.g. How do you feel the travel information was presented? What do you like and dislike about the website? What other information would you like to see?)						

San Antonio TransGuide						
http://www.transguide.dot.state.tx.us						
Name:					Logon Time:	
Logon date:						
						Difficulty Level in Locating Information
Scenario: You are traveling north on US-281 from the San Antonio city center. Can you determine the following information about your trip?						Easy → Hard N/A
Traffic conditions (e.g. travel time, speed, congestion) along the route		1	2	3	4	5 N/A
Incidents (e.g. accidents, stalled vehicles) along the route		1	2	3	4	5 N/A
Construction (e.g. road closures, lane closures) along the route		1	2	3	4	5 N/A
Weather conditions on your trip		1	2	3	4	5 N/A
Please provide further comments on your experience with the San Antonio TransGuide website. (e.g. How do you feel the travel information was presented? What do you like and dislike about the website? What other information would you like to see?)						

SmarTraveler (Boston)						
http://www.smartraveler.com						
Name:					Logon Time:	
Logon date:						
						Difficulty Level in Locating Information
Scenario: You are traveling south from the Boston city center on I-93. Can you determine the following information about your trip?						Easy → Hard N/A
Traffic conditions (e.g. travel time, speed, congestion) along the route		1	2	3	4	5 N/A
Incidents (e.g. accidents, stalled vehicles) along the route		1	2	3	4	5 N/A
Construction (e.g. road closures, lane closures) along the route		1	2	3	4	5 N/A
Weather conditions on your trip		1	2	3	4	5 N/A
Please provide further comments on your experience with the SmarTraveler website. (e.g. How do you feel the travel information was presented? What do you like and dislike about the website? What other information would you like to see?)						

Traffic.com (Washington D.C.)

<http://www.traffic.com>

Log in information

User Name: usersurvey

Password: 8star39M

Name:

Logon date:

Logon Time:

	Difficulty Level in Locating Information					
	Easy	→	Hard	N/A		
Scenario: You are traveling west from the Washington D.C. city center on I-66. Can you determine the following information about your trip?						
Traffic conditions (e.g. travel time, speed, congestion) along the route	1	2	3	4	5	N/A
Incidents (e.g. accidents, stalled vehicles) along the route	1	2	3	4	5	N/A
Construction (e.g. road closures, lane closures) along the route	1	2	3	4	5	N/A
Weather conditions on your trip	1	2	3	4	5	N/A

Please provide further comments on your experience with the Traffic.com website. (e.g. How do you feel the travel information was presented? What do you like and dislike about the website? What other information would you like to see?)

Washington State Department of Transportation

<http://www.wsdot.wa.gov>

Name:

Logon date:

Logon Time:

	Difficulty Level in Locating Information						
	Easy	→	Hard				N/A
Scenario: You are traveling north on I-5 from Seattle in the Pudget Sound Region. Can you determine the following information about your trip?							
Traffic conditions (e.g. travel time, speed, congestion) along the route	1	2	3	4	5		N/A
Incidents (e.g. accidents, stalled vehicles) along the route	1	2	3	4	5		N/A
Construction (e.g. road closures, lane closures) along the route	1	2	3	4	5		N/A
Weather conditions on your trip	1	2	3	4	5		N/A

Please provide further comments on your experience with the Washington State DOT website. (e.g. How do you feel the travel information was presented? What do you like and dislike about the website? What other information would you like to see?)

Please leave any final comments on the traveler information sites included in the study.

APPENDIX C: TALLY OF SUBJECTIVE EVALUATION RATINGS

Locality	Traffic Conditions					Incidents					Construction					Weather									
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5					
	N / A					N / A					N / A					N / A									
Public/Statewide 1	9	1	0	0	0	9	1	0	0	0	7	3	0	0	0	0	9	1	0	0	0	0	0	0	0
Public/Statewide 2	8	0	0	1	0	4	0	0	2	1	1	5	2	0	2	0	0	8	0	0	1	0	0	1	0
Public/Statewide 3	6	1	3	0	0	4	4	1	0	1	0	3	4	1	1	1	0	2	3	0	1	1	1	1	3
Public/Statewide 4	3	3	2	1	1	0	2	4	3	0	1	0	2	5	2	0	1	0	1	2	0	1	1	1	5
Public/Statewide 5	1	1	2	2	1	3	4	0	4	2	0	0	2	5	0	1	0	2	3	2	1	2	1	2	0
Public/Metropolitan 1	7	2	0	0	0	8	1	0	0	0	0	8	1	0	0	0	0	6	1	1	1	1	0	0	0
Public/Metropolitan 2	5	4	0	1	0	0	6	3	0	1	0	0	4	5	0	1	0	0	3	1	2	0	2	0	2
Public/Metropolitan 3	3	3	3	0	1	0	4	2	1	0	3	0	4	0	0	1	4	0	4	1	2	1	2	1	0
Private/Metropolitan 1	6	1	0	2	0	0	6	3	0	0	0	0	3	4	0	0	0	1	0	1	0	1	0	2	5
Private/Metropolitan 2	1	2	3	1	1	1	1	3	1	1	1	2	2	2	0	1	1	3	1	0	1	3	0	1	4

LESLIE STENGELE

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APPLICATIONS OF ITS FOR PLANNED SPECIAL EVENTS IN TEXAS

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SUMMARY

The purposes of this report were: (1) create a literature review of planned special events and an intelligent transportation systems (ITS) overview, (2) examine three case studies which showed benefits of ITS in planned special events, (3) examine the current practices of ITS in planned special events in Texas, (4) create a case study and apply ITS to a planned special events, and (5) develop a list of findings from the case study.

A questionnaire was administered to six districts of the Texas Department of Transportation. All six of the districts responded with either an e-mail response or telephone interview. The responses helped determine how each district views planned special events, the current ITS infrastructure, the use of ITS in planned special events, coordination in special event planning and operations, and possible future usage of ITS in planned special events.

The findings from the review of the literature, questionnaires, interviews, and various other sources were:

- ITS is a system: each part is crucial
- For planned special events ITS must be able to go portable.
- ITS must be reliable.
- ITS planning should have venues of planned special events as a focus.
- Changeable message signs (CMS) are a useful and reliable way to communicate information and manage traffic for planned special events, when operated correctly.
- Closed circuit television (CCTV) is the best monitoring source and excellent public relation tool to the media for planned special events.
- Parking information is very important to motorists during planned special events.
- Using ITS during planned special events allows motorists to be better informed. Also, using ITS, may allow for less personnel that may be needed to manage and direct traffic; therefore, a lower safety concern is produced for personnel.
- Interagency coordination is a prerequisite for ITS in planned special events that crosses institutional boundaries.

The literature review and questionnaire were used as guidelines to apply ITS to a current traffic management plan in order to improve traffic management and lower demand on each particular road during graduation ceremonies at Texas A&M University. The use of CCTV and CMSs are expected to provide major benefits in the test case study. From the case study, questionnaire, and literature review the previously mentioned findings were determined.

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INTRODUCTION

A planned special event is “a public activity with a scheduled time, location, and duration that may impact the normal operation of the surface transportation system due to increased travel demand and/or reduced capacity attributed to event staging (1).” Planned special events can have a significant impact on the travel safety, mobility, and travel time reliability on the surface transportation system. As a result, the goals of managing a planned special event are: achieving predictability, ensuring safety, maximizing efficiency, and meeting public and event patron expectations (2). Since planned special events typically have a known time, location, and duration, engineers have the opportunity to anticipate, coordinate, and plan what the resulting impacts may be on the surface transportation system. This luxury of managing traffic is not available for unplanned events (3).

Intelligent transportation systems (ITS) are tools that can have a large positive impact on the goals of managing planned special events. ITS can be applied to a planned special event in several ways. The information a motorist obtains before, during, and after an event can be enhanced by changeable message signs, media, highway advisory radio, and other ITS techniques. Also, traffic demand management can be enhanced with the use of ITS. With the application of ITS in these three areas of planned special events many benefits can arise. These benefits include: reduced congestion, improved mobility, improved travel safety (1), and improved patron confidence in travel time, motorist information, and mass transportation to events. Both motorists who are attending the event and those who are not attending the event will experience the positive aspects that using the application of current technology of ITS at planned special events will bring.

The increase and enhancement of the use of ITS tools in both areas that contain current ITS systems and areas that do not contain such systems is of equal importance. Bringing ITS into smaller venues where no current system is in place can be as important as implanting ITS at a large venue with a current system.

Problem Statement

Congestion as a result of planned special events has a significant impact on traffic flow on roadways serving an event venue. Management of these events is critical to the traffic flow. Conducting a study of ITS and planned special event practices in Texas will allow one to examine what Houston, San Antonio, Dallas, Fort Worth, El Paso, and Austin TxDOT Districts are currently doing to manage motorist information, traffic flow, and traffic demand management during planned special events. With the ever-increasing amount of drivers using the surface transportation facilities, there is a need to manage planned special events effectively. Engineers need to explore and implement both new intelligent transportation systems and successful current systems especially in Texas cities where the population growth rate is among the highest in the nation.

Scope

Applications of ITS technology with managing travel for planned special events in Texas were identified. The focus was six TxDOT districts. Summarizing and comparing the information obtained, allowed the author to state their findings and make recommendations for best practices. Through examining planned special events the author looked solely at how ITS interacted with planned special events by effecting traffic management, motorist information, and traffic demand.

Research Objectives

The primary objectives of this research are:

- Conduct a literature review on current up-to-date planned special events and ITS product information;
- Examine and summarize current ITS practices for planned special events in Texas;
- Compare different ITS techniques used in planned special events;
- Apply knowledge of ITS uses with planned special events to a case study;
- Draw findings based on the usage of ITS in planned special events.

STUDY APPROACH

This research project was divided into four major sections. In the first section, a literature review was conducted. The literature review consisted of an overview of planned special events and a description of various ITS technologies that are available. Included in the literature review are application examples of ITS for planned special events. Next, a questionnaire was sent out to six Texas Department of Transportation districts. The purpose of the questionnaire was to find out the ITS infrastructure of each of the selected districts, to determine how the engineers at the various districts viewed planned special events, and to understand how the traffic operators at each districts applied ITS to planned special events. The results of the questionnaire also provided information on agency coordination and the future possibilities of ITS in planned special events in Texas. The third step was to use the knowledge obtained through the research and then apply the newly gained insight of ITS in planned special events to a case study. The case study was applying ITS to a current traffic management plan for graduation ceremonies at Reed Arena in College Station, Texas. The last step was to summarize a list of findings based on the questionnaires, literature review, and case study experience.

LITERATURE REVIEW

Overview of Planned Special Events

A planned special event is “a public activity with a scheduled time, location, and duration that may impact the normal operation of the surface transportation system due to increased travel demand and/or reduced capacity attributed to event staging (1).” Stakeholders charged with managing and controlling traffic during planned special events have many challenges. These challenges include:

- Managing intense travel demands;
- Mitigating potential capacity constraints;
- Influencing the utility associated with various travel choices;
- Accommodating heavy pedestrian flow (1).

When planning for special events several main goals exist. The goals of managing travel for planned special events are:

- Achieving predictability;
- Ensuring safety;
- Maximizing efficiency;
- Meeting public and event patron expectations (2).

Many stakeholders are involved in planning and preparing for venue such as planned special event that has a significant impact on traffic flow. With such a wide variety of stakeholders, intense planning is necessary for a planned special event. When the traffic management plan is carried out successfully, many benefits will arise to both the community and stakeholders. The motorists will receive a transportation system that provides reduced congestion, increased mobility, improved safety, and the drivers will experience less frustration while traveling. Transportation officials, as a result of a thankful community, will have more faith instilled into them by the public, which in turn results in more political support. With the new-found political support, agencies can develop and incorporate new technologies to improve everyday traffic congestion. Also, new transit riders can be attracted to a planned special event as a result of a successful transit program. Communication and sharing of equipment between the many agencies is enhanced. Sharing of information and equipment will save the cities and states time and money. Lastly, the community as a whole will benefit. If a community can prove that it can handle large events, then more venues will come to town. The ability to attract planned special events because of good traffic management will fuel the economy and promote tourism. Also, smaller venues would be more likely to lease the services of traffic management if they feel it will help their event operate smoothly.

Planned special events can be classified by the following characteristics and types:

- Location
- Area
- Time
- Attendance
- Audience
- Event type (Table 1)
- Scope
- Duration (2)

The practice of managing travel for planned special events involves advance planning, management, and evaluation activities encompassing five distinct, chronological phases: (Figure 1) (1).

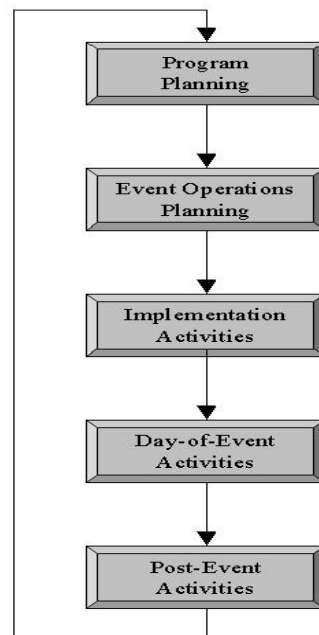


Figure 1. Planned Special Event Management Phases (1)

Table 1. Planned Special Event Types and their Characteristics (1)

Event Type	Characteristics
Discrete/recurring event at a permanent venue	<ul style="list-style-type: none"> • Time specific duration • Specific starting and ending times • High peak arrival rates • Weekday event occurrences • Known venue capacity • Advanced ticket sales
Continuous event	<ul style="list-style-type: none"> • Occurrence over multiple days • Arrival and departure of event patrons throughout event day • No sharp peak arrival or departure rates • Capacity of venue unknown • Located at temporary venues
Street use event	<ul style="list-style-type: none"> • On a surface street requiring temporary closure • Affects background traffic flow • Unknown capacity of spectator viewing area • No charge and tickets for spectators
Regional/multi-venue event	<ul style="list-style-type: none"> • Located at multiple venues • Time specific duration or continuous or both • Regional market area
Rural event	<ul style="list-style-type: none"> • Rural or rural/tourist area • High attendance attracting people for a regional area • Limited roadway capacity • Lack of regular transit services

Intelligent Transportation Systems Techniques

ITS has been defined as “the use of information technology to improve travel and manage traffic on America’s highways and transit systems. The goal of the national movement is safer, quicker travel. Indirect benefits are improved productivity, a cleaner environment, and new business opportunities for America (5).” ITS technology is becoming one means of improvement for many aspects of transportation. Managing planned special events is no exception. With the use of this technology, the motorists are capable of making better-informed and more comfortable decisions. Also, the managers of the roadway system can easier and more effectively control and observe the events in real time. NCHRP recently conducted a survey of the tools and techniques used by agencies involved in special event planning (3). The results of the NCHRP survey are shown in Table 2. Many of the commonly used techniques are ITS which are specially highlighted.

Table 2. NCHRP 309 Tools and Techniques Currently Used (3)

Tools and Techniques	Frequency
Motorist Information	
• Changeable message sign	29
• Media partnerships	25
• Pre-event informational campaigns	25
• Highway advisory radio	10
• Other	4
Traffic Management	
• Traffic cones	29
• Temporary lane closures	29
• Portable static signs	28
• Traffic management teams	22
• Traffic management centers	20
• Law enforcement motorcycle patrols	18
• Traffic responsive signal systems	18
• Law enforcement service patrols	18
• Non-law enforcement motorcycle patrols	15
• Video and closed circuit television	15
• Reversible lanes/movable barriers/temp. contra-flow	15
• Electronic loop detection	13
• Aircraft patrols	11
• Portable traffic signals	6
• Major capacity improvements	6
• Ramp metering	4
• Other	1
Travel Demand Management	
• Park-and-ride lots	24
• Alternative routes	18
• Parking management	16
• Economic or incentives for public transportation	9
• Automobile-restricted zones	8
• Major transit improvements	4
• Economic or preferential incentives for walking/biking	2
• Alternate travel hours	2
• Other	1

Changeable Message Signs (CMS)

Changeable message signs have a changeable display. This feature allows a variety of information to be given to the motorist. By allowing sign messages to be changed from a remote location, the information given to the motorist can be up-to-date and real-time, and therefore, most helpful and accurate. This information can range from travel times, lane closures, other infrastructure changes, parking lot occupancy, directions to help the motorist avoid congestion/incidents, and many other traveler information displays.

As seen in Table 2, changeable message signs are already being widely used in planned special events. A study conducted by C. Dudek in Dallas demonstrated that the usage of changeable message signing can have a significant impact on route diversion to a planned special event. Different types of messages were tested in the study. Some messages were found to be more effective than others, but all the messages had a large influence on motorists and significantly increased the route diversion to the planned special event (6,7).

CMSs are both portable and permanent and can provide many benefits. Congestion can be reduced by providing information to motorists in advance of the event, so an alternative route may be chosen. Also, the motorists can be informed of potential problems that might occur along the route to the event (1). In Table 2 CMSs are only listed in motorist information, but it is evident the CMS also effect traffic management and traffic demand on a certain routes.

Composing a message for a CMS requires personnel at the traffic management centers to consider numerous factors. The engineers or operators must consider the content and length of the message as well as memory load for motorists when designing messages for the CMS.



Figure 2. A Portable CMS (Courtesy of Wisconsin DOT) (1)

Traffic Management Center (TMC)

A traffic management center is the central communication hub for traffic information (3). At the TMC various agencies can work together to best monitor and control the traffic operations. Many of the technological tools used in planned special events are housed in this area. The tools contained at the TMC are: (1) maps displays showing real-time traffic and transit conditions, (2) video display walls, (3) changeable message signs, (4) closed-circuit television control systems, (5) telephone and radio communications, and (6) incident management and traffic signal control systems (1).

A portable TMC is sometimes used in planned special events. Many of the same ITS tools that can be operated from a permanent TMC can be also operated for a portable TMC if the technology is available. The portable TMC allows traffic engineers and others responsible for managing traffic at a planned special event to be close to the venue and also enables one to install temporary portable technology that can be operated through a smaller facility rather than the large central TMC.

Highway Advisory Radio (HAR)

Highway advisory radio is a tool that contains many of the same uses as the CMS. Information from the HAR is normally broadcasted on 530 AM, 1610 AM, or 1680 AM frequencies. HAR is available in both permanent and portable forms. HAR can provide benefits that cannot be obtained with CMS. By using a HAR, traffic operators are able to convey a longer more detailed message to the drivers. Through the use of the HAR traffic operators can advise drivers exactly what is going on and how to avoid it. Information such as detours, parking, events, hazards, and various other traffic conditions that may arise can be broadcasted on the HAR. FCC rules and regulations must be followed, and a special section is written in the FCC regulations for HAR.

Three disadvantages can be associated with the use of HAR. A traffic operator must inform the motorists that a HAR exists by installing signs such as those shown in Figure 3. Then, the traffic operator must convince the individual to tune to the radio station by either flashing amber lights or designing a message that will convince the motorist to tune to a certain station. In a research study, conducted by J. Dabney and C. Dudek, in New Braunfels, Texas, HAR usage was examined. The HAR was used to communicate traveler information for the WurstFest celebration. The results of the study showed that one-third of the motorists tuned to the radio station, and of that third, two-thirds diverted to an alternate route (8). Secondly, the HAR can be limited due to geographic conditions because the AM frequencies may not be reliable or effective in all areas of the country (e.g. mountains). An investigation should be done to make sure HAR is a reasonable alternative for motorist information before it is implemented (3). Lastly, the user interface for changing recorded messages can be very difficult, requiring a significant amount of time and occasionally resulting in errors (9).



Figure 3. Portable HAR and Portable and Static Signage for HAR (10)

Closed-circuit Television (CCTV)

CCTV is one of the oldest forms of monitoring traffic for any event. CCTV allows for monitoring of real-time traffic during event ingress and egress operations. The CCTV can be portable and the images produced by the cameras can be monitored at a permanent TMC or a portable TMC. This real time visual image allows for engineers to see and get a feel of how the traffic is behaving and adjust plans accordingly. CCTV videos allow operators to obtain data of volume and speed that can be used later for planning and analysis.



Figure 4. CCTV in El Paso, TX (11)

Traffic-responsive Traffic Signal System

Traffic-responsive traffic signal systems allow for adjustments to the cycle length, splits, offsets, and phasing when traffic conditions change. Adjustments are made in response to data obtained from electronic loop detectors and video detection. Proper adjustment of the four characteristics of signal timing can greatly increase traffic progression and efficiency. An extension of green time on a roadway leading to a venue during peak arrival time could minimize congestion and increase the level of service of the roadway. For non-responsive signal systems special timing plans can be developed and used in the areas of recurring planned special events.

Vehicle Detectors

Vehicle detectors play much of the same role as the CCTV. Detectors are used to monitor the volume or speed of traffic. Based on the data received, the traffic management team can make decision on how to manage traffic flow. Data from vehicle detectors can also be saved for future use for the next planned special event that will occur at the particular venue.

Telephone Information System/Hotline

A telephone information system is used to provide motorists up-to-date, real-time information. The motorists can dial a number and reach a computer service that they are able to navigate through menus and find information pertaining to the traffic in a desired area. Some telephone information systems allow motorists to report an incident in an area. Early detection and verification of incidents can result and would allow for quicker response times by the highway agencies. As a result an improvement incident management system could occur. Although telephone information systems are a very useful tool, the development of such a system is an expensive undertaking. A national initiative of using 511 as a universal number to call to get travel information has reported several success stories in the states that currently use this technology (12).



Figure 5. 511 Telephone Information System Icon

Overhead Lane Control Signals

Overhead lane control signals (LCS) are changeable signals that are located over each lane of a roadway. LCS indicates information to the motorist of what lanes to travel in, whether a lane is closed, or when a driver should merge to another lane. A lane closure or merger could be a result of an incident that the motorist may not be aware of, but the traffic operators at the TMC through loop detectors or CCTV, have discovered and are trying to manage the traffic in advance. Also, overhead lane control signals are used to indicate what lanes the motorists should travel in to reach a certain venue. For instance, overhead lane control signals can indicate that motorists can use both of the two right lanes to reach the planned special event destination.



Figure 6. Overhead Lane Control Signal in El Paso (11)

Portable Traffic Signals

The Manual on Uniform Traffic Control Devices (MUTCD) defines portable traffic signals as a temporary traffic control signal that is designed, so that it can be easily transported and reused at different locations (13). The MUTCD also requires that the signal:

1. Meet the physical display and operational requirements of a conventional traffic control signal.
2. Be removed when no longer needed.
3. Be placed in the flashing mode when not being used if it will be operated in the steady mode within 5 working days; otherwise, it shall be removed.
4. Be placed in the flashing mode during periods when it is not desirable to operate the signal, or the signal heads shall be covered, turned, or taken down to indicate that the signal is not in operation (13).

Because of the requirements placed by the MUTCD, the portable traffic signal serves well in continuous planned special events of long duration such as the Olympics or a street closure for a movie. The portable traffic signal improves safety by eliminating a flagman that might have been directing traffic. If the portable traffic signal is timed properly, the level of service of an intersection can be increased as opposed to placing a temporary stop sign; however, a long event of large magnitude is needed to warrant such a device.



Figure 7. Example of a Portable Traffic Signal (14)

Dynamic trailblazer signs

Dynamic trailblazer signs inform the motorists of information of how to leave or reach a venue. Much congestion and frustration occurs when a driver does not know how to leave the venue in the direction in which the traffic management plan directs them to go. The dynamic trailblazer signs allow for this information to be displayed to the driver and also can give real-time information informing the driver how far or how long they are from their destination. Figure 8 shows an example of a dynamic trailblazer sign. Under a bypass condition as shown for I-45 South in Figure 8 the motorists are routed an alternate way from the freeway. When the bypass sign is blank this is the default condition. In the default condition the directional arrow is pointed in the same direction as a standard static sign. (15)



Figure 8. Example of a Dynamic Trailblazer Sign (15)

Changeable Speed Limit Signs

Changeable speed limit signs both inform the motorist of information of traffic conditions and help control traffic flow. Changeable speed limit signs have a dynamic message sign to display a current speed limit based on real-time traffic data or current weather conditions. Changeable speed limit signs are a tool whose purpose is to reduce speed variation, lower speed related accidents, and promote stable traffic flow. Creating a stable traffic flow can help provide a safer, less stressful and faster commute to a special event. A cost-benefit analysis, conducted by J. Wilkie, of a section of the Capital Beltway in Maryland showed that from accident costs alone the benefit is approximately 3.25 times the cost of installing a changeable speed limit system (16).

Ramp Meters

Ramp meters are traffic signals installed on entrance ramps of freeways to control the rate at which the traffic enters the freeway. By controlling when vehicles enter the freeway, it is anticipated that the

merging vehicles will have less of an effect on slowing through traffic and cause fewer accidents. Ramp metering can lessen congestion and provide more consistent travel times. However, ramp metering can cause queuing on entrance ramps and spillback on the access and secondary streets.

Users of freeways with ramp metering can experience less turbulence at the ramp junctions where most congestion occurs. The result of less turbulence at access points can result in improved efficiency of the mainline freeway, thus reducing the overall trip time for a motorist to their destination such as a planned special event (1).



Figure 9. Example of Ramp Metering

Incident Management Systems

Incident management systems involve detecting, confirming, responding, and clearing an incident. For every minute an incident takes to move from the roadway lanes, the resulting traffic congestion can last much longer. Restoring the traffic to normal control is the goal of incident management, and this task requires coordination among many agencies in a region. In planned special events it is critical to restore traffic to its normal flow pattern. Figure 10 shows a freeway service patrol or emergency response unit in Georgia. Incident management units can help clear up incidents because many tools needed are already on board and can be very helpful if the emergency response units are located near a planned special event.



Figure 10. Emergency Response Unit (17)

Advanced Parking Systems

Parking management systems are designed to monitor the use of and location of parking spaces. Knowledge of available parking can reduce the likelihood of drivers circulating through an area to search for a parking spot. Also, when a "lot is full" is displayed on a sign far enough in advance of a parking facility, drivers are able to modify their parking plans. Furthermore, selling tickets with advanced parking information and an assigned spot could help reduce parking confusion. In addition, at frequent venues an automatic toll system would be useful by not causing back up of cars waiting to get into the lot.

Applications Examples of ITS for Planned Special Events

Although several planned special events occur every year throughout the United States, few planned special events have literature documenting benefits of ITS usage during the event. The following sections summarize several examples of the benefits of ITS for planned special events.

Atlanta 1996 Olympic Games (18)

The 1996 Atlanta Olympic Games brought on a major push in the use of ITS in traffic management and motorist information. The Atlanta metropolitan region was the location of the most ambitious ITS deployment in the United States at that current time. The deployment included the establishment of eight regional agencies, including a traffic management center, six traffic control centers, and one transit information center. The ambitious plan also included a travel information showcase (TIS), an extension of the Metropolitan Atlanta Rapid Transit Authority (MARTA) Rail network and new high occupancy vehicle lanes (18). The goal was to successfully accommodate the twenty-five million people who would attend the events over the seventeen-day period. This was the largest Olympic Game to date, and had more paying spectators than the Los Angeles and Seoul Olympic Games combined.

In addition to building centers, Atlanta's ITS infrastructure was increased. Eighty-nine CCTVs were installed and 319 video imaging cameras were installed on the freeways. The CCTVs verified sixty-one percent of the incidents that occurred during the 1996 Atlanta Olympic Games (18). Furthermore, twenty CCTVs were built on arterials for the 1996 Atlanta Olympic Games and thirty-seven were planned to be built in the future. Throughout the freeways forty-four CMS were placed, and seventeen of these signs were placed on the high occupancy vehicle (HOV) lanes. In addition, twelve HAR cells were placed around the city in strategic locations. During the Olympic Games the incident response team, the HEROS, covered 2,200 miles/day and responded to eighty-five incidents per day which was a sixty percent increase from the HEROS normal amount of incidents.

The ITS MARTA '96 program was created to increase the amount of transit riders during the Olympics, and the new technology was hoped to create an increase in mass transit usage during other times of the year. The program included creating a geographic information system. Also, included in the program was the use of fiber optic links to allow MARTA to access other agencies CCTVs. Automatic vehicle location was installed that enabled transit operators to know the location of the vehicles at all times. Automated passenger counts were used that now enabled MARTA to keep track of the amount of passengers who boarded and left at each location. Passenger Routing and Information System (PARIS) was available online to people who wished to plan their routes out based on the bus system. A smart card system was put into place that allowed passengers to swipe a card that would be debited for each ride; however, only 1.9 percent of passengers during the 1996 Atlanta Olympic Games used the smart card because free fare was offered with an Olympic Game ticket, and other discounts were offered that were not available if the smart card was used. As a result of the various technologies implemented the transit system increased 170 percent in passengers during the weekdays and had a 104 percent increase on the weekends during the 1996 Atlanta Olympic Games (18).

The Georgia Department of Transportation also focused on Advanced Traveler Information Systems. This system consisted of: CMS, HAR, Traffic Advisory Telephone Services (TATS), Bulletin Board Service (BBS), kiosks, and Atlanta's transportation information system (TIS). The TATS and BBS which would have provided real-time traffic information via the telephone or Internet, respectively, did not come online for the games. Also, the HAR was shut down during the first week of the Olympic Games because the operators were not certain that the signs, that flashed indicating to the motorists to tune to the proper radio station, were working correctly. One hundred kiosks were placed around the city that provided: real-time traffic and incident data from the Advanced Traffic Management System (ATMS), route planning, transit schedules and PARIS, weather, airline information, rideshare, special event information, and Olympic route planning and parking. Lastly, Atlanta's TIS included: Internet, cable television,

interactive television, in-vehicle navigation devices, and personal communication tools. Seven hundred thousand people had access to Georgia's travel information station, and the interactive television was placed in several hotels with a map printing option. A result of a survey conducted in the *1996 Atlanta Centennial Olympic Games and Paralympics Games Event Study* stated that the Internet was the most useful tool for traveler information for the 1996 Atlanta Olympic Games, and 80 percent of the respondents made one or more changes to travel plans or decisions based on what the Internet displayed (18).

The *1996 Atlanta Centennial Olympic Games and Paralympics Games Event Study* stated "ITS technologies can have a positive impact on incident management, and they offer potential for future improvement in the area of traffic and transit management and traveler information. Achievable goals should be set for ITS deployments in connection with major events. Interagency coordination is a prerequisite for ITS deployments that cross institutional boundaries (18)."

Salt Lake City 2002 Winter Olympic Games

The 2002 Winter Olympic Games had an extensive ITS system. The goal was to accommodate the approximately 1.7 million attendees of the game without them having to worry about traffic congestion. This goal was shown to be achieved in a poll that was taken by the *Salt Lake City Tribune* after the Games. Eighty-seven percent of the participants who took the poll rated the transportation systems as either good or excellent. Only four percent of the participants rated transportation as one of the two largest negatives of the Games (19).

The ITS system used for managing traffic during the Winter Olympic Games can be divided into two components: Advanced Traffic Management System (ATMS) and Advanced Traveler Information System (ATIS). Under ATMS a TMC and several satellite centers were deployed to manage traffic effectively. Over 600 traffic signals were under control by the operation center and satellite centers. Traffic detectors existed at every half-mile on all freeways in the area. The data obtained from the traffic detectors was sent to the TMC. CCTV were also located along the freeways every six-tenth of a mile and allowed for a user to pan, tilt or zoom the cameras. The CCTV system was noted to be clearly the most valuable surveillance tool during the Winter Olympic Games, and with the ever-increasing importance of public safety in the transportation system, the CCTV will become an even more important tool during day-to-day operations (2). Incident management was improved as a result of the increased surveillance ability.

Figure 11 shows the various sites where some of the sixty-three CMS were placed. The ATMS team thought the CMSs and CCTVs were invaluable tools in the traffic management plan. CMS was the most valuable tool to display information to the motorists while the CCTVs provided a traffic-management tool to the traffic operators because of the surveillance images that the CCTVs provided.



Figure 11. Location of CMS at 2002 Olympic Games (2)

HAR also provided motorists with traffic information and assisted with the management of traffic by conveying knowledge of alternate routes when an incident or traffic congestion occurred. Twelve transmitters for HAR were placed around the region. Although much user information could be provided through the radio, several complications occurred. The ability to change messages was difficult due to interruptions in cellular communications attributed to heavy cell phone use by visitors and event patrons, so it was difficult to provide real time information. Also, some of the batteries of the units went out making the HAR temporarily unavailable and thus causing a loss of faith by the drivers in the system (2).

ATIS consisted of four main means to communicate information. First, a website called CommuterLink (CLW) was used. The information that could be obtained for the website was: traffic conditions, roadway conditions, weather, and Olympic information. Figure 11 is from the CommuterLink website and showed messages from the various CMS. During the Winter Olympic game period the CommuterLink website had over eight times as many hits as it did during any other period of the same length. The accuracy and availability of the incident information was the best compared to the HAR or 511 service. (2)

HAR and CMSs were used to give information to the motorists. The 511 was another means of information dissemination. Of the people that used 511 two-thirds used it for traffic information. During the first two days 4000 calls were received each day as opposed to 290 calls received on a typical day in May in 2002.

Because of the successful planning and use of ITS to convey information and manage traffic at the 2002 Olympic Games, most visitors were pleased with the transportation system (3).

Phoenix International Raceway (PIR)

Phoenix International Raceway (PIR) hosts many car racing events which have audiences that range from 1,000-150,000 people. There was a desire for improvement in transportation and parking at the PIR. Since PIR is a site that holds many events, the techniques used for special events planning and management could become permanent (3).

Motorist information is disseminated through portable and permanent CMS signs along the freeway as well as three HAR radio transmitters, which cover a radius of three miles around the site. Traffic operators monitor the traffic flow at three TMCs through CCTV cameras. The cameras allow for real-time decisions by system operators. Also, vehicle detectors are used primarily for post-event counts and analysis. Dynamic trailblazer signs are located near primary decision points and assembled with illuminated display direction arrows. Dynamic trailblazer signs are the primary traffic control in the area near the racetrack (3). Traffic demand is controlled by encouraging the use of park-and-ride facilities. Maps are published on their web site (Figure 12) and hard copies are handed out to show the various methods to arrive at the desired parking lot.

Most of the means of information flow is through the ITS infrastructure to the TMC centers. The results of this management system, which relies heavily on ITS infrastructure, are significant. In 1998 the average travel time to PIR from Phoenix was two to three hours. In 1999 these times dropped to forty-five minutes and by 2000 they were reduced to twenty to thirty minutes. This large reduction in time improves quality of life for the drivers and also has a positive impact on air quality. Parking lot clearance also was reduced by two hours through new technology applications. These notable improvements in traffic and parking operations occurred despite a noted overall increase of 50,000 total vehicles (annual traffic) between events occurring in 1998 and 2000 (3).

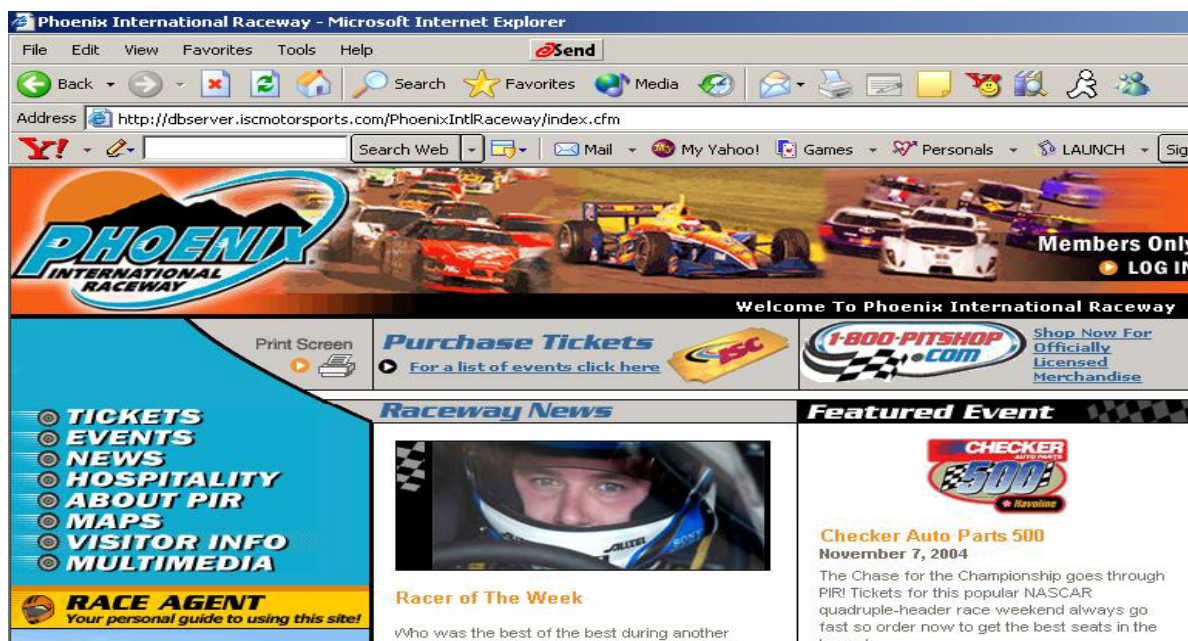


Figure 12. Phoenix International Raceway Website Containing Links for Routes and Parking Maps

QUESTIONNAIRE AND INTERVIEW RESPONSES

Personnel from several districts of the Texas Department of Transportation (TxDOT) were contacted to answer questions regarding ITS and the use of ITS during planned special events. The target for this study of ITS in planned special events was the TxDOT Districts that contained the largest and fastest growing cities in the state. Of the six districts contacted, two decided to do phone interviews and four responded by emailing the questionnaire back. Table 3 contains a list of the contacts and Appendix A has a copy the questionnaire that was sent out. This questionnaire formed the bases for the two phone interviews. This section summarizes what was learned through literature, questionnaires, and interviews.

Table 3. Texas Department of Transportation Contacts

Contact	Texas Department of Transportation District
Sally Wegmann	Houston
Brian Burk	Austin
Irma Rojas	El Paso
Richard Cortez	Dallas
David Rodrigues	San Antonio
Tai Nguyen	Fort Worth

ITS Usage and Venues

Each TXDOT District respondent was asked to use a checklist developed by the author and display what types of ITS capabilities that their TxDOT District currently was using. The responses list in Table 4 were compared to an ITS deployment update for 2002 which was a survey conducted across the United States to discover what ITS technology different agencies were using and what plans each agency had to implement new ITS technology (20).

Table 4. Current Applications of ITS Technology

System/Device	Houston	San Antonio	Austin	Dallas	Fort Worth	El Paso
Traffic Management Center	√ ^P	√	√	√	√	√
Dynamic Message Signs	√ ^P	√ ^P	√ ^P	√ ^P	√ ^P	√
Highway Advisory Radio	√ ^P	√*	√ ^P			
Closed-Circuit Television	√ ^P	√ ^P	√	√ ^P	√	√
Traffic-Responsive signal system	√ ^P	√				
Vehicle Detectors		√ ^P	√	√	√	√
Telephone Information System/Hotline						
Overhead Lane Control Signals	√	√	√		√	√
Portable Traffic Signals						
Dynamic Trailblazer Signs						
Changeable Speed Limit Signs		√				
Ramp Meters	√		Proj under const		√	√***
Incident Management Systems	√	√	√			
Electronic Parking fee collection system	Coming to BIA		√			
Advanced Parking Information Systems	√**	√ (AlamoDome)				
P = portable also available * = bid out for 2	** Texans football color-coded ticket		*** (15)		BIA – Bush Intercontinental Airport	

Each respondent to the questionnaire listed several temporary and permanent venues where ITS played roles in traffic management and motorist information. Table 5 displays the ITS infrastructures name and website for each TxDOT District, and Table 6 lists examples of planned special events in each TxDOT District. Figure 13 shows the various locations of the TxDOT districts that responded to the questionnaire.

Table 5. TxDOT’s ITS Infrastructure Names and Websites

Texas Department of Transportation District	ITS Name	Website
Houston	TransStar	http://www.houstontranstar.org
Austin	-	-
El Paso	TransVista	http://www.transvista.dot.state.tx.us
Dallas	DalTrans	http://dfwtraffic.dot.state.tx.us
San Antonio	TransGuide	http://www.transguide.dot.state.tx.us
Fort Worth	TransVISION	http://dfwtraffic.dot.state.tx.us

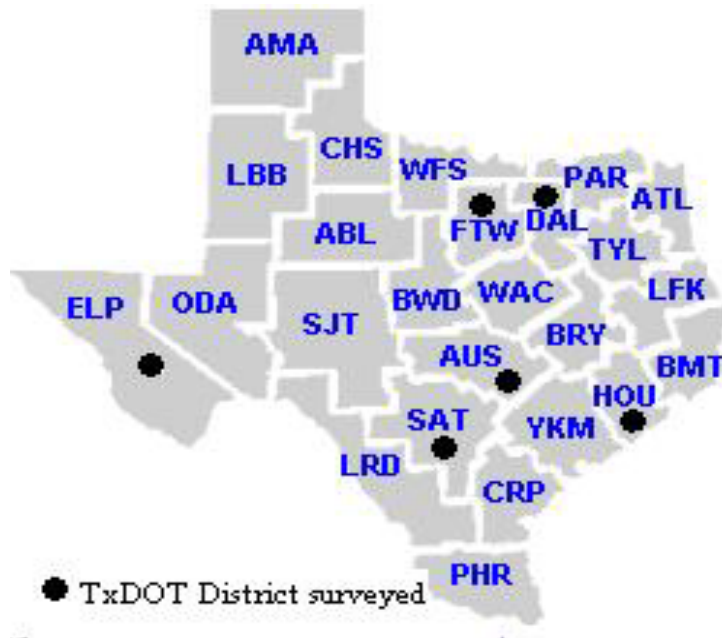


Figure 13. Various TxDOT Districts Who Were Sent and Responded to Questionnaire

Table 6. Permanent and Temporary Venues with ITS Used

City	Permanent Venue & ITS used	Temporary Venue & ITS used
Dallas	<ul style="list-style-type: none"> • <u>Cotton Bowl</u> - permanent and portable DMS and courtesy patrol • <u>Texas Motor Speedway</u> - portable DMS, portable CCTV, and courtesy patrol 	<ul style="list-style-type: none"> • Street events that generate 50,000 + vehicles - portable DMS
San Antonio	<ul style="list-style-type: none"> • <u>AlamoDome</u> - lane control signals, DMS, CCTV, loops • <u>SBC</u> - same as AlamoDome 	<ul style="list-style-type: none"> • <u>Fiesta Week</u> - CCTV, DMS, LCS
Austin	<ul style="list-style-type: none"> • No permanent venue for planned special events with regular use of ITS infrastructure - Zuelker Park is in planning 	<ul style="list-style-type: none"> • <u>Graduation party of President George W. Bush's daughter</u> - DMS, freeway closed with traffic controller
Fort Worth	<ul style="list-style-type: none"> • <u>Texas Motor Speedway</u> - permanent and portable DMS 	<ul style="list-style-type: none"> • <u>Mayfest</u> - portable DMS • <u>Air show at Alliance Airport</u> - portable DMS • <u>Stock show parade</u> - portable DMS • <u>Air show at joint reserve base</u> - portable DMS • <u>4th of July Willie Nelson picnic</u> - portable DMS
Houston	<ul style="list-style-type: none"> • <u>Minute Maid</u> - Astros game a non traffic event • <u>Compaq Center</u> - Lakewood Church • Reliant Stadium - Ramp closure, rodeo used DMS signs for park-and-ride, Texans football games have advanced parking systems, Super Bowl gave travel times (unique) 	<ul style="list-style-type: none"> • <u>Mardi Gras</u> - Galveston - DMS signs how long the ferry wait is, direction of parking, direction of access, and notifications, i.e. ramp closures
El Paso	<ul style="list-style-type: none"> • <u>Sun Bowl Stadium</u> - DMS and courtesy patrol • <u>Cohen Stadium</u> - same • <u>Special Events Center</u> - same • <u>Socorro ISD Student Activities Complex</u> - same • <u>El Paso County Coliseum</u> - same 	<ul style="list-style-type: none"> • <u>Sun Bowl Parade</u> - DMS and courtesy patrol • <u>Downtown Street Festival</u> - same • <u>Chamizal National Park Outdoor Concert Series</u> - same

Houston (21)

Houston is the one of the largest cities in the nation. Houston's mobility ranks among the worst in the nation. Houston ranks third in annual delay per peak travel and fourteenth in travel time index that is 1.39. Travel time index is the ratio of peak travel time to an off peak flow, which means a 1.39 travel time index is thirty-nine percent higher than normal off peak flow (22). For example, if it takes 20

minutes to get to a certain destination with minimal traffic, then in Houston a motorist can expect it to take 1.39 times as long or 27.8 minutes. The TMC in the TxDOT Houston District operates 24 hours a day. Since Houston has such a large population and severe traffic congestion, ITS is part of the solution to reduce the traffic congestion.

Because of Houston's facilities and size, many events take place each year in Houston. It is estimated that 144 "major" planned special events take place in Houston in an average year (20). This is a reasonable number considering that Houston is the home to three professional sport teams. Because of the frequency of these events at Minute Maid Park, Reliant Stadium, and other venues, these events are considered non-traffic events to the TxDOT. The facilities are believed to be adequate to handle the extra flow that is provided by these events. However, once a year, large events require the need for ITS to manage traffic. Such planned special events include the 2004 Super Bowl, George Bush's 80th birthday celebration, Mardi Gras in Galveston, the Rodeo, and the 2004 Baseball All-Star game. Different aspects of ITS were used for each one the planned special events.

During the Super Bowl CMS signs were used to divert hazardous material vehicles off of the 610 Loop which is where the stadium is located. Figure 14 shows a CMS diverting certain types of truck traffic away from the Super Bowl.



Figure 14. Hazard Material Message on CMS during Super Bowl in Houston (23)

The Super Bowl traffic management plan consisted of the use of a portable ITS system. The portable ITS system included the use of a portable TMC. As indicated in Table 4, Houston is the only TxDOT district surveyed to have a portable TMC. The portable TMC can be seen in Figure 15. Also, Houston is one of the few TxDOT districts with ramp metering. As of now ramp metering in the Houston District only operates 6:30 AM – 6:30 PM which excludes many planned special event times. As a result of coordination between the Harris County Office of Emergency Management, Regional Incident Management System (RIMS), and the Mobile Operations Center (portable TMC), the traffic during the Super Bowl never backed up onto the freeway. The Super Bowl was described as "the best in-bound movement in years and fastest exit we have ever seen" by *NFL Transportation* (23). The RIMS was originally developed for weather incidents, but it is now seen as an invaluable tool to managing traffic at planned special events.



Figure 15. Portable TMC in the TxDOT Houston District (23)

Mardi Gras which is held in Galveston (about fifty miles south of Houston) is a large event that puts a strain on both the I-45 and the ferry system in Galveston. The primary traffic management focus during this event was to give motorists accurate traveler information. The CMSs on I-45 designated how long the wait was to the ferry system, directions for parking and access, and other notifications such as ramp closures.

The Rodeo is a joint effort by the city, TxDOT, and Metro system to provide the fastest route and easiest parking to the event. CMS signs are used to promote park-and-ride systems. About one-third of the patrons use this system who attend the Rodeo.

Former President George H. Bush's 80th birthday celebration brought about another useful tool of the ITS system. The ITS of the district was used for security purposes. The truck traffic was diverted, and the cameras could have been used as security tools. The ITS tools were used in partnerships with other agencies such as the case was in the Super Bowl and President George H. Bush's 80th birthday celebration. As ITS grows so will the desire for inter-agency communication and use of the product. ITS is a key component to managing the transportation system.

Personnel from the TxDOT Houston District plan on adding some CMS signage to highway 288 to manage traffic heading to the 288 Speedway. As all CMS in Houston, the messages the CMS displays can be read at home on the computer at the Houston TxDOT District's ITS website (24). Also, Houston's TxDOT District uses ITS for 4th of July celebration near the Sam Houston Raceway to keep traffic moving by not allowing drivers to park on the freeway to observe the fireworks display. Currently, event coordinators are in charge of the individual planned events, and no partnerships have been reached for the usage of the ITS system. Houston only provides information for the traffic motorists when deemed necessary and not advertisement for these events.

Austin (25)

The Austin District of TxDOT is one of the smaller cities surveyed, but Austin is fast growing and so are the needs of transportation. It has the worst traffic congestion of any medium size city. In fact, it ranks 14th in annual delay per peak traveler and is the only medium size city to have over a 1.30 travel time index (22). However, as for planned special events most of them fall outside of the business hours of the TMC which are 6 AM – 10 PM Monday thru Friday.

The Austin District's main areas of planned special events are the University of Texas area, Dell Diamond, and Zuelker Park. These venues influence the positioning of ITS infrastructure. The Austin District engineers want the cameras to be placed near areas of abnormal flow. Also, CMS will not be put up near flashing signs which are located near many of the venues that hold special events. Currently, no ITS infrastructure is located on US 79 near Dell Diamond, but because of congestion and a large amounts of crashes, there has been a voiced demand for CMS and CCTV near the ballpark. Cameras and other ITS infrastructure will likely be placed near Zuelker Park. Zuelker Park experiences large amount of traffic and parking problems during the Christmas period for Trail of the Lights. Austin's District uses lane control signals during peak times of the day to indicate the direction of traffic flow, and various messages on the permanent CMS during the day to inform motorists of traffic information. In addition the Austin District uses HAR to help manage traffic. The Austin District has two permanent HAR and a portable HAR.

No formal coordination has been used during planned special events. At the graduation party of President George W. Bush's daughter the freeway was closed, and this information was displayed through CMSs. Also, TxDOT's Austin District was asked for the CCTVs to be turned off or pointed down, so that the Bush party could not be seen for security purposes. During most planned special events the event planner with provide the CMSs or the other type of devices to aid with motorist information or traffic flow to the particular planned special event. Austin District's portable CMS are used solely by the maintenance crews. Coordination using ITS equipment has been used for management of commercial vehicle operations, and this experience may lead the pathway for future ventures in inter-agency coordination both public and private in planned special events.

El Paso (26)

The El Paso District of TxDOT was the smallest city surveyed in Texas and, also, had the lowest annual delay per peak traveler, and lowest travel time index of 1.18 (22). El Paso also had one of the fewest number of planned special events when compared to the other five cities (20). Because the demand of traffic due to planned special events is low, they have not had an influence on future ITS planning. Future ITS planning is based solely on traffic operation and management.

El Paso Districts CMSs are used to notify the public of street closures and other traffic information for parades, festivals, and concerts. The El Paso District plans to install a HAR system that will cover seventy-six miles by 2005 (20). The system would be able to broadcast planned special event information regarding traffic routes, detours, and event parking.



Figure 16. ITS Capabilities in El Paso Which Could be Applied to Planned Special Events – Overhead Lane Control, TMC, CCTV, and DMS (11)

Dallas (27) and Forth Worth (28)

The Dallas-Fort Worth Metroplex is the one of the largest urban areas in the nation. The Dallas-Fort Worth mobility conditions are slightly better than those of Houston (22). Fort Worth is also the second fastest growing big city in the nation (29). The large size of the Metroplex makes effective transportation management even more critical to this growing area. Both cities have a separate ITS systems, but are often discussed together, and share a common website.

Currently, CMS, CCTV, and courtesy patrols are ITS components that the Dallas-Fort Worth TxDOT Districts use to manage the planned special events in the district’s area. Texas Motor Speedway is a major venue in which ITS is used to manage traffic. Portable and permanent CMSs, as well as portable CCTVs are used to manage the traffic heading to the Texas Motor Speedway. Furthermore, additional ITS field equipment will be installed in the area surrounding the Texas Motor Speedway. The placement of signs in throughout the City of Dallas is based on four criterions: frequency of incidents in the area, volume of traffic affected, major freeway construction projects, and special event generators (30). As noted special events play a role in pre-planning the placement and utilization of ITS elements. ITS uses the latest technology to manage traffic congestion and these principles can relate to planned special events. The Dallas-Fort Worth TxDOT districts use three principal methods: (1) monitoring traffic by using closed-circuit television and traffic detector displays, (2) informing motorists about conditions by using dynamic message signs and lane control signals, and (3) intervening when there are incidents such as accidents and disabled vehicles blocking traffic (30).

Smaller planned special events in the Dallas-Fort Worth District are believed to be sufficiently managed by portable CMS and/or portable CCTV. Portable ITS would be more cost effective and most likely have a fee associated with the event organizer. At the present ITS is only brought in if a street event generates 50,000 vehicles, and portable CMS is usually used. A special events website was suggested for pre-trip planning and notification. The Texas Motor Speedway has a website and maps. An example of a Texas Motor Speedway’s map is seen in Figure 17 that shows the various routes that inbound traffic should travel coming from various directions. The current Dallas-Fort Worth District’s ITS website (30) allows individuals to view real-time images and messages from all cameras CMSs, respectively. A special event notification link would be beneficial.

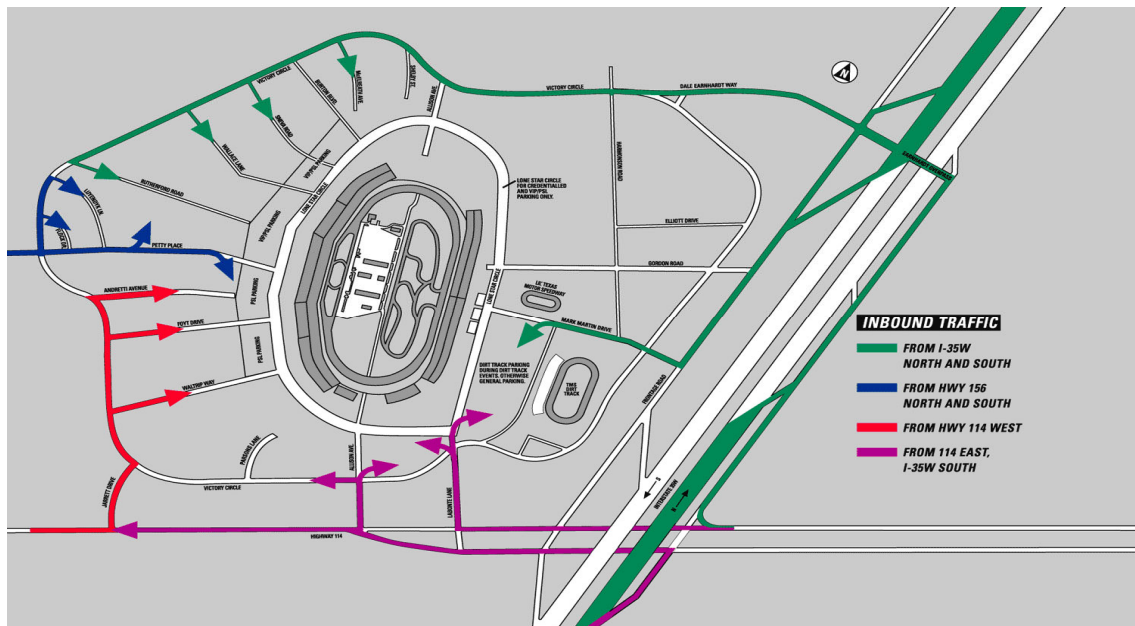


Figure 17. Texas Motor Speedway’s Inbound Distribution Traffic Flow (31)

Both the Fort Worth and Dallas TxDOT Districts emphasized the importance of communication and coordination between the various stakeholders in planned special events. Coordination between parking lot attendants and those directing traffic would help. ITS can act as a communication tool and can be applied to the parking problem. Also, real-time information needs to be delivered to the user. This information needs to be accurate and reliable. It was suggested that real-time information could be delivered via portable HAR units. Neither district has these units. Also, to manage traffic better the implementation of center-to-center software integration between various agencies in the region needs to take place.

San Antonio (32)

San Antonio is one of the top ten largest cities in the nation. Along with Fort Worth it is also one of the fastest growing cities. With the opening of the Toyota plant in 2006, San Antonio will continue to grow, and the economy will continue to rise. San Antonio may pass Dallas and become the 8th largest city in the nation (20).

The San Antonio District of TxDOT has two main permanent venues where planned special events take place. The Alamodome and the SBC Center traffic management systems contain: lane control signals (LCS), CMS, CCTV, and loop detectors. During Fiesta Week many of the same techniques are used to manage the traffic during the week-long party. The CMSs are used to inform the traveling public on which exit to take, or any other information that might be vital to the motorist. The LCS has a red X to indicate if a ramp is closed. At the SBC Center the LCS is used to manage traffic. Figure 18 shows a typical lane control signal on SBC Parkway. Cameras are used to monitor conditions, and video is made available to the media, so they can report on the current traffic conditions.



Figure 18. SBC Parkway Lane Control Signal

The City of San Antonio conducted a study for the usage/placement of the ITS Equipment prior to the construction of the SBC Center, which houses basketball games and the yearly two week rodeo. The

study indicated that traffic around a planned special event needs to be planned and accounted for carefully. This was extremely important for the SBC Center because it sometimes has three events running simultaneously. Portable CMSs can be located near a planned special event to help in distributing information to the motorists. The placement of other ITS equipment is to create a means to best inform the traveling public of “real time” conditions. Special events can result in large traffic delays, and the public needs to understand and rely on the information provided. This information could be displayed with other real-time data on the website for pre-trip planning. The City of San Antonio has teamed up with TxDOT, the SBC Center, and AlamoDome to manage traffic and provide the best possible traffic information.

The City of San Antonio is building a City/County Incident Management Center at Brooks City and have requested to link fiber-optic communications with the San Antonio TMC. The request is being considered by TxDot. The incident management center could prove to be a valuable source to managing traffic at planned special events, such as RIMS was for the Super Bowl in Houston.

San Antonio has another valuable resources in their ITS arsenal. AWARD a railroad grade crossing system is designed to help motorists avoid delays caused by railroad operations that cross freeways or frontage roads (33). The advance railroad crossing warning system could be helpful at a planned special event near a railroad track.

It appears San Antonio will be building toll roads, and this will be at the edge of their current ITS system. Knowledge used in toll roads could be applied to planned special events, such as developing automated parking tags for a venue.

EXAMPLE CASE STUDY

Using the different ITS techniques and knowledge gained about planned special events, an examination was made of a particular planned special event. The current traffic problems were identified in the current traffic management plan and, then, ITS tools were applied to solve these problems. Reed Arena on the Texas A&M University campus in College Station was chosen because it is a venue that could have ITS infrastructure built or a portable system brought in to help in the traffic management plans. After an interview with Douglas Williams, Assistant Director of Transportation Services, it became apparent that the biggest traffic demand problem occurs during graduation at Reed Arena. Graduation is a two-day event that draws in a number of people from out of town, who are not familiar with the College Station area. Graduation is also a venue that draws very few people who choose to walk to the event, unlike many other events at Reed Arena that people walk to.

The first step was to identify the problems that occurred during the two-day period of graduation. During the meeting with Douglas Williams, several problems were identified based on experience and prior knowledge. Figure 19 and Figure 20 are maps that show the main areas of interest for the graduation ceremonies at Reed Arena. Three of the four CMSs that will be recommended are located in this area. Table 7 contains the several problems identified and are separated by the different aspects of planned special events: motorist information, traffic management, and traffic demand. Figure 19 shows key traffic problem locations. Figure 20 is the traffic management plan provided by Texas A&M University Transportation Services. In addition to the original traffic management plan, Figure 20 also has some of the ITS infrastructure added to the diagram.

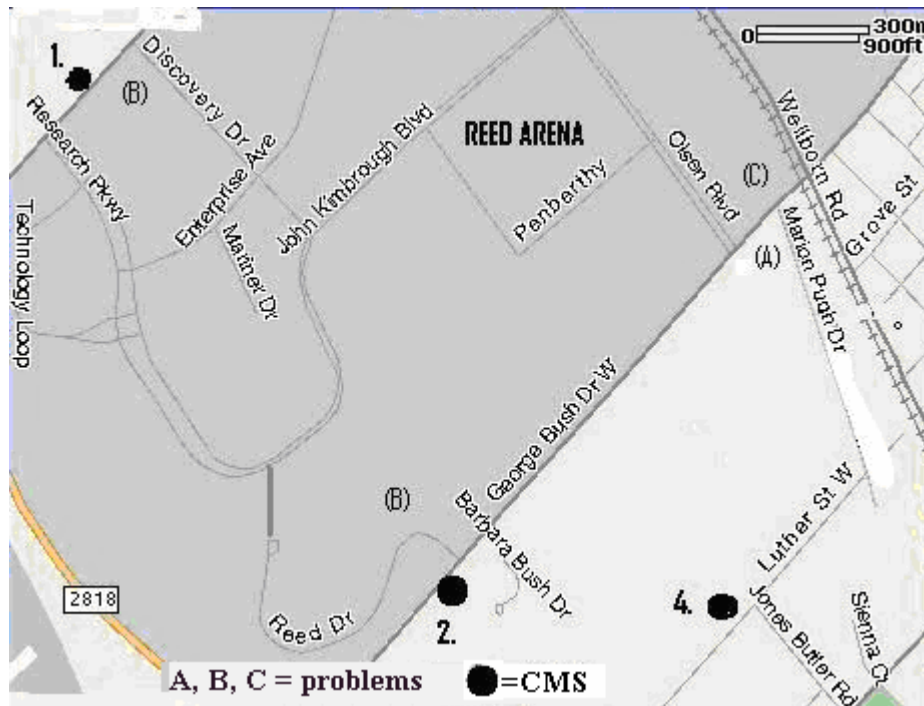


Figure 19. Map of College Station Surrounding Reed Arena (34)

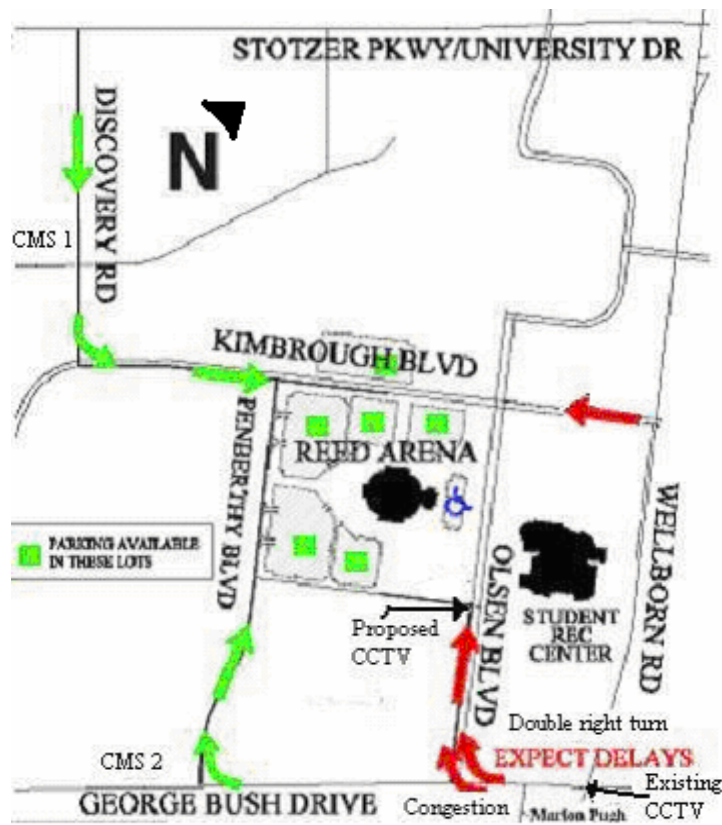


Figure 20. Traffic Management Plan with ITS (35)

Problems Identified**Table 7. Problems with Graduation at Reed Arena**

Special Event Management Category	Problem
Motorist Information	<p>Traffic directions for before and after graduation exist on the Internet. Transportation services would like to advertise that traffic directions are available on the Internet.</p> <p>Changes in traffic flow (making a double right hand turn) do not appear to be known by motorists, even the motorists familiar with the area. This lack of knowledge is assumed because of previous observations with motorists using only the far right lane on George Bush Dr. to turn right onto Olson Blvd, even though at graduation times two right turn lanes exist. [See Figure 19 – (A) and Figure 20]</p>
Traffic Management	<p>Discovery Drive Route and Read Drive routes to Reed Arena have been observed by individuals to be rarely used for graduation traffic. [See Figure 19 – (B)]</p> <p>The train system at George Bush Dr. and Wellborn Rd. can experience large backups.</p> <p>Marion Pugh experiences large back-ups at George Bush Dr. because motorists try to cross all lanes (4) turning left, so they can turn right to get to Reed Arena. [See Figure 19 – (C)]</p>
Traffic Demand	<p>Since the event is graduation, it is assumed that families already carpool. People are dressed in nice attire and, therefore, most will not walk great distance. Most people will park in the Reed Arena lots. With pre-event planning and increased motorist information, peak travel demand on each route could decrease because of the spreading out of traffic.</p>

Solutions using ITS*Motorist Information*

Pre-event planning is important for motorist information. A website currently exists that contains a before and after graduation traffic plan. Figure 21 shows Texas A&M University's Transportation Services (TS) website that has an individual section for special events. The goal would be for the people

to look at the different maps and observe the different routes that are available to get to Reed Arena. Three different ways to share this information for pre-event planning were brainstormed.

- Transportation Services already advertise some of their various services on the radio, and it would be beneficial to include information on the traffic management plans in the advertisement.
- The cheapest and most feasible solution would be a mass e-mail. The e-mail would be sent to all graduating seniors and the subject would say: “Traffic management plan for graduation, please forward to your parents”.
- Many families stay in hotels prior to graduation, so a copy of the traffic management plan would be placed at the desks of the hotels. The traffic management plan is seen in Figure 20 but would also contain a list of directions so the motorist would understand the various routes to the four different routes leading to Reed Arena.

In addition, developing a train warning system like AWARD in San Antonio and providing a link from the (TS) traffic page (Figure 21) would encourage the use of this site. The linked page would simply state how long it will be until a train that would cross George Bush Drive. The advanced warning of a train would be invaluable knowledge to the residents of College Station throughout the year. In the graduation case, if a motorist knew a train was coming, their route could be altered from George Bush Drive to University Drive (see Figure 22). This is granted that the other pre-game information was supplied, and the motorist knew they could take Discovery Drive or Olson Blvd. off of University Drive to Reed Arena.



Figure 21. Texas A&M University Transportation Services Website (35)

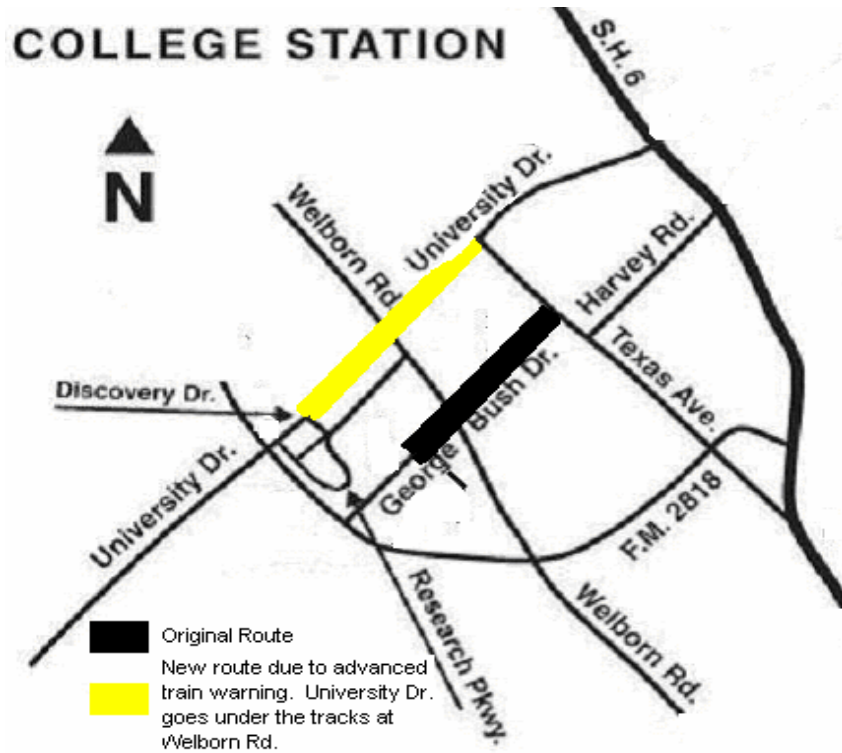


Figure 22. Alternate Route Due to Advanced Train Warning System

During the day of the event, the traffic management information could continue to be given through announcements on the radio. CMSs would be used in strategic spots to convey motorists to do what the transportation officials want them to do to make the overall transportation system work the most effectively and efficiently. A HAR would be installed to provide more detailed complete descriptive information to the motorists. The HAR would be permanent and could be a tool the TS could use year around to provide information to motorists for other events such as basketball games, football games, and theater productions. Four CMS signs would be placed. Two of the CMS signs (CMS 1 and CMS 2) would be to inform the motorists of the alternate routes that are available to Reed Arena. Another one of these signs (CMS 3) would make drivers aware far enough in advance of the temporary right two turn lanes on George Bush Dr. that turn onto Olsen Blvd (Figure 20), so that the two right turn lanes can be utilized more efficiently. The final CMS sign (CMS 4) would encourage users to avoid Marion Pugh and go to an alternate route. The CMS four sign would be controlled by loop detectors on Marion Pugh and would light only when congestion occurred. Marion Pugh could, also, be observed by traffic operators through the CCTV located at George Bush Dr. and Wellborn. A static sign would be placed on S.H. 6 just before Texas Avenue indicating when the HAR is in service. The HAR sign would be like the flashing static HAR sign in Figure 3. The placement of these signs is show in Figure 23. The potential displayed messages are listed in Table 8.

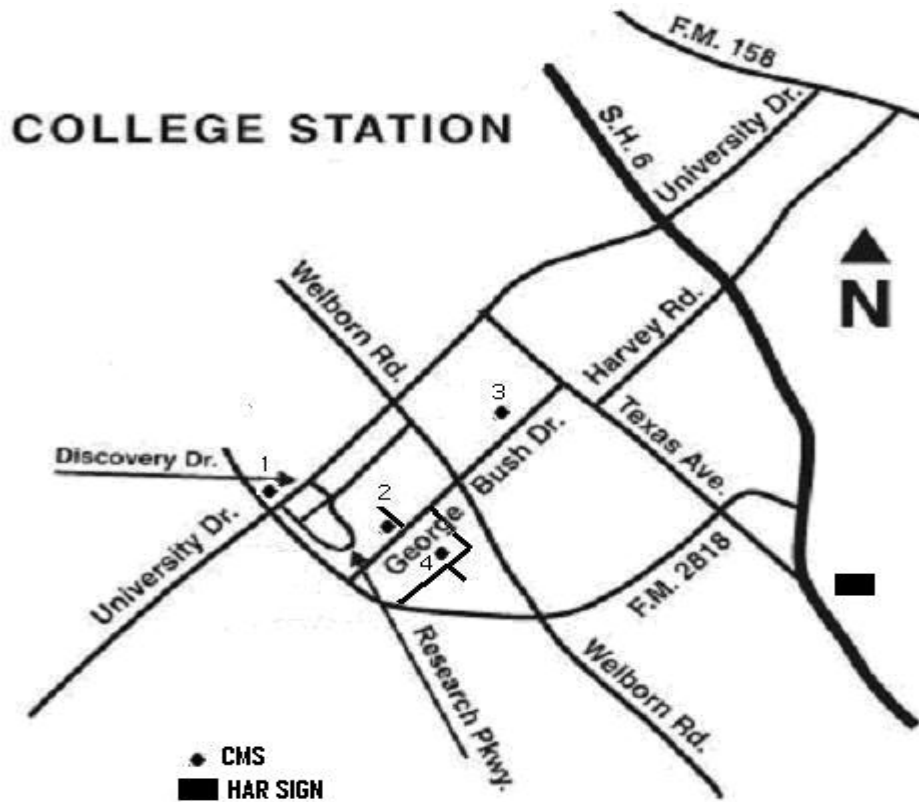


Figure 23. Location of CMS (not to scale)

Table 8. Possible CMS Messages

CMS Number (see Figure 23)	Location	Message 1	Message 2
1	Before Discovery Dr. facing inbound traffic	REED ARENA USE DISCOVERY AVOID DELAY	TUNE TO 1610 AM
2	Before Reed Rd. facing traffic going towards Welborn Rd.	REED ARENA USE REED RD AVOID DELAY	TUNE TO 1610 AM
3	Located near Bissel Rd. facing traffic going towards Welborn Rd.	REED ARENA USE TWO RIGHT LANES	TRUST US
4	On the corner of Luther and Jones Butler	CONGESTION AT MARION PUGH	No message 2. Message 1 only shows when congestion exists via the information through loop detectors.

Traffic Management

There are four main ITS devices that will be used for traffic management in the Reed Arena traffic management plan:

- The CMS will inform motorists of the various routes, and motorists will take these routes which will result in better traffic management and will distribute the demand on each route. Furthermore, consideration should be given to utilize the CMS for diversion to alternate routes in case of an incident on the major routes to and from the arena.
- The current CCTV cameras placed at George Bush and Wellborn will be used to monitor the event in real time. These cameras, which are already in place, will help with surveillance on the day of graduation, but also, they can be used for future planning based on what is observed. Also, pan/tilt/zoom cameras should be placed on Olsen Blvd. near the Student Recreational Center and Reed Arena. These two new additional cameras would video the traffic flow from the traffic signal on George Bush and Olsen Blvd, as well as, video the parking decisions that the motorist and traffic controllers (courtesy patrol) make. The video from the live feed CCTV could help traffic operators communicate to the courtesy patrol through the radio with up-to-date conditions information.
- HAR will provide the motorist will more detailed route information than the CMS. The HAR would also report incidents and other traffic problems that might arise.
- A portable TMC would be established and be used during the various planned special events. In the TMC, the CCTV would be monitored and the HAR and CMSs could be changed when needed. The portable TMC would not need to be large and the portable TMC seen in Figure 15 would be as large as needed. The portable TMC could serve as a headquarters for all personnel during the planned special events.

The CMS will assist in providing information and managing traffic. CMS number four would display the message during peak traffic times as indicated by the loop detectors or observed by the CCTV. It is assumed that the sign's message will affect only some motorists who will either use Holloman Drive or FM 2818. If FM 2818 is used, the motorist attending graduation will no longer use Olsen Blvd., but will be redirected by CMS number two and take Reed Rd. CMS number three may have a flashing message. In Maryland a new double right exit is being used, but no motorist would use both lanes. As a result the CMS simply flashed "Trust Us" after the original message. The new message improved the compliance to the sign (36). This idea might help compliance to CMS number three. In addition, the CMSs would also flash a message informing the motorists to tune their radios to the correct station to listen to the HAR (Table 8).

The traffic management plan for the graduation has been slightly altered compared to the original plan located on the Transportation Services website. Figure 20 shows this new plan. The new plan incorporates some of the newly added ITS infrastructure. E-mail, television, flyers, and radio were used in pre-day events. CMS, HAR, CCTV, and portable TMC were the devices chosen to improve motorist information, traffic management, and traffic demand. As noticed in this made-up case study, the previous case studies, and findings, CCTV and CMS are crucial elements to disseminating up-to-date motorist information and surveillance tools for planned special events.

Solution Summary

Table 9 lists the previously mentioned ITS solutions listed by priority and describes the benefits associated with each technology.

Table 9. Case Study Solution Summary

Priority	ITS	BENEFITS
(1)	Pre-event dissemination of information to motorists: <ul style="list-style-type: none"> • Mass e-mail, • Radio, • Pamphlets distributed at local hotels, • CMS and HAR 	Motorists and event patrons will know the various travel routes to take, and thus the traffic will be managed and traffic demand on each route might be reduced.
(2)	CMS 4	Motorists will use both right turn lanes on George Bush Drive. (Note: CMS can be used year round for other planned special events or construction activities.)
(3)	HAR	HAR can disseminate larger and more detailed traffic directions and incident information to motorists
(4)	CMS 1 & CMS 2	Motorists will be provided information of two different routes to Reed Arena. Also, notifies user of the existence of the HAR.
(5)	CCTV	Traffic operators will have surveillance during the planned special event, and this surveillance can contribute to real-time management of traffic.
(6)	CMS 4	Motorists will be saved from the long wait due to congestion at Marion Pugh and George Bush Dr. The sign will only be operated at times with indication from the loop detectors, CCTV, or a fixed time before and after the graduation ceremonies.
(7)	Portable TMC	A central hub for the planned special event traffic management team will be provided. Could be used during other planned special events. Lower priority because event monitoring through CCTV, changing the CMS and HAR messages could be done at an office or other location.
(8)	Loop detectors	Data allows traffic operators to know when congestion is occurring. CMS 4 could operate with this technology.

FINDINGS

- ITS is a system: each part is crucial
- For planned special events ITS must be able to go portable.
- ITS must be reliable.
- ITS planning should have venues of special events as a focus.
- Changeable message signs (CMS) are a useful and reliable way to communicate information and manage traffic for planned special events, when operated properly.
- Closed Circuit television (CCTV) is the best monitoring source and excellent public relation tool to the media for planned special events.
- Parking information is very important to motorists during planned special events.
- Using ITS during planned special events allows motorists to be better informed. Also, using ITS, may allow for less personnel that may be needed; therefore, a lower safety concern is produced for personnel.
- Interagency coordination is a prerequisite for ITS in planned special events that crosses institutional boundaries.

ITS is still in its infancy, and over the last ten years large improvements have been made. Agencies are, also, users of the data collected by ITS. By analyzing the data collected at each event, traffic operators can make improvements to the traffic management plan based on where the problems occurred. ITS makes the data collection easier, and therefore, documentation of successes should become more abundant over the upcoming years. ITS is a system where the cameras provide visual analysis, the loops provide data, and the LCS or CMS can route the driver a certain way, and an efficient transportation management system results.

As documented by the 2002 Winter Olympic Games and the San Antonio questionnaire, the management of special events through the use of the ITS equipment is best seen through the use of CMS and sharing of camera images with the media and operators of the system. The more signs and camera feeds that are available make the system more creditable, and thus, the public is better informed. The ITS system is new to the public, and with more education and experience the public will trust and use the available resources more frequently.

HAR is a good system to use for planned special events. A simple static sign or CMS sign telling users traveling to a planned special event to tune to a radio station avoids giving useless extra information to those who do not need it. A telephone information system will work in the same manner and will be more reliable, but it is not always cost effective to establish for a single planned special event.

ITS is not a cure-all. It is an excellent tool. ITS has to potential to aid engineers in their goals to provide roads with a high level of service by using reversible lanes and traffic responsive signals. ITS can keep a consistent flow of traffic through ramp metering. ITS can be used as a tool to solve problems such as drastically reducing travel time to the PIR, but not every problem that may be faced in traffic at a planned special event can be solved by ITS.

When applied, ITS can provide information, manage traffic, and help with traffic demand. All three are important in managing planned special events, and all of these aspects will improve if ITS is used. ITS needs to be portable to best be able to satisfy the needs of large special events, since portable can be used anywhere, anytime. Along with these benefits, ITS can have other applications during planned special events, such as security. With this growth, communication and coordination between many agencies and planned special event venues need to developed, so the public and transportation agencies can get the best use of their dollar and can utilize the infrastructure to handle both normal traffic and planned special event traffic.

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APPENDIX A

ITS in Planned Special Events Questionnaire

Thank you for taking the time to complete this short questionnaire. Your responses will guide the development of recommendations and conclusions for the use of ITS in planned special events in addition to a case study application.

This research is performed under Texas A&M University's Mentor Program in correlation with a class. The paper will be published in the SWUTC Compendium: Papers on Advanced Surface Transportation Systems, 2004.

1. Indicate the ITS infrastructure, including permanently installed systems and devices and portable equipment, that currently exists in your area.

<u>System/Device</u>	<u>Permanent</u>	<u>Portable</u>
Traffic management center		
Dynamic message signs		
Highway advisory radio		
Closed-circuit television		
Traffic-responsive signal system		
Vehicle detectors		
Telephone information system/hotline		
Overhead lane control signals		
Portable traffic signals		
Electronic blank-out signs		
Dynamic trailblazer signs		
Changeable speed limit signs		
Ramp meters		
Incident management systems		
Satellite traffic management center		
Electronic parking fee collection systems		
Advanced parking information system		
Other:		

2. Indicate permanent planned special event venues (e.g., stadiums, arenas, amphitheaters) in your area where event traffic management operations include the regular use of ITS infrastructure.

Permanent Venue

ITS Infrastructure Used in Event Traffic Management

3. Indicate planned special events at temporary venues (e.g., parade - street, festival – park) in your area where event traffic management operations include the regular use of ITS infrastructure.

Event/Venue

ITS Infrastructure Used in Event Traffic Management

4. Describe the potential application of ITS technologies (including portable devices) for managing and controlling traffic for planned special events occurring at temporary venues, smaller venues in the metro area, or rural venues.
5. Have stakeholders in your jurisdiction completed a post-event report that includes a cost and/or benefits assessment of ITS technologies used in managing traffic for a planned special event?
6. Have stakeholders in your jurisdiction formed public-private relationships to assist in obtaining and/or deploying ITS equipment for planned special events traffic management?
7. How do planned special events influence future ITS planning in your region?
8. Do you have any suggestions of new ITS system and/or device applications that will improve traffic management and control for future planned special events?
9. Describe future ITS infrastructure deployments in your area that may be used to manage traffic for planned special events.
10. Do you have any documents or plans on the use/performance of ITS for planned special event traffic management in addition to photos showing ITS equipment in action during an event?

Thank you for your time. Any reports of ITS usage especially in planned special events or pictures of ITS in usage during special events would be appreciated.

They can be emailed to J-Whitacre@ttimail.tamu.edu

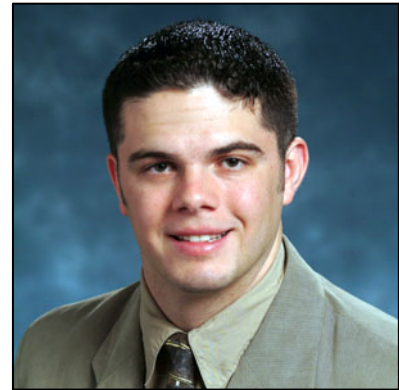
Mailed:

Jeffrey Alan Whitacre
1804B Woodsman Dr.
College Station, TX 77840
210-386-4744

Or other arrangements to be picked up could be made.
Thank you.

JEFFREY A. WHITACRE

Jeffrey A. Whitacre is from San Antonio, Texas and came to Texas A&M University in the fall of 2000. He will receive his Bachelor of Science Degree in May of 2004 with a specialty in Transportation. During his time at A&M, Jeffrey worked as an intern in both Land Development and Transportation. His work experience was with Jones & Carter, Inc. in Houston, Texas and Pape Dawson Engineers in San Antonio, Texas. He will continue his work toward his Master of Engineering in Civil Engineering at Texas A&M University and will graduate in May 2005. While obtaining this degree he will work as a Graduate Research Assistant at the Texas Transportation Institute in the Center of Transportation Safety. His interests are in urban planning, safety, and human factors.



While at Texas A&M, he was heavily involved in campus and Civil Engineering activities. He was a member of the American Society of Civil Engineers and served as an officer for one term. Also, he was a counselor during two summers for Texas A&M fish camp, served as a designated driver for a year and a half for Caring Aggies are Protecting Over Our Lives (CARPOOL), and is a proud member of ONE ARMY, a selective leadership and service men's organization. Along with this heavy involvement, he maintained at the top of his class and was chosen to be in Chi Epsilon.

**THE ROLE OF TRANSPORTATION MANAGEMENT CENTERS IN
ADDRESSING TERRORISM-RELATED THREATS AND EMERGENCIES
IN METROPOLITAN AREAS**

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SUMMARY

Transportation management centers (TMCs) using intelligent transportation system (ITS) technology have emerged as effective tools in fighting traffic congestion and improving safety in metropolitan areas. Their surveillance, detection, information dissemination, and advanced communication technologies, used in concert with the relationships these centers have fostered with the public safety community through effective coordination, cooperation, and communication on traffic incident management issues have proven very valuable in combating traffic congestion resulting from recurring and non-recurring incidents. These same tools can now be used as weapons in a new fight – the fight against the threat of terrorism in this country.

This paper is used to examine the role of metropolitan area TMCs, and the ITS infrastructure they operate, in preparing for, detecting, preventing, protecting against, responding to, and recovering from terrorism-related threats and emergencies. It will give a transportation agency an idea of the value of these tools for homeland security, but also of the issues that must be considered for them to be effective. An exploration of the relationship between the advanced transportation management and emergency management communities in this environment shows that while advancements have been made since the terrorist attacks of September 11, 2001, there is still much more that can and should be done. By means of an extensive literature review of case studies, reports, articles, and surveys conducted from 2002 to the present, and discussions with industry experts, the paper features the developments that have taken place since 9/11 in incorporating TMCs and ITS into homeland security plans, and the barriers that have inhibited further progress.

Lastly, recommendations are presented here which will be applied to the development of strategies to better position the Georgia Department of Transportation's NaviGator Transportation Management Center and Intelligent Transportation System to aid the rest of the homeland security community in safeguarding the Metropolitan Atlanta area against terrorism. Through the development of the *NaviGator Terrorism Response Action Plan (N-TRAP, pronounced "entrap")*, the author explores ways in which training, the development of TMC plans and procedures that map to the Homeland Security Advisory System, and modifications and enhancements to NaviGator's internal arrangements and external relationships can effectively bolster homeland security in Metro Atlanta.

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INTRODUCTION

Very often when transportation infrastructure is thought of in terms of homeland security, it is regarded in one of two ways. In one way transportation infrastructure is identified as a potential target for some form of terrorism-related activity. Major transportation corridors, such as interstates with heavy traffic volumes; bridge and tunnel structures; urban public transportation hubs with large gatherings of people, such as bus or rail terminals; and, most notably, airports and commercial aircraft, are all considered potential targets for large-scale acts of violence. By attacking these types of facilities, large numbers of people can be injured or killed, and such an incident will surely disrupt the movement of goods and services, hinder the mobility of emergency responders, and cause fear that would severely affect the economic viability of the immediate area and the country as a whole. The nation's transportation infrastructure is also often seen as a potential conduit for terrorist activity. The large amount of un-inspected containerized freight passing through national ports is very vulnerable to being used to carry out acts of terrorism. Commercial vehicles carrying hazardous materials are widely considered possible instruments for carrying out terrorist attacks. We have seen an example of how a commercial airliner can be turned into what some may liken to a weapon of mass destruction, as was accomplished with devastating consequences on September 11, 2001.

While protection of our transportation infrastructure, both from harm and from being used to harm citizens, must remain at the forefront of homeland security initiatives, this same infrastructure is sometimes an untapped resource in the fight against terrorist activity. Specifically, transportation management centers (TMCs) operating intelligent transportation systems (ITS), which have proven successful in mitigating recurring and non-recurring congestion, providing routine traveler information, and managing traffic incidents, can also play an important role in homeland security. These centers use technology for detection, monitoring, surveillance, management of traffic flow, communications, and for the dissemination of information to large numbers of people. All of these capabilities are also vitally important in homeland security.

According to the Intelligent Transportation Society of America (ITS America), "ITS provides tools and enhanced opportunities to help safeguard the transportation system against a variety of threats, both natural and human-caused, help the transportation system and its operators react swiftly and responsively in case of disruptions, and materially help agencies with primary responsibility to respond." (1) While the ITS industry has readily acknowledged these capabilities, emergency managers have not been as swift to embrace the contributions of TMCs and ITS, as evidenced by the lack of their widespread utilization in emergency management plans.

It is important to note that TMCs and ITS have not been totally excluded from emergency response plans. TMCs with ITS technologies are routinely integrated in plans to manage major traffic incidents and the traffic impacts of special events. The recently released handbook entitled "Managing Travel for Planned Special Events" illustrates several uses of ITS and TMCs in helping to successfully manage all phases of these events, from post event evaluation to advanced planning for future events. (2) Many metropolitan areas have response plans in place for emergencies due to natural disasters, such as hurricanes, floods, and earthquakes, some of which incorporate the existing ITS capabilities of the area's TMC. For example, recognizing the value of ITS for emergency response, and in reaction to lessons learned from events during Hurricane Floyd in 1999, the Georgia Department of Transportation (GDOT) has deployed a Coastal Evacuation System comprised of closed circuit television (CCTV) surveillance cameras, traffic monitoring detectors, highway advisory radio (HAR), weather stations, and changeable message signs (CMSs) – all operated from the state's TMC.

The American Association of State Highway and Transportation Officials (AASHTO) has published guidance on how existing emergency response plans can be updated to address the new terrorist threat. This guidance specifically identifies advanced transportation technology as an essential homeland security component. With existing plans and this new guidance, many metropolitan areas may be closer

to the realization of TMCs as homeland security tools against willful man-made disasters than one may imagine.

In addition to guidance that details what is to be done to better incorporate ITS into homeland security, the means by which to do so are also in place. The U.S. Department of Transportation's (US DOT's) ITS Deployment Tracking Database for 2002 indicated that of the 75 largest metropolitan areas in the country, 27 ranked high in their deployment of integrated intelligent transportation systems, 30 ranked as medium, and 18 ranked as low. (3) This was a result in large part to a challenge issued by Secretary of Transportation Federico F. Pena in 1996. "I'm setting a national goal: to build an intelligent transportation infrastructure across the United States to save time and lives, and improve the quality of life for Americans. . . I want 75 of our largest metropolitan areas outfitted with a complete intelligent transportation infrastructure in 10 years." (4) This challenge launched a national wave of ITS deployment and integration projects. Advanced traveler information systems (ATIS) to provide information about the condition of the transportation system to users, and advanced transportation management systems (ATMS) to better operate the entire network have emerged as the predominant systems. The Secretary's acknowledgment that these types of projects were vital to the safety and mobility of the nation validated and legitimized what proponents of ITS had known for many years. Eight years have passed, seeing tremendous advancements in these projects.

The US DOT's ITS Deployment Tracking Report is the primary means of following the nation's progress toward reaching Secretary Pena's goal. At the time of the challenge, the focus was on traffic congestion, and public safety primarily in the context of traffic incident management and the reduction of secondary crashes. Post 9/11, however, this mandate took on greater implications for homeland security, as it put into motion the deployment and integration of an extensive network of tools that can effectively address national security concerns as well. An examination of trends reveals that the level of both ITS deployment and integration have increased significantly since 1996, and plans are in place to continue this trend through the 2005 milestone, though progress is slightly behind planned levels as shown in the figure below from the 2002 Deployment Tracking Report.

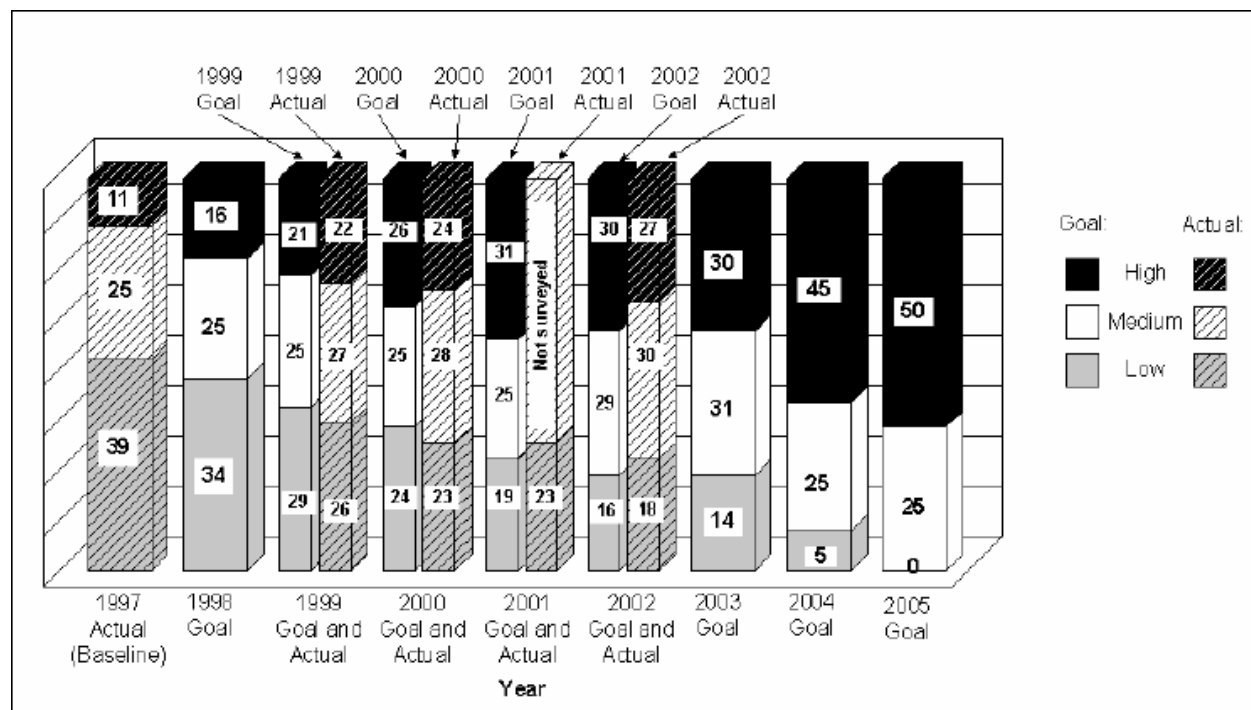


Figure 1. Deployment Goals and Actual Deployment Levels for 75 Metropolitan Areas

Consequently, as several major metropolitan areas have already deployed TMCs and ITS, or have plans to deploy them in the next few years, there is in place in some areas of the country an operations, communications, surveillance, monitoring, detection, incident management, and information dissemination network that can and should play a role in securing against terrorist activity. Appendix A contains a compilation of the 2002 US DOT's Deployment Tracking results from surveyed metropolitan areas on the types of ITS components deployed, and the extent of their deployment in place or planned through 2005.

Problem Statement

Although many metropolitan areas have employed TMCs using ITS technology in response to traffic congestion, and to facilitate traffic management for incidents, special events, and even catastrophic natural disasters, there is a tremendous opportunity and need to further employ these systems in the fight to secure our urbanized areas against terrorist attacks. These types of events have certain characteristics that differ from those typically managed by TMCs. Nonetheless, TMCs have demonstrated capabilities that can be used in preparedness, detection, protection, prevention, response, and recovery from willful man-made disasters. In recognition of the potential role of TMCs in light of the events of 9/11, there have been some advancements made in further incorporating them, and the ITS infrastructure they operate, into planning and response to terrorism-related incidents. There is still, however, much more that needs to be done to take full advantage of these advanced transportation resources. Further deployment, utilization, and, indeed, advancement of these centers and systems are needed in order to enhance the country's metropolitan areas' homeland security efforts.

Research Objectives

The objectives of this research were to identify the role of transportation management centers as homeland security tools in addressing terrorism-related threats and emergencies in metropolitan areas, and to provide guidance on increased inclusion of these centers and their ITS technology in emergency management planning and response. In doing so, the research was used to:

- Evaluate the current state of the practice in major metropolitan areas with ITS infrastructure operated by TMCs on the use of these centers and systems for homeland security purposes;
- Compare and contrast the current state of the practice with the state of the practice in 2002 when several post 9/11 studies were conducted regarding the level that TMCs should be incorporated into emergency planning and response;
- Identify institutional and technological barriers in the utilization of TMCs and their ITS infrastructure for homeland security;
- Synthesize findings on ways in which TMCs with ITS deployments have been used to serve a metropolitan area in preparing for, detecting, preventing, protecting against, responding to, and recovering from a national security emergency; and
- Apply findings to a case study of Georgia's NaviGator Transportation Management Center and Intelligent Transportation System, and identify how they can be used as more effective tools in the homeland security efforts of the Metro Atlanta area.

Scope

This research will be focused on the use of TMCs and ITS technologies for homeland security relating specifically to surface transportation. The scope of the work will be limited to TMCs responsible for the management of roadways, and highway tunnels and bridges. Time is not available to delve into public transportation or rail. The work will be limited to those ITS applications which are controlled from TMCs. The work will also be limited to terrorism-related threats and disasters in metropolitan areas. Disaster response in rural areas, or due to natural causes such as hurricanes and earthquakes, will be studied only as they may relate to this subject.

Approach

This research was conducted primarily through a review of available literature. There were several reports, studies and surveys completed in 2002, having been undertaken to address the concerns about transportation security that arose from the 9/11 terrorist attacks. Recommendations made as part of these studies on how to better secure transportation assets and improve emergency response in the event of another terrorist attack were considered. The author also studied the very detailed 9/11 case studies and lessons learned reports that were completed.

Since 2002, this subject has garnered the attention of many state and local governmental agencies, such as the Federal Highway Administration (FHWA), Emergency Management Agencies (EMAs), and state departments of transportation; professional organizations such as AASHTO, the Transportation Research Board (TRB), the Institute of Transportation Engineers (ITE), and ITS America; the private industry; and academia. Special transportation security task forces, Blue Ribbon Panels, and committees were formed, many of which commissioned additional studies and reports. These were also studied as part of the research. All information found was used to compare progress made in integrating TMCs and ITS into homeland security, and formulate recommendations for further inclusion. Discussions with industry experts proved most valuable, and rounded out the knowledge base for this research. Finally, research findings were applied to a real world case study of a metropolitan area TMC.

THE TERRORIST THREAT

The United States government defines terrorism as: “Premeditated, politically motivated violence perpetrated against non-combatant targets by subnational groups or clandestine agents, usually intended to influence an audience.” (5) The intent of terrorism is to instill so much fear in the beleaguered group that it will acquiesce to the terrorists’ demands in order to stop the reign of violence. Certain regions of the world have lived with terrorism for centuries. Terrorism has almost become a way of life in the Middle East. Until recently, terrorism of a large scale on U.S. soil was a relatively rare occurrence, except for a few notable incidents. The World Trade Center (WTC) was bombed in 1993, the Federal Building in Oklahoma City was bombed in 1995, and the Empire State Building was the site of a sniper attack in 1997. But these events pale in comparison to the devastation caused by the attacks on the Pentagon and World Trade Center on the morning of September 11, 2001.

One need only to refer to “9/11” to describe these terrorist attacks and to elicit the images that are indelibly etched in the minds of many Americans – images of devastation and death, but also of heroism and patriotism. These tragic events had a remarkably profound impact on America, likely changing its way of life forever. A new term was even introduced into the American, and even global, vocabulary – homeland security – highlighting Americans’ need to again feel safe and secure on their home soil. Three commercial aircraft were used to enact these attacks, and another was thwarted by heroic passengers before it could reach its intended target. Hundreds of lives were lost aboard the aircraft themselves, and thousands at the WTC and Pentagon were killed or critically injured. While these particular incidents were not aimed at the surface transportation system, it was nonetheless greatly impacted, and TMCs with ITS technology were on hand to respond to these impacts.

The WTC attacks took place at 8:46 a.m. and 9:03 a.m. in the Lower Manhattan area of New York City, with normal weekday rush hour underway. Following the initial crashes and the subsequent collapse of the two WTC towers, transportation managers in the area had to contend not only with the spontaneous evacuation of over one million residents and workers from the immediate area, and a tremendous influx of emergency responders to the scene of “Ground Zero”, but also with the destruction of many key transportation operations centers and transit hubs, and loss of life of many in the area’s transportation community. (6)

In the midst of all of this death and destruction, transportation management still had to carry on, and the area's TMCs stepped up to meet the challenge, enabled by their ITS assets. ITS was used in decision support for the closure of roadways and bridges. Information on transportation restrictions and closures was disseminated to the public via permanent and portable CMSs and HAR from Delaware to Connecticut. TRANSCOM, the Transportation Operations Coordinating Committee, and the I-95 Corridor Coalition, two alliances founded in traffic management, operations, and ITS, disseminated information between their member organizations and to the public. The Port Authority of New York and New Jersey, responsible for the tunnels, bridges, and transit facilities in the area, used all of its available ITS resources: CMSs diverted trucks to the upper level of the George Washington Bridge for screening; vehicle monitoring and surveillance systems provided data on the traffic back-ups; and HAR at their facilities provided information to the public and the trucking community. (7) The INFORM TMC on Long Island was also fully engaged in traffic management and traveler information activities resulting from the attacks.

Following the attacks on the WTC, the northern Virginia TMC immediately went into emergency operations mode. Managers there were in the process of enacting emergency response procedures because of the catastrophic events in New York City when Flight 77 flew directly overhead as it proceeded to crash into the Pentagon. (8) The TMC then began emergency operations in earnest to manage the partial self-evacuation from Washington, D.C. that ensued. "The Smart Traffic system made possible instantaneous implementation of control measures over a wide area without wasting major manpower and other resources, making them available to rescue operations. Among its vital initial responses were signal coordination, suspension of construction lane closures, and reconfiguring HOV facilities (to clear major corridors for outgoing traffic from D.C.)." (9) While emergency response to the incident site and the no-notice evacuation itself wreaked havoc on the transportation system, it was also affected for days to come as new traffic restrictions and security check points at sensitive government facilities and military installations were introduced.

TMCs and Emergency Operations Centers in Maryland and Washington, D.C. were also involved in the response, with advanced technological capabilities which included)(8)

- Scrolled running commentary displayed on large screens;
- Posting "sterile images" of video that, for example, would show realtime situations at bridges;
- A situation reporting system that keeps track of incidents;
- A video link to Virginia Department of Transportation bridges and gateways; and
- Full traffic control and intersection control of the District's 1,500 traffic quadrants.

The events of 9/11 demonstrated how effectively transportation could be used as both a target and a medium for carrying out acts of terror. This realization served as a wake-up call not only for the aviation community, but the entire transportation community, and rightly so. Research by the Mineta Transportation Institute on terrorist attacks and serious crime involving public surface transportation systems indicates that 58 percent of international terrorist attacks in 1998 were on transportation targets, and of these, 92 percent were on surface transportation. (10) Recognizing that the U.S. surface transportation infrastructure was not exempt from such acts, a call to action was issued on April 21-22, 2002, when the AASHTO Board of Directors adopted a set of recommendations relating to homeland security for inclusion in reauthorization of the Transportation Equity Act for the 21st Century (TEA-21), which is now referred to as SAFTEA, the Safe and Flexible Transportation Efficiency Act of 2003. "Therefore government has a responsibility to minimize the vulnerability of critical transportation infrastructure assets and to prepare for transportation's role in emergency response and recovery. While the emergency management community has the lead on many of these matters, there are key issues with significant additional resource implications that must be faced by the federal and state departments of transportation. These include: upgrading state DOT emergency operations capabilities; protection of key facility assets; and improving emergency traffic management capacity." (11)

AASHTO further recommended that in order to be effective, ITS must be deployed uniformly across the entire transportation network in each metropolitan area. The table on the following page represents details of a strategy proposed in response to AASHTO’s recommendations. The table illustrates the coverage of ATMS and ATIS treatments needed to improve a TMC’s response to emergency management.

Table 1. Strategy Assumptions for National Highway Emergency Management and Monitoring System (11)

Location	Treatment	System	Coverage
Largest 78 Metropolitan Areas	<ul style="list-style-type: none"> • Remote traffic detection • CCTV (medium scan) • Variable message signs (VMS) and other traveler information systems 	<ul style="list-style-type: none"> • Interstate, freeways, and other principal arterials 	<ul style="list-style-type: none"> • Full instrumentation on high volume facilities ($v/c \geq 0.75$) • High incident locations on moderate volume facilities ($v/c \geq 0.50$) • Spacing of cameras and detectors varies from 1-3 miles, VMS at 3-5 miles

In addition to the metropolitan area deployments proposed, it was further recommended that ITS be deployed along key fort-to-port routes on the Strategic Highway Network (STRAHNET). STRAHNET is the 61,000 miles of road, 45,400 miles of Interstate, and 15,600 miles of other public highway that provide access to and from various military installations critical in transporting equipment and personnel during deployment operations (9). It was further recommended that data be integrated and shared among urban and statewide transportation management centers, and that six Regional Strategic Management Centers be developed across the country. (11)

AASHTO’s Board of Directors acknowledged that although emergency management in its broadest context is the responsibility of local, state, and federal EMAs, there is a subset of management activities that falls under the purview of transportation agencies working in close concert with other stakeholders. These activities fall under the category of Emergency Transportation Operations (ETO). In general ETO includes critical transportation functions performed during emergencies, such as: (12)

- Planning for events that can be anticipated, such as hurricanes and winter storms;
- Detection, verification and monitoring of emergency conditions and status;
- Damage and capacity assessments performed for the transportation system;
- Identification and management of public safety lifeline routes and transportation needs;
- Traffic control strategies to support emergency response and evacuation;
- Managing unexpected capacity reductions on detours and evacuation routes;
- Development of event-specific operational strategies to address response phases;
- Warning and public information/traveler alert requirements;
- Stabilization of traffic demand in the affected area; and
- Those activities necessary to coordinate with local, state and federal authorities regarding the closure, re-opening, operation and configuration of the transportation system under emergency conditions.

All of the above ETO activities can be addressed or supported to some degree by a TMC using ITS technology. The transportation impacts of any type of emergency, whether it be a natural disaster such as a hurricane, earthquake, flood, or ice and snow event; an unintentional man-made disaster such as a fire or hazardous materials release; or a willful act of mass destruction and violence such as the attacks of 9/11, can be managed so that safety and efficiency of the response and the recovery are improved. There are differences in terrorism-related threats and emergencies, however, which must be taken into account, as they affect the ETOs described above, and even require unique ETO activity specific only to these types of incidents. These differences include those shown on the list below: (10)(13)(14)

- Large numbers of people may be the target of an attack, or may be impacted by its immediate aftermath.
- Transportation infrastructure itself may be the target of an attack, e.g. bridges, railway stations, or communications hubs, or be indirectly impacted, e.g. closure of surface streets due to exclusion zones around sensitive buildings or facilities, or collateral damage to fiber optic cables.
- A terrorist attack could occur at any time, with or without warning, when available response resources are insufficient.
- The nature of a terrorist attack may be outside the envelope of knowledge and experience of transportation operations staff, e.g. use of weapons of mass destruction (WMDs), delaying an accurate assessment of need and appropriate response.
- Transportation response resources must be available but may also need to be protected from the incident as the consequences of a terrorist attack involving WMDs, specifically biological, chemical, and nuclear devices, spread.
- A terrorist attack carried out with WMDs may result in widespread contamination of critical transportation equipment and facilities, for which appropriate provisions for decontamination must be established.
- Possible signs and consequences of terrorist incidents must be identified and appropriate actions taken to ensure personal safety, and the initial management of the area as a potential crime scene.
- A terrorist attack could comprise multiple primary and secondary events over a short period of time, designed to create confusion and lure emergency responders and civilians into a 'trap'.
- Several agencies and non-traditional players may be involved in a terrorism-related incident, such as the military, Office of Homeland Security, U.S. Secret Service, Transportation Security Administration, Federal Bureau of Investigation (FBI), etc.
- Federal agencies (e.g., the FBI) assuming command of the incident may establish a Joint Operations Center (JOC) that may or may not be physically collocated with the local Emergency Operations Center.
- A terrorist attack and/or the resulting emergency response and evacuation may impact all transportation modes. Pedestrians, personal vehicles, commercial vehicles, and transit must be dynamically coordinated as the changing conditions of one may impact the others.
- A terrorist attack requires evacuation plans that provide alternative routing for the possibility that the attack has rendered critical infrastructure or a quarantined area unavailable for evacuation and may comprise multiple, and/or clustered disasters impacting evacuation in a relatively short timeframe.
- The potential for a terrorist incident at high visibility events (e.g., Olympics), where there may be a great influx of visitors not normally accounted for in disaster evacuation scenarios, requires that special evacuation plans be developed to address these sites.
- Terrorism-related incidents may have delayed or long-lasting effects that expand geometrically in scope, even affecting mutual aid jurisdictions.
- Terrorist attacks may cause strong public reaction, including panic and anger, that may make effective management of traffic difficult.

SYNTHESIS OF CURRENT PRACTICE

A review of the literature revealed many issues relating to a TMC's role in using its ITS infrastructure in all phases of terrorism-related threats and emergencies. The results of previously conducted surveys and case studies were reviewed, lessons learned from the 9/11 attacks on the WTC and Pentagon were studied, and findings and recommendations from articles, studies, and reports on the topic have been evaluated and summarized. What follows is an overview of some of the principal practices and issues raised in regard to the role of TMCs and ITS in the various stages of an emergency as defined by the Office of Homeland Security - preparedness, detection, prevention, protection, response, and recovery.

The TMC and Preparedness

Prior to 9/11, the TMC's primary role in emergency preparedness very closely mirrored that of the transportation agency as a whole – it was centered mainly on preparing for natural disasters. Terrorism-related threats and emergencies were not prominently “on the radar”, though some agencies reported preparation for man-made disasters. Not surprisingly, preparedness measures for terrorism have become more a part of TMCs' activities since 9/11. Homeland security preparedness is the first step in making sure that the TMC is equipped to handle any type of terrorist threat or emergency.

Preparedness begins with an awareness of all of the potential threats that exist and of the consequences of various types of terrorist activity; followed by the development of emergency response plans that address the unique characteristics of these national security events. Readyng personnel in a TMC through appropriate training, exercises, and the development of necessary procedures, and preparing its facilities and equipment through vulnerability assessments and the implementation of countermeasures to mitigate the risks identified, are integral parts of the preparedness process. This phase also involves establishing inter-agency and inter-jurisdictional plans and agreements detailing how all agencies involved will work together during an emergency. These plans should include such issues as what intelligence and threat information is appropriate for the homeland security community to share with transportation managers, and how they in turn will use such information. Some of the issues relating to preparedness are discussed in further detail in this section.

Emergency Management Plans

State emergency management plans typically do not include a great deal of detail regarding transportation, as it is seen primarily as a support function to address transport of emergency resources and victims, and to supply equipment and manpower to set up barricades. Most states' emergency management plans, (also called emergency operations plans or emergency response plans), are structured to mirror the Federal Response Plan (FPR) in that they are divided into Emergency Support Functions (ESFs). Transportation is primarily addressed in ESF #1. ESFs in state emergency management plans basically offer high-level guidance, with the details left up to the responsible agency. Some states have already developed, or have plans to develop, an annex specifically for terrorism.

The Federal Response Plan is now being incorporated into the new National Response Plan (NPR) as per Homeland Security Presidential Directive No. 5 (HSPD-5). The NPR is a comprehensive document linking relevant emergency response plans such as: (15)

- Federal Response Plan;
- U.S. Government Interagency Domestic Terrorism Concept of Operations Plan;
- Federal Radiological Emergency Response Plan;
- Mass migration response plans; and
- National Oil and Hazardous Substances Pollution Contingency Plan.

A post 9/11 study to look at how well transportation elements were included in emergency management plans revealed that there was neither a clear nor consistent understanding of transportation's role in emergency response. According to study results, fewer than half of the surveyed states reported having any type of traveler information, transportation infrastructure protection, or identification of evacuation routes in their state's plans. ITS elements were not considered in any of the surveyed plans, nor had they been adequately updated to reflect the new terrorism threat. (16)(17) Since that time some progress has been made, reflecting an increased awareness both of the capabilities of TMCs and their ITS assets, and of their potential to improve emergency response. Progress has also been made to address the unique characteristics of terrorism-related emergencies. In some instances, acknowledging the importance of TMCs and ITS for homeland security, resources have been redirected from other routine activities to further bolster these assets.

Not only must a TMC ensure that it is incorporated correctly in the emergency management plans of the appropriate local and/or state EMAs, and the more detailed plans developed by the state DOT, it must also prepare plans to govern its response through the development of a TMC Emergency Response Plan. No matter how knowledgeable and experienced TMC personnel believe themselves to be to handle acts of terrorism and the impacts they may have on the transportation system, a formal, institutionalized plan should be generated. The agency as a whole, including staff at all levels, must know and be prepared to carry out their duties using these formal plans as guidance. The plans must also include any involvement with other entities internal and external to the state DOT that the TMC must interact with in the event of an incident.

A starting point in the development of an emergency response plan for a TMC is to define an ETO Mission Statement, with associated goals and objectives. These will detail the TMC's capabilities and activities during an emergency, with specific terrorism-related emergencies appropriately addressed. From that point, a Concept of Operations and Standard Operating Procedures (SOPs) for various threat or event scenarios can be generated, along with resources, communications protocols, contact information, inventories, contingency plans, etc. The Systems Engineering Approach can also be used in plan development. Information on resources to assist with systems engineering can be found in the FHWA's ITS/Operations Resource Guide for 2004. These plans must be continually fine-tuned through exercises and drills, and by reviewing lessons learned as other emergencies occur.

An emergency response plan for a TMC should include actions to be taken at various threat conditions of the Homeland Security Advisory System (HSAS). This system was created by Homeland Security Presidential Directive No. 3 (HSPD-3) to serve as a framework for communicating to governmental agencies and the public the current condition of the terrorist threat, and the various levels of vigilance, preparedness, and readiness that should be assumed. Various threat conditions of the HSAS are color-coded as depicted in the figure below. A TMC should make sure that it is adequately prepared for homeland security threats and emergencies by establishing procedures that are to be followed at every level of the HSAS. It is important that plans not only focus on the High (Code Orange) and Severe (Code Red) Threat Conditions, but on all levels. Particularly during times of Low (Code Green) Threat Condition, TMCs can take time to make sure plans are in place, and focus on training and fostering good communication, cooperation, and coordination among partnering agencies. An example of actions that a TMC can take at every Threat Condition is summarized in the NaviGator Case Study at the end of this paper.



Figure 2. Homeland Security Advisory System Codes

Assisting in developing evacuation and alternate route plans is a critical TMC preparedness activity. TMCs with ITS technology can play a vital role in this by providing mapping tools and historical information on traffic conditions at potential points of origin, destination, and along the evacuation route to identify any operational deficiencies. TMCs have in-depth incident management experience that can serve as an asset to the evacuation planning and implementation processes. TMCs may also plan future deployment of ITS devices to correspond with planned evacuation routes so that there can be ATMS and ATIS in place to facilitate evacuation management.

Preparedness for a terrorist incident encompasses the development of a Continuity of Operation Plan (COOP) for the TMC. A COOP is defined as “a plan that details how essential functions of an agency will be handled during any emergency or situation that may disrupt normal operations, leaving office facilities damaged or inaccessible.” (18) COOPs are vitally important for TMCs, which may be damaged or rendered uninhabitable by a terrorist strike; however the same incident making it crucial that the emergency services the center renders can still be carried out if at all possible. Vital elements of a COOP for a TMC can be modeled after the Federal government’s COOP. These elements can include:

- **Plans and Procedures** to detail exactly how critical functions will be maintained or reestablished;
- **Identification of Essential Functions** to determine which functions the TMC will continue to provide until it can be brought fully back on line;
- **Delegation of Authority** to define which TMC personnel will be responsible for which COOP tasks;
- **Order of Succession** to identify alternate personnel for critical functions and decision-making in the event primary personnel are not available;
- **Alternate Facilities** must be identified that can immediately accommodate the TMC personnel and equipment needed to perform ETO duties in a threat-free environment;

- **Interoperable Communications** to define requirements for essential center-to-center and center-to-remote communications capability;
- **Vital Records and Databases** to ensure that all documentation (such as contact lists and inventories), software, and equipment are available for continued operation, even at an alternate site; and
- **Tests, Training and Exercises** to ensure that personnel are frequently trained on COOP activities so that if needed, they can respond quickly.

Development of a Disaster Recovery Plan (also called a Business Recovery Plan) is another key TMC preparedness activity. Following a disaster that greatly impacts the TMC itself, managers must begin the process of restoring it to full functionality. The time needed for recovery can vary widely depending on the magnitude of the disaster and its impact on the TMC. Some elements of the disaster recovery process include: (19)

- **Document recovery needs in a Business Recovery Plan** detailing what the TMC will do to recover. The FEMA web site has a checklist of issues that should be considered (20);
- **Record damages and losses** with photographs and sketches to document the extent of damage;
- **Apply for assistance as needed**, seeking assistance where appropriate as some disasters may have very costly impacts;
- **Resume operations as quickly as possible during recovery**, even from an alternate site; and
- **Revise emergency management plan** as needed based on lessons learned from the disaster.

Training

The events of September 11th launched an unprecedented focus on the interrelation between transportation and security, and consequently an interest in training programs that address them. Prior to 9/11, training provided to most TMC personnel focused on job-specific duties (or “hard skills”) and customer service training (or “soft skills”). If TMC personnel were included in any training for emergency situations, it was mainly related to inclement weather operations. A terrorism-related emergency represents unfamiliar territory for most TMC personnel, and one for which training must be provided. Traditional training for natural disasters, though essential, may not be adequate to address the special circumstances that may surround a terrorist attack.

A study was conducted in August of 2002 for AASHTO’s Transportation Security Task Force, which included a survey of states to determine their training needs for terrorism-related incidents. (21) As evidenced by the study findings:

- In 65 percent of the state DOTs surveyed, most emergency training was only delivered to maintenance workers;
- About 70 percent of DOTs surveyed provided in-house security training to their employees, but most of this training addressed 1) handling hazardous materials situations, or 2) emergency responses to disaster situations;
- A majority of DOTs surveyed (about 80 percent) had not made major changes to their in-house training activities since September 11th to include broader security related training initiatives;
- Most DOTs surveyed (about 60 percent) wanted federal input and support on how to develop security-related training;
- A handful of state DOTs were developing or providing security training that was more advanced than most DOTs; and
- A significant number of DOTs were using external resources to provide security training, especially State EMAs.

The AASHTO survey also included best practices and examples of innovative ways state DOTs were delivering terrorism-related training to their employees. Oregon DOT has an in-house training program

on WMDs for its maintenance personnel called B-NICE (Biological, Nuclear, Incendiary, Chemical, and Explosive). Course instructors teach participants how to identify and respond to these types of incidents, as well as how to protect themselves, preserve crime scenes, and be aware of potential secondary devices. This type of program can be tailored to a TMC's incident management or service patrol units.

California DOT (Caltrans) uses a "Train the Trainer" format that allows for a broader dissemination of information to local and state agencies. Caltrans is also a leader in providing a wide variety of security-related training to its employees, as well as to external agencies, and in delivering this training in a variety of ways. The Virginia Department of Transportation (VDOT) also has an innovative training approach. VDOT uses an Anti-Terrorism Kit with quick reference materials to aid employees in recognizing and responding to these types of incidents.

Most, if not all, TMC personnel, as well as their field counterparts in incident management and service patrol units, would be called upon to remain at work or report to work in the event of a terrorist incident. Washington State DOT has developed a training course which serves the need of their employees to provide for the safety of their loved ones while they are at work. This program, called the Self and Family Preparedness Class, helps to prepare employees and their families for disaster so that when the time comes, employees can focus on doing their jobs safely and efficiently, without being overly distracted by worry for their families. This program adds to employees' job satisfaction and well-being with the knowledge that their agency is concerned for the safety of their families.

The AASHTO survey illustrated that 80 percent of state DOTs, had not changed their approach to training since 9/11 and had not taken advantage of the wide array of training that was available through state, federal, and even non-governmental resources. Homeland security training for TMC personnel today has still not kept pace with training for other emergency responders. Many Departments of Transportation may be under the erroneous assumption that an emergency is an emergency, and that the in-house training their maintenance personnel have had for years will serve them well in a terrorist attack. Terrorism awareness training, how to conduct vulnerability assessments of the TMC and field ITS infrastructure, hazardous materials response, identification of WMDs, Incident Command System training – all of these would benefit employees of a TMC, as well as their field response teams. State DOTs are aware of the need for improved homeland security training, with 65 percent of the states surveyed in 2002 reporting that their training programs were not sufficient to address terrorism.

It is also important to note that much of the terrorism-related training available today does not focus specifically on transportation, and state DOTs may not feel the training is relevant enough to expend staff time and money to attend. FEMA's Emergency Management Institute (EMI) offers several terrorism-related courses that would benefit transportation managers in meeting the specialized needs of these types of incidents. One such course that has been found to be relevant in meeting DOTs' training needs is the Integrated Emergency Management Course (IEMC) Option E915 – Homeland Security. The course is used to educate participants to better prepare for, and respond to, the consequences of a terrorist event and is delivered by placing participants in a disaster simulation. (22) The Transportation Operations Preparedness and Response Workshop conducted around the country for the FHWA by Booz Allen Hamilton is another very relevant training opportunity for transportation personnel along with other emergency responders from the region. This workshop raises awareness of how transportation is affected by emergencies such as a terrorism incident, and begins the dialogue between agencies, who may not have worked together before, that will form the foundation for better interaction under emergency situations.

Vulnerability Assessments

Identification of critical transportation assets, conducting vulnerability assessments of these assets, and determining the potential impact of their being attacked to public safety and mobility, are essential

activities in a transportation agency's preparedness for potential terrorist attacks. Vulnerability assessment is comprised of six basic steps: (23)

- Step 1 – Identify critical assets
- Step 2 – Assess vulnerabilities
- Step 3 – Assess consequences
- Step 4 – Identify countermeasures
- Step 5 – Estimate countermeasure cost
- Step 6 – Review operational security planning

In addition to its role in assessing the vulnerability of other infrastructure with its mapping tools and archived data on traffic operations, a TMC is itself considered a critical asset, and thus managers must assess its vulnerability to acts of terrorism. As defined by Presidential Decision Directive (PDD) 63, issued on May 28, 1998, critical infrastructure is infrastructure that, if compromised, would significantly diminish the abilities of: (9)

- The federal government to perform essential national security missions and to ensure the general public health and safety;
- State and local governments to maintain order and to deliver minimum essential public services; and
- The private sector to ensure the orderly functioning of the economy and the delivery of essential telecommunications, energy, financial and transportation services.

In addition to “infrastructure”, which is generally considered to be roads, bridges, and tunnels, this also includes the other critical transportation assets of facilities, equipment, and personnel. Included in this definition are TMCs and ITS components such as roadway monitoring equipment, traffic signal and control systems, CMSs, and communications systems. The following are examples of threats to transportation assets resulting from acts of terrorism using WMDs. (24) TMC personnel must consider the vulnerability of personnel, facilities, and equipment to these and similar threats:

- Structural or functional damage or destruction resulting from vehicles carrying explosives;
- Casualties resulting from the blast or fire;
- Dispersion of biological or chemical warfare resulting in a shut down of the system and human casualties or illnesses; and
- Collateral damage to telecommunication lines, power lines, and other infrastructure or facilities.

TMCs should be considered potential targets for terrorist activity, both as a primary target, and as a secondary mark to disrupt their emergency response capabilities. The vulnerability of a TMC as a terrorist's target can be assessed by answering questions similar to those that could be posed regarding high rise buildings or other high-risk targets: (25)

- What are the locations of critical or vulnerable facilities? Is there perimeter security?
- Has the building been structurally hardened?
- Is there adequate access control?
- Are there electronic monitoring systems and are they adequate?
- Are incoming utilities (water, power, and communications) secure?
- Are there adequate security personnel, and how well are they trained?
- Are these precautions linked together in a sensible plan, and are there redundancies in the system in case one link should fail?
- Is access to existing security plans or building design plans restricted?
- Is access to computer systems (both hardware and software) restricted?

The consequences of a TMC being the victim of an act of terrorism and being rendered inoperable must be weighed in respect to its vulnerability to security breaches. The “defensive properties” of the TMC must be evaluated. This will determine how susceptible the TMC is to being attacked, and how much effect a disruption will have on its ability to carry out its essential functions, and on its ability to recover. Defensive properties can be broadly categorized as: (9)

- Redundancy - the ability of extra components of a system to compensate for failed components;
- Robustness - the insensitivity of system performance to external stresses;
- Resilience - the ability of a system to recover following an incident; and
- Security - the means of detection, deterrence, and prevention of a willful attack.

Interagency Agreements

“Coordinate! Communicate! Cooperate!” This is the mantra of many traffic incident management programs, most of which have acknowledged the value of having all emergency response stakeholders working together to lessen the impact that traffic incidents can have on safety and mobility. All agencies working well together does not happen by magic – it takes hard work and time to build trusting, mutually beneficial relationships. The Illinois Terrorism Task Force uses a phrase at its meetings that is most appropriate, “Check your logo, check your ego at the door!” (26) Turf wars and mistrust can hinder response to a terrorist attack; and unfamiliarity between disparate agencies, many of whom may have never worked together before, can lead to inefficient delivery of emergency service for recovery.

It is beneficial to have agreements in place before an incident occurs that define expectations and dictate what is to be done, how it will be done, and who will do it. The agencies that have worked together to develop these plans will be more successful in executing a well coordinated response than those that do not have plans, or that have plans that were developed without the input of all stakeholders. TMCs, ITS, and their communications, information dissemination, and data, voice, and video-sharing capabilities are widely thought of as being facilitators to enable and encourage this type of interagency planning and coordination.

Emergency Management Plans, Memoranda of Understanding (MOUs), Memoranda of Agreement (MOAs), mutual aid agreements, etc., all serve to help coordinate emergency activities. Mutual aid agreements that are developed with consideration for terrorism-related incidents and resource-sharing are very important. Uncertainty over the nature and scale of these types of incidents and how they may affect individual jurisdictions may make emergency managers reluctant to share resources, desiring instead to keep them in the event they are needed later.

A synopsis of the activities a TMC can undertake to prepare its facilities, equipment, and personnel to better respond to terrorism-related threats and emergencies is shown in Table 2. Each of the activities can be accomplished or supported by the advanced technologies and operational procedures that TMCs and ITS afford.

The TMC and Detection

Detection involves intelligence-gathering - identifying that a homeland security-related event is about to happen, or has just happened, and notifying the proper authorities. Early detection may allow for the incident to be deterred, or at least may help to mitigate its impacts. Many metropolitan areas have extensive surveillance and monitoring systems operated by TMCs. The possibility exists now more than ever that a TMC operator, or incident management or motorist assistance personnel, will be the detector of an incident or first on the scene after it occurs. Specialized training will allow for accurate detection and verification of terrorist activity. If an incident is detected by some other means, TMC personnel must quickly communicate this information to field personnel to activate their response and keep them out of harm’s way.

Managers of TMCs should ensure that surveillance and monitoring includes all critical transportation assets. They must also be cognizant of what are the most likely targets of a terror attack. Even attacks on non-transportation targets can have a significant effect on the transportation system as vehicles and pedestrians flee the scene, and emergency vehicles flock to the site. Emergency response and evacuation planning, and plans for the future deployment of ITS should take these sites into account. Transportation facilities in close proximity to the following venues should be closely monitored for suspicious activity during times of heightened threat levels: (2)

- High profile government buildings;
- High profile national monuments, especially with large attendance;
- Public utilities infrastructure of modern and large cities;
- Sports and recreation facilities with large attendance;
- Large educational institutions, especially those with high profile;
- Chemical manufacturing and aerospace facilities; and
- Businesses critical to the economy.

A synopsis of the activities a TMC can perform to detect suspicious activity to deter an incident from occurring, or to quickly detect that one has occurred so that its effects can be minimized is given in Table 3.

Table 2. Synopsis of TMCs’ Preparedness Activities (1)(12)(13)(27)

Incident Stage	TMC and ITS Functions
Preparedness	<ul style="list-style-type: none"> • Monitor HSAS and develop plans for each Threat Condition • Modify existing emergency response plans to reflect special terrorism considerations and update these plans as needed • Participate in the development of evacuation plans • Coordinate work zone activities so they do not all impact traffic at the same time on parallel routes in case of a terrorist incident or other incident with no forewarning • Reduce the time required for implementation and setup of evacuation strategies using modeling and simulation tools • Improve management of evacuation routes to accommodate evacuation for events of various severities • Identify critical infrastructure • Conduct vulnerability assessments, set priorities, identify gaps, and prepare to close gaps • Develop operational procedures to protect first responders • Participate in training, workshops, tabletop exercises, simulations, etc. • Utilize data and tools to analyze transportation system performance, and use these data and tools to plan ahead for various “what if” scenarios • Utilize tools and technology to foster center-to-center communication and coordination between agencies, with the media and the public

Table 3. Synopsis of TMCs' Detection Activities (1)(12)(13)(27)

Incident Stage	TMC and ITS Functions
Detection	<ul style="list-style-type: none"> • Use field personnel to identify suspicious activity or signs of wrong-doing • Once detected, verify the emergency, identify potential hazards, define the impact area, and notify public safety and other response agencies • Monitor critical infrastructure • Use surveillance systems to detect indicators of a potential disaster, a disaster that is occurring, or a disaster that has occurred • Provide assistance in determining the nature of the disaster, extent of damage, and any potential hazards, including sharing information collected from environmental sensors

The TMC and Prevention

Prevention involves all activities that are undertaken to keep a terrorist attack from happening. Though much of the national focus on prevention of terrorism-related incidents for surface transportation is on monitoring freight movement and border crossings to prevent WMDs from being transported and used in an attack, the TMC's role in prevention cannot be underestimated. Simply knowing of the surveillance capabilities of a TMC, or that incident management units routinely patrol an area, may serve to deter a terrorist from attempting to sabotage critical transportation assets. Surveillance can also stop an attempted attack before it can be completed. Preventive measures that can be supported by a TMC include greater information gathering and sharing, surveillance, and diligent coordination and cooperation among multiple stakeholders. (1)

A synopsis of the activities a TMC can perform to prevent an incident from occurring, using its surveillance and information-sharing capabilities as deterrents, or as means of thwarting an attack in the making is given in Table 4.

Table 4. Synopsis of TMCs' Prevention Activities (1)(12)(13)(27)

Incident Stage	TMC and ITS Functions
Prevention	<ul style="list-style-type: none"> • Utilize sensors and analysis tools to head off terrorist activity along roadways, tunnels and bridges • Monitor critical infrastructure using closed circuit TV surveillance cameras • Monitor critical infrastructure using field incident management and motorist assistance personnel • Increase awareness and vigilance of all personnel

The TMC and Protection

In regard to TMCs and ITS, protection of transportation assets involves deterring an attack that has begun or is about to begin; and protection of the public by making the transportation network as responsive as possible. By providing diversions, alternate routes, and suitable emergency response and evacuation routes under dynamic conditions, citizens can be directed away from the impacted area. As an example, VDOT uses ITS technology at many of its critical assets for detection and protection. “In case of a direct attack on any of VDOT’s assets that are monitored by ITS, the system sensors have the capability to alert the control center immediately, provide visual confirmation, disseminate information to travelers (thus preventing escalation of damage by incoming traffic), and implement incident responses by controlling gates and signals.” (2)

A TMC must also safeguard itself, and must maintain its function to monitor critical assets and provide information to the public and other agencies. Central to this capability is protection of its information systems. In an April 1997 briefing to the Board of Directors of AASHTO, William J. Harris, then Commissioner of the President’s Commission on Critical Infrastructure Protection stated, “The transportation infrastructure...is more vulnerable now than previously because it is adopting ever larger dependencies on other infrastructure. Therefore it is no longer sufficient to take care of its roads and rails and runways. It must also be concerned with the potential for attacks on ITS installations or on other aspects of telecommunications and computer processing activities that are essential for effective transportation systems.” (28) In response to this need, ITS America has developed some industry privacy principles, Maryland DOT has completed ITS Security Requirements and Implementation Recommendations, and the FHWA has published an Information Security Awareness Overview document. (28)

A synopsis of the activities a TMC can perform to protect critical assets from terrorism-related threats, and protect the public if an incident occurs is given in Table 5.

Table 5. Synopsis of TMCs’ Protection Activities (1)(12)(13)(27)

Incident Stage	TMC and ITS Functions
Protection	<ul style="list-style-type: none"> • Utilize tools and technology to harden critical infrastructure, as well as communications and information systems and transportation operations centers • Utilize tools and technology to provide and activate alternate routes and transportation system redundancy at critical points

The TMC and Response

Once a terrorism-related incident has taken place, a TMC’s response to minimize its impacts on the public and the transportation system must begin immediately. Response typically comprises those activities that take place within 24 hours of an event’s occurrence. Even if the TMC’s own facilities and equipment are compromised, it must be prepared to respond through an established COOP. The TMC must also be prepared to immediately begin support functions to facilitate other emergency response agencies to perform their duties. As demonstrated on 9/11, a TMC can provide this support in a number of ways - one of the primary ways is by facilitating communication, both between agencies through integrated voice, data, and video systems, and to the public through ATIS; and by facilitating an orderly evacuation if one becomes necessary, and even if one spontaneously occurs. Some of these issues relating to emergency response are discussed in further detail in this section.

Communication

Center-to-center, center-to-remote, and remote-to-remote communications are at the heart of emergency response efforts. Effective communications correlates directly to successful emergency response, just as communication break-downs can directly contribute to failures. Communications issues took center stage in the 9/11 terrorist attacks. Questions still revolve around whether or not New York City firefighter's and law enforcement officer's lives could have been saved had there been better radio communications between them, their headquarters, and other responders prior to entering the WTC before its collapse.

A TMC's role in communications is critical, as it often serves as a central communications hub for many responders, and delivers this information to the public and the media. As an example of effective communications under adverse circumstances, TRANSCOM kept information flowing in spite of the destruction of, and damage to, many of its participating centers by faxing over 800 reports about each agency's operating decisions following the attacks. (29)

A TMC's ITS surveillance and monitoring infrastructure can be damaged in a terrorism-related incident, or power or communication failures could render them useless. When this happens, TMC personnel must rely on the communication of information from on-site personnel to make important traffic management decisions. Thus, lack of communications can have effects that reach far beyond the immediate operational inefficiency, and adversely affect both transportation management decisions and traveler information, and consequently all emergency transportation operations. Following the August 2003 blackouts in the northeast, a New York City Transit newsletter quoted one of its dispatchers as saying, "For transportation, I think the blackout was worse than 9/11. And the reason, no communication." (30) This statement underscores the importance to transportation of maintaining communications during an emergency, no matter what the cause.

In the event a terrorist strikes, communications with a TMC's field personnel (incident management and service patrols) is more important than ever. These field units may be first responders at "ground zero", and must be able to communicate back to the center precisely what has happened. The TMC must also be able to provide field personnel with potentially life-saving information regarding protective measures that should be taken if they encounter WMDs. Therefore it is vitally important to have communications that can withstand unfavorable conditions, as well as back-up forms of communication.

Intra-agency communications can be challenging enough under emergency conditions, but inter-agency communications can be particularly problematic. Issues of different hardware, radio frequencies, radio protocols and codes, and disparate priorities and incident command structures all are obstacles that need to be overcome. Even if systems are interoperable, a terrorist attack may render the infrastructure inoperable due to damage to cellular towers or loss of power. Something as innocuous as radio communications impaired in tunnels or other radio "dead spots" may also hinder response efforts.

In a meeting one month after the 9/11 attacks, the United States Conference of Mayors convened over 200 mayors and others involved in emergency response in Washington, D.C. to discuss the effects the attacks were having on their cities, and how they could best prepare for such events. The need for interoperable communications was one of the key issues they raised then, and was a recurring theme at subsequent meetings. As a result of aggressive lobbying by this body, \$154 million in Homeland Security and Department of Justice funds was allocated in 2003 to improve communications interoperability. (31)

Though a step in the right direction, the funding will not meet the tremendous needs identified in a recent survey of 192 cities conducted for the Conference of Mayors. The results of this survey indicated that communications interoperability had not progressed significantly since 9/11, primarily due to lack of funding. The survey indicated that only 66 percent of the cities surveyed reported communications interoperability between their local police, fire, and EMS; and only 23 percent of that small subset reported additional interoperability with transportation agencies. Of all respondents to the survey, an

overwhelming majority, 86 percent, reported that they do not have interoperable communications with the state transportation department. (31) Voice and data interoperability of transportation and public safety is one of the focus areas of the FHWA's Public Safety and Security Program. (32)

Integrated TMC and Public Safety Systems

A high level of integration of systems is a key success factor for inter-agency communications during the response phase of a homeland security incident. The ability to communicate electronically between disparate systems to share voice, data, and video can greatly improve the efficiency of response. The successful integration of TMCs and other emergency response agencies to address homeland security issues will likely be accomplished by a combination of institutional agreements (whether formal or informal), coordinated operational procedures, and technological integration of computer and communications systems.

The latter of these efforts will require a project which may be undertaken with in-house staff, but most likely involve consultants. The successful marriage of the disparate agencies involved dictates that institutional dynamics be considered equally important as the technical aspects of the projects. A study was conducted by the University Transportation Center of Alabama in 2003 which looked into how ITS and Emergency Management systems could be successfully integrated. The study yielded some interesting results: (33)

- The three factors that contribute the most to a project's success are organizational efficiency, data analysis capability, and public benefit, with public benefit being the most important. Therefore, any project integrating ITS and emergency services must demonstrate how it will benefit the public. Projects with the greatest perception of public benefit will have more stakeholder participation and more motivation to do what is necessary to ensure its success.
- Transportation stakeholders are usually the initiators and owners of these projects, and have the most power to influence the success or failure of the ITS and emergency management integration. Surprisingly, however, these agencies tend to have the least expertise and the least likelihood to look for new and innovative solutions. While transportation entities enjoy this "power" in integration projects, they must be careful to keep in mind that all stakeholders must be engaged for the project to be successful – there can be no "my way or the highway" mentality.
- First and second responders involved in such projects are perceived by themselves and others as having little power. These groups may tend to lose interest in integration projects, rendering them ineffective.
- The first and second responder community ranked organizational efficiency as highly important. Thus, in order to successfully "sell" an integration project to them, and keep them engaged, a link to how the project will help them perform their duties more efficiently must be emphasized.
- The Commercial Private Sector stakeholders, such as vendors and consultants, have the greatest amount of expertise, use of innovation, and organizational support to successfully complete an integration project. These resources should be used fully to make sure both transportation and emergency management stakeholders remain engaged.
- Factors found to contribute most to the failure of an ITS and emergency management integration project are: organizational inertia, uncertainty, lack of skills and procedures, interoperability, and difficulty finding funds.
- "Success breeds success", and as integration projects get further along and have documented achievements, the interest and involvement of all stakeholders increases, contributing to more successful outcomes.
- Factors found to contribute most to the success of these projects are: efficacy (the power to produce intended effects), climate of trust, shared understanding, sense of equality, and geographic proximity.

Technological challenges of integrating very different hardware and software systems, the institutional issues discussed above, as well as privacy concerns and priority differences, have been successfully overcome, though the obstacles are great. Two examples of successfully integrated systems include:

- **The Integrated Incident Management System (IIMS).** IIMS links New York City and New York State public safety and transportation agencies in a coordinated incident management system. This innovative project, which was funded by the US DOT's ITS Public Safety Program, provides electronic sharing of incident data and video between several TMCs, police, fire, and EMS, and very importantly, their response vehicles. Information can be entered from the field or from one of the centers, and all involved entities have access to it. This system was just coming on-line in 2001. (34)
- **Capitol Wireless Integrated Network (CapWIN).** "CapWIN is a state-of-the-art wireless integrated mobile data communications network being implemented to support federal, state, and local law enforcement, fire and emergency medical services (EMS), transportation, and other public safety agencies primarily in the Washington, DC Metropolitan area. The purpose of CapWIN is to greatly enhance communication and messaging systems, effectively creating the first multi-state, inter-jurisdictional transportation and public safety integrated wireless network in the United States. CapWIN provides a "communication bridge" allowing mobile access to multiple criminal justice, transportation, and hazardous material data sources." (35) CapWIN came on-line in 2003, and therefore did not play a role in the response to the 9/11 Pentagon attack, however critical lessons were learned during that time. In a 2003 press release, CapWIN's interoperable voice and data integration was cited by the Office of National Capitol Region Coordination (ONCRC), an office of the U.S. Department of Homeland Security created to coordinate homeland security in the Washington, D.C. metropolitan area, as a vital homeland security tool. (36)

Traveler Information

An emergency will result in the need to inform large numbers of travelers in real time of dynamically changing transportation system conditions. Under emergency conditions a TMC will typically: (13)

- Provide information on road closures, infrastructure damage, debris removal, and restoration activities related to highway systems and facilities;
- Provide real-time traffic information and traffic reports for roads within the affected area or on roads leading into the area;
- Provide updated transit service information for the disaster area; and
- Assign appropriate personnel at key disaster sites to oversee operations and to provide consistent, verified public information to emergency management agencies, public information officers, and the media.

The traveler information needs resulting from a terrorist attack are different from those which TMCs are accustomed to addressing. Traveler information in these situations takes on an even more profound, life-saving role than the avoidance of normal commuter congestion. The transportation information delivered in response to a terrorism event can instill calm to avoid panic and chaos which could lead to injuries and death; save lives by diverting people away from harm and out of the affected areas as safely and efficiently as possible; and can help to clear routes for emergency responders to get to the aid of victims as quickly as possible. Providing motorists with the information they need to make informed decisions to avoid congested or dangerous conditions is a critical step in helping the system to recovery quickly. Providing traveler information is an essential function and TMC personnel must ensure that appropriate resources are dedicated to maintaining this service, accounting for it in their COOP should the facility be damaged or need to be evacuated.

Requests for traveler information well beyond those normally serviced by a TMC should be anticipated and planned for, both operationally and technologically. The volume of requests for information will

depend largely on the location, nature, and severity of the attack, and the day and time in which it is carried out. It will also depend on the public's familiarity with the traveler information services available on a routine basis. Obviously an attack taking place on a weekday while most people are at work and school will generate a larger volume of requests than one taking place at other times. Unfortunately, the very nature of terrorism will make it more likely that an incident will occur so as to affect the most people, at the worst time, and in the most severe means possible.

Sources of information and information dissemination must keep pace with quickly changing conditions. Reporting old or erroneous information could have devastating effects following a terrorist incident. As demonstrated on 9/11, the transportation system can be stressed not only by vehicles, but by pedestrians as well. For this reason, traditional vehicle detection technology on which much of today's traveler information is based may be ineffective, even if they survive damage from the attack. Deploying TMC personnel into the field, relying on incident management units and service patrols for more frequent updates, and coordinating with other responding agencies for information are alternative means of acquiring information.

It is vitally important that information relayed to the public during times of a terrorism-related crisis be delivered consistently, and with "one voice" across all agencies. There should be no situations where the TMC is telling the public one thing, and a transit agency, emergency management agency, law enforcement, or the media are saying something contrary. This was the case in the Washington, D.C. area following the attack on the Pentagon, resulting in mass confusion and wasted time and resources sorting things out. (29)

Traveler information can be delivered in a variety of ways by a TMC – via 511 or other telephone services, changeable message signs, and web sites. Many lessons were learned from 9/11 regarding what worked well and what systems were challenged. Some of the issues surrounding these methods are discussed below.

511/ Other Telephone Services

Most of this country's experience with a TMC's response to a terrorist attack has come from the September 11th attacks on the WTC and the Pentagon. Neither of these areas had a 511 service in place at the time of the attacks, so exact information on how the service would have responded or been affected cannot be determined. They did, however, have other traffic information telephone services in place at the time which can be used for evaluation. Even though TRANSCOM does not normally provide information directly to the public, but only to its 100 participating agencies, on 9/11 the public, in its urgent need for information, contacted them and TRANSCOM staff provided information. (10) Other TMCs in the region were also flooded with calls from the public.

Based on lessons learned from the 9/11 terrorist attacks, the Implementation Guidelines for Launching 511 Services (version 1.1) gives guidance on how these services should be configured to address emergency situations. A TMC providing this type of service should consider these guidelines as they design and operate 511 services:

- With automated systems, emergency messages should preempt any other type of message or menu options. As the event progresses and as call volumes dissipate, more options may be allowed.
- A pre-recorded message should begin the call, with an option to speak with an operator.
- Messages must indicate that long waits are to be expected, and should direct callers to the TMC's website for additional information.

While a TMC's primary focus is typically providing information on the condition of the transportation system it manages, in a terrorist incident the public will need information across all transportation modes

(including walking, ferries, private carriers, transit, commuter rail, etc.), as well as other types of information relative to evacuation. Specific information may be requested regarding: (13)

- Services available along evacuation routes;
- Services available at evacuation destinations, such as information regarding hotel rooms, gas, bathrooms, restaurants, shelters, and accommodations for people with special needs (e.g., the disabled, elderly and those traveling with pets or livestock);
- Evacuation route conditions, such as the expected travel time to their destinations, incidents, road closures, lane closures, and weather;
- The route to a certain destination;
- Availability of alternative routes; and
- Travel conditions for the return home.

While a TMC may not have this information readily available, they must nonetheless be prepared to answer these questions if asked, or provide callers with contact information where they can obtain the information. TMC staff with regional, multi-modal experience is very beneficial during these crises.

Capacity is a key issue for a 511 service in times of homeland security incidents. Experience has shown that systems can quickly become overloaded, wait times can be unacceptably long, and calls can be dropped. Landline and cellular providers may have differing capacity options, and may respond differently to increased volumes of traveler information calls. They may also be impacted differently depending on the nature of an attack. In designing capacity for telephone-based traveler information services TMCs must consider both types of services. Capacity design options for 511 service include: (10)

- Design to a locally determined spike demand, such that the 511 system can be expected to maintain normal or near normal service during the emergency;
- Design to normal levels of demand, but with the feature to activate additional capacity when needed;
- Design to normal levels of demand, and plan to address any spike in demand on an as-needed basis; and
- Design to normal levels of demand and not attempt to address any spike in demand related to a homeland security emergency, on the basis that the 511 service is locally determined to be an inappropriate means to address such situations relative to other options, e.g. local media or law enforcement.

Changeable Message Signs (CMSs)

Permanent and portable changeable message signs were used with great effectiveness on 9/11. Transportation agencies took full advantage of their resources, and lent and borrowed signs as needed. Within minutes CMSs in the New York City area posted messages advising of bridge and tunnel closings. The closest signs to the WTC site displayed “AVOID MANHATTAN” messages. (7) “NEW YORK CITY CLOSED TO ALL TRAFFIC” messages were posted on signs approaching the area. Even hundreds of miles away CMSs throughout the northeast warned travelers away from the New York City and Washington, D.C. areas. In Atlanta, Georgia, CMSs were used to post “AIRPORT CLOSED” messages to attempt to avoid freeway traffic congestion near the airport exits.

Web sites

The Metropolitan Transportation Authority’s website, which normally gets 200,000 hits per day, received 10 million hits per day in the week following the 9/11 attacks, while SmarTraveler Website hits were up by approximately 100,000 to slightly in excess of 500,000. (10) As long as the field infrastructure on which the web site’s information is based is functional, and the computer systems and power are

maintained, a TMC's web site can remain operational and be a tremendous asset during times of emergency. Telephone call volumes may create a greater demand than the supply of phone lines can accommodate, and the web site can be a desirable alternative. It was reported that at one TMC on 9/11 once a recording was posted on the call-in number to go to the web site for information, calls significantly dropped off as people hung up and accessed information on-line.

Evacuation

In the event of a terrorism event, the public will self-evacuate from areas of danger. These types of "no-notice" evacuations differ from those transportation agencies are accustomed to managing as a result of natural disasters, such as hurricanes, when an agency may have several days notice in which to carry out an evacuation. But even these sudden evacuations can be managed with the help of TMCs and ITS technology so that they are carried out as efficiently and safely as possible.

Among the automated tools currently in use by TMCs offering some level of evacuation support are the Conditions Acquisition and Reporting System (CARS) used by several states; and the Regional Incident Management System (RIMS) used by Houston's TransStar. There are also tools under development called Planning, Analysis, and Real-time Operations Support Tools which will be very beneficial to a TMC's ability to better manage evacuation traffic. They will provide critical planning support, traveler information, information on services, traffic management, and resource sharing for evacuations. Through integration with a TMC's ATMS and ATIS, these tools will combine real-time ITS technology with planning and simulation technology. One such tool being developed with the support of the FHWA is called TrEPS, Traffic Estimation and Prediction System. Benefits of this type of tool include:

- Real-time modeling capabilities to identify and integrate optimal route selection and traffic control strategies into response;
- Automated guidance and support for implementing recommended traffic control strategies and evacuation routes in a coordinated and timely manner; and
- Ability to assess the performance of the transportation system and make adjustments in real-time according to emerging conditions.

There are also other efforts underway to improve evacuation traffic management. According to Vincent Pearce, Emergency Transportation Operations Team Leader with the FHWA's ITS Joint Program Office, that office has just initiated a \$20 million program of research on no-notice evacuations. It includes:

- ITS supporting improved response by towing/recovery and hazmat;
- Transportation operations and technology in biohazard situations;
- Traffic management technology to enhance emergency response;
- State of the practice in no-notice evacuations;
- Low-cost evacuation route surveillance;
- Monitoring evacuations using vehicle-infrastructure integration;
- Communicating with the public using ATIS during disasters;
- Emergency transportation operations in rural areas;
- Rapid restoration of ITS following a disaster;
- Real-time evacuation management and modeling;
- Harmonization of transportation and public safety incident management standards; and
- Completing and deploying incident management standards.

A synopsis of response activities performed by a TMC in the event a terrorist attack is carried out is shown in Table 6. These activities serve to carry out the transportation agency's emergency transportation operations functions, as well as support the activities of other agencies and the public.

These activities include those of the TMC’s incident management and service patrol field units who may be among the first responders.

Table 6. Synopsis of TMCs’ Response Activities (1)(12)(13)(27)

Incident Stage	TMC and ITS Functions
Response	<ul style="list-style-type: none"> • Notify law enforcement, emergency management, and other response agency personnel • Develop detour routings • Review and possibly terminate existing work zone closures • Transfer transportation control and management to alternate centers • Receive dispersion information for nuclear, biological, or chemical attacks or other disasters involving hazardous materials to modify transportation management strategies, determine evacuation requirements, and inform and protect transportation agency response personnel • Adapt traffic control strategies and provide traveler information to protect the public from exposure to hazards in incidents involving nuclear, biological, or chemical agents • Support communications between transportation personnel and their families and loved ones • Monitor and control transportation systems and infrastructure, and coordinate transportation activities with other agencies • Monitor and coordinate the closure of high-risk facilities such as bridges and tunnels • Assist state and local government entities in determining the most viable available transportation networks to, from, and within the disaster area • Identify specific traffic management actions to maintain a smooth flow for transport of emergency resources • Share evacuation information among all transportation and non-transportation agencies • Coordinate traffic control strategies supporting emergency response across jurisdictions • Integrate with existing Incident Command System practices of public safety agencies • Optimize the use of available roadway capacity to avoid operational failures that can cause gridlock, long hours of delays, vehicle breakdowns, frustrated travelers, and significant risks to the evacuees • Improve management of the local streets that provide access to and from evacuation routes • Improve the efficiency of detecting, responding to, and clearing incidents on evacuation routes • Improve the warning and preparation information provided to evacuation destinations • Maintain emergency services access to the disaster area and the evacuation routes • Provide hazardous materials containment response and damage assessment • Assist with evacuation of persons from immediate peril • Transport materials, personnel, and supplies in support of emergency activities • Provide all available and obtainable transportation resource support including:

<p>Response</p> <p>(cont'd)</p>	<p>vehicular traffic flow data and information from permanent and temporary monitoring sites for roads within the affected area or on roads leading into the area</p> <ul style="list-style-type: none"> • Provide information on road closures, infrastructure damage, debris removal, and restoration activities related to highway systems and facilities • Monitor and control transportation systems and infrastructure, and coordinate transportation activities with other agencies (local, state, and Federal) • Develop an architectural framework to maintain communication and foster coordination between responding agencies • Utilize tools and technology to determine and disseminate real-time information about the system to other responders and the public • Utilize tools and technologies to re-route traffic if the system itself is under attack • Restrict certain routes to specific vehicle types • Remotely operate reversible lanes and reconfigure HOV lanes to maximize traffic flow in one direction on major facilities
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The TMC and Recovery

Recovery includes those activities undertaken beginning typically 24 hours after the incident occurred to bring the system back to normal, or at least resume critical services. Depending on the nature of the terrorist attack, full recovery could take several months, or even years. TMCs and ITS are essential to short-term recovery following an incident. The information TMCs can gather from its roadside devices can be relayed to the public to help balance traffic load for better flow of emergency and evacuation routes. Management of re-entry traffic is another TMC recovery function. Recovery from a terrorist attack involving biological or chemical substances may also require a decontamination process for the TMC’s facilities and equipment.

A synopsis of activities performed by a TMC to help the transportation system recovery from a terrorist attack is shown below.

Table 7. Synopsis of TMCs’ Recovery Activities (1)(12)(13)(27)

Incident Stage	TMC and ITS Functions
<p>Recovery</p>	<ul style="list-style-type: none"> • Ensure the efficient, safe and secure reentry of evacuees • Coordinate road clearance activities • Provide real-time traffic information to the public and other agencies for roads in and leading to the area, and along the evacuation route • Decontaminate facilities, vehicles, equipment • Monitor and control traffic flow through traffic signal timing, and arterial and freeway management • Assist in developing alternative transportation services if necessary to replace capacity lost in the attack • Provide tools and technologies to create a flexible, reconfigurable transportation system to meet emergency needs • Provide enhanced ability to execute plans for alternative modes/alternative routes in emergency conditions

	<ul style="list-style-type: none"> • Provide tools and technologies to make maximum use of available capacity through load balancing
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ENABLERS

There are many factors that enable a TMC to successfully engage in homeland security efforts – a role that is not a new “add-on”, but more an acknowledgement and expansion of its current capabilities. Through a review of the literature and the author’s own experience, the following are identified as enablers for TMCs and ITS to take on this role:

- Homeland security objectives are not only compatible with a TMC’s primary objectives of transportation mobility and safety, but often mutually reinforcing. A safer transportation infrastructure with adequate operational capacity will be a more robust system that can survive and recover from man-made disasters more readily; (37)
- The surveillance, monitoring, public information and communications technologies already in place and being operated by TMCs are known to be important components in all phases of a terrorism-related incident;
- The relationships and operational procedures that TMCs have already established with the public safety community through working together on traffic incident management form the basis for effective homeland security coordination;
- In some cases interoperable communications and integrated systems are already in place between TMCs and other emergency responders;
- Funding to help a TMC in preparing for terrorism-related incidents can come from a number of non-traditional sources, possibly allowing these activities to be undertaken without taking funding away from other routine activities;
- TMC personnel who operate and maintain technologically advanced ITS components have expertise, and there may be little learning curve needed for any new technologies to better support homeland security;
- The TMC has emergency transportation operations experience dealing with major traffic incidents and natural disasters that require multi-agency, multi-jurisdictional response, and can translate this “all-hazards” experience into more catastrophic incidents;
- The automated tools TMCs have available to them for traffic management can free up manpower from other emergency responders that can better be utilized in other response activities;
- TMCs are typically operational 24 hours a day, and thus can respond immediately, and at any time to an incident; and
- The reason that TMCs and ITS have not been incorporated to a larger degree is more a lack of awareness than opposition. Once the homeland security community is aware of the TMC’s capabilities, they are generally receptive to working together.

INHIBITORS

The extent to which TMCs and ITS have still not been incorporated further into many metropolitan areas’ plans to address terrorism is indicative that there are still barriers that must be overcome. Some of these barriers include:

- The homeland security community is accustomed to working with a DOT’s maintenance department for emergency situations, and may not be familiar with the capabilities of the TMC and its ITS infrastructure;
- There are difficulties inherent with trying to get a number of disparate agencies to work together in the face of competing priorities, turf wars, inertia to maintain the status quo, and limited resources; (38)

- The different levels of funding and different mechanisms for securing funding for homeland security initiatives can be a barrier, as agencies find it difficult to jointly fund multi-agency initiatives;
- Because terrorism-related incidents are rare occurrences, limited resources may not be expended on them in lieu of more pressing day-to-day transportation and public safety issues;
- Technological challenges of communications systems that are not interoperable, and traffic management and CAD systems that cannot share data electronically can inhibit the efficient flow of information that is critical during an emergency;
- Lack of experience about what is involved in preparing for and responding to a terrorist incident may serve to immobilize progress as TMCs struggle with where to begin, both technologically and institutionally;
- Unfamiliarity between the myriad of agencies that would be involved in a terrorism-related incident may impede planning and response efforts;
- Transportation is thought of more in terms of its support functions during an emergency, and not in terms of its more proactive operations, management, and public information capabilities, and therefore may not be included to the degree necessary in emergency planning; and
- Lack of training of TMC personnel in terrorism issues and the incident management structure under which an incident would operate is a prime inhibitor in its contributions to homeland security.

GEORGIA NAVIGATOR CASE STUDY



The information gathered during this research is intended to assist a TMC in identifying its roles and responsibilities in homeland security, considering the issues involved, and determining what steps it should take to better position itself to react to whatever terrorism-related threats and emergencies may occur in the area. The information will now be applied to a case study of an actual TMC and ITS – Georgia’s NaviGator. This case study is not meant to be exhaustive, but will look at a few of the issues raised as the managers of NaviGator seek to develop a plan of action to equip the TMC and the ITS it operates to become effective tools in Metro Atlanta’s homeland security initiatives – specifically issues surrounding training, system surveillance and management, agency communications, and traveler information.

NaviGator Background

GDOT’s NaviGator Intelligent Transportation System is one of the most comprehensive, highly integrated, and geographically and functionally extensive ITS deployments in the country. Conceived in the early 1990’s to manage the increasingly congested traffic conditions in the Metropolitan Atlanta area, and jump-started by the announcement that Atlanta had won its bid to host the 1996 Olympic Games, NaviGator is a legacy system that has managed to grow and keep abreast of technological advancements in ITS. NaviGator has 153 miles of full ITS instrumentation, and features statewide freeway management, incident management, and traveler information services. The ITS Deployment Tracking Survey has ranked Atlanta as having a high level of deployment and integration since the survey began in 1997.

The headquarters for NaviGator is the Transportation Management Center located in Atlanta in the Wayne Shackelford Building. The building houses all of GDOT’s Operations Division, which consists of the Office of Traffic Operations as well as Traffic Safety and Design, Maintenance, and Utilities. The

TMC adjoins the Georgia Emergency Management Agency, and is located on the same complex as the Georgia National Guard, Department of Defense, and the Georgia Department of Public Safety. Recognizing the value of its TMC in emergency traffic operations, GDOT located its EOC in the TMC facility. The TMC operates on a 24 hours a day, seven days a week, 365 days a year basis. It is staffed with a blend of GDOT managers and supervisors; GDOT and consultant Console Operators, Highway Emergency Response Operator (HERO) Dispatchers, and Public Relations/Media personnel; and consultant Customer Service Representatives (CSRs). Console Operators are primarily responsible for incident management, while CSR's answer *DOT Traveler Information telephone calls, providing traffic information to the public, but also receiving information called in regarding incidents observed and requests for assistance by HEROs. The TMC is further supported by GDOT systems engineering personnel, technicians, and Information Technology (IT) staff.

The NaviGator TMC may be one of the most secure TMCs in the country. It is located on an access-controlled complex, which is secured on a continual basis by National Guardsmen and State Troopers. During times of heightened alert, access to the property is further restricted to only personnel working on the compound. Visitors to the complex may not be allowed to enter at all, or may have to be escorted onto the property by whomever they are visiting, or by security personnel. External access to the building is controlled by a swipe card entry system. Underground parking is available for the security of TMC personnel who work at night; access to this garage is also swipe card controlled. Security guards are on duty inside the building on a continuous basis. Internal access is also controlled with swipe cards, with only those persons needing access to certain areas being granted that access. There are also internal and external surveillance cameras at the TMC that can be accessed through the NaviGator System.

The TMC is integrated with several locally operated Traffic Control Centers (TCCs) in surrounding Metro Atlanta jurisdictions. These TCCs are responsible for arterial traffic management. The Metropolitan Atlanta Rapid Transit Authority (MARTA) also has a NaviGator workstation in its Transit Operations Center. In 2002, the Macon Regional TMC, which is jointly operated by GDOT and local city and county personnel, was opened to address freeway and arterial traffic management needs in central Georgia. The flow of data and information is excellent in Metro Atlanta as all existing TCCs are integrated into the NaviGator System and use common software, hardware, and communications protocols. All agencies can access and control each other's surveillance cameras, but can only view another jurisdiction's incidents and CMS messages.

The HERO Unit is the incident management unit of NaviGator, clearing Metro Atlanta's freeways of lane blocking debris, crashes, and stalls; setting up traffic control for longer-duration incidents to allow other emergency responders a safe environment in which to work and through which motorists can safely pass; and providing motorist assistance services for stranded motorists. In order to become certified, HEROs must pass an extensive training program, which includes Emergency Vehicle Operations, 1st Responder for Emergency Medical Services, and 1st Responder for Hazardous Materials. HEROs patrol designated Metro Atlanta interstate routes comprising 170 miles during peak traffic periods, and 232 miles during the off peak, operating 24 hours a day on weekdays, and 12 hours on the weekends.

Another component of NaviGator is the Traffic Signal Electrical Facility (TSEF). TSEF is responsible for the installation, maintenance, and timing of traffic signals for the entire state. TSEF technicians are also responsible for providing preventative and responsive maintenance of all TMC and field ITS devices statewide and serving as ITS Construction Coordinators, providing technical assistance for ITS construction projects throughout the state.

The entire ITS program, including all aspects of the NaviGator System, the ITS Engineering Unit, the TMC, HEROs, and TSEF are part of the Office of Traffic Operations. For the purpose of this case study, the broad heading of "NaviGator" will be used to represent the entire program and each of these units.

The NaviGator System consists of the following components:

- **1,361 fixed black & white video detection system (VDS) cameras (1,262 cameras in Metro Atlanta)** for automated collection of vehicle speed, volume, and occupancy data, allowing for the detection of traffic incidents and congestion;
- **319 full-color, pan/tilt/zoom CCTV surveillance cameras on freeways (287 cameras in Metro Atlanta)** for monitoring of traffic conditions, and traffic incident detection, verification, and management;
- **207 CCTV cameras on arterials (187 cameras in Metro Atlanta)** for monitoring and management of arterial traffic conditions;
- **96 slow scan cameras (10 cameras in Metro Atlanta)** for monitoring of traffic conditions, and traffic incident detection, verification, and management in areas outside of NaviGator's fiber communications network;
- **101 CMSs (80 CMSs in Metro Atlanta)** displaying automated and operator-generated travel time, traffic incident, construction/maintenance lane closures, and AMBER Alert messages;
- **48 weather reporting and monitoring stations** throughout the state providing data on precipitation, visibility, ambient and ground temperature, and wind speed;
- **5 ramp meters** that regulate the flow of traffic onto the freeway on I-75;
- **Presence Detection System** comprised of 37 VDS cameras providing automated detection of stopped vehicles in the travel lane along a segment of an area interstate where there is not adequate emergency shoulder width to which a motorist could relocate if their vehicle became disabled. When a stopped vehicle is detected, the system is designed to alert TMC personnel who verify the incident and dispatch a HERO to the scene, and to automatically post a warning message on upstream CMSs;
- **Coastal Evacuation System** comprised of surveillance, monitoring, vehicle detection and traveler information components located along Georgia's Atlantic Coast to facilitate evacuations from that area, particularly due to hurricanes;
- **Adverse Visibility Warning System** to warn motorists when visibility is limited in along an area of I-75 prone to smoke and fog;
- **63 radar units (29 in Metro Atlanta)** for automated collection of vehicle speed, volume, and occupancy data, allowing for the detection of traffic incidents and congestion; and
- **418 miles of fiber optic cable (240 miles on Metro Atlanta freeways; 150 miles on Metro Atlanta arterials)** for communications to field devices, hubs, and between TMCs and TCCs.

Also included in the NaviGator System are the following traveler information and agency communications services:

- **NaviGator Traveler Information Web Site.** This award-winning web site provides site visitors with statewide incident information including crashes, stalls, and construction / maintenance lane closures; access to still images from all CCTV surveillance cameras; all current CMS messages; a trip time calculator; weather station data; special traffic alerts and news; and a new My NaviGator feature, which allows visitors to customize NaviGator information to their own prescribed routes. My NaviGator also disseminates traffic information on routes subscribers designate using e-mail, pagers, and PDAs.
- **NaviGator Traveler Information Telephone Service (*DOT)** has CSRs providing real-time traffic information 24 hours a day, seven days a week, 365 days a year. Motorists may also call *DOT to request assistance from HEROs, and report incidents they encounter. This is a free cellular phone call for customers of four area cellular service providers, accounting for over 48 percent of the Metro Atlanta cell phone market.
- **NaviGator Traveler Information Displays** are located in Welcome Centers all over the state, as well as large centers and private business. These units display traveler information customized to the particular location, such as incidents, travel times, construction / maintenance lane closures, traffic alerts, streaming video image tours from select cameras in the area, and CMS messages.

- **NaviGator Web** is the web services version of the NaviGator software which was developed under the Metropolitan ITS Integration (MITSI) Project, an earmark project demonstrating center-to-center communications between disparate agencies - the NaviGator TMC, MARTA, and the City of Atlanta 911 Center. NaviGator Web is in the beta-testing stage at this time.

Over the next six years, the NaviGator Program will greatly expand under the Fast Forward Transportation Program recently announced by Governor Sonny Perdue. Fast Forward is an accelerated congestion relief program that will expand NaviGator coverage area by 84%. It will also include an expansive ramp metering program; a significant increase in the number of HEROs and their coverage area; and an expansive traffic signal upgrade and efficiency optimization program for Metro Atlanta arterials.

Metro Atlanta and Terrorism

The issue of homeland security is of utmost importance to Georgians since 9/11, and GDOT acknowledges the benefits of leveraging Georgia's significant amount of ITS infrastructure and on-going homeland security initiatives to address it. With a population of well over 4,000,000 residents; several nationally and internationally prominent businesses, sports venues, and government offices; and Hartsfield-Jackson International Airport, one of the busiest airports in the world, Atlanta cannot be considered exempt from possible acts of terrorism. In fact, during the 1996 Olympic Games, a terrorist's pipe bomb killed one person and wounded several others during festivities in Centennial Olympic Park, and there have since been bombings of a gay nightclub and an abortion clinic in the area. GEMA reports that it has responded to 16 large-scale disasters since 1990, and has learned lessons from each event to fine-tune its preparedness to manage a terrorist attack should one occur here. (39)

GDOT Commissioner Harold Linnenkohl is part of the Homeland Security Task Force created by the state's Emergency Management Agency. This Homeland Security Task Force is a part of the Georgia Department of Public Safety and is comprised of representatives from all homeland security responder and stakeholder groups. Georgia is one of only a few states that have created a security taskforce in cooperation with other state agencies. Georgia recently hosted the international Group of Eight (G8) Summit, the experiences from which will further enhance its homeland security program.

NaviGator Terrorism Response Action Plan (N-TRAP)

Lessons learned from this research, including conversations with industry experts and GDOT senior management, review of available literature, and first-hand experience with the NaviGator System have led the author to formulate the NaviGator **Terrorism Response Action Plan, N-TRAP** (pronounced "entrap"). The purpose of **N-TRAP** is to begin the process of preparing NaviGator's human resources, facilities, technologies, and processes to be effective partners in Georgia's homeland defense, particularly those efforts in the Metro Atlanta region. This case study will look at various aspects of this plan; however it is not to be considered the extent of the **N-TRAP** initiative. This will only form the basis for the development of a comprehensive program that will evolve over time. The issues to be considered in this case study include emergency response planning using the HSAS, training, and the evaluation of four strategies identified in AASHTO's guidance on updating existing emergency response plans to address terrorism-related threats and emergencies: internal arrangements for system surveillance and management, public information, and agency communications; and external relationships also relative to system surveillance and management.

N-TRAP and the Homeland Security Advisory System

As part of **N-TRAP**, an emergency response plan will be developed to include actions NaviGator personnel will take at various HSAS Threat Conditions. Examples of proposed actions, summarized in Table 8, were developed as a result of lessons learned from the literature review; results from a 2002

AASHTO survey (40), and the author’s experience with the NaviGator TMC and ITS program. These actions are proposed by the author for illustration purposes only; do not reflect any policy or commitment by GDOT; and are not all-inclusive of actions that will be taken at any given threat condition. This proposed list will be refined as further emergency response planning is completed.

Table 8. Proposed N-TRAP Activity at Various HSAS Threat Conditions

Threat Level	Suggested Protective Measures	Suggested TMC Protective Measures
<p>Low Condition (Green)</p> <p>This condition is declared when there is a low risk of terrorist attacks. Federal departments and agencies should consider the following general measures in addition to the agency-specific Protective Measures they develop and implement:</p>	<ul style="list-style-type: none"> • Refining and exercising as appropriate preplanned Protective Measures; • Ensuring personnel receive proper training on the Homeland Security Advisory System and specific • preplanned department or agency Protective Measures; and • Institutionalizing a process to assure that all facilities and regulated sectors are regularly assessed for vulnerabilities to terrorist attacks, and all reasonable measures are taken to mitigate these vulnerabilities. 	<ul style="list-style-type: none"> • Develop NaviGator ETO mission statement, with associated goals and objectives • Develop a NaviGator Emergency Response Plan to address terrorism and ensure that all personnel are aware of the plan and are provided training to implement it • Develop a COOP for the TMC to include loss of communications and loss of power contingencies • Develop a Disaster Recovery Plan to address those issues necessary to recover if the TMC is impacted by a disaster • Take part in terrorism-related training, workshops, and exercises • Develop a Personal and Family Preparedness training program • Tailor training received in train-the-trainer format to NaviGator, and deliver to personnel • Update contact lists and system inventories • Cross-train NaviGator personnel through the GOLD Exchange Program • Foster existing emergency management stakeholder relationships through coordination, communication, and cooperation on routine matters • Establish new emergency management stakeholder relationships • Work with other agencies and jurisdictions in the development of emergency response plans, and ensure all plans are appropriately aligned • Ensure that traffic signal timing plans for critical corridors and evacuation

<p>Low Condition (Green)</p>		<p>routes are developed for ETO</p> <ul style="list-style-type: none"> • Perform a vulnerability assessment of the TMC, field devices, and personnel, and develop projects to minimize vulnerabilities and consequences of failures • Develop ITS design standards, and hardware and software specifications that will improve the system’s ability to withstand and respond to a terrorist incident • Conduct no-notice drills; fine tune response plans; and provide training to address needs identified during the drills • Ensure all personnel are trained to keep doors to secure areas closed and locked in the TMC and in state vehicles
<p>Guarded Condition (Blue)</p> <p>This condition is declared when there is a general risk of terrorist attacks. In addition to the Protective Measures taken in the previous Threat Condition, Federal departments and agencies should consider the following general measures in addition to the agency-specific Protective Measures that they will develop and implement:</p>	<ul style="list-style-type: none"> • Checking communications with designated emergency response or command locations; • Reviewing and updating emergency response procedures; and • Providing the public with any information that would strengthen its ability to act appropriately. 	<ul style="list-style-type: none"> • Ensure employee know threat level has been raised to Code Blue and if or how it will affect their duties • Update established SOPs at TMC, HEROs, and TSEF • Perform inspection of all NaviGator TMC and field devices and communications • Review the TMC’s Emergency Action Plan and ensure employees and visitors are adhering to all security policies, and are familiar with mail-handling and bomb threat procedures • Review swipe card issuance data, and disable inactive cards • Ensure pre-established emergency supplies are purchased and stockpiled, and equipment is operational and staged to be readily available • Communicate with complex security personnel and inform TMC employees of any new security measures • Perform facility evacuation drills to test COOP • Include information regarding change in threat level on web site and traveler information displays
<p>Elevated Condition (Yellow)</p> <p>An Elevated Condition is</p>	<ul style="list-style-type: none"> • Increasing surveillance of critical locations; • Coordinating emergency plans 	<ul style="list-style-type: none"> • Ensure employees know threat level has been raised to Code Yellow, and if or how it will affect their duties

<p>declared when there is a significant risk of terrorist attacks. In addition to the Protective Measures taken in the previous Threat Conditions, Federal departments and agencies should consider the following general measures in addition to the Protective Measures that they will develop and implement:</p> <p>Elevated Condition (Yellow) cont'd</p>	<p>as appropriate with nearby jurisdictions;</p> <ul style="list-style-type: none"> • Assessing whether the precise characteristics of the threat require the further refinement of preplanned Protective Measures; and • Implementing, as appropriate, contingency and emergency response plans. 	<ul style="list-style-type: none"> • Increase routine monitoring of CCTV surveillance cameras at predetermined intervals • Carefully monitor transportation facilities near special events and at sites known to be potential terrorist targets • Work with other agencies and jurisdictions in ensuring established emergency response plans are appropriate to address the specific threat, and revise plans as necessary • Verify that the nature of the threat does not warrant that more specific actions be taken • Identify abandoned vehicles, particularly those located near critical infrastructure, bridges, and tunnels, or other security-sensitive locations, and keep law enforcement informed if deemed suspicious • Ensure that all emergency communications devices are tested, operational, and readily accessible • TMC and field personnel are to be watchful of suspicious activity as they go about their normal duties
<p>High Condition (Orange)</p> <p>A High Condition is declared when there is a high risk of terrorist attacks. In addition to the Protective Measures taken in the previous Threat Conditions, Federal departments and agencies should consider the following general measures in addition to the agency-specific Protective Measures that they will develop and implement:</p>	<ul style="list-style-type: none"> • Coordinating necessary security efforts with Federal, State, and local law enforcement agencies or any National Guard or other appropriate armed forces organizations; • Taking additional precautions at public events and possibly considering alternative venues or even cancellation; • Preparing to execute contingency procedures, such as moving to an alternate site or dispersing their workforce; and • Restricting threatened facility access to essential personnel only. 	<ul style="list-style-type: none"> • Ensure employees know threat level has been raised to Code Orange, and if or how it will affect their duties • Review Emergency Response Plan to determine if it is appropriate in light of current threat • Consider limiting access to the TMC • Prepare EOC for activation by setting up telephones, computers, supplies, contact lists, and emergency response plans • Maintain communications with Homeland Security Task Force agencies • Stock TMC with emergency food, water, and other supplies • Increase monitoring of CCTV surveillance cameras around critical infrastructure • Communicate and coordinate procedures with other GDOT offices,

<p>High Condition (Orange) cont'd</p>		<p>TIME Task Force, Regional Traffic Operations Task Forces, and NaviGator User Group</p> <ul style="list-style-type: none"> • HEROs and TMC Operators are to identify abandoned vehicles, and have those located near critical infrastructure, bridges, and tunnels, or other security-sensitive locations immediately towed by local law enforcement or State Patrol • Develop an on-call schedule so that management level NaviGator personnel are on-call to respond to unusual circumstances • Develop TMC staffing schedules and communicate expectations for reporting to work and remaining on duty in the event an incident occurs • Ensure alternate work sites are prepped in the event they are needed • Pre-stage emergency response equipment and material so they are readily available • Monitor pre-established evacuation routes for obstructions such as maintenance activity or malfunctioning traffic control devices. Remove obstruction, perform repairs, or revise plans as necessary • TSEF to ensure that emergency traffic signal timing plans are ready to be implemented • Inspect uninterruptible power supply (UPS) and generator to ensure they are fully operational and prepared for loss of power
<p>Severe Condition (Red)</p> <p>A Severe Condition reflects a severe risk of terrorist attacks. Under most circumstances, the Protective Measures for a Severe Condition are not intended to be sustained for substantial periods of time. In addition to the Protective Measures in the previous Threat Conditions, Federal departments and agencies also should consider the following general measures in addition to the agency-</p>	<ul style="list-style-type: none"> • Increasing or redirecting personnel to address critical emergency needs; • Assigning emergency response personnel and pre-positioning and mobilizing specially trained teams or resources; • Monitoring, redirecting, or constraining transportation systems; and • Closing public and government facilities. 	<ul style="list-style-type: none"> • Ensure employees know threat level has been raised to Code Red, and if or how it will affect their duties • Restrict access to facility to employees, essential contractors, and vendors only • Implement a schedule so that NaviGator management personnel are on-site at all times during this threat level if the nature of the threat warrants it • Assign HEROs and TSEF field personnel to monitor specific security sensitive sites and critical infrastructure

<p>specific Protective Measures that they will develop and implement:</p>	<ul style="list-style-type: none"> • 	<ul style="list-style-type: none"> • If specific targets are identified, monitor those targets closely until the threat subsides • Place Severe Threat Condition alert message on CMS, HAR, welcome center displays, and the web site • Prepare to staff the EOC if it is activated • Develop scripts for CSRs, Operators, PR, and Media personnel so that a single message is being delivered on if and how transportation is affected • Alter HERO routes to focus on critical corridors, special events, and critical infrastructure • Closely monitor evacuation routes for anything that may hinder traffic flow • Prepare for military mobilization procedures
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N-TRAP and Training

Adequate training for NaviGator personnel is vital. Management, TMC, TSEF, and HERO personnel will improve their ability to effectively respond to terrorist incidents by taking advantage of several courses offered by GEMA through the Georgia Public Safety Training Center. Some of the courses to be scheduled for NaviGator personnel include: (41)

- Emergency Response to Domestic Biological Incidents - Operations Level;
- Emergency Response to Terrorism: Basic Concepts;
- Emergency Response to Terrorism: Operations Course;
- Hazardous Materials Contingency Planning;
- Incident Command System/Emergency Operations Center Interface (ICS/EOC);
- Incident Management/Unified Command for Weapons of Mass Destruction/Terrorism Incidents;
- Incident Response to Terrorist Bombings – Awareness;
- Mass Fatalities Incident Response;
- Incident Command System: ICS;
- Terrorism;
- Awareness of Weapons of Mass Destruction; and
- Response to Weapons of Mass Destruction.

Courses taught in a “train the trainer” format will be sought, as they will allow for the broadest possible dissemination of knowledge among employees at minimal cost. This format would also allow GDOT to tailor the training to its specific needs. All available training mechanisms will be utilized - drills, simulations, tabletop exercises, classroom, web-based, video, and publications. Specific NaviGator training materials and reference guides will be developed and distributed to employees.

Breadth and depth of training for NaviGator personnel will ensure that personnel at all levels are equipped to step in and perform effectively if the need arises. Through the NaviGator TMC’s own G.O.L.D. (**Generating Opportunities for Leadership Development**) Program (which has as its vision a

Traffic Operations workforce that is empowered to grow professionally, equipped to assume leadership roles, and excited about their contribution to local and national transportation efforts), a cross-training initiative called “The GOLD Exchange” has recently been created. This cross-training will now be expanded to ensure that all personnel can respond effectively to carry out critical functions in the event primary personnel are unavailable during a terrorism-related incident.

Other *N-TRAP* training will be directed toward ensuring that NaviGator technicians maintain some capability to trouble shoot and repair critical equipment. Reliance on maintenance contracts is unavoidable given limited personnel resources and an expansive and complex system, however in the event of a catastrophic incident, systems may fail and contract personnel will likely not be available in a timely manner, or may not be available at all. Initial and refresher training will be provided to these employees, and user manuals will be maintained in a central location. Performance of routine preventative maintenance on systems will increase familiarity with the devices and sustain a technician’s knowledge base after training is completed.

Participation in Information Technology training is critical for GDOT’s IT personnel who support NaviGator as well. Consultant System Integrator personnel may not be readily available in an emergency, but NaviGator system hardware and software must remain functional to be able to respond to the event. Training in how cyber-terrorism can affect the system and countermeasures that can be employed will be proposed for IT personnel. Training opportunities for traffic simulation and modeling software applications will also be explored.

Consideration will be given to scheduling the Federal Highway Administration’s Transportation Operations, Preparedness, and Response Workshop. This workshop will enhance NaviGator personnel’s awareness of the issues surrounding emergency transportation operations, and will bring together other stakeholders as well. Unlike other homeland security workshops that have been held in Georgia, this will deal specifically with transportation operations issues. The workshop will likely be planned through the Metro Atlanta Traffic Incident Management Enhancement (TIME) Task Force. The TIME Task Force includes representatives from police, fire, EMS, towing and recovery, transportation, media, and others stakeholders working together to improve traffic incident management in the region. Most of the TIME Task Force members would be involved in some way were a national security event to occur in the Metro Atlanta area.

Recently, approximately ten NaviGator employees participated in the US DOT’s Technical Training by Telephone (T3) Webcast entitled "Effects of Catastrophic Events on Transportation System Management and Operations," in which staff from the John A. Volpe National Research Center gave an overview of how transportation systems responded to and were affected by six catastrophic incidents:

1. Blackout, New York New Jersey-Connecticut Metropolitan Area, August 14, 2003
2. Blackout, Great Lakes Region, August 14, 2003
3. Terrorist attach, New York, N.Y., September 11, 2001
4. Terrorist attach, Washington, D.C., September 11, 2001
5. Rail tunnel fire, Baltimore, Maryland, July 18, 2001
6. Earthquake, Northridge, California, January 18, 1994

This training was very effective in delivering information to a relatively large number of NaviGator employees at no cost to the Department. Future relevant T3 training sessions will be accessed.

Application of Guide for Updating Highway Emergency Response Plans for Terrorist Incidents Checklists

AASHTO’s Guide for Updating Highway Emergency Response Plans for Terrorist Incidents was used to begin formulating plans for *N-TRAP* activities. The guidance document contains several checklists for

internal arrangements and external relationships that enhance a transportation agency’s ability to effectively prepare for and respond to terrorist emergencies. Internal arrangements are centered on organizational structure, training, operational procedures, communications and equipment needed for incident response. External relationships address the agency’s role in the broader emergency management community, and how its facilities, personnel and equipment can be used to support local, statewide, and federal emergency management efforts. The four checklists which most closely reflect the contributions of TMCs and ITS were applied to the NaviGator Case Study, and the results formulated as action items for *N-TRAP*. The four areas addressed were:

- Internal Arrangements: System Surveillance and Management;
- External Relationships: System Surveillance and Management;
- Internal Arrangements: Public Information; and
- Internal Arrangements: Agency Communications.

N-TRAP and Internal Arrangements: System Surveillance and Management

This strategy refers to the full use of DOT command, control and surveillance technologies to assist in emergency response following a terrorism incident. Program modification considerations are taken directly from AASHTO’s guidance, and addressed as they relate to NaviGator. These considerations will be incorporated into the development of *N-TRAP* as potential action items.

Table 9. Internal Arrangements: System Surveillance and Management

Consideration	Key <i>N-TRAP</i> Activities:
<p>How can existing devices, e.g., cameras, variable message signs, be utilized in helping response?</p>	<ul style="list-style-type: none"> • Routinely monitor CCTV surveillance cameras for signs of suspicious activity, with increased vigilance during times of heightened threat conditions. Surveillance cameras on transportation facilities located near prominent sporting and convention venues will be closely monitored during special events. • Develop policies governing heightened surveillance for critical infrastructure sites, such as bridges, tunnels, and other security-sensitive locations to address what to look for; what sites should be targeted for heightened surveillance; frequency of surveillance; and what to do and who to contact if suspicious activity is identified. • Utilize ramp meters to regulate, or even halt, the flow of traffic onto the freeway should an incident occur necessitating restriction of freeway traffic, or to allow emergency response vehicles to pass. • Utilize video and data from the VDS to detect unusual changes in traffic flow that may signal that some incident is about to take place or has just taken place. • Utilize freeway and arterial CMSs to warn motorists away from hazardous incidents; divert them to predetermined alternate or evacuation routes; allow for better emergency vehicle access; and to balance system load during recovery. • Develop a library of generic “Terrorism Threat and Emergency” messages for CMSs, HAR, IVR, etc. covering various terrorist attack scenarios to facilitate faster implementation. • Deploy portable ITS units and portable CMSs obtained from contractors on GDOT construction projects to supplement permanent signage, or in the event that permanent signs are damaged in the attack or rendered inoperable due to loss of communications or power.

	<ul style="list-style-type: none"> • Develop policies governing the use of CMSs to display messages regarding elevation of the HSAS threat condition, i.e., at what threat condition will CMSs be used; for how long will messages be displayed; which CMSs will be used and during what times of day; priority of these messages over other types of messages; and appropriate message content. • Dispatch TSEF signal timing personnel to aid locals in remotely or manually changing signal timing to predetermined plans to move traffic out of harm’s way, and manage increased traffic demand. • Utilize data and video from weather monitoring and reporting stations to monitor atmospheric conditions that will help to track dispersal of hazardous chemicals in a WMD incident. • Share all video, data, and information to the broadest extent possible with other emergency responders using NaviGator, NaviGator Web, or other means. • Ensure that GEMA’s NaviGator workstation is functional and that GEMA personnel are properly trained on the use of the NaviGator system. Also volunteer NaviGator staff to man the workstation at GEMA during SOC activation.
<p>Is the deployment of ITS devices being planned with adequate consideration to responses to a terrorist incident?</p>	<ul style="list-style-type: none"> • Evaluate existing and planned NaviGator hardware, software, and system architecture for homeland security implications. Make modifications as feasible to the current system, and to future specifications and requirements. • Identify critical ITS devices; to the extent economically feasible, harden these devices to withstand a terrorist attack; and equip them with back-up communications and power. • Expand the NaviGator System under the Fast Forward Transportation Program to fully cover all Metro Atlanta’s interstates and major limited access freeways to facilitate alternate and evacuation routing capability, and enhance incident management and advanced traveler information services that will be needed in the event of a terrorist attack. • Ensure that the NaviGator Business Plan, which is currently under development, adequately addresses how the system will need to be positioned, technologically, functionally, and financially over the next five years to better address homeland security issues. • Consider terrorism related information-sharing needs between all stakeholder groups during the Regional and Statewide ITS Architecture Development processes, using the new Disaster Response and Evacuation User Service, as well as information gathered as GDOT’s Emergency Response Plans are updated to include terrorism incidents.
<p>How can the flow of data and/or information be affected by a terrorist incident?</p>	<ul style="list-style-type: none"> • Conduct a Vulnerability Assessment of all NaviGator facilities and equipment to determine their redundancy, resilience, robustness, and security. • Consider modifications to NaviGator software for enhanced access and control of devices and incidents between jurisdictions to allow for more flexibility to respond to an emergency situation. • Complete beta testing and deploy NaviGator Web to allow for more agencies to have access to NaviGator data, even if telephone lines and fiber optic communications are compromised in a terrorist attack. • Maintain TMC operations unless the building is damaged or employees’ safety is endangered, in which case COOP procedures will ensure that communications are maintained by forwarding telephones to an alternate site, using remote NaviGator workstations, NaviGator Web, or some other alternate form of communications.

	<ul style="list-style-type: none"> • Identify and prepare alternate work sites, such as the Macon Regional TMC or local TCCs in the event the TMC must be evacuated. Make appropriate hardware and software modifications to allow operations to continue from the alternate site. • Maintain power to the TMC following an incident using an Uninterruptible Power Supply (UPS) with a diesel fuel generator to keep essential functionality, including telephone, computer systems, and air conditioning operational for as long as possible, depending on the power demands. • Dispatch TMC or TSEF personnel if communications are lost to field devices, to manually adjust traffic signal and ramp meter timing, and change CMS and HAR messages as needed. • Investigate and implement measures, such as utilization of digital video, to eliminate the single point of failure of the centralized video switch as all data processing, data archiving, video switching, TCC access, and camera control pass through the TMC. • Employ HEROs or other NaviGator personnel to relay information back to the TMC about the incident, and traffic conditions on affected and evacuation routes if communications to field devices is lost. • Utilize relationships established with law enforcement, fire, and other transportation agencies developed through the Georgia NaviGator Users Group, the Metro Atlanta TIME Task Force, and the Metro Atlanta Regional Traffic Operations Task Force to employ their field personnel as probes to update the TMC on conditions. Jointly develop SOPs and checklists on predetermined update frequencies and types of information needed for terrorism incidents with all probe personnel. • Work with local media outlets and traffic reporting services. Give consideration to exchanging increased video control by media, as well as access to more video feeds, for access by the TMC to aerial video down-linked from media’s traffic helicopters. • Inspect NaviGator’s aerial surveillance system that was previously installed on a Georgia State Patrol helicopter to determine if it is functional, and can possibly still be used. Investigate helicopters on which to potentially mount this unit. • Train all NaviGator personnel involved in communicating information in times of emergency on the Incident Command System (ICS) in order to know who needs what information, and when do they need it. • Work closely with personnel from GDOT’s Communications Division and Public Information Officers (PIOs) from law enforcement, fire, and other local agencies who are part of the Metro Atlanta Public Information Network (MAPIN) to keep accurate information flowing following a terrorist attack.
<p>Assuming there is more than one DOT operations center, what is the relationship of the centers in terms of response? Is there the ability to shift control depending on the locale of an incident?</p>	<ul style="list-style-type: none"> • Make modifications to NaviGator hardware, software, or architecture to allow full functionality from other TCCs or the Macon Regional TMC so they can be used as an alternate site in the event a terrorism incident renders the TMC inoperable or uninhabitable. • Accelerate the deployment of 2070 Advanced Transportation Controllers (ATC) for signalized intersections along evacuation and alternate route corridors. Modify software to facilitate integration into NaviGator, allowing traffic signal control from the TMC if a TCC is damaged. • Develop agreements between the NaviGator TMC and local TCCs governing when and how control will be shifted and how facilities will be shared in the

	<p>event one or the other becomes damaged or uninhabitable as a result of a terrorist incident.</p>
<p>If there is only one DOT operations center, is there any way to provide redundant or backup services in the event a terrorist incident affects the primary operations center?</p>	<ul style="list-style-type: none"> • Utilize NaviGator Web to the extent possible to remotely access and control NaviGator field devices if all centers are rendered inoperable. NaviGator staff may even be able to work from home. • Implement measures to decentralize data and video communications to eliminate the TMC as a potential point of failure so that other TCCs or remote locations can maintain full functionality as long as field devices and hubs remain operational.
<p>Are the DOT centers secure or can they be secured during a terrorist incident?</p>	<ul style="list-style-type: none"> • Conduct a Vulnerability Assessment of the TMC facility; to determine the resilience, robustness, redundancy, and security of the center. Develop mitigation strategies where gaps are found in any of the four defensive properties. • As part of the Vulnerability Assessment, conduct a Security Audit of the NaviGator TMC, Macon Regional TMC, and local TCCs to determine if current security measures are adequate, including an assessment to determine if additional surveillance cameras are needed; if the swipe card system is appropriately secure from tampering or other malfunctions; and if the TMC’s Operations Center and equipment room are adequately protected. • Ensure all employees are familiar with the TMC Emergency Action Plan. Distribute the plan, conduct training, no-notice drills and exercises. Update the plan to include new threats and lessons learned from incidents that occur. • Work with security personnel on the Confederate Avenue Complex to determine if additional security measures are needed for this facility.
<p>Should the capabilities of existing centers be expanded for security needs?</p>	<ul style="list-style-type: none"> • Obtain more arterial and freeway traffic management and conditions data collection capability through the deployment of field infrastructure or utilization of such technology as cellular telephone or toll tag tracking. • Integrate arterial traffic management into the NaviGator TMC’s freeway traffic management system to make the system more responsive as incidents on one facility affect the other; and to allow for dynamic routing of evacuation and emergency responder traffic. • Deploy an incident detection system (IDS) at critical infrastructure that uses machine vision surveillance with a digital, looping incident recording system that automatically saves 20 seconds of video prior to the detection of an incident. Upon detection of an incident an alert would be sent to the TMC and the video file can be reviewed, and archived if necessary. • Utilize ITS infrastructure already in place at the TMC and MARTA and the City of Atlanta 911 center to share incident and video images among regional emergency responders. Develop standard operating procedures and training for appropriate use of camera images; clearly define roles and responsibilities for each agency; establish security levels, and protocols for proper response if security-sensitive activity is detected.
<p>Should more command, control and surveillance devices be deployed which can be controlled or monitored from the centers and add to response effectiveness?</p>	<ul style="list-style-type: none"> • Consider infrastructure identified by GDOT as critical for deployment of ITS devices, such as incident detection systems and CCTV surveillance cameras, if none currently exist. • Design redundancy into future fiber optic communications cable configuration. • Determine critical signalized intersections and provide LED signal heads with solar power and wireless communications to maintain operation in the event of power or communications loss.

	<ul style="list-style-type: none"> • Deploy NaviGator arterial surveillance near large transit hubs, sporting and convention venues, and any location where large numbers of people gather that may attract a terrorism-related incident. • Review the Atlanta evacuation plan to ensure that adequate surveillance, monitoring, and traveler information devices are in place. If none exist or if more devices are needed, NaviGator expansion plans will include the installation of devices at strategic locations leading up to and along the evacuation route. Redundancy will be included in these systems should the route become saturated, or key devices rendered inoperable. • Additional portable ITS devices will be purchased and retained from ITS expansion projects so that if permanent devices become inoperable or contaminated, back-up devices will be available. • Revisit the use of HAR in the Metro Atlanta area as a means of relaying information regarding evacuation routes, road closures and other information that cannot be placed on a CMS. Take advantage of lessons learned from the previous work, as well as technological advancements over the last few years, to determine if HAR is a viable ATIS alternative in the area. • Accelerate procurement of the Automated Location and Dispatch System (ALADS) for HERO vehicles, which will allow tracking of HERO location using GPS. ALADS will give HEROs the capability to wirelessly receive incident information from the TMC, and transmit data to the TMC by means of a hand-held and/or dash-mounted keypad.. • Install dash- and/or rear-mounted CCTV surveillance cameras on HERO vehicles for transmission of locally captured CCTV images to the TMC. These enhancements will greatly improve the HEROs’ emergency response capabilities, particularly in the event of a terrorist attack where the HERO may encounter WMDs, and need guidance from TMC or other off-site emergency personnel. • Work with Georgia Tech’s Center for Emergency Response Technology, Instruction, and Policy (CERTIP) on ways HEROs and other first responders can test and use the handheld, portable, and affordable technology being developed there to enhance detection and response capabilities. (42)
<p>Do the DOT centers have simulation capability to quickly model traffic outcomes of a terrorist incident?</p>	<ul style="list-style-type: none"> • Explore ways in which TSEF technicians who routinely utilize CORSIM and SYNCHRO to develop and test traffic signal timing plans, can work with the ITS Engineering unit to use these applications to model traffic movement following a terrorist incident. • Secure additional training for NaviGator personnel in traffic simulation and modeling tools. Currently NaviGator’s ITS Engineering Unit performs manual incident cost and delay analyses on major incidents. • Utilize consultant services to provide traffic modeling expertise should the need arise before GDOT staff is suitably knowledgeable.

N-TRAP and External Relationships: System Surveillance and Management

This strategy refers to the full use of state command, control and surveillance technologies to assist in emergency response following a terrorism incident. Program modification considerations are taken directly from AASHTO’s guidance, and addressed as they relate to NaviGator. These considerations will be incorporated into the development of *N-TRAP* as potential action items.

Table 10. External Relationships: System Surveillance and Management

Considerations	Key <i>N-TRAP</i> Activities:
<p>Is the state emergency management agency aware of the full capability of state DOT surveillance, detection and communications capabilities?</p>	<ul style="list-style-type: none"> • Conduct a NaviGator outreach and awareness campaign for GEMA. Although the NaviGator TMC is located adjacent to GEMA, personnel from each agency may not be familiar with the other. Recent personnel changes at both agencies make it necessary to introduce or re-introduce NaviGator to GEMA. • Invite GEMA and other Homeland Security Task Force members to the TMC for a brief overview of NaviGator, followed by a demonstration showing how the TMC would respond in an emergency situation. The presentation and demonstration will build upon lessons learned as detailed in the case studies of the 9/11 attacks, and the role of TMCs in the Washington and New York areas. • Conduct an internal outreach effort to other GDOT offices and Districts, particularly the Metro Atlanta District Office and Maintenance Office, which have primary responsibility in GDOT’s emergency operations in the Atlanta area, to make them aware of how NaviGator can support their emergency transportation operations activities. • Use attendance at GEMA’s training courses as an outreach effort to get to know homeland security personnel from other agencies; learn more about those agencies; and also raise awareness about the TMC and its ITS technologies. • Follow up initial introductions by developing and maintaining personal and institutional relationships between the two communities through routine communication.
<p>Should the capabilities of existing DOT centers be expanded to provide better statewide security?</p>	<ul style="list-style-type: none"> • Utilize portable surveillance and monitoring devices, in areas where permanent installations are not warranted, in the event that an evacuation from Atlanta may overload transportation systems throughout the state. • Complete installation of CMSs being constructed at weigh stations several miles outside Atlanta, and consider additional locations for installation, as CMSs can protect motorists by diverting them away from the metropolitan area in the event an attack occurs. • Deploy additional Traveler Information Displays at Welcome Centers and Rest Areas to aid in diverting motorists away from Atlanta in the event of a terrorist attack, and to provide information about re-entry conditions to evacuees. • Work with the local trucking industry on the Georgia Highway Watch Program, using the TMC as the contact center. Truck drivers are very familiar with the road, weigh stations, truck stops, fueling centers and rest areas, and can be trained to recognize particular hazards or identify unusual activity; e.g.: trucks hauling hazardous waste; suspicious CB radio traffic; curious requests from strangers; staged traffic crashes; etc. as they travel regularly through ports, airports, bridges, and tunnels – all critical infrastructure that should be closely monitored. • Integrate NaviGator Web, data from the Coastal Evacuation System detector stations, and GEMA’s Hurrevac evacuation modeling software to improve real-time evacuation route monitoring and planning for future evacuations by monitoring traffic conditions on and adjacent to major evacuation routes. Real time conditions information may help to alert rural jurisdictions of heavy volumes heading in their direction. • Work with GEMA to develop plans and operational procedures for re-entry following a terrorist incident requiring evacuation. Re-entry poses significantly different challenges and information requirements than the

	<p>evacuation process. Core infrastructure such as power, phone, data and cellular services may be unavailable. This will hinder communications between the significant number of public and private sector personnel who will need to be coordinated in an orderly re-entry into the affected area prior to civilian re-entry.</p> <ul style="list-style-type: none"> • Work with GEMA to develop NaviGator applications that can aid in tracking hazardous cargo using GPS. GEMA tracks the movements of critical loads of nuclear material typically traveling from the Savannah River site in South Carolina west across the state to Alabama. Nuclear material movements are tracked using the Waste Isolation Pilot Project (WIPP).
<p>Can the DOT propose new uses of technology that will improve statewide emergency preparedness and response?</p>	<ul style="list-style-type: none"> • Utilize NaviGator’s wealth of archived data to aid in emergency preparedness as managers can use historical data about traffic patterns during routine and major traffic incidents to anticipate and plan for emergency traffic behaviors. • Introduce NaviGator Web to the emergency management community statewide. Among other capabilities, NaviGator Web will provide the means to control IP addressable CCTV cameras that can be installed anywhere in the state. • Accelerate deployment of the 2070 ATC controllers to allow for more real-time adjustment of traffic signal timing, even across jurisdictional boundaries. Focus deployment on planned evacuation routes and other security sensitive corridors. Integrate ATC software into NaviGator for enhanced functionality. • Investigate how Utah’s ITS and Public Safety demonstration project may be incorporated into NaviGator. The project demonstrated inter-agency emergency response coordination between a TMC’s ITS and a public safety CAD system. UDOT and GDOT share common NaviGator base software through the Multi-State ITS Software Consortium.
<p>Who controls the flow of data and/or information, e.g., can the state emergency operations center control DOT cameras?</p>	<ul style="list-style-type: none"> • Explore allowing increased NaviGator access and control privileges for GEMA and other homeland security agencies. GDOT maintains hierarchal control of NaviGator assets, but all agencies with privileges and the appropriate hardware and software can access and control cameras, check message sign status, and monitor incidents. A NaviGator computer is located in the State Operations Center with all of these capabilities. • Make NaviGator Web, available to the homeland security community. Strict access controls, standard operating procedures, and agreements will be developed governing allowable use. • Consider proposing that a TMC representative be located at the SOC during activation, operating the NaviGator workstation and relaying information to the TMC. Typically only one representative from GDOT is located in the SOC when it is activated. This will free up GEMA resources from working the NaviGator workstation.
<p>What is the relationship of the DOT center to other state and local emergency operations centers?</p>	<ul style="list-style-type: none"> • Utilize relationships already established between the TMC and local entities such as TCCs, the Macon Regional TMC, and statewide 911 dispatch centers, as well as the Georgia NaviGator Users Group, Metro Atlanta TIME Task Force, and Metro Atlanta Regional Traffic Operations Task Force to extend outreach efforts to local EMAs. • Develop a statewide incident management program similar to the Metro Atlanta TIME Task Force. Although the TIME Task Force is primarily geared toward coordinating the clearance of incidents caused by vehicle crashes, stalls, or debris, the relationships, training, and operational procedures developed through such a Task Force will enhance the ability of participating agencies to work together effectively in the event of a national security emergency.

<p>Will personnel be exchanged between centers during an emergency, and are the personnel likely to be exchanged trained to carry out their responsibilities?</p>	<ul style="list-style-type: none"> • Register TMC personnel for GEMA’s terrorism-related training courses so that they may be valuable assets to work in coordination with other GDOT personnel in the SOC. • Offer training to GEMA’s staff on all aspects of the NaviGator system so that if the need arises, they will be trained to work in the TMC.
<p>Should the DOT emergency operations center be co-located with the state emergency operations center or other public safety centers?</p>	<ul style="list-style-type: none"> • Investigate means by which coordination between the TMC, EOC, and SOC can be improved, such as better utilization of the NaviGator computer at the SOC and NaviGator Web. There does not appear to be a need to co-locate the centers at this time due to their close proximity. • Make NaviGator Web available to other public safety centers so that “virtual co-location” between these centers and the TMC can be achieved.
<p>Should more command, control and surveillance devices be deployed which can be controlled or monitored from the centers and add to response effectiveness and statewide security?</p>	<ul style="list-style-type: none"> • Utilize the Statewide ITS Architecture Development process to discuss terrorism-related ITS deployment and integration issues with stakeholder groups using the new Disaster Response and Evacuation User Service as a guide. • Use information gathered from the update of GDOT’s Emergency Response Plans to include terrorism incidents to determine additional statewide ITS deployment and integration needs. • Investigate alternative sources of funding for deployment and integration projects to enhance homeland security, as these projects may be eligible for federal or state homeland security grants. • Utilize lessons learned from other types of emergencies, such as the recent Gulf and Atlantic Coast hurricanes that impacted Georgia, to identify and correct deficiencies in coverage area, and to further enhance NaviGator technological capabilities and TMC’s operational procedures.

N-TRAP and Internal Arrangements: Public Information

This strategy refers to the use of DOT resources for information dissemination including public information personnel and traveler information systems. Program modification considerations are taken directly from AASHTO’s guidance, and addressed as they relate to NaviGator. These considerations will be incorporated into the development of *N-TRAP* as potential action items.

Table 11. Internal Arrangements: Public Information

<p>Considerations</p>	<p>Key <i>N-TRAP</i> Activities:</p>
<p>Are DOT public information personnel part of departmental emergency management and well-briefed on emergency management procedures and information dissemination techniques following a terrorist incident?</p>	<ul style="list-style-type: none"> • Enroll the NaviGator TMC’s Public Relations representatives and Media Liaisons in terrorism-related training, including training in the Incident Command System. Suggest that other GDOT Communications personnel attend similar training. • Encourage PIOs from other public safety agencies who are part of MAPIN to meet to discuss how information dissemination for terrorism-related threats or emergencies will be handled; and advise them of the TMC’s role in information dissemination.

<p>Does the DOT own advanced traveler information systems? How might these be used to convey information to the public during or following a terrorist incident?</p>	<ul style="list-style-type: none"> • Develop protocols governing when and how NaviGator’s existing ATIS components will be used to relay information about terrorist threats and emergencies to the public. It is anticipated that different components will be used for different scenarios and threat conditions. • Accelerate implementation of a planned Interactive Voice Response (IVR) System for automated information dissemination to supplement calls taken by NaviGator CSRs. Design the system so that sufficient capacity exists to allow for the spikes in demand that will follow an incident. • Migrate to 511 service, as the number recognition would be very beneficial to travelers unfamiliar with the existing NaviGator traveler information phone number. • Integrate local transit emergency operations information as appropriate, such as fares and schedules, into NaviGator. • Provide special training to all personnel receiving calls from the public on the appropriate information to disseminate, as well as information that should be obtained if the caller is relaying information relating to a terrorism-related incident.
<p>Are the advanced traveler information systems resilient to possible effects of a terrorist incident?</p>	<ul style="list-style-type: none"> • Utilize the NaviGator Vulnerability Assessment to examine all ATIS components. Vulnerabilities will be identified and rectified where appropriate. • Develop specifications for new components, such as HAR, which include requirements that units be portable, hardened to withstand acts of terrorism, and protected from intentional tampering. • Provide wireless access and control, redundant communications, and back-up power capabilities for ATIS devices at crucial sites, such as along planned evacuation routes and at key decision points. • Generate predefined generic CMS and HAR messages so that valuable time is not lost developing appropriate messages if an incident takes place. Posting these messages initially will allow time for more event-specific messages to be generated.
<p>Does the DOT have portable traveler information equipment that can be quickly deployed?</p>	<ul style="list-style-type: none"> • Deploy the portable ITS units from NaviGator’s Coastal Evacuation System, which include a CMS and HAR, to areas of greatest need following a terror attack. • Make modifications to portable ITS units to improve communications and power reliability, ensuring that the ability to remotely post and update CMS and HAR messages is maintained throughout a terrorism incident. During such incidents, it may not be safe to go to the site, or traffic conditions may make it impossible for field personnel to get to the site to update messages as necessary as conditions change. • Consider the purchase of more portable ATIS units to be stored at the HERO and TSEF facilities. Existing units are stored in South Georgia, and may not be available as quickly as needed. • Arrange with local contractors on GDOT construction projects to borrow portable CMS and advanced work zone management systems, as well as personnel to deploy and operate them, to supplement GDOT’s own resources if the need arises during an incident.

N-TRAP and Internal Arrangements: Agency Communications

This strategy refers to the special requirements for DOT center-to-center, center-to-field, field-to-field communications and general intra-agency communications. Program modification considerations are taken directly from AASHTO’s guidance, and addressed as they relate to NaviGator. These considerations will be incorporated into the development of ***N-TRAP*** as potential action items.

Table 12. Internal Arrangements: Agency Communications

Consideration	Key <i>N-TRAP</i> Activities
Are existing communications resistant to WMD?	<ul style="list-style-type: none"> • Conduct a Vulnerability Assessment to identify the susceptibility of the communications systems to a terrorism incident involving WMDs, and propose risk management strategies. • Investigate means of internal communications that are resistant to attack from WMDs. The TMC communicates to its field personnel and between GDOT centers using two-way direct connect devices, alpha-pagers, PDAs, e-mail, and telephone - all of which are susceptible to damage or destruction in an attack. Loss of fiber optic cable, telephone lines, and power could immediately or over time render them inoperable.
Is there sufficient redundancy to provide adequate communications even in large-scale WMD incidents?	<ul style="list-style-type: none"> • Explore utilization of the Government Emergency Telecommunications Service (GETS), an emergency telephone service provided by the National Communications System (NCS) in the Information Analysis and Infrastructure Protection Division of the Department of Homeland Security. GETS provides emergency access and priority processing in the local and long distance segments of the Public Switched Telephone Network (PSTN). It is intended to be used in an emergency or crisis situation when the PSTN is congested and the probability of completing a call over normal or other alternate telecommunication means has significantly decreased. (43) • Develop loss of communications protocols for all NaviGator field personnel detailing actions to be taken and reporting sites in the event they cannot communicate with the TMC. • Retain low-tech communications media wherever possible: plain old telephone system; radio and television; printed material; facsimile machines; two-way radio; short-wave radio; and sneakers have been found to be most effective when other communications fail. (44) • Dispatch personnel to manually control roadside ITS devices and traffic signals at key sites in the event loss of communications or power outages affect remote control. First determine that it is safe to do so, depending on the nature and severity of the incident.
Are DOT personnel equipped with adequate numbers of working and reliable communications devices?	<ul style="list-style-type: none"> • Conduct an internal communications assessment to ensure field units have adequate communications capability. Determine if alternatives or supplements to the existing two-way direct connect and 800 MHz. radios are warranted. • Investigate the use of such technology as two-way pagers with text messaging capability, satellite phones, and long-distance walkie-talkies, etc. to be used should communications fail. • Determine which personnel should be provided with which technology since it will not be economically feasible to equip all personnel with redundant communications.
Are the communications links prone to a cyber-	<ul style="list-style-type: none"> • Utilize the NaviGator Vulnerability Assessment to explore the susceptibility of the communications system to cyber-attack. Consider countermeasures

<p>attack coincident with a terrorist incident that might disrupt communications?</p>	<p>proposed for implementation.</p> <ul style="list-style-type: none"> • Continue utilization of software protections such as up-to-date anti-virus software, frequently changing passwords and maintenance of firewalls. • Ensure that GDOT’s IT and Systems Integrator personnel are made aware of the recent work that has been completed by ITS America and the Maryland DOT regarding information security, so that lessons learned and best practices can be incorporated into NaviGator. • Consider installing back-up power for radio repeaters throughout the area.
<p>Are there adequate communications links between DOT centers?</p>	<ul style="list-style-type: none"> • Review the fiber optic communications cable configuration between the NaviGator TMC, GDOT headquarters, HERO headquarters, and the Metro Atlanta District Office to ensure that a redundant path is available should the primary fiber links become damaged. Take steps to remedy any deficiencies found. • Conduct a center-to-center communications audit to determine if existing means of communicating between GDOT centers is adequate. • Consider utilizing a dedicated, fail-safe communications technology between GDOT headquarters and the TMC, however this is less critical since the TMC is in such close proximity to the headquarters office. In the event of a national security emergency, GDOT decision-makers would be on-site at the EOC, which is located in the TMC. • Secure at least one satellite telephone to ensure communications capability is maintained. • Explore other types of communications systems not currently used, that would achieve redundancy, such as: <ul style="list-style-type: none"> • State microwave telephone systems; • Satellite information systems; • Vehicle scanners; • Auxiliary radio system; and • Emergency radio system
<p>Are there procedures or protocols to permit and enable the exchange of data and/or information?</p>	<ul style="list-style-type: none"> • Develop procedures and protocols governing how NaviGator Web will be used to enable inter-agency incident information-sharing and control of devices via the Internet.

RECOMMENDATIONS

TMCs using the advanced technologies of ITS have been put to the test in response to catastrophic acts of terrorism, and have proven to be up to the challenge. Because TMCs and ITS are still considered by many to be the “new kids on the block”, their managers must reach out and “introduce” themselves to others in their “community” – in this case – the homeland security community. Based on information gathered in the preparation of this paper, including the lessons learned from 9/11 and other incidents, the following recommendations are made regarding further including TMCs and ITS in emergency management planning and response to terrorism:

- First and foremost, state DOTs with TMC and ITS deployments in metropolitan areas should ensure that the state’s emergency management community is fully aware of its capabilities. To a large degree the homeland security community does not know what advanced transportation

resources the state has, and will fall back to the traditional posture of using the DOT only as support to transport goods and people.

- In order for a TMC to respond effectively in the event of a terrorist attack, its realm of operation must extend into the field by way of its incident management or service patrol units that may be on-site, and into the EOC - in all cases fully participating in the response process.
- The different priorities and experiences of all players in the homeland security arena must be taken into consideration. When TMCs begin to work with these stakeholders, their differences should be acknowledged and appreciated as they offer a richer perspective of the issues.
- Inter-agency relationships must be developed and fostered through routine communication, coordination, and cooperation in order to be most effective under emergency conditions. Existing traffic incident management task forces and traffic operations task forces are good means of accomplishing this.
- It is very important that a TMC not prepare to respond to terrorist threats and incidents in isolation. Developing and fostering interagency relationships and agreements with all other homeland security partners must take place during the planning and preparedness phase.
- A TMC must play a very active role in preparedness planning, as it will also have a central role in response. It is very unlikely that a TMC will perform as needed in an emergency situation if it has not been at the table as plans are developed and individual and agency relationships are established.
- Both technology and inter-agency relationships must be developed. One without the other will not provide the solid foundation needed for efficient response in times of emergency.
- Planning to respond to terrorist threats and emergencies is no different than other planning, in that a TMC must “plan the work and work the plan”. An “all hazards” approach to emergency preparedness is very effective; however these incidents have different characteristics that set them apart from other incidents the TMC may be accustomed to managing. These differences must be identified and taken into account.
- Conducting Vulnerability Assessments, and developing Continuity of Operations Plans and Disaster Recovery Plans are essential in safeguarding the TMC and its ITS infrastructure from security risks, and in ensuring they can continue to carry out critical functions in times of emergency.
- Training, including refresher training and cross-training, is essential at all levels of the TMC organization in order for its personnel to respond effectively in a terrorism threat or emergency.
- ITS Architectures, strategic plans, business plans, and plans for software and hardware upgrades must include consideration for the implications of homeland security in order to begin to incorporate the necessary requirements into future systems.

CONCLUSIONS

The advancements that have been made in both transportation security and emergency transportation operations since 9/11 have been impressive. Resources from local and national levels have been directed to improving all aspects of emergency management, from prevention to recovery. Through these efforts TMCs and ITS have emerged as valuable tools in all phases of an emergency due to terrorism. Their effectiveness was demonstrated on September 11th, and progress is being made continually to further enhance their capabilities. Nonetheless, there still remains much work to be done to fully incorporate these resources into emergency management plans. The idea that these facilities and technologies are superfluous add-ons to other agencies’ homeland security programs must be overcome. By taking the lead in breaking down these barriers, a TMC can have a profound effect on the metropolitan area it serves.

A few years ago, ITS America promoted the benefits of ITS for safety, traffic congestion mitigation, and routine incident management with the slogan “Saving Lives + Saving Time = Saving Money”. Today this slogan has a weightier meaning than ever in light of the homeland security benefits of ITS. TMCs and

ITS can save countless lives by preventing critical infrastructure from being attacked; protecting citizens from the impacts of terrorist attacks that have occurred; and managing traffic and providing information to allow emergency services to get to victims as quickly as possible. Time can be saved by quickly detecting suspicious activity and providing information to first responders to mitigate the impacts of the incident; and by providing efficient evacuation routes to get citizens out of harm's way with the information they need to make their own informed travel decisions. And lastly, money can be saved by preventing acts of terrorism from destroying critical transportation assets, and by helping the transportation system, and the economic viability of the community that depends on it, to be restored to normal as quickly as possible. If applied properly and applied now to homeland security efforts, TMCs and ITS can even help to bring ITS America's current vision closer to reality – "Zero Fatalities and Zero Delays!"

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APPENDIX A

ITS DEPLOYMENT TRACKING SURVEY TRENDS FROM THE 2002 REPORT

ITS Component	Type of Deployment	1997	1999	2000	2002	2005
Arterial Management	Arterial miles covered by HAR	211	841	831	6,392	7,534
	Arterial miles covered by VMS	560	2,205	1,848	2,260	4,602
	Signalized intersections covered by electronic surveillance	NR	11,042	25,207	38,362	51,205
	Signalized intersections under centralized or closed loop control	50,961	58,136	61,179	67,635	86,619
Emergency Management	Vehicles under CAD	47,718	64,724	71,445	80,525	91,795
	Vehicles with in-vehicle navigation capabilities	698	1,609	1,896	6,821	29,278
Freeway Management	Freeway miles covered by HAR	1,805	2,504	2,480	4,087	6,368
	Freeway miles covered by VMS	560	2,205	1,848	2,260	4,602
	Freeway miles managed by lane control	82.6	860	732	1,143	1,382
	Freeway miles under electronic surveillance	2,649	2,084	2,335	2,161	2,370
Incident Management	Arterial miles covered by CCTV	847	1,302	1,704	3,584	7,552
	Arterial miles covered by free cellular phone call to a dedicated number	47	932	2,795	12,869	15,787
	Arterial miles covered by incident detection algorithms	71	315	3,220	1,098	1,589
	Arterial miles covered by service patrols	312	3,641	6,705	8,769	10,826
	Freeway miles covered by CCTV	1,480	2,337	2,541	3,845	6,877
	Freeway miles covered by free cellular phone call to a dedicated number	47	3,878	21,811	14,489	15,442
	Freeway miles covered by incident detection algorithms	1,328	1,579	1,389	1,826	4,462
	Freeway miles covered by service patrols	5,349	6,275	6,658	9,227	10,971

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She has a professional interest in traffic operations, but also a personal one as she prefers to spend less time stuck in traffic and more time with her husband, Angelo, and her three beautiful children, Angelo II, Sydney, and Dhylan.

USE OF TRAVEL TIME INFORMATION ON DYNAMIC MESSAGE SIGNS

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SUMMARY

The overall goal of this research project was to analyze existing travel time documentation and current practices from operational Traffic Management Centers (TMC); and then develop guidelines to assist TMC managers in making the decision for providing travel time information displayed on DMSs. It is intended to assist the TMC operations with decision-making regarding the display of travel times on DMSs. This project included the review of eleven documents, Internet web pages or articles relating to travel time information.

Additionally, eight operational TMCs and FHWA were interviewed for information related to their decision to display or not to display travel time information. From this information, seven guidelines were developed to assist a TMC manager in what to consider in making the decision to display travel time information and the recommended steps to follow in developing a travel time system. These guidelines are to first identify the rationale to implement travel times, evaluate system infrastructure necessary to support travel times, select travel time corridors and develop message formats tasks, initiate implementation and testing and conduct evaluation and determine system requirements.

Next the first four guidelines were used to analyze the Kansas City Scout systems for the purpose of determining whether KC Scouts ITS infrastructure was adequate to support the display of travel time information. The Kansas City Scout analysis and the documented findings are included in this report. The three remaining guideline steps were analyzed and Kansas Cities approach is documented in this report but execution of these steps were not feasible in the timeframe of this report.

Further work to enhance this research might include information on methods of calculating travel time, operational guidelines and use of delay messages in conjunction with travel time.

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INTRODUCTION

Advanced traveler information systems (ATIS) are an important part of the management and operations of our increasingly congested highways. Traffic management centers (TMCs) often use traveler information services to provide real-time notification of facility or system traffic conditions to travelers so they may better manage their commute. Components of traveler information messages include travel times, congestion, and delay information. The transportation agency may choose to provide the motoring public value-added information by disseminating travel time and delay information on dynamic message signs (DMSs). The motoring public often is critical of DMSs that are frequently blank, so as to not hastily move to message content that is not applicable, the transportation agency must then determine what types of information best suit the customer. In a December 2001 study on traveler response to information, (1) the author concluded that the following types of information were most valuable: data on incident location, types of incidents, delay, data on queue lengths and recommendations about alternative routes with directions to them. While the agency may focus on incident information, due to interest in travel time and delay information, an increasing number of transportation agencies have decided to display travel time information on DMSs. These agencies must overcome issues including reliability of data and fear of losing public credibility due to inaccurate travel times displayed on DMSs.

PROBLEM STATEMENT

In many cities with TMCs, DMSs display many types of information including travel time, congestion and/or delays. To best meet the needs of the traveling public, guidelines should be developed to help determine when and how to display travel time.

SCOPE

This research will be focused on the development of operational guidelines to display travel time information on DMSs. It is not intended to address how accurate travel times should be but rather to compare successful deployments using travel time information and others that may have decided against providing this type of traveler information. This research will draw upon practices from programs that display travel times, delay and congestion information on DMSs.

RESEARCH OBJECTIVES

The overall goal of this research was to provide guidance for providing travel time displayed on DMSs. It is intended to assist the TMC operations with decision-making regarding the display of travel times on DMSs. The primary objectives of this research was to:

- Determine customer/agency preferences on travel time information from existing data and through documentation provided by a telephone survey and/or literature review;
- Conduct surveys to determine factors that lead to use of travel times displayed on DMSs by selected TMCs;
- Determine level of detection deployed from surveyed TMCs to correlate the ability to effectively display travel time information;
- Identify existing practices for displaying travel times on DMSs;
- Identify level of software automation for displaying traveler information related to travel times;
- Determine operations policy, procedures and guidelines for the display of travel time information;
- Determine the DMS message priority level for display of travel times as compared to other message types; and

- Develop guidelines for display of travel times on DMSs including accuracy, geographic identity and frequency of updates.

STUDY APPROACH

Task 1: Literature Review

A literature review was used to gather existing customer survey information on traveler information preferences. This information was used to determine: (1) what types or formats of traveler information might be preferred for display on DMSs and (2) what guidance exists for message formatting criteria.

Task 2: Develop Telephone Interview Questionnaire

The survey included a brief introduction of the objectives of the research as well as the schedule. Following the introduction, the following types of information were asked:

- Gain a general overview of the TMC operation;
- Request objective data related to the topic such as customer surveys on preferences in traveler information;
- Gather knowledge of the data collection infrastructure, methods of calculating data and how the data is used;
- Gather information on the message content; and
- Gather information on operating policies and procedures.

Task 3: Develop Guidelines for determining most effective display of DMS travel times

Guidelines for the establishment of DMS travel times display was developed for agencies planning to implement travel time information. These guidelines walk the agency through the necessary issues, concerns and policies necessary to establish the what, when and where for displaying travel time information to the motoring public.

Task 4: Peer review

Reviews of the developed guidelines from task 3, were sought from other agencies that currently display travel time information. The intent of this review was to assess the usefulness of the developed guidelines and to make any updates or corrections based on comments or suggestions as the result of the peer review.

Task 5: Application of Guidelines to the Kansas City Scout Freeway Management System

The reviewed and updated guidelines were applied to the Kansas City Scout system as an example implementation. This paper provided a summary of the use of the guidelines in the process of establishing travel time display on DMSs throughout the Kansas City metropolitan area freeways.

LITERATURE REVIEW RESULTS

For the purpose of this paper, a dynamic message sign is defined as a programmable traffic control device that displays information and is located alongside freeways. For purposes of this document, the type of DMS is focused on a 3-line sign with at least 15 characters per line. The term DMS is often used interchangeably with variable message sign (VMS) and changeable message sign (CMS).

From the telephone survey, there was generally a lack of empirical data the agency had collected in their city on what the motoring public desires related to traveler information. Typically the agency had general information from web site emails and general feedback, but in depth public surveys were not the general rule. However, the general belief is that the public desires more extensive use of DMSs, furthermore, it is the policy of FHWA to promote the use of more information, explicitly travel times, on DMSs. Often there are complaints and advice offered through their public web site emails and other general sources but seldom a statistical analysis of regional traveler information desires. Agencies look to use the DMSs more frequently or have a desire to provide enhanced real-time traveler information. Consistently, time and expense were cited as reasons surveys had not been conducted. In a paper by Jon Bottom and Jane Lappin titled "Investigation of Traveler Information and Related Travel Behavior in the San Francisco Bay Area" (2) it was cited that travelers obtained their information predominantly from radio and television with the Internet noted for per-trip info from 1 to 4 percent. This correlates to a customer survey of Metro Atlanta Drivers in January 2003 (3) where up to 5 percent of Atlanta area travelers routinely get their traveler information from the Georgia Navigator web site.

Other literature by Cambridge Systematics, Inc. (4) and Lappin, J./Bottom, J., (1) would indicate that the motoring public prefers traveler information updated every minute with detailed information of comparative travel times and alternate routes. Another desirability is an estimate of the time of delay on the usual route from unexpected traffic congestion. A descriptor style message that provides the traveler information but allows the driver to interpret and make decisions is preferred by some. However, others prefer a prescriptive message that also provides an action.

A study conducted by Texas Transportation Institute (5) showed that 90 percent of the 260 people from five cities (Dallas, El Paso, Fort Worth, Houston and San Antonio), interpreted travel time messages on DMSs as approximate. The results also showed that displaying messages with the time stamp information did not enhance drivers' understanding that travel times were not precise.

SURVEY RESULTS

A survey of several state departments of transportation (DOTs) was conducted to gather information on current practices. Several state DOT's are now using travel times on DMSs. However there are several others that choose not to and a third group that do not post DMS travel times due to lack of data collection infrastructure to collect travel time data.

CommuterLink (Utah DOT) (6)

CommuterLink is the Utah DOT's advanced transportation management system. It uses speed-trap loop detectors polled at 20-second increments to collect volume and speed data. Sensors are spaced approximately every half-mile along the freeways in the Salt Lake Valley to accurately measure traffic flow and quickly isolate problem areas. Congestion sensor coverage is currently expanding into the Ogden, Provo and Park City areas. They are operational from 5 a.m. to 11 p.m. 7 days a week by the department of transportation and the remaining hours for a 24/7 operation by the department of public safety. Currently, no travel time is displayed on DMSs due to concerns about accuracy. The DOT's preference is to use "delay" messages with estimated delay time in minutes. The general format is:

**CONGESTION
400 S-BECK ST
20 MIN DELAY**

**CONGESTION
I-15 AT 400S
30 MIN DELAY**

GuideStar (Minnesota DOT) (7)

Minnesota GuideStar is the state's intelligent transportation system (ITS) program. The TMC operates from 5:30 a.m. to 8:30 p.m. Monday through Friday, 10 a.m. to 6 p.m. Saturday and 11 a.m. to 7 p.m. Sunday. The system offers 24/7 coverage as the state police take over the operations during the remaining hours. GuideStar currently does not display travel times but is planning to launch their program late summer 2004. A recent public perception survey indicated that travel time information is desired at over 3 points on a 1-5 scale with 5 being highly desired. The freeways in Minneapolis and St. Paul are instrumented with single loop detectors at 0.5-mile spacing including many ramps for ramp metering. They have been working to calibrate the detection on several corridors and will launch on a single DMS to begin the effort with up to 37 DMSs posting travel times in the future. There are no active plans to provide travel times on their systems web site, but it is likely to be an enhancement. GuideStar will post travel time messages during the rush hours, and they will be considered a low priority message. The format will generally be:

**TRAVEL TIME TO
DOWNTOWN 7 MIN**

**TRAVEL TIME TO
I-494 X MINS**

INFORM (New York State DOT) (8)

INFORM is the advanced traffic information system for Long Island, New York. It covers Long Island's 35-mile central corridor, comprising the Island's major east/west highways and its busiest north/south connecting routes for 190 miles of deployment. INFORM operates 24 hours/day, 365 days a year. The DOT currently does not display travel times on DMSs but is working on a diversion travel time sign project. This project will include a DMS insert panel on static signs providing travel times using alternate routes. The source of the data will come from spot speed data, toll tags and transponders. The system will display travel times continuously leaving the existing DMSs to display relevant information on travel conditions.

MONITOR (Wisconsin State DOT) (9)

MONITOR is Milwaukee's advanced transportation management system. Travel times are estimated using speed trap loop detection and are located in the urban area at half-mile spacing but varies when outside the urban area. The system is operated from 5 a.m. to 7 p.m. however travel times are automated 24 hours a day. The travel times are estimated for an overall trip length of 15 miles or less to enable better reliability. The program has received good public acceptance and support. The public has also provided feedback when the travel times are in error by alerting the operations center. The travel time had been provided on the Internet and calibration took place over a long period of time until a level of accuracy was achieved to provide the information to the DMSs.



Figure 1. Typical DMS Travel Time Display in Wisconsin (9)

NAVIGATOR (Georgia DOT) (10)

NAVIGATOR is Georgia DOT's advance traffic management system. Travel times are estimated using a video detection system. The average speed of a series of detection stations (usually 6-10 miles) is received every 20 seconds. The segment is then broken into two zones with two sub-zones each. Travel times are based on one-minute cycles. Video detection cameras, at 1/3-mile intervals define the sub-zones. The value of the average speed is put into a 4x4 look-up table with 16 possible travel time messages so each sign can display an appropriate, predetermined message. In general, Georgia DOT is very pleased with the system performance but would like to expand the algorithm to ultimately be able to provide delays over 20 minutes.

Public perception of the travel times is generally good (3). The public preferred travel times to initial system messages such as "Traffic Moving Slowly" or "Traffic Moving Well" type messages. All travel time messages on DMSs are also displayed on the web site.

Travel times are displayed on DMSs from 6 AM to 9 PM weekdays and 8 AM to 8 PM weekends. This has virtually silenced the public's complaints of the blank signs. As mentioned, GaDOT is considering an algorithm change to further improve capabilities so as to not require the lookup table and add the ability to show times over 30 minutes. 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 is also shown on NAVIGATOR'S website.

Typical DMS messages:

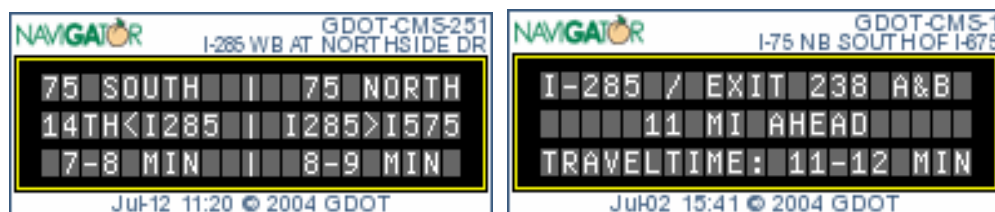


Figure 2. Typical DMS Travel Time Display in Atlanta (11)

TransGuide (Texas DOT) (12)

TransGuide is Texas DOT's advance traffic management system in San Antonio. Travel speeds from speed-trap loop detectors are used. Detectors are in each lane at a general spacing of 0.5 mile and are polled in 20-second increments. For the first eight years of the system, no travel times were posted on the

DMSs. Public acceptance of travel times on DMSs has been very good as it has alleviated public concerns that the message signs were seldom used (13). TransGuides' DMSs display travel times from 6:00 AM to 10:00 PM unless other higher priority information is displayed. 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 is also displayed on TransGuide's web site.



Figure 3. Travel time Message Displayed by TransGuide (13) in San Antonio

TranStar (Houston, TxDOT) (14)

Houston TranStar is Houston's Advanced Traffic Management System. TranStar provides travel time based on AVI (automated vehicle identification) transponder and toll tags. Due to Houston's extensive HOV (high occupancy vehicle) lanes that have motorists using transponders, data for travel time is readily available. Transponder tag readers are placed at 1-5 mile intervals along freeways and HOV lanes. DMSs display the travel times to popular landmarks or routes, which are updated every 10 minutes. Internet display includes travel time in a minutes range along with distance and speed. Public acceptance has been good following previous concerns that signs were blank too often.

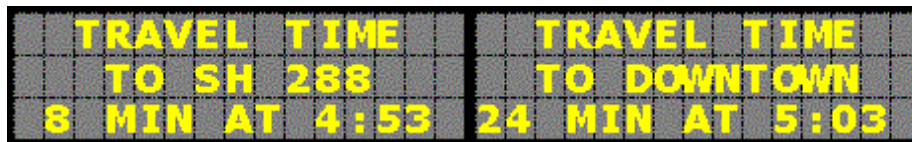


Figure 4. Typical Travel Time Display on DMSs by TranStar in Houston (15)

Traffic Systems Center - Chicago (Illinois DOT) (16)

Illinois DOT manages the Traffic Systems Center and Gary-Chicago-Milwaukee (GCM) Corridor's Gateway Traveler Information System. They use single induction loops at half-mile spacing with full count station loops every 2-3 miles polled at 20-second intervals. Aggregate 5-minute data is utilized to generate congestion limits and travel times. IDOT recently converted from utilizing 'congestion limits' messaging to travel time messaging where appropriate and is reviewing software modifications required to sign for utilizing both indicators in a two-phase messaging format. The ATMS caps the travel time segment speed at 55 mph, a tunable threshold. Segment lengths are dependent on both sign location and the key reference points in the system such as downtown Chicago and O'Hare International Airport. The Illinois State Toll Highway Authority utilizes travel times, as well, and is considering the use of combine IDOT and Tollway information for cross jurisdictional travel time segment messaging. Currently, Tollway travel messaging is formatted like Sample A below and is based on the Tollway's IPASS toll tag readings. The travel time messaging is currently running 24/7 in some locations. Examples of a travel time displays are as follows:

19 MINUTES TO DOWNTOWN

TRAVEL TIME TO:	
HARLEM	19 MIN
TRI-STATE	31 MIN

SUMMARY OF INVESTIGATIONS

From the literature review and survey is a listing of the findings:

- While the objectives to display travel times on DMS by state DOTs vary, the perceived public perception that DMSs are often blank is a big factor. While the DMSs at these agencies mentioned are used often, the public perception is the DMSs should display information more frequently as often mentioned in the agencies website emails responses and general public feedback.
- The importance of adequate detection instrumentation and software is critical for displaying travel times. In general, DOT's with spot detection at less than one-mile spacing, or closer, are the ones providing travel times. There are some reporting successes with using transponder toll tags to post travel times. There were no DOT's that post travel times in this review with spot detection spacing greater than one mile in urban areas.
- The time of day to display travel times varies widely from automated 24/7 to only during peak hours.
- The format of the messages also varies greatly. However, most state DOTs that display travel time have DMS message formats that indicates some form of "Travel Time To".
- Corridor selection and segment selection is also critical element.
- In general, travel times on DMSs appear to be well accepted by motorists according to the information provided in the survey.

SUGGESTED GUIDELINES

From information gathered through literature search and survey of State DOTs, the following guidelines were developed.

Step 1 – Identify the rationale to implement travel times.

A main focus of ITS is the mitigation of the impacts of non-recurring events on the system and its users. One of the main goals cited, from a traffic management viewpoint, is to provide motorists real-time route guidance. In real-time, a driver can decide to choose which route is the best route to travel based on travel times. This provides better management and operations of the freeway system by better utilizing the system's capacity. Since this requires extensive data collection infrastructure on multiple corridors, it is often only beneficial for systems with extensive data collection infrastructure. However, there are companies that are looking at providing travel times by tracking cell phones that would require no field data collection infrastructure.

A second reason to implement the display of travel times on DMSs, is that the calculation and display of travel times can be used as another system performance measure to enhance the level of system performance monitoring. Travel time information is one of the transportation system's outputs that is greatly impacted by the accuracy and completeness of the field data being collected. Therefore, if you measure the amount of time travel time is calculated and displayed over time, you can measure the reliability of the system, data being collected and the performance of the DMSs. A better understanding of the transportation system's reliability can be used by the TMC staff to improve overall system operations (4). A third reason is that travel times can provide the motorist with a sense of system reliability. In prior years, FHWA suggestions were to only use the DMSs for the display of incident or

traveler information only. Under this concept, motorists traveling along the freeway would not know if the system was operational unless there was an incident and a DMS was in use. If the same motorist sees travel time information being displayed on the DMSs along his route of travel he knows the system is functioning. If he sees the information everyday, he knows the system is performing every day. That sense of every day operation with the accuracy of the travel time information being displayed, can lead to a sense of confidence in the reliability of the transportation system on the part of the motorist.

TABLE 1. Summary of TMC Detection Types and Travel Time Formatting

Traffic Mgt. Center	Detector Type	Detection Spacing	Travel Time Format
TransStar – Houston	Transponder/toll tags	1-5 miles	TRAVEL TIME TO DESTINATION X MIN at 5:30
MONITOR - Milwaukee	Induction Loops	¼ to ½ mile urban 2-3 miles rural	TRAVEL TIME TO STREET/PLACE X MIN STREET/PLACE X MIN
TransGuide – San Antonio	Induction Loops	½ Mile	TRAVEL TIME TO DESTINATION X-X MIN DESTINATION X-X MIN
NavaGAator – Atlanta	Video Detection	1/3 Mile	DESTINATION/EXIT NO DISTANCE AHEAD TRAVEL TIME: X-XX MIN
Traffic Systems Center - Chicago	Single Induction Loops	Generally ½ Mile	TRAVEL TIME TO: HARLEM 19 MIN TRI-STATE 31 MIN
GuideStar – Minneapolis/St. Paul	Single Induction Loops	Generally ½ Mile	TRAVEL TIME TO DESTINATION X MIN
SmartCenter – VDOT	Induction Loops/RTMS	½ mile single loop trap loops at 1 mile	Delay Messages
CommuterLink - UDOT	Induction Loops	½ Mile	No Travel Time Delay Messages are Used

The display of travel time messages can also reduce the public's concern about blank DMSs and shows value added usage of the investment. The KC Scout TOC have received many e-mails and letters from the public and local agencies asking why such large message signs have been installed and then only used to display incident data on an infrequent basis. This same concern was voiced in the phone interviews from other TMCs across the nation. On the other hand, some DOT's seem to have no public concern about perceived blank DMSs.

These three possible objectives are not all-inclusive, and many other reasons may exist for displaying travel times. Displaying travel time information means additional information for drivers to absorb. There is concern that DMSs should remain blank unless urgent, non-recurrent events occur in which delay messages might be necessary.

Step 2 – Evaluate system infrastructure necessary to support travel times.

From the evidence in this survey, it generally appears that half-mile spot detection is common for the agency to be confident in its ability to provide travel time information however there are examples of some with one mile or more spacing. Other methods of data collection such as automated vehicle location, cellular phone and global positioning have promising applications but are not yet widely used in the cities where travel times are being display on DMSs. However, simply having closely spaced speed detection is not enough. The detection must be well maintained and reliable. Should the detection system have a high failure rate, it might preclude the agency from providing reliable travel times and affect the program's credibility.

For an existing system, a method of assessing the detection data is needed. The ground truth travel time would be collected and compared to data sample over a length of time that would allow for reoccurring and non-reoccurring events. Some agencies reported collecting this information for a minimum of 30 days. Once collected, an assessment of the reliability of the data should be interpreted. One DOT reported travel times that might be only 70 percent accurate, but they believed that would provide adequate information to the drivers. In the memorandum from FWHA (*17*), it suggests that data with error rates of 20 percent produce useful traveler information. Suggestions such as taking accurate latitude and longitude measurement of the field detectors were noted.

While the focus may be on vehicle speed detection and the ability to accurately collect this data, it is also necessary to consider DMS placement to enable posting accurate travel time. DMSs are often deployed for purposes of traffic diversion and placed prior to critical interchanges. A DMS may not be placed near detection and may affect the accuracy of the segment since the start of the segment may not coincide. Without proper placement of DMSs, some segment's accuracy could be affected. Careful consideration of DMS placement correlated to the detection placement should be considered.

It should also be noted, as cited in this survey, that some agencies had worked to provide travel times using a manual calculation method which was found to be too labor intensive. Therefore, a move to travel times will likely require additional software development.

Step 3 – Select travel time corridors

There should be early consideration of potential political ramifications when choosing a corridor on which to offer travel times. For example, if the corridor crosses important geographical or jurisdictional boundaries. Since success for an initial deployment is important, a test corridor that provides the best guarantee for success should be chosen. Items that help choose a successful corridor include: political considerations, consistency and quality in detector data, variable in the routes travel times and key destinations along the route.

Other factors that should be considered in selecting a corridor are:

- A corridor that has a high variability in travel times is a good candidate. This will allow the travel time messages to change more often as opposed to a corridor that is not as variable and the times change infrequently.
- Choose a corridor that has distinct segments of freeway with major interchanges or destination points.
- Is detector data reliable or does it require frequent tuning and maintenance?
- Is any construction planned for the route that would conflict with a launch of travel times?
- Are DMSs positioned well and frequent enough to provide adequate coverage?
- Is traffic directional such as a morning rush into downtown?
- Many of the surveyed DOT's were uncomfortable projecting travel times in excess of a 15-mile corridor. This may have effect upon selecting the corridor.

Step 4 – Develop message formats

A first step in developing message formatting is to decide the target of the message. The selected hours of operation for travel time display affect the target audience. If, for example, peak hour only is selected, local commuter traffic formatting might be favorable.

Example of a travel time message formatted for local traffic:

<p>TRAVEL TIME TO US 281 27-30 MINS IH 10 OVER 30 MINS</p>

This is a local traffic format because the information provided is destination related not distance related. Therefore, the travel time is less meaningful to the motorist unfamiliar with the area. However, this format is advantageous because it requires less text to convey travel times and is understood by local commuters.

Example of a travel time message formatted for out of town traffic:

<p>I-285 / EXIT 238 A&B 11 MI AHEAD TRAVELTIME: 11-12 MIN</p>
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This message format above suits both local and non-local commuters. The information provides distance information for those not familiar with the area and an exit number. However this format conveys travel time to only one destination at a time – unless phasing messages are implemented.

In selecting a message format, consider using both styles of messages that could be adjusted according to tourist seasons. If a city experienced most of its tourist traffic during a certain time of the year, a message format catering to out of town traffic could be used in place of the standard local commuter format. The disadvantage is potential confusion when switching formats.

Message Length

The maximum message length, as recommended by the “Guidelines for Changeable Message Sign Messages” (18) which guides length of messages and the appropriate units of measure as a single phase if possible. The development of travel time messages should conform to accepted principles of DMS message design.

Message Priority

Many agencies identify travel times as lower priority messaging replaced by incident messages. Guidelines as to when to repost travel times following a high priority message are necessary. Travel times might be reposted to the DMSs when the incident is clear or upon a pre-determined threshold of traffic conditions. A possible list of DMS message prioritization might be as listed below (15).

1. Emergencies, such as evacuations or closures, required by DOTs, the State, Emergency Management Agency (SEMA), local law enforcement, or the military.
2. Hazardous and/or uncommon road conditions that require motorists to alter their driving, such as severe weather conditions, accidents, work zone activities, or other incidents.

3. Traveler information and suggested alternative routes for delays and/or congestion caused by planned or unplanned events. Alternative routes are suggested with caution; sufficient trailblazing must be provided.
4. AMBER Alerts.
5. Travel Time and Air Quality Messages.
6. Advance notice for scheduled incidents, such as lane closures, road closures, moving operations, or special events.
7. Other public information that improves highway safety and reduces congestion.

Travel time range

One area where there is a good deal of disagreement among agencies is the choice of travel time ranges. Some agencies display an exact travel time but switch to a range during longer delays. Others post a two-minute spread on all travel times and may switch to a three minute spread on longer travel times. Desired perception is the biggest factor in determining which format to display. A single number suggests an exact travel time, but a travel time range it perhaps more accurate and there is less risk involved.

Step 5 – Determine System Requirements

At this step the general concepts and high level requirement will have been discussed. This step should detail what the system should do and how the system will be interfaced by the operator, software and hardware requirements, monitored, status reporting and tested. A description of the Federal Highway Administration (FHWA) requirements for system design are shown below.

Items to detail in this stage may include that listed below:

- Should travel time be capped so as to not exceed the posted speed limit. (Ex. 10 mile segment posted at 60mph, travel time would not show less than 10 minutes).
- Should a buffer in display of time be considered to account for variability in data.
- Should travel time upper and lower thresholds be established? For example, many agencies do not post travel times less than 5 minutes and often an upper threshold might be displayed as “30+ MIN”.
- What will be the level of automation of posting and reposting the travel time following clearance of a higher-priority message?
- Will travel times be post to 511?
- What type of system status and monitoring will be required?
- Will there be an Internet component?

All of these items that if considered as enhancements, should be evaluated as well as what components of the existing system will require revision. A determination of the effects upon the existing system would be considered in regards to hardware, software, infrastructure and documentation revisions.

Step 6 – Initiate Implementation and Testing

From the survey, many different methods of implementation were found. Some agencies have developed travel times and posted them to the Internet before displaying on DMSs. Others have developed travel times and started by displaying them first on DMSs. Yet others collect the data and provide the information to private industry for broad distribution of the information.

An implementation plan should be developed. It would include what gets implemented in what order. The plan might wish to consider implementing its development in stages or if system-wide deployment would be better. The implementation plan would need to detail how this deployment would take place.

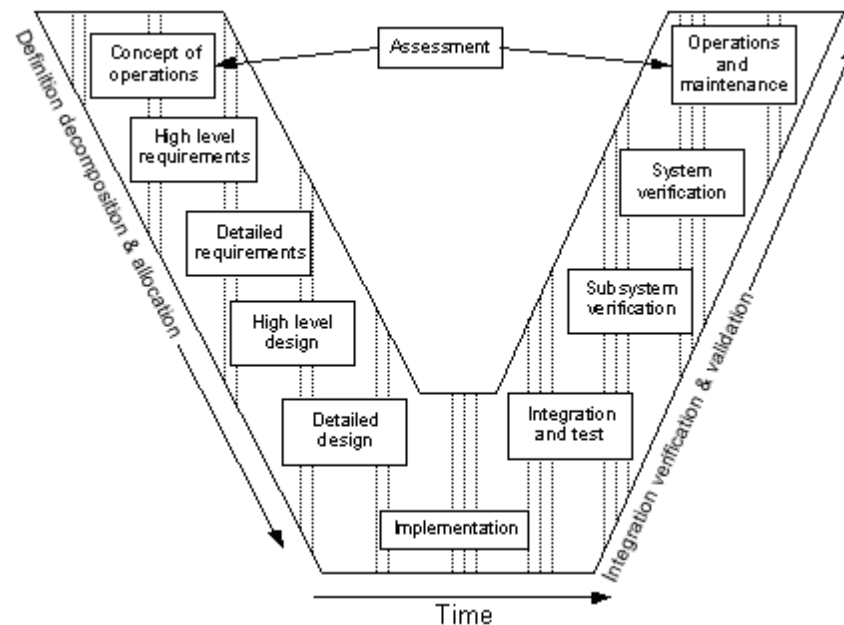


Figure 5. Systems Engineering Life-Cycle Process (19)

Step 7 – Conduct Evaluation

Evaluation is a key step in the systems engineering life cycle analysis. One component is the analysis of the data component. A plan should be put in place for data collection and evaluation that data is maintained at a level of acceptable accuracy as well as a plan to reevaluate this information on a regular basis. Also, a public perception survey or customer survey should be planned to determine the customer's acceptance and a check on the systems reliability.

PEER REVIEW OF GUIDELINES

These travel time guidelines were sent for peer review and responses were received from Kansas, Utah and Illinois Departments of Transportation operations personnel. The following comments were received from these peer reviews and were either beyond scope for this study or were general in nature and resulted in no changes in the document, but they were still worth noting.

It was thought that the paper could have gone into more technical discussion of how travel time is calculated including discussions on error trapping routines to catch bad or missing data.

It was also suggested that a discussion be included on using delay time or travel time and which might be most appropriate in which situation or could both be used. For example, on a travel time corridor which an accident occurred, should a message such as, "ACCIDENT AT FIRST ST - TRAVEL TIME – 30 MINS" be used?

It was also suggested that an additional step be included (after step 6) entitled "Operational Guidelines" that would provide guidance to operators. Even though the system would be automated, there still needs to be a process spelled out for operator intervention. For example, what do the operators do in the following cases:

- They think that the travel time is inaccurate for some reason.
- They receive a complaint from the public.

- There is clearly a malfunction.

Comments on Step 1: Policies where safety messages are being used as a default type messaging is appropriate if these messaging do not effectively become ‘static.’ It was thought that motorists getting good travel messages will not get tired of the signs even if default messaging is an operational policy. If these default messages have variety, perhaps rotating weekly or by day of the week.

Comments on Step 2: Factors in accuracy are considered to be length of segment and overall stability of flow. The longer the segment the less accurate the travel time will be due to variations in flow due to incidents, construction, sun glare, etc. The longer the segment, the more likely an event can make the DMS travel time irrelevant as they travel downstream toward the DMS travel time destination point. Regarding overall stability of flow, the free flow conditions or ‘stable’ congested flow validating travel times is fairly straightforward. When doing validation work, one should look at the system published travel times through the duration of the test trip and look at the average and the travel time produced at the beginning. As congestion builds or diminishes the travel time is always a little behind, since no predictive algorithms are in place. If the algorithms are not measuring speed, the assumptions and calculations need review and tuning.

Comments on Step 3: Corridors with high variability are good choices because the variability is why the motorists have interest in travel times, but these are also the most difficult corridors to ensure accuracy.

Comments on Step 4: It is reasonable that a message targeting a non-commuter is good enough for the commuter. If landmarks are used (and most of the time they are for travel times) there is see no reason the terminology to reference the landmark cannot be tweaked or appended to even help the folks ‘just passing through’.

Comments on Step 5: In the case study section regarding accuracy, the concept of using ranges is a very good one, particular for long segments. On shorter segments, with very short travel times like 1-2 minutes, the concern is that for such a short segment is there value in the travel time

Comments on Step 6: Suggestion that a requirement that the contractor test-drive more than one corridor when evaluating the accuracy. Results during free flow, as peaks build ‘steady’ congestion, and as peaks subside are of interest in the overall evaluation. The criteria for determining the ‘good’ vs. ‘bad’ are difficult to define.

APPLICATION OF GUIDELINES – CASE STUDY

Kansas City Scout (Missouri and Kansas DOT)

KC Scout Overview

Kansas City Scout, Missouri and Kansas DOT’s Advanced Transportation Management System (ATMS), is a joint venture between KDOT and MoDOT. Scout’s mission is to enhance safety, improve traffic flow, and to reduce congestion, fuel consumption, and air pollutants throughout Metropolitan Kansas City. Kansas City Scout is a traffic management system designed, implemented and operated jointly between the Kansas and Missouri departments of transportation.

Currently, Scout monitors approximately 75 miles of the areas most congested freeways. Over time Kansas City has extended its metropolitan reach to become the third largest city in the nation based on land area. Kansas City Scout – The country’s largest initial deployment, bi-state, 75-mile traffic management system uses high-resolution video cameras, electronic message boards, roadway sensors and highway advisory radio supported by new technology and software specifically designed for this system,

to monitor traffic conditions, help clear congestion, coordinate with emergency services, and provide traffic updates to travelers.

The main source of traveler information in Kansas City is the media. Newspapers provide information about lane closures, construction and other planned events; radio and television report incidents and congestion, as well as the scheduled events. For the real-time conditions, reporters monitor police and emergency radio, contact dispatchers, and obtain information from the motorist assistance patrol. They also depend on reports from travelers on the roads, and air surveillance of the roads. Local agencies also provide information, such as planned lane closures, to the media.

KC Scout has three Highway Advisory Radios (HAR) in the region. HAR is used to inform the public anytime that traffic flow is impeded in the downtown area. The transmitter has a range of approximately two miles and has seventeen beacons that can be turned on when the HAR is in use. The HAR is activated remotely by phone by the KC Scout personnel.

Step 1: Identify the rationale to implement travel times.

The reason for which many agencies implement a travel time system is to provide the traveling public with traveler information to help decide on alternate routes. Kansas City's freeway infrastructure provides few effective alternate freeway routes to divert traffic around problem areas. With the exception of I-635 and I-670, most alternate routes require traffic to use major arterials to get around problems on the freeways. As the freeway system becomes fully instrumented over the next ten years, some limited viable alternate freeway routes will become available to allow the diversion of traffic on alternate freeways instead of arterial roads. This will make the use of travel times more of a route determination factor.

Early on in the KC Scout development effort, it was decided that KC Scout would not put general messages on DMSs. They would only display incident, road closure or congestion information. This coincides with the belief that constantly displaying messages on every DMS may cause many motorists to ignore the message on the DMS when it displays a message because of an incident, road closure or unusual congestion. Even though KC Scout has received some limited public feedback as to the blank DMSs, KC Scout has not changed their policy.

Therefore, KC Scout's main reason for implementing a Travel Time system is for the purpose of providing as much information to the driving public as possible within the limitations of the current field instrumentation.

Step 2: Evaluation of system infrastructure necessary to support travel times.

In evaluating the field infrastructure implemented for the Phase I deployment, 1/3 to 1/2 mile spacing of vehicle detectors are adequate to obtain the necessary traffic information to determine travel times on three corridors traveling each direction. The areas where instrumentation is lacking (I-35 around the I-635 intersection, I 70 from Noland road to the I-470 intersection and the I-435 entry into the Grandview Triangle) will have additional system deployed in the next two years. The vehicle detectors used in the KC Scout system, shown in Figure 6, are a combination of double loops, single loops and radar detectors. The double loops and the radar detectors, once calibrated, provide adequate speed data to be used for travel time calculations. The Kansas stretch of I-435 has a combination of single loops with one lane containing a double loop at each vehicle detector station. This section will require some calibration of the single loop speed processing parameters and some evaluation to determine the accuracy of the speed data from this section of freeway.

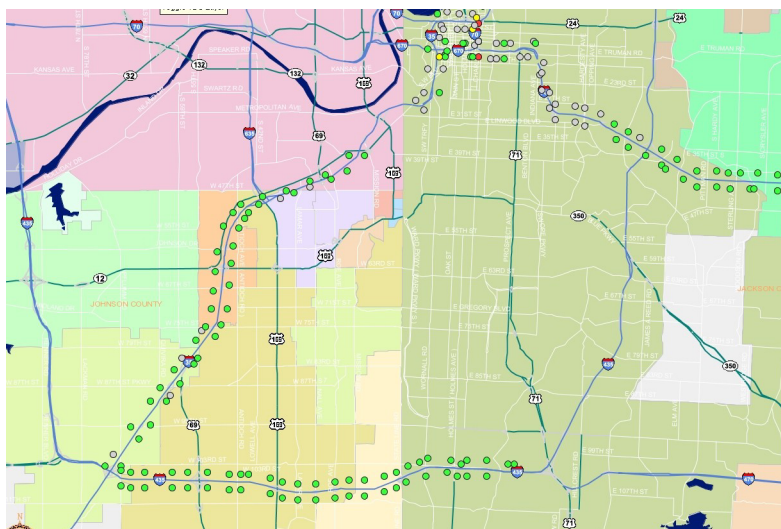


Figure 6. Kansas City Coverage Area of VDS

An additional task that will need to be performed on the ATMS software before a travel time system can be developed is the tuning of the Vehicle Detector Station (VDS) failure management parameters. Currently, many of the VDSs will show loops as cycling between hard failed and OK. In the hard failed state, the speed data is not used by the system. In many cases the volume and speed data reported from the VDS appears to be within a normal range but does not meet the parameters defined in the system based on the other lanes, previous readings and the expected ranges. The KC Scout system was based on the CalTrans ATMS system where the volume of traffic is considerably higher than off-peak volumes in Kansas City. To use this section of freeway to calculate travel times will require tuning of the failure management parameters to better align with the volume patterns of Kansas City.

Evaluation of the DMS locations, shown in Figure 7, for Kansas City identifies another problem that will need to be handled in the implementation of a travel time system for KC Scout. During the planning and design phase of the KC Scout project, DMS placement was based on the incident management requirements and not travel time requirements. DMSs were primarily placed upstream of major freeway intersections and on major freeway approaches to the metro area. This placement of DMSs is not necessarily optimal for travel time displays. For example, I-435 east from I-35 to the Triangle (I35, I435 & 1470) would have four travel segments with 4 DMSs. The DMSs are located almost in the middle of each segment, not at the beginning. So rather than just displaying the time to the start of the next segment, KC Scout will need to display time to the next several segments to provide the traveling public with useful information. For example, the DMS located at I-435 and Pflumm (one mile east of I-35) is in the middle of the I-35 to US 69 segment, this DMS need to display the travel time to US 69 as well as the travel time to Metcalf Ave and State Line for the information to be useful.

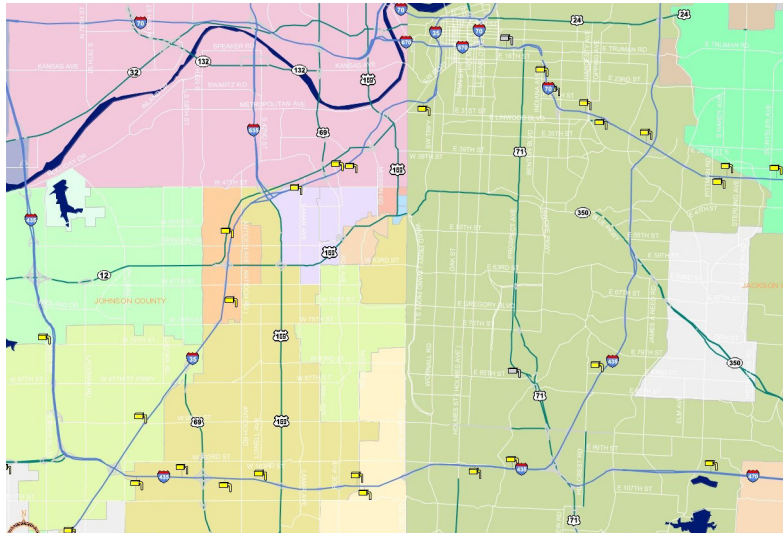


Figure 7. Kansas City Coverage Area of DMS

Step 3: Selection of travel time corridors.

Within the KC Scout Phase I system, there are three corridors of freeway for which travel time information can be collected. Each of these three corridors can be broken down into two or more travel segments in each direction. Table 2 shows the composite instrumentation for each of the three corridors and their associated segments.

Table 2. Area Composite Instrumentation

Corridor	Direction	Segment	Distance	No. Segments	No. of DMSs	No. VDSs
I-35 from I-435 to the downtown loop	Northbound		15.0	3	4	28
	Segment 1	I-435 to Shawnee Mission Blvd	6.0		1	12
	Segment 2	Shawnee Mission Blvd to I-635	3.0		1	6
	Segment 3	I-635 to Downtown Loop	6.0		2	10
I-35 from S/W Blvd to I-435	Southbound		11.0	3	3	18
	Segment 1	SW Blvd to I-635	2.0		1	4
	Segment 2	I-635 to Shawnee Mission Blvd	3.0		1	7

	Segment 3	Shawnee Mission Blvd to I-435	6.0		1	7
I-435 from I-35 to the Blue River	Eastbound		10.4	4	4	23
	Segment 1	I-35 to US 69	2.3		1	5
	Segment 2	US 69 to Metcalf Ave	2.0		1	4
	Segment 3	Metcalf Ave to State Line	3.1		1	8
	Segment 4	State Line to The Blue River	3.0		1	6
I-435 from I-470 intersection to I-35	Westbound		11.4	4	4	22
	Segment 1	I-470 Intersection to State Line	4.0		1	9
	Segment 2	State Line to Metcalf Ave	3.1		1	5
	Segment 3	Metcalf to US 69	2.0		1	4
	Segment 4	US 69 to I-35	2.3		1	4
I-70 from the downtown loop to Noland Road	Eastbound		10.0	2	3	18
	Segment 1	18 th Street to I-435	4.0		2	8
	Segment 2	I-435 to Noland Road	4.0		1	10
I-70 from Noland Road to the downtown loop	Westbound		10.0	2	6	24
	Segment 1	Noland Road to I-435	4.0		2	8
	Segment 2	I-435 to Downtown loop	6.0		4	16

As evidenced by the table above, any of the corridors would work for the first implementation of Travel times. To select the corridor for the first implementation of travel times KC Scout will use the following criteria:

1. Adequate coverage of vehicle detectors.
2. Adequate coverage of DMSs.
3. Variability in traffic flows.
4. Distinct segments.
5. Segment of the corridor in both Kansas and Missouri.

Table 3 shows the evaluation for each of the above criteria on each of the three corridors.

Table 3. Evaluation of Corridors

Corridor	Adequate coverage of vehicle detectors	Adequate coverage of DMSs	Variability in Traffic Flow	Distinct Segments	Segment of the corridor in KS and MO
I-70	Yes	Limited DMS coverage on the EB direction	Yes, WB in am and EB in the pm	2	No
I-35	Yes but currently small gaps in VDS coverage. VDS adding in next year or two.	Yes	Yes, NB in the a.m. and Southbound in the pm	3	Yes but only about 2 miles and one DMS sign in Missouri.
I-435	Yes	Yes	Yes, EB at the West end a.m. WB at the West end and EB at the East end pm.	4	Yes about 60% Kansas and 40% Missouri.

According to these criteria, the I-435 corridor, shown in Figure 8, would be the best choice for the first implementation of a travel time system for KC Scout.

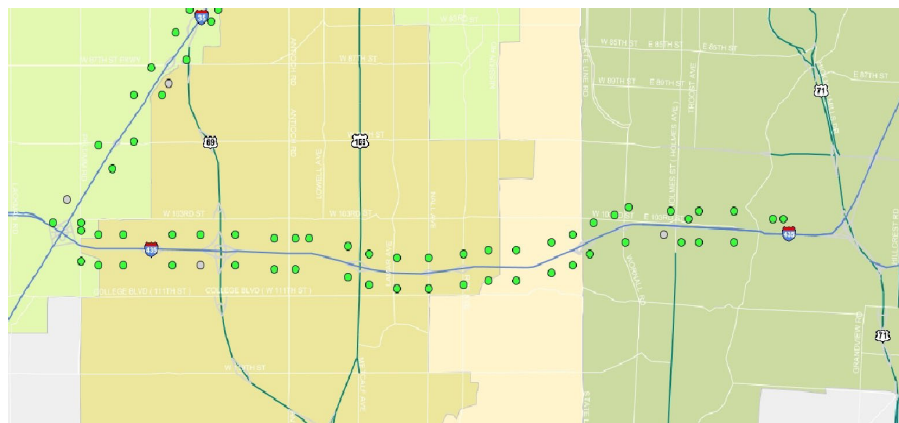


Figure 8. Preferred Corridor I-435 for First Implementation

Step 4: Develop message formats.

There are a couple of considerations to take into account when designing the travel time message formats. First, KC Scout will not be installing additional DMSs or travel time specific message signs along the freeway system to support implementation of a travel time system. Second, during the first six months of operation, KC Scout staff noticed a definite slow-down in traffic flow as drivers approach a DMS displaying a two-phase message. For that reason, KC Scout has made every effort to make all DMS displays for incident and congestion limited to a single-phase display. This same policy will be carried forward into the travel time system. So for travel time implementation, the basic constraint of a single message sign with three lines of 21 characters each will be the driving force in the design of travel time message formats. This constraint will require the travel time system to limit un-necessary information while still providing enough information to the driving public to be meaningful.

Since many of the DMS locations are not at the intersections corresponding to the start of a timed freeway segment, KC Scout proposes to use the “time to destination” format in it’s travel time messages. Space is also saved by not having to provide the “to” and “from” location. The common practice of putting the ‘Travel Time’ label on the top line of messages appears to provide un-necessary data on the message board. It would be better utilized as a third line for travel time information.

Therefore, it is suggested that KC Scout’s travel time message formats use a single-phase three-line message. This will provide the capability to provide travel times for up three segments along each corridor. This should be adequate since of the six identified corridors, only two have more than three segments. The first line will be the travel time to the closest end segment. The second line will be the travel time to the next closest end segment. The third line will be for the travel time to the end of the last segment in that corridor.

Additionally, since the selected demonstration stretch of freeway (I-435) is a beltway around the city, the format of the travel time messages for the demonstration effort will be designed for the local commuter and not the necessarily for the none local traveling motorist.

The next task is to determine is how the actual travel duration information will be displayed. The decision on whether to display a single time in minutes or to display a range of time is a tough decision. It really comes down to how accurate do you feel the travel time information is and how accurate do you want to portray this information to the traveling public. To the general public, the display of a single number implies a more accurate time figure than the display of a range of minutes. (i.e. displaying a time of 1 minute to the next exit is more precise than displaying 1-2 minutes to the next exit. Likewise, using a figure of 8.5 is more accurate than using 8 or 9.)

As for the accuracy of travel time information, traffic flows are by nature, unstable and hard to predict with total accuracy. When travel times are calculated every 30 second, the results will fluctuate with every calculation. Therefore, a method needs to be developed to smooth the fluctuations. A simple smoothing method is to calculate travel times using a moving average. This tends to smooth out large spikes in the data between samples. The moving average needs to be fairly short as not to distort the travel times as congestion begins to build or ease up. It is recommended that KC Scout start with a 5 minute moving average because congestion builds very rapidly and then diminishes in 10 to 15 minutes in the Kansas City metro area. Once travel times are calculated, the travel time should be rounded to the nearest minute.

The next issue is how to calculate the time range. Start by calculating a range that provides a reasonable amount of safety that the traveler will complete the segment within the specified time but not make too large of a time range as to be discounted as not providing useful data. Here the travel time range is affected by the amount of confidence in the accuracy of the calculated travel time information, the distance of the segment and the speed that traffic is flowing. Analysis and calculations will be performed,

but the real impact is the confidence in the calculated speed data. As a general rule of thumb, many agencies would rate the accuracy of their VDSs as +/- 10%. But in the KC Scout I-435 corridor, Kansas elected to use never-fail loops placed in the roadway when the freeway was constructed years before the KC Scout system was developed. At each location there are single loops in each lane with one lane having a speed trap loop. This reduces the accuracy of the speed data collected on the Kansas side of the I-435 Corridor. Therefore, it is suggested that a factor of 20% be used for the I-435 Corridor. That means the time displayed on the DMSs will be the calculated travel time as the first number and the travel time plus 20% as the second number.

Below is an example of a proposed travel time messages for the I-435 eastbound traffic at the Pflumm DMS.

TO US 69	4-5 MIN
TO METCALF	7-9 MIN
TO BLUE RVR	12-14 MIN

An additional item is the hours of operation of the travel time messages to be displayed on the DMS. The Kansas City area has two distinct peak travel periods where freeway congestion is an issue. During the remainder of the day or night, traffic flows at the posted speed limits unless there is an incident, special event or road construction with lane closures. It is during these peak periods that travel time information would be of value to the traveling public. For KC Scout, these times are proposed to be from 6:00AM to 10:00AM and from 2:30PM to 7:30PM to begin. It is likely that during other times of the day the times would not generally vary and would thus become more of a static message.

Step 5: Determine system requirements.

The KC Scout system was designed and developed in accordance with the FHWA ITS design guidelines. Therefore, the KC Scout ATMS system has a full set of requirements and design documents that were developed during the development of the system. These documents include:

- User Requirements Document
- System Requirements Document
- System Architecture Document
- Communications Architecture and Design Document
- Implementation Phasing Plan
- System Design Document
- Acceptance Test Plan
- Acceptance Test Procedures
- Configuration Management Plan
- System Installation Plan
- Integration Demonstration Plan
- Operators Manual
- System Administrator's Manual
- Traffic Engineer's Manual
- Field Diagnostic Manual

KC Scout is currently in an operation state with system maintenance and enhancements controlled by the Configuration Management Plan. Software Problem Reports (SPRs) are the vehicle for documenting and controlling changes to the ATMS System. The travel time System will be handled as an enhancement SPR. As SPRs are implemented into the ATMS system, the above documentation will be modified as necessary to reflect the implemented SPR.

The following table lists the sample system requirements for implementing a KC Scout travel time system.

Step 6: Implementation and Testing.

To implement this capability, KC Scout will select a single corridor and develop a travel time system to report travel times along both directions of the freeway. After the travel time system has been operating for a couple of months, KC Scout will assess the traveling public's view on the usefulness of the information provided. Based on that information, KC Scout will decide whether or not to implement travel times on the other corridors.

Implementation of the KC Scout Travel Time System will be through the assignment of a SPR to the Software Maintenance contractor. The contractor will implement the necessary changes into the ATMS software baseline based on the requirements, defined freeway segments and message formats provided by KC Scout. The contractor will test the changes, develop documentation updates for the documents listed in Step 5 and install and perform acceptance testing of the travel time system.

Step 7: Evaluation.

Acceptance testing provides the testing of the travel time software functions and performance. But the real evaluation of the travel time system comes from an evaluation of the usefulness of the information provided to the traveling public. Collecting this kind of information can be time consuming and costly. KC Scout already has several methods to collect traveler feedback on the usefulness of an implemented travel time system. The KC Scout Web page (www.kcscout.net) could be used to collect feedback. A web-based survey could be developed and placed on the KC Scout web page for users to provide feedback on the effectiveness of the travel time displays along the I-435 corridor. Another unique method of distributing survey forms would be through the freeway motorist assist patrols. When they provide assistance to motorist along the freeway, they can distribute the survey form to the public. Last, the customer support center for MoDOT is located in the TOC and feedback from callers can be solicited or collected from the public's call-in to customer support personnel.

As the data is returned either through the mail, phone calls or via the web site, the public's evaluation of the travel time can be collected and analyzed. Once significant data has been analyzed, a decision on whether to expand the travel time system to the entire KC Scout system can be made.

Table 4. Sample System Requirements

Requirement Number	Description
251	The ATMS system shall calculate Travel Time information from collected VDS data along I-435 from I-35 to the Blue River eastbound and westbound from the I-470/I-435 intersection to I-35.
252	Travel time calculations will be performed every 30-second cycle and will be reported as a moving average for each VDS. The moving average sample size shall be a Traffic Engineer tunable parameter within the system.
253	Travel Time plans; we will use a single-phase three-line message.
254	The DMS message format is as follows:

	<p>The first line will be the travel time to the closest end segment.</p> <p>The second line will be the travel time to the next closest end segment.</p> <p>The third line will be for the travel time to the end of the last segment in that corridor.</p>
255	Travel times displayed will be in minutes with calculations rounded up to the nearest minute.
256	The time displayed will be the calculated travel time as the first number and the travel time plus 20% as the second number.
257	From the device pull down menu, the operator shall be able to select the display of travel time information. A window will be displayed to showing the travel time being displayed for each segment of the I-435 Corridor.
258	The operator shall have the ability to turn the travel time system on or off.
259	When the travel time system is turned on, the system shall automatically display travel time on the pre-determined DMSs along the I-435 Corridor. If a message is currently displayed on one of the DMSs used for travel time display, system will give the operator the opportunity to overwrite the DMS display or leave the existing message alone and automatically display the travel time message when that DMS is blanked by the operator.
260	When an incident or other operator commanded message is placed on a DMS currently displaying travel times, the system will automatically return that DMS to the display of travel times when the incident or other message is blanked.

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- Rick Knowlden – NYDOT Nick Thompson – MnDOT

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APPENDIX A: SURVEY QUESTIONS

Survey Questionnaire for Agencies with an implemented Travel Time or Delay Time Display System

Agency Interviewed: _____

Person Interviewed: _____

Phone number: _____

Date Interviewed: _____

Introduction

The information gathered from this research is to be applied to the development of a universal set of guidelines that can be applied to an agencies implementation of travel time display on Dynamic Message Signs (DMSs). This survey is intended to collect information related to various Traffic Management Center's (TMC's) best practices for the display of travel time information on DMSs. I am aware of the information FHWA has recently requested on Homeland Security, Amber Alerts and Travel Time information display from TMCs across the nation and I will attempt to not duplicate that effort here.

General Information

1. What are the hours of operation for your TMC including holidays, coverage of freeways, etc?
2. Provide a general overview of your operations.
3. How many DMSs are deployed in your system?
4. How are the DMS deployed?
5. What is the current level of acceptance by the motorists of your traveler information for both DMSs and web site?
6. Do you have any surveys or data to support your findings?

Policy

7. Do you have any policy, procedure and guidelines established regarding DMS messages related to traveler information?
8. Why did your agency decide to display travel time information?
9. Do you have any study reports that assisted your agency in making the decision to display travel times?

TMC Characteristics

10. Are DMS message posted to a website and if so in what formats, ie text, graphic, etc?
11. What is the Web Page Address?
12. During what schedule are Traveler Information messages displayed on the DMSs and website and how often are they updated?
13. What level of automation exists for the display of traveler information such as fully automated, partially or none and explain?
14. Do you have cost figures on the software to build your initial ATIS (travel time/delay) module?

Messaging Use and Content

15. What traffic condition descriptors comprise your traveler information DMS messages?
 - a. Travel time messages?
 - b. "Delays ahead" messages?
 - c. Congestion messages?
 - d. Accidents/incidents messages?
 - e. "Traffic moving well" messages?
16. What are the formats and content for travel time information messages displayed on your DMS?
17. What are the thresholds of minimum and maximum times displayed?
18. How do you adjust for travel times related to the posted highway speeds?
19. Can you provide your criteria or look up tables for the method of calculation?
20. How do you calculate your travel times with regard to your detector spacing?
21. What is your method of detection and how often is it polled and spaced?
22. What type of location references are included in DMS travel time messages?
 - a. Cross street
 - b. Exit number
 - c. City neighborhood (e.g., downtown)
 - d. Traffic generator or landmark (e.g., airport)
 - e. Major towns/city suburbs

Other Issues

23. What were the major issues encountered during your decision making process to implement Travel Times displays?
24. What is the estimated accuracy of your posted Travel Times?
25. How did you verify accuracy of your posted Travel Times?
26. If you had to do it again, what would you do different?
27. How did you select travel segments for determining travel time displays?
28. Were there any political considerations in making the decision to display travel times?
29. What were the major roadblocks to implementing the travel time displays on DMSs?

Survey Questionnaire for Agencies without Travel Time display:

Agency Interviewed: _____

Person Interviewed: _____

Phone number: _____

Date Interviewed: _____

Introduction

The information gathered from this research is to be applied to the development of a universal set of guidelines that can be applied to an agencies implementation of travel time display on Dynamic Message Signs (DMSs). This survey is intended to collect information related to various Traffic Management Center's (TMC's) best practices for the display of travel time information on DMSs. I am aware of the information FHWA has recently requested on Homeland Security, Amber Alerts and Travel Time information display from TMCs across the nation and I will attempt to not duplicate that effort here.

General Information

1. What are the hours of operation for your TMC including holidays, coverage of freeways, etc?
2. Provide a general overview of your operations.
3. How many DMSs are deployed in your system?
4. How are the DMS deployed?

Policy

5. Do you have any policy, procedure and guidelines established regarding DMS messages related to traveler information? (Can a copy be sent?)
6. What traffic condition descriptors comprise your traveler information DMS messages?
 - a. “Delays ahead” messages”
 - b. Congestion messages?
 - c. Accidents/incidents messages?
 - d. “Traffic moving well” messages?
7. Why did your agency decide NOT to display travel time information?
8. Do you have any study reports that assisted your agency in making the decision NOT to display travel times?

RAY WEBB



Ray handles the day-to-day job of running the Kansas City Scout Traffic Operations Center (TOC) – the “hub” of information and activity for the 75-mile Scout system. There you will find dozens of monitors with access to each of the 75 cameras and hundreds of traffic sensors on Scout’s 75-mile system. Ray manages several staff members specially trained to monitor and maintain the Scout system. He answers to a bi-state Board of Directors comprised of authorities from both the Kansas and Missouri departments of transportation, the Federal Highway Administration and the Mid-America Regional Council (MARC) – Kansas City’s metropolitan planning organization.

Besides answering to two state DOTs, another of Ray’s biggest challenges involves his operational duties. He and his staff oversee the development of Scout policies and operating procedures. Ray also leads Scout’s efforts in creating and sustaining valuable partnerships with other traffic-oriented organizations and emergency service agencies including local police, fire and ambulance units who are most often first responders to freeway incidents. Those policies, operating procedures and partnerships all lend themselves to helping determine how Scout staff will respond to an array of incidents affecting traffic on the Scout freeway system.

Ray joined MoDOT in 1989 – the same year he earned his B.S. in Civil Engineering from the University of Missouri, Rolla. He worked for MoDOT in various departments including Materials, Construction, Traffic and Design before he joined the Scout team in early 2000. He is a registered professional engineer in the state of Missouri.

Ray makes his home in Lee’s Summit with his wife, Jyl, and three children.

**IMPROVING OPERATIONS PERFORMANCE MEASURES FOR THE
OREGON DEPARTMENT OF TRANSPORTATION**

by

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ABSTRACT

This paper examines freeway operations and how measures have evolved for application in project and program justification, selection, and prioritization through the data collection processes of Advanced Transportation Management Systems (ATMS). The paper also highlights the progression of performance measures in United States, the fundamentals of performance measures, and how measures can be more effective in evaluating freeway operations in urban areas. Research was accomplished primarily through the investigation of published literature and when applicable, follow-up information was obtained from professionals working in this field. Based on the work and success of others generating effective operations performance measures, recommendations are made for implementation at the Oregon Department of Transportation. The recommendations includes the manner in which ATMS in Portland, OR can improve the data it is currently collecting and archiving for use in operations performance measures.

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INTRODUCTION

Background

The Interstate Era has passed. Transportation agencies are no longer building highways at a pace to keep up with traffic demand; Oregon included. A comparison of vehicle miles traveled (VMT) and lane miles demonstrate this relationship. Figure 1 shows that the VMT in Oregon has increased steadily over the last 30 years in comparison with new lane miles built. This means that managing the transportation system to provide the most efficient use of infrastructure is paramount.

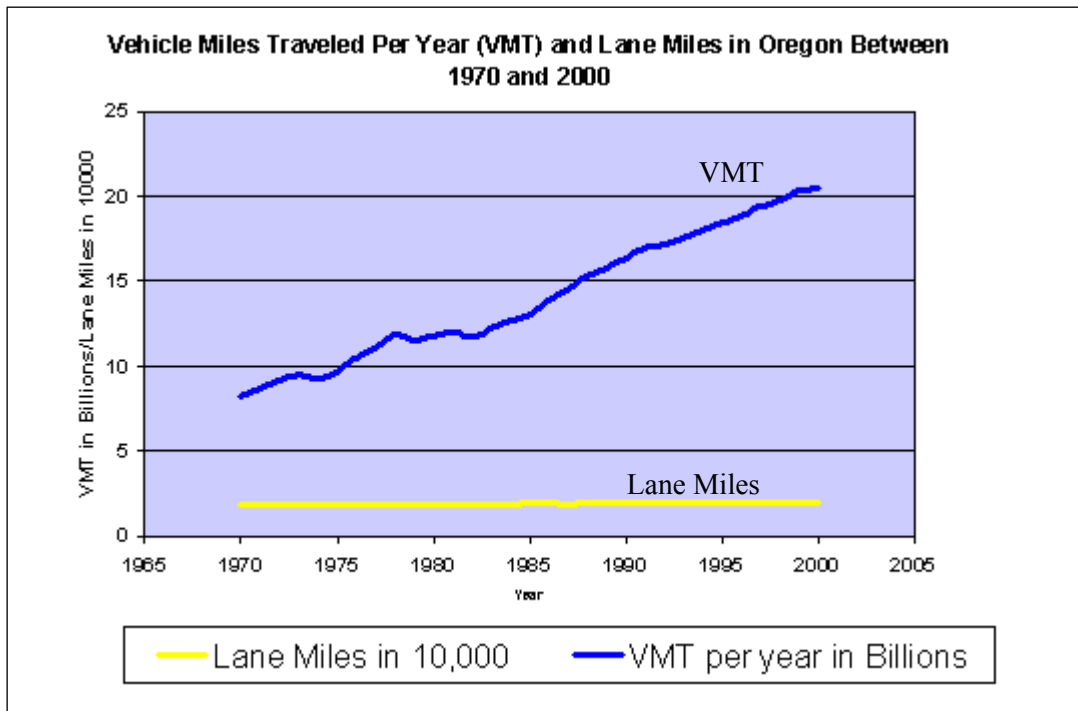


Figure 1. Oregon Vehicle Miles Traveled (VMT) in Billions, State Owned Highways Only, 1970 to 2000

The nation's roads are providing mobility that affects virtually everyone. When mobility is restricted there are societal costs that are reflected in the economy in terms of cost of goods, lost time, and wasted energy. Quality of life is also adversely affected by increased pollution and reduced access to needed services. Many of these costs have been measured and studied. In the United States, congestion costs approximately 68 billion dollars annually due to delay and wasted fuel. Roadway users lost an estimated 3.6 billion hours and consumed 5.7 billion extra gallons of fuel (1).

Many agencies have responded to their changing role from builders to managers of the highway system. Advanced Transportation Management Systems (ATMS) have been developed in urban areas to integrate Intelligent Transportation Systems (ITS), communication networks, and roadside infrastructure to centrally control each function. Ramp metering, high occupancy vehicle (HOV) lanes, variable message signs (VMS), cameras, incident responders, and other programs managed by the ATMS have generally been successful though their benefits can be difficult to measure.

Many states have systems to manage and measure pavement conditions, traffic volumes, road inventory, and safety. Transportation agencies utilize these measures to help identify problem areas and allocate resources. For example, the Safety Priority Index System (SPIS) in Oregon is used to create a list of areas

that need safety improvements based on crash data. Each year the top 10 percent SPIS sites are evaluated and investigated for safety problems. After further analysis, appropriate projects are initiated and funded. On the other hand, few state departments of transportations (DOTs) utilize an operations management system with developed measures of effectiveness that display trends in transportation system operations.

Problem statement

Transportation agencies need performance measures that will enable them to effectively justify and manage existing operations programs, determine priorities for starting and expanding programs, consider strategic alternatives, and allocate future funds. At the heart of all performance measures are data. As measures are developed to be more detailed and effective in the decision-making process; appropriate, accurate and reliable data become increasingly important. Improvements to the quality of operational data can be made to make archived data from the ATMS a cleaner source for use in progressive operations performance measures.

Objectives

The purpose of this paper is to take a brief look at operations performance measures and the work done at the national level as well as identifying progressive work done at the state-level. Oregon's future direction in the area of operations performance was discussed and areas of improvement identified. Several objectives were established in order to achieve this goal. The research objectives were:

- Summarize the history and evolution of performance measures;
- Discuss the fundamentals of performance measures;
- Examine the measures used for freeway operations;
- Summarize and discuss general recommendations for measures and;
- Develop a strategy for improving measures in Oregon.

Scope

Performance measures that are meaningful with respect to freeway operations in the Portland Metropolitan Area are of primary interest. Measures for arterials, incident management, traveler information, and transit will not be considered. Measures that can be used to allocate resources and to prioritize needs will be of greatest interest.

MEASURES HISTORY

Within this section is a brief history of the data collected and the methods used to monitor and measure highway performance. This discussion is intended to provide some background that can show how measures must change over time to accommodate current needs.

Highway Performance Monitoring System

The Highway Performance Monitoring System (HPMS) is a national-level highway information system that includes data on the extent, condition, performance, use and operating characteristics of the Nation's Highways (2). The program was originally developed in 1978 as a continuing database to replace special biennial condition studies performed by states since 1965 (2). The purpose of the HPMS program was to support a data driven decision process within the Federal Highway Administration (FHWA), Department of Transportation (DOT), and Congress (2). The measurements from HPMS were used for establishing authorization and appropriation legislation. The HPMS system has progressed over time and is still in use today.

Traffic data are a significant part of HPMS and the procedures for gathering this data are documented in the *Traffic Monitoring Guide* (TMG). The TMG presents a basic program structure for traffic monitoring at the state level. The guide provides specific examples of how statewide data collection programs should be structured, describes the analytical logic behind that structure, and provides the information highway agencies need to optimize the framework for their particular organizational, financial, and political structures (3).

Oregon has operated a statewide counting program for many years. This program has produced traffic volume tables and maintained permanent, automatic traffic recorders (ATR) since 1937. The count program continues today and follows the guidelines in the TMG to provide the traffic elements needed for the HPMS submittal. The count program consists of three types of counts: permanent, classification, and short-term.

Permanent counts are obtained from approximately 140 ATRs utilizing inductive loop detectors strategically located throughout the state to continually collect hourly vehicular volume by lane and direction. This hourly data makes up the backbone of the collection effort. From this data the following items can be calculated: peak hour, design hour factor, directional splits, seasonal factors, growth factors, day of week factors. ATRs have traditionally been the most complete and richest source of traffic data.

Classification counts show the types of vehicles that make up of the traffic stream at approximately 400 locations throughout the state. The counts are performed either manually or by machine on a three-year update cycle. The counts are typically captured from 8 to 24 hours in duration. Thirteen vehicle types are distinguished based on number of axles and axle spacing. Factors from these counts are calculated to adjust the short term counts.

Short-term counts are obtained from approximately 6000 count locations utilizing pneumatic, rubber tubes performed on a three-year rotational basis. The tubes tally how many axles pass over the tube and activate an air switch in the equipment over a 48-hour period. The 48-hour counts are divided in half and adjusted with over-count factors from classification counts and temporally with factors from the ATRs to arrive at annual average daily traffic figures (AADT). AADT is a staple measure of traffic using a facility and can be applied toward other measures such as volume to capacity ratio (V/C) and level of service (LOS).

The outcome of many studies based on the HPMS data affect highway agencies. The HPMS data are used in a number of key analytical tools, including the HPMS Analytical Package, the Surface Transportation Efficiency Analysis System (STEAM), the Highway Economic Requirements System (HERS), and the ITS Deployment Analysis System (IDAS), as well as a host of State-specific planning and performance modeling systems (2).

Government Performance and Results Act of 1993

In 1993, President Clinton signed the Government Performance and Results Act of 1993 (GPRA). Public Law 103-62 created a long-term goal setting process to improve federal program effectiveness and public accountability by promoting a new focus on results, service quality, and customer satisfaction (4). The law further institutionalized performance measures in the federal government and required that specific measures be established and tracked for most major federal programs (5). This created a structured approach for focusing on a program's strategic plan, goals, and performance as well as provided a mechanism for reporting program performance for use in setting new goals and standards; detecting and correcting problems; managing, describing, and improving processes; and documenting accomplishments (4).

Under the GPRA, all federal agencies were required to draft and submit five-year strategic plans with clearly stated strategic goals, annual performance plans describing how they would carry out these strategic plans, meet their goals, and annually report on their progress (4). This would take effect for the

fiscal year 1999 budget cycle. In 1996 the ITS Joint Program Office (JPO) set program goal areas directly related to the ITS Strategic Plan and established (6). The goal areas included improving traveler safety, improving traveler mobility, improving system efficiency, increasing the production of transportation providers and conserving energy while protecting the environment (6). Within each goal area measures of effectiveness were identified.

PERFORMANCE MEASURES FUNDAMENTALS

The purpose of this section is to define and profile the make-up of a performance measures system. Although the information is not specific to operation performance measures, the principle are applicable.

Definition of Performance Measurement

The National Performance Review (4) defines performance measurement as a process toward achieving predetermined goals, including information on the efficiency with which resources are transformed into goods and services (outputs), the quality of those outputs (how well they are delivered to clients and the extent to which clients are satisfied) and outcomes (the results of a program activity compared to its intended purpose), and the effectiveness of government operation in terms of their specific contribution to program objectives.

Elements of Performance Measures Systems

The lists below were obtained from the FHWA, Office of Transportation Management web site to highlight the basics of performance measures (7)

In general, a good measure:

- Is accepted by and meaningful to the customer;
- Tells how well goals and objectives are being met;
- Is simple, understandable, logical, and repeatable;
- Shows a trend;
- Is unambiguously defined;
- Allows for economical data collection;
- Is timely; and
- Is sensitive.

A successful performance measurement system:

- Comprises a balanced set of a limited vital few measures;
- Produces timely and useful reports at a reasonable cost;
- Displays and makes readily available information that is shared, understood, and used by an organization; and
- Supports the organization's values and the relationship the organization has with customers, suppliers, and stakeholders.

Outcome and output measures are types of measures that result from a performance measurement system. An outcome measure is an assessment of the results of a program activity as compared to its intended purpose (4). An output measure is tabulation, calculation, or recording of activity or effort (4).

An important part of a performance measure system is how it supports resource allocation decisions. A measure is fully utilized when an informed, data driven decision can be made to use limited resources to their fullest potential to reach the goals of the agency. Oregon wants its operational performance

measures to protect current program funding levels, justify expanding programs, identify project locations, select project priority, and have the ability to measure other services.

FREEWAY OPERATIONS MEASURES

This section summarizes the work done nationally for freeway operations measures. Two reports will be examined, the Urban Mobility Report and the Mobility Monitoring Study, to show the measures calculated from the available data.

Urban Mobility Report

The Texas Transportation Institute (TTI) performs the Urban Mobility Report (UMR) annually. The 2003 report includes 75 urban areas and focuses on the trends from 1982 to 2001 and analyzes issues that the motoring public, transportation officials, and policy makers often raise regarding traffic congestion and urban mobility (8).

The UMR uses HPMS-like data for traffic volumes. Traffic volumes are calculated into daily vehicle miles traveled (DVMT) by multiplying AADT by the applicable highway segment length. Estimates from the HPMS database as well as other local transportation data sources are also used (8). Speed data is not measured directly; rather it is modeled or estimated from occupancy information. The advantage to using the HPMS data for this study is due to the consistent nature of the source data from urban area to urban area. As detailed in the section about HPMS, it is a mandated program that has guidelines for the collection of the data inputs. This allows urban areas to be ranked according to measures calculated from the study because all roads are factored into the HPMS model.

There are many measures that come from this study. The results for the 2000 and 2001 report incorporate the effect of widely implemented operational treatments, public transportation service and high-occupancy vehicle lanes (8). A sample of the 2001 report for the Portland-Vancouver area shows the calculated Travel Time Index in Figure 2. Each column represents one year starting with 1992 to the far left, moving right until 2001. These numbers display the trend that Travel Time Index is increasing over time which means congestion is worsening. However, the measure doesn't provide enough detail to identify problem points on the system by location or by time of day..

System Performance										
Travel Time Index	1.20	1.24	1.25	1.32	1.31	1.35	1.34	1.37	1.40	1.44
Rank	19	14	15	11	12	9	11	11	11	8
Annual Delay (Person-Hours)										
Total (000)	14,168	18,380	18,791	24,462	25,086	27,752	28,948	31,123	34,357	37,975
Rank	26	23	25	23	23	23	24	24	25	24
Recurring Delay (%)	44	45	45	46	46	46	46	46	46	46
Incident Delay (%)	56	55	55	54	54	54	54	54	54	54
Delay per Person (person-hours)	11	14	14	18	19	19	20	21	22	24
Rank	25	18	25	18	21	23	21	23	22	22
Delay Saved by Public Transportation (person-hours)										
Total (000)	4,150	4,025	4,485	5,430	6,285	7,265	8,855	10,485	11,420	12,820
Delay per Person	3.3	3.2	3.4	4.1	4.6	5.0	6.0	6.9	7.5	8.1

Figure 2. Urban Mobility Report for Portland-Vancouver (1992-2001) (8)

Mobility Monitoring Study

The 2002 Mobility Monitoring Study (MMS) is published from the work of the Texas Transportation Institute and Cambridge Systematics, Inc. and incorporates archived operational data from 23 cities in the United States. The archived operational data typically consisted of speed, volume, and occupancy information at sub hourly intervals on instrumented sections of the urban freeway system. The first report

was completed using data from the year 2000. Unlike the Urban Mobility Report, comparisons are not made between cities due to limited coverage of the operational data (9).

The Mobility Monitoring Study serves two functions. First, information in the report increases awareness of archived operational data (9). The information that can be gained from archived data is significant if the data limitations are understood and if the right data quality steps are performed (9). Data quality control is the process of eliminating records from the data set that are not valid. Records can be invalid if they are negative, out of acceptable ranges, or have illogical speed, volume, and occupancy relationships. In 2002, eighty percent of Portland, Oregon’s potential data set was available for the MMS. After the MMS quality control procedure, approximately 56% of the possible volume and speed data remained for the analysis (9). By using the data in the MMS helped researchers to identify needed improvements to the data (9).

Second, the data can be used to investigate issues (9). The effect of operational treatments and programs as well as local variations in travel demand can be studied in much greater detail than with any other data source at relatively low cost (9). The data is considered low cost because it wasn’t collected exclusively for investigational studies; rather the data was archived as part of another program such as ramp metering that bore the cost for the infrastructure. Figure 3 shows the participating cities and the operations data they provided.

Exhibit 3-3. Summary of Archived Data Characteristics for 2002

Participating City	Freeway System Monitored, %	Traffic Sensor Technology	Data Level of Detail	
			Time	Space
Albany, NY	10% (10 of 104 mi.)	Single and double loop detectors	15 minutes	by lane
Atlanta, GA	18% (73 of 300 mi.)	Video imaging and microwave radar	15 minutes	by lane
Austin, TX	22% (23 of 105 mi.)	Double loop detectors	1 minute	by lane
Charlotte, NC	12% (13 of 92 mi.)	Microwave radar	30 seconds	by lane
Cincinnati, OH/KY	27% (47 of 176 mi.)	Double loop detectors, video imaging, microwave radar	15 minute	by direction
Detroit, MI	39% (110 of 282 mi.)	Single and double loop detectors	1 minute	by lane
Hampton Roads, VA	11% (19 of 181 mi.)	Double loop detectors	2 minutes	by lane
Houston, TX	61% (298 of 368 mi.)	Probe vehicle (AVI), limited double loop detectors	Anonymous individual probe vehicle travel times by link. Loop data are 20 seconds by lane.	
Los Angeles, CA	86% (579 of 676 mi.)	Single loop detectors	5 minutes	by lane
Louisville, KY	9% (12 of 137 mi.)	Microwave radar, loop detectors, video imaging	15 minutes	by direction
Milwaukee, WI	100% (111+ of 111 mi.)	Loop detectors, microwave radar	5 minutes	by lane
Minneapolis-St. Paul, MN	60% (190 of 317 mi.)	Single loop detectors	30 seconds	by lane
Northern Virginia	46% (59 mi of 127 mi.)	Loop detectors	1 minute	by lane
Orlando, FL	20% (32 of 157 mi.)	Double loop detectors	1 minute	by lane
Philadelphia, PA	37% (128 of 347 mi.)	Microwave radar, passive acoustic detectors	1 minute	by lane
Phoenix, AZ	30% (53 of 179 mi.)	Double loop detectors, passive acoustic detectors	5 minutes	by lane
Pittsburgh, PA	27% (78 of 284 mi.)	Microwave radar, passive acoustic sensors	1 minute	by lane
Portland, OR	39% (54 of 137 mi.)	Double loop detectors	15 minutes	by lane
Sacramento, CA	54% (57 of 105 mi)	Loop detectors	5 minutes	by lane
Salt Lake City, UT	100% (80+ mi of 80 mi.)	Double loops, microloops, acoustic detectors	60 minutes	by direction
San Antonio, TX	36 % (77 of 211 mi.)	Double loop detectors, acoustic detectors	20 seconds	by lane
San Diego, CA	66 % (163 of 248 mi.)	Loop detectors	30 seconds	by lane
Seattle, WA	41 % (116 of 241 mi.)	Mostly single loop detectors	5 minute	by lane

Figure 3. Participating Cities of the 2002 Mobility Monitoring Study and the Operations Data Provided (9)

The detailed data sets used in the MMS allowed researchers to examine how mobility and reliability relate to time of day, the overall system, the individual, and how these vary over time (9). Below are descriptions of the measures used as described by the MMS.

Mobility Measures

Travel Time Index: ratio of average peak travel time to an off-peak (free-flow) standard, in this case 60 mph for freeways. For example, a value of 1.20 means that average peak travel times are 20 percent longer than off-peak travel times (10).

Percent of Congested Travel: the congested vehicle-miles of travel divided by total vehicle-miles of travel. This is a relative measure of the amount of travel affected by congestion (10).

Reliability Measures

Buffer Index: The extra time (buffer) needed to ensure on-time arrival for most trips. For example, a value of 40 percent means that a traveler should budget an additional 8 minute buffer for a 20-minute average peak trip time to ensure 95 percent on-time arrival (10).

Planning Time Index: Statistically defined as the 95th percentile Travel Time Index. This measure also represents the extra time most travelers include when planning peak period trips. For example, a value of 1.60 means that travelers plan for an additional 60 percent travel time above the off-peak travel times to ensure 95 percent on-time arrival (10).

Exhibit PDX-15. Mobility and Reliability by Section and Time Period

Section	Length (mi)	Travel Time Index				Buffer Index			
		Morning (6a-9a)	Midday (9a-4p)	Evening (4p-7p)	Average peak period	Morning (6a-9a)	Midday (9a-4p)	Evening (4p-7p)	Average peak period
Highway 217 NB: 72nd Ave. to Walker Road	5.95	1.13	1.10	1.25	1.19	24%	13%	32%	28%
Highway 217 SB: Walker Road to 72nd Ave.	6.01	1.12	1.09	1.26	1.20	42%	27%	44%	43%
I-205 NB: ORE 99E to Division	10.33	1.12	1.12	1.27	1.20	40%	38%	51%	46%
I-205 SB: Airportway to ORE43	16.27	1.11	1.07	1.22	1.17	27%	17%	37%	32%
I-5 NB: Stafford Road to Jantzen Beach	21.81	1.21	1.24	1.60	1.41	23%	41%	51%	38%
I-5 SB: Jantzen Beach to Nyberg Road	18.5	1.36	1.30	1.47	1.42	23%	42%	48%	36%
I-84 EB: Morrison/I-84 to 39th Street	2.5	1.04	1.30	2.05	1.60	5%	73%	59%	35%
I-84 WB: 207th Street to 33rd Street	12.3	1.60	1.30	1.28	1.45	44%	38%	28%	37%
US 26 EB: Helvetia Road to Skyline Road	10.1	1.29	1.23	1.46	1.37	69%	57%	84%	76%
US 26 WB: Skyline Road to Murray Street	4.06	1.25	1.19	1.82	1.54	29%	39%	84%	57%
Average for all Sections		1.24	1.19	1.42	1.33	33%	36%	49%	41%

- ◆ Several freeway sections have a significant directional congestion difference during the peak periods. In most cases, that difference also exists for peak reliability levels.
- ◆ At least eight freeway sections have midday congestion levels near or above morning peak congestion. Six of the 10 sections also have similar or greater reliability problems in the midday than in the morning peak.

Figure 4. Exhibit PDX-15 from the 2002 Mobility Monitoring Study for Portland, Oregon (9)

Figure 4 displays the same mobility measure, Travel Time Index, as the Urban Mobility Report, but due to greater coverage of data collection instrumentation and the high resolution of the data, sections of freeway can be analyzed in greater detail. The analysis can be taken to the time of day level as well as include measures such as the reliability as shown in Figure 4.

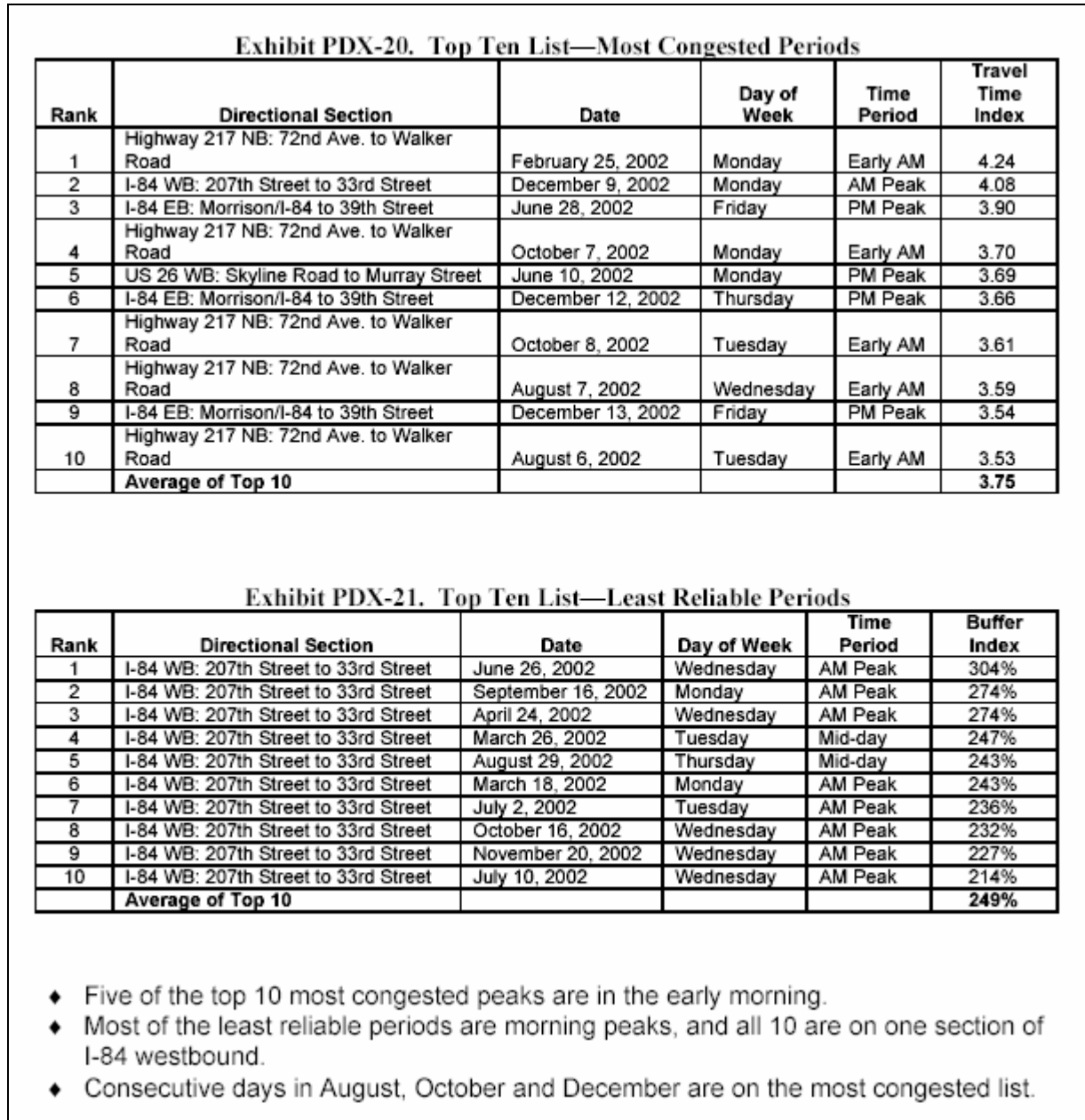


Figure 5. Exhibit PDX-20 and Exhibit PDX-21 from the 2002 Mobility Monitoring Study for Portland, Oregon (9)

A next logical step in the analysis of the data used to create Figure 4 is to create lists or rank the freeway sections by the mobility or reliability measure. Figure 5 shows examples of two such lists. The first is a top ten list of the most congested periods. The second is a top ten list of the least reliable periods. From

the first list, it can be seen that five of the top ten most congested periods are on Highway 217, between 72nd Avenue and Walker Road in the north bound direction. A closer look reveals that all these congested periods occurred on weekdays in the early morning. The second list seems to be very revealing about the least reliable section of freeway in Portland. Ten of the top ten are on the same highway segment and eight of the ten time periods are in the morning peak. Both lists are examples of tools that can be used to effectively identify problem areas as well as direct funding to help remediate the problems.

Figure 6 is an interesting example of how speed data can be displayed to illustrate bottleneck locations and times, but also data quality problems. Figure 6 is a colored speed graph that indicates changes in traffic speed during the average day on south bound Interstate-5 in Portland, Oregon. The horizontal axis is time of day and the vertical axis is milepost. Not uncommon to urban areas, there are times in the morning and evening of slow traffic. The speed graph supports this concept. What does seem out of place is the section of 30 to 40 mph speeds between Alberta and Lombard Street that occurs at all hours of the day. Compared to the rest of the system that is operating at free flow speed during early morning hours leads to the conclusion that the data may be incorrect. Further investigation may indicate that there was a construction project or some other reasonable explanation, however to be the most useful, these anomalies in the data either need to be identified or corrected.

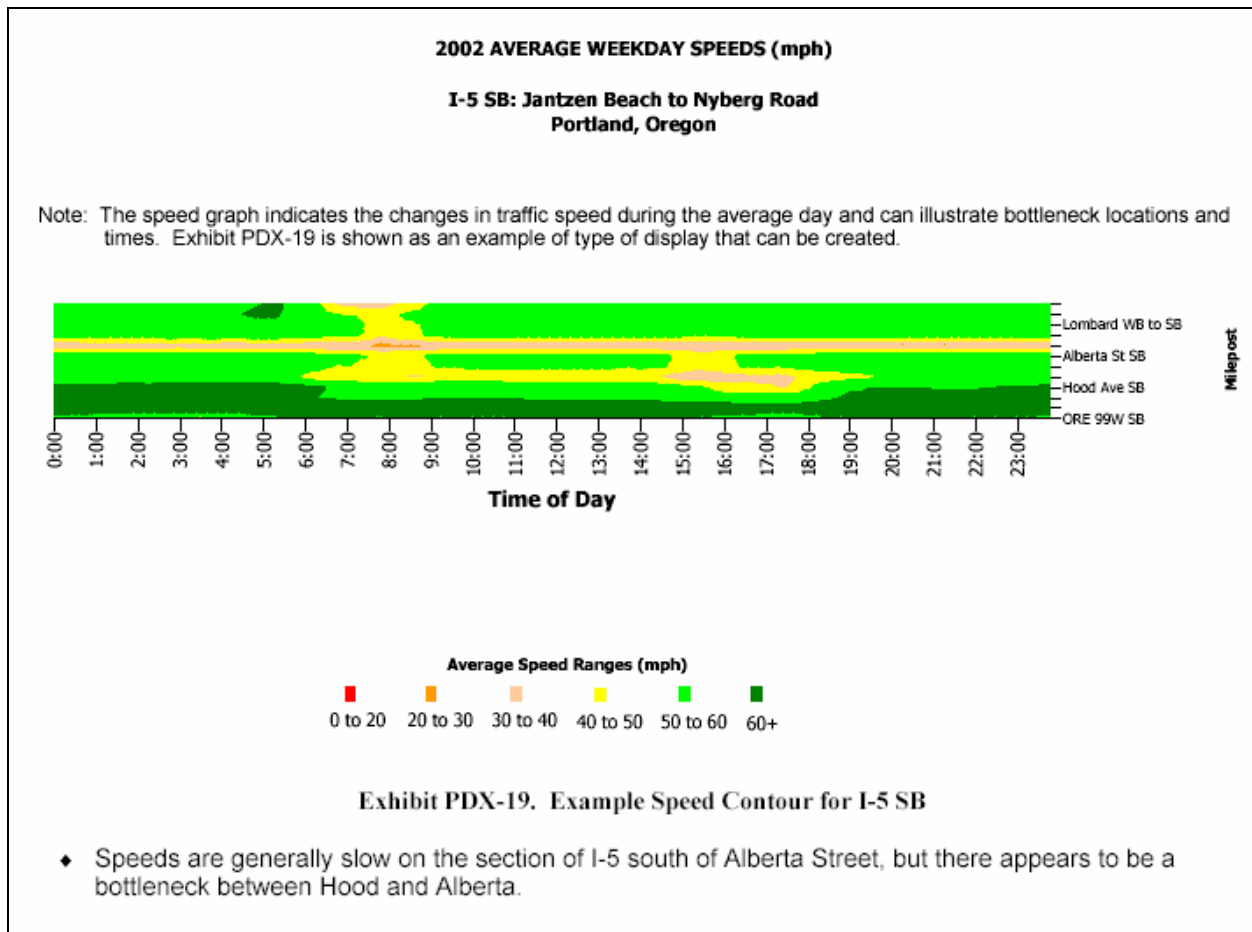


Figure 6. Exhibit PDX-19 from the 2002 Mobility Monitoring Study for Portland, Oregon (9)

Figures 4, 5, and 6 show the reports that can be produced from MMS analysis to show problem areas at the corridor level such as bottlenecks, time of day variations, and persistent congestion. These measures can help make operational decisions which in turn can be measured for effectiveness. Although the data

was put through some quality checks by the MMS, systematic errors can't be detected. Systematic errors are inherent errors associated with the data collection technology or installation of the technology. These errors can be hard to uncover because the data can remain within acceptable ranges. Also, the MMS only considered mainline data and incident data was not considered (2).

Reoccurring and Non-Reoccurring Congestion

Congestion can be classified generically into two categories. The first category is reoccurring congestion which results when there is more demand than available capacity for the highway. The second category is non-reoccurring congestion. Non-reoccurring congestion is the result of crashes, construction, weather, special events, or other incidents. Incident management programs have been implemented in many cities help mitigates the effects of non-reoccurring congestion by clearing incidents faster.

Although the scope of the paper did not include measures for incident management, the progressive work in the area and how it relates to freeway mobility is relevant. The goal of the work is to measure reoccurring and non-reoccurring congestion separately. Once separated, programs and projects can be evaluated to measure their impact on the mobility and reliability of the freeway system individually.

FINDINGS

Findings from the research regarding freeway mobility measures and the data involved are listed below:

- The majority of the work in the area of freeway mobility measures is done at the national level utilizing consultants with the experience and modeling tools required to work with large data sets.
- As performance measures become more specific and detailed, the resolution of data must increase.
- To make better management decisions at the corridor level, corridor data are needed. Preferably real measurements like ATMS data, not modeled HPMS-like data.
- There is a large opportunity to improve archived operations data. Roughly half of Portland's ATMS data was unusable in 2002 MMS. If the data can progress to higher levels of precision and accuracy then the use and value of the data increases.

GENERAL RECOMMENDATIONS

General recommendations from the research regarding freeway mobility measures and the data involved are listed below:

- Agencies that are currently or considering the collection of operations data, could consider their archiving strategy with the all users in mind. This would involve the inclusion of field personnel, operators, and analysts in the planning stages of the architecture. Each group could communicate their perspectives and needs early in the process.
- Current data collection efforts could improve the quality of data by implementing a quality control program that includes the field device maintenance, data checks, and data warehousing metadata.
- Agencies should decide what measures they want to calculate and collect the necessary data at the appropriate resolution. Agencies can participate in national studies and benefit from the measures that result.
- The ATMS data gathered for performance measures should be used to improve the HPMS data sets.

IMPROVEMENTS FOR OREGON'S FREEWAY OPERATIONS DATA

Quality Control

For the 2002 Mobility Monitoring Study, Portland had approximately 54 miles of the more than 137-mile freeway system which was included in the archived data system (9). This is roughly 40 percent coverage of the urban freeway system. The traffic volume and speed data were collected using mostly double inductive loops on the mainline lanes at ramp metering locations. This data are collected at 20 second intervals and archived at the 15 minute level. The 15 minute data were provided for the Mobility Monitoring Study. After quality control was applied, the percent of possible data records was reduced from 80 to 56 percent for the analysis (9). This means that out of all the possible data records, 56 percent of the volume and speed data were available for the study.

Systematic data errors are the responsibility of the Oregon DOT and may preclude the operations data (volume and speeds) from being useful in HPMS, travel times, real-time ramp metering, and other data analysis that tie into data sources monitored and checked more closely. The operational traffic volume data were measured and compared at a location where there were both detectors for ramp metering as well as an ATR to see if the ramp meter data could be included into the HPMS data set. The two data sets were compared for a day and cross checked manually against a video taken at the location. A graph of the results, Figure 7, shows that the video matched the ATR most closely and that the ramp-meter was over counting by roughly 10 percent. A Portland State University study that evaluated the ramp meter system in Portland found from a small sample that ramp meters correctly measure speeds, but over counted volume by 8 percent and that 5 axle trucks may be double counted (11). The implication of the difference is significant to the HPMS program. Traffic reported on Portland's urban ATRs typically increase or decrease by less than 3 percent per year. An 8 to 10 percent change is considered unacceptable.

When using inductive loop technology as the detection method, over counting large trucks can occur when the height of a trailer on a tractor-trailer combination is higher than the detection zone of the inductive loop. The ramp meter at the test location used a four-foot square inductive loop that had a detection height of roughly 2.7 feet. The ATR utilized a 6-foot round loop which increased the detection height to a total of 4 feet. If the trailer section of a truck caused loop detection to terminate between the tractor and the rear axles of the trailer, two vehicles would be counted instead of one. There are other reasons that could cause an over counting condition and blanket adjustment across all detectors may not be an appropriate measure to correct the problem. Other reasons for the difference between the ATR and ramp meter data could be caused by the loop amplifier sensitivity which if too high can detect vehicles in adjacent lanes. The traffic counting algorithms that process the field data may handle situations such as slow speeds, tail gaiters and lane changing differently as well. Over counting is not the only problem. With any large system there are installation and communication issues as well. As part of an improved quality control program, technicians could begin to reconcile some of the volume data issues.

Another area of improvement is in the data archiving process. Currently, the algorithms used to check the operational data are very limited. They check only for data out of simple ranges and for broad error codes. One example of a data archiving flaw occurs when a 20 second data interval that has a legitimate 0 volume count cause a divide by 0 error. This error appears the same as a communication error and results in the invalidation of that data interval. The errors caused by legitimate data cause more data to be invalidated as the records are merged into 15 minute and hourly summaries. Speed data algorithms are also a concern. Speeds for individual lanes are averaged together to create a single directional average speed for operational speed maps as well as archiving. If one lane has a speed error, then the directional calculation continues as if the lane had a 0 speed and averages the zero with the other speeds from the other lanes. This causes the speeds to appear lower than what was actually occurring. Many of these problems are known and can be fixed. The fixes will enhance the quality and usefulness of the ATMS volume and speed data.

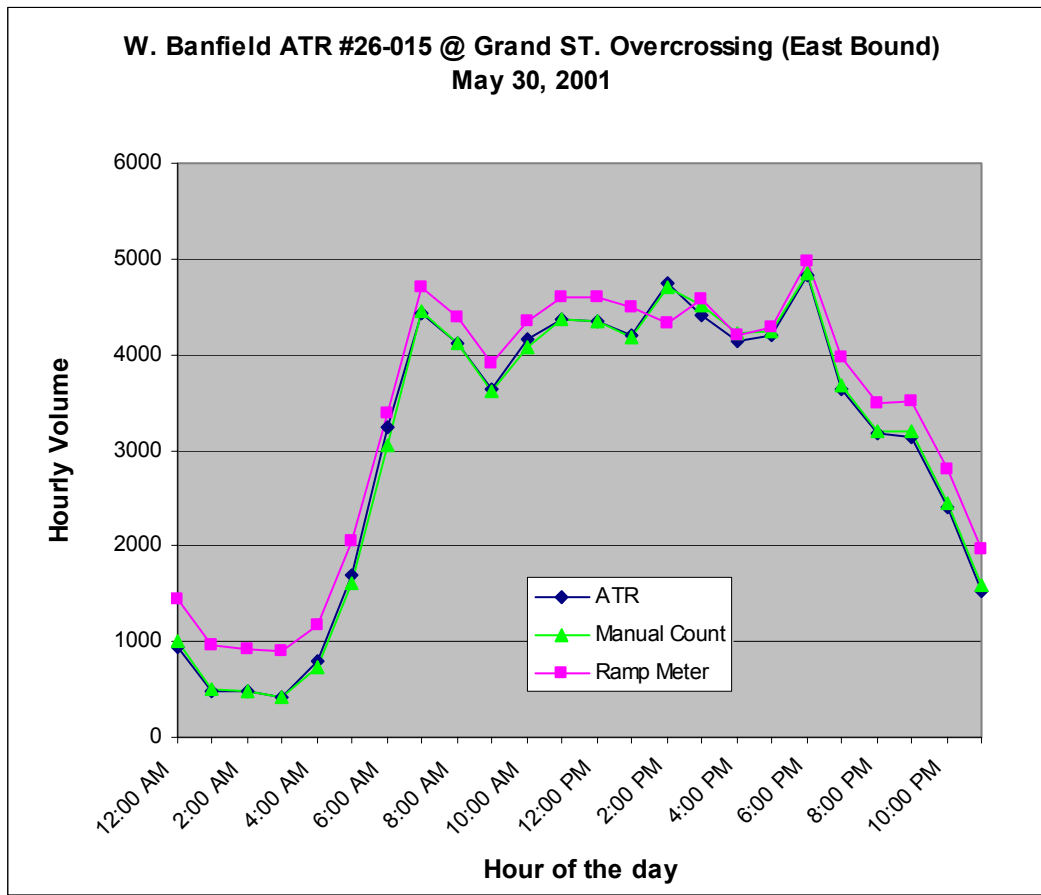


Figure 7. Comparison of a Ramp Meter Count, ATR Count and Video Count Conducted on Interstate 84 in Portland, Oregon

Partner with Portland State University

Like neighboring states Washington and California that have strong partnerships with local universities, Oregon should continue to develop its relationship with Portland State University (PSU). Current PSU faculty has a strong interest in mobility issues and has used and become familiar with the operations data for recent studies. Through the use of the data, much insight has been gained into the potential, as well as the problems with the data. PSU has become a valuable resource for identifying and overcoming ATMS data challenges. There is a project underway to provide the university the 20 second operations data directly for research purposes. It may become practical in the future for PSU to be the institution that checks, archives, and disseminates the operations data.

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**EVALUATION OF THE FREEWAY SERVICE PATROL PROGRAM
IN THE BIRMINGHAM, ALABAMA REGIONAL AREA**

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ABSTRACT

Freeway Service Patrols typically offer a broad range of services. All offer basic motorist assistance, debris removal and vehicle clearance. In addition, some offer first aid, basic field repairs and traffic control assistance. Motorists have responded very favorably to service patrols particularly regarding the timeliness of assistance given, feeling of safety and security derived from uniformed personnel assistance and free services. In the study areas, freeway service patrols operated only on parts of the local freeway network, bridges, and other controlled-access facilities.

When starting a new service patrol program or seeking to improve an existing one, talking to existing program sponsors provides invaluable advice. A visit to observe an existing program can help the new program sponsor learn from the experiences of others and avoid costly mistakes. This paper surveyed various freeway service patrols from around the country. The service patrols are located in Tennessee, North Carolina, Texas, Georgia, Maryland, Missouri, South Carolina and Utah. The survey results include name, sponsor, centerline miles patrolled, number of vehicles, and number of operators, estimated annual assists and annual budget.

Local incident responders were surveyed using a telephone questionnaire to discuss the freeway service patrols and their role at the freeway incident scene. An understanding of roles can help emergency responders, police, firefighters, department of transportation personnel, tow operators and others coordinate their responses and clear incidents quickly and effectively.

The quick removal of incidents is vital to producing the safety benefit which decreases the possibility of secondary crashes and ultimately restoring roadway capacity. A public information campaign and / or legislation must be in place in order to achieve an effective incident management or freeway service patrol program.

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INTRODUCTION

Urban traffic congestion is a growing national problem. In many metropolitan areas traffic congestion is the most serious regional problem. Traffic congestion can be classified as recurring or non-recurring. Based on Federal Highway Administration (FHWA) studies, about 80 percent of all incidents are non-recurring. The largest categories of non-recurring incidents are disabled vehicles. It is estimated that each minute of lane blockage results in up to five to ten minutes of congestion. (1, 2, 3)

Many large metropolitan areas are utilizing freeway service patrols (FSPs) as one approach to help mitigate the congestion problem when incidents occur. When an incident occurs on the freeway system, personnel operating service patrols are present to provide invaluable services such as directing traffic, providing medical assistance, quick repairs, fuel and oil, and clearing debris, to name a few. Also FSPs can be an effective way to detect and clear incidents. Patrols assist in locating incidents, minimizing incident duration, restoring full capacity to the facility and reducing risks for motorists and patrol personnel.

In response to increasing traffic congestion and air quality degradation in the Birmingham area, the Alabama Service and Assistance Patrol (A.S.A.P.) began operations in 1997 with five trucks and ten operators. The purpose of the A.S.A.P. program is to improve the safety and efficiency of the freeway system by providing basic services (e.g., refueling, tire-changing) to motorists in need and supporting the management of traffic incidents (e.g., providing traffic control for the incident scene). While the program has been widely viewed as worthwhile and successful, a thorough evaluation of its benefits and potential improvements has not been undertaken.

Statistics show that incident management programs, including FSPs, provide an extremely valuable service. Service patrol program expansion should always be considered in areas where they are currently operating and they should be implemented in more urban areas in the U.S. In the Birmingham Alabama Regional Area, there are increasing traffic volumes on the freeway system along with the increasing number of incidents. This trend has caused a need to review current practices. The goal is to continue to improve the freeway service patrol in the Birmingham Regional Area therefore helping to improve overall the regional incident management program.

Research Objectives

In order to arrive at the point of making recommendations for improving the Birmingham Area freeway service patrol program, there are six research objectives established in order to achieve this goal. The objectives are as follows:

- Identify the role of the freeway service patrols in incident management programs that are located in urban areas in the US;
- Determine current practices on how Alabama and other state department of transportations (DOTs) are using their FSPs in responding to incidents;
- Compare the archived assist data from the Birmingham freeway service patrol to the information gathered from other cities;
- Collect feedback from the incident response team members in the Birmingham area by conducting surveys;
- Make recommendations for improvement in the freeway service patrol program to Alabama Department of Transportation (ALDOT), Department of Public Safety (DPS) and other decision-makers;
- Apply those recommendations to an action plan for ALDOT to implement programs in other parts of the state.

Scope

This research was limited to studying freeway service patrol programs that are operated or sponsored by State DOTs. Also a review of literature pertaining to freeway service patrol programs or incident management programs was included in this research. In order to meet the objectives of this research, telephone interviews were conducted with transportation professionals from State departments of transportation and local incident response team members who coordinate and / or work with the freeway service patrol program.

By reviewing documented evaluations of freeway service patrols and ascertaining best practices, approaches to providing motorist assistance found successful in other regions but not yet applied in Alabama can be identified.

STUDY APPROACH

Four procedural steps were followed while conducting the research project with the purpose of performing the evaluation of the freeway service patrol in the Birmingham Alabama regional area. Each procedure is described in this section.

Literature Review

A search of current literature was done in order to establish the state of practices for operating FSPs programs around the country. The review included information that was available on the Internet as well as performing database searches to retrieve published documents. The information gathered is presented in the Background section of this report.

Data Collection

The primary source of information collected was derived from conducting surveys of several freeway service patrol programs operated by state DOTs in order to establish current practices. The survey was conducted by telephone and email using a survey form (See Appendix A) designed to keep a consistent method of questioning. The individuals contacted have a direct oversight of the freeway service patrol programs for their areas.

A survey was also conducted of the local freeway incident responders in the Birmingham Alabama Area to get information about their role and concerns as it relates to incident management. (See Appendix B) Table 1 is a list of the individuals contacted from State DOTs and Table 2 is the list of local incident responders contacted and the organization with which they are associated.

Data Analysis and Application

The information from the survey was developed to describe the current practices of each organization with regard to the operation of their freeway service patrol. The results of the analyses are presented in the form of charts that describe the programs system, FSP information, and potential benefits.

REVIEW OF FSP PROGRAMS

Across the US, the concept of FSPs is not a new one. One of the oldest known comprehensive FSPs was the Chicago Emergency Traffic Patrol, better known as the Minutemen. The program began in April 1960 and continues today with a fleet of at least 51 vehicles (Morris, 1994). However, only a select few FSPs have a long and distinguished history comparable to that of the Minutemen. Most patrols were initiated during 1990s; in fact, 33 FSPs made their debuts in the first eight years of that decade (Fenno, 1998).

Many metropolitan areas turned to FSPs as a cost-effective means of dealing with the ever increasing problem of urban congestion. The trend caught on, and today there are well over 50 FSPs in existence. With so many FSPs in operation, the type and quality of service provided does vary. Sponsorship and funding for freeway service patrols comes from a variety of sources including public agencies, public-private partnerships, and entirely private entities. These sponsoring organizations receive funding from combinations of federal, state, and local taxes and also private funds. The operational aspects of freeway service patrols differ as well. For example, some services patrol only the morning and evening peak periods, while a select few patrol twenty-four hours a day. The types of vehicle utilized for patrolling vary also. A majority use pickup trucks, but 28 percent utilize tow trucks (Fenno, 1998).

With the introduction of many FSPs in the last decade, a number of reports are available describing the operations and cost-effectiveness of these patrols. Many reports include measures of effectiveness. There appear to be three primary methods for generating these benefits. The three methods include simulation, real-time modeling, and personal preference surveys/economic models.

Table 1. DOT Survey Contacts (4, 5, 6, 7, 8, 9, 10, 11, 12, 13)

Contact	Organization
Archie Wells	North Carolina Department of Transportation
Dave Kinnecomm	Utah Department Of Transportation
Gary Olgetree	Tennessee Department Of Transportation
Robert Warren	Missouri Department of Transportation
Mark Demidovich	Georgia Department of Transportation
Alvin Marquess	Maryland State Highway Administration
Kenny Larimore	South Carolina Department of Transportation
Mickey Campbell	Tennessee Department of Transportation

Table 2. Local Survey Contacts (14, 15, 16, 17)

Contact	Organization
Jim Christian	Alabama Department of Transportation
Billy Phillips	Alabama Department of Public Safety
John Griscom	Jefferson County EMA
Capt. Willis	Birmingham Fire & Rescue

Raleigh, North Carolina (18, 13)

The Incident Management Assistance Patrol (IMAP) is operated by the North Carolina Department of Transportation as a component of the Incident Management Program in Raleigh Metro Area. (Figure 1) The role of IMAP is to provide traffic control during freeway incidents as well as assisting stranded motorists.

There are 10 employees who work in the program including the operators and dispatch personnel with 10 vehicles in their fleet. They cover a total of 72 freeway centerline miles. Hours of operation are from 6:00 am to 8:00 pm, Monday – Friday. The service patrol operators are notified mostly through local law enforcement of an incident, while other incidents are found by driving planned routes. IMAP offers the usual motorist services such as tire changes, fuel, cell phone, jump starts, etc. The FSP vehicles are equipped with air compressors, push bumpers, front and rear winches, arrow boards and other equipment. There is also State legislation to allow the removal of disabled vehicles from travel lanes. IMAP also has

an agreement with the Department of Public Safety giving them authority on the freeway to remove vehicles that are blocking travel lanes.



Figure 1. IMAP Logo

Salt Lake City, Utah (19)

UDOT'S Incident Management Program has been in place since 1994. The program provides both routine courtesy service patrol on freeways and emergency response to incidents. The program has been very successful and gained a great deal of support within UDOT and with the Utah Highway Patrol.

There are 13 employees with 15 service patrol vehicles. (Figure 1) The FSPs cover about 125 miles of freeway in the Salt Lake City, Provo and Ogden area. It operates on a budget of 1.2 million annually. The hours of operation is from 6:00 am to 6:00pm, Monday – Friday utilizing two work shifts. In addition to the usual equipment that is found on service patrol vehicle, these trucks are also equipped with changeable message signs.



Figure 1. IMT Patrol Vehicle

Currently there is no quick clearance legislation addressing vehicles that block travel lanes. Most motorists, when approached, are very cooperative to move or allow their vehicle to be relocated from roadway to shoulder area. It was also noted that response cards given to motorist who receive assistance has proven to be very effective in measuring feedback or public perception.

Nashville, Tennessee (11)

The HELP Program in Nashville has continued its focus on the most heavily traveled routes in the metro area to allow prompt response to incidents that would otherwise cause widespread and prolonged congestion, secondary crashes, and related problems. There are 22 service patrol program employees

along with 22 program vehicles. The HELP patrols 70 miles of freeway in the Nashville area from 6 am till 10:30 pm, seven days a week.

The HELP Program operates on an annual budget of 1.5 million dollars. Figure 2 shows a HELP operator with his truck and a display of standard equipment available to assist the operator and other incident responders. (When “in service,” the operators always wear a reflective vest.) The HELP supervisors drive a heavy-duty pickup truck with much of the same equipment and the capacity to transport several passengers when necessary.



Figure 2. HELP Operator, Truck and Equipment

Incidents are detected by receiving calls from metro police and motorists as well as drive ups by the operators. On January 2, 2004, legislation was passed to allow HELP operators to remove vehicles from travel lanes, giving them the authority that the troopers and local police possess. There is also a memorandum of understanding between TDOT and Department of Public Safety for obstruction removal on the interstate.

Kansas City, Missouri (8)

The Motorist Assist (MA) Program is a roving freeway service patrol program in the St. Louis and Kansas City Metro areas. The program began operating during the morning and evening rush hours in January 1993. The service was expanded in 1996, 1999 and again in 2002 to include longer hours of operation and coverage areas. As of January 4, 2003, The Kansas City area is providing 24/7 coverage. This entails utilizing MA from 5:30 AM to 8:00 PM and two Emergency Response (ER) vehicles on call from 7:00 PM to 5:30 AM. Combined, the program maintains a total of 24 vehicles, with a minimum of four used for 24 hour service. (Figure 3)

MAP patrols 164 miles of freeways in the Kansas City area. The program provides support during incidents, relocation of vehicles on the travel-way onto the shoulders, providing minor mechanical assistance to disabled vehicles, removal of debris from the roadway, assisting lost motorists with directions and state maps, minimizing the time spent on the traveling lane to reduce delay for other vehicles, providing initial traffic control at incidents when required, reporting freeway incidents to the MoDOT dispatcher and accidents to the appropriate agency, and assisting drivers free of charge by changing flat tire, supplying fuel and calling a tow truck. The annual budget for the MAP program is 1.5 million dollars.



Figure 3. Motorist Assist Vehicle (MODOT)

Atlanta, Georgia (9)

The Highway Emergency Response Operators (HEROs) provide the key component of the Georgia Department of Transportation's Incident Management program. As the GDOT strives to reduce congestion on the highways, HEROs will respond quickly to incidents and clear the roads so that the normal traffic flow can be restored.(Figure 4)



Figure 4. GDOT Incident Response Unit Logo (HERO)

Funding for the HERO program has been provided by Congestion Mitigation/ Air Quality (CM / AQ) Fund under the guidance of the Atlanta Regional Commission's (ARC) Incident Management Task Force. The Task Force members include the Federal Highway Administration (FHWA), Georgia DOT, traffic reporters, emergency and first-response agencies and the private sector.

The annual budget for 2004 is 4.5 million dollars and is planned to increase to 6 million in 2005. There are 45 service patrol operators, 4 supervisors, 2 managers, and one administrator involved in the program. Currently there are 45 vehicles that patrol 220 miles of freeway in the Metro Atlanta area and operates 24 hours a day, seven days a week with limited coverage nights and weekends.

The TMC operator dispatches the HERO operators to an incident where they provide traffic control for the various responders at the scene. In addition to traffic control, motorists assistance is provided such as tire change, water, gas, cell phone use, pulling disabled vehicles off roadway, minor vehicle repair, etc.

The HERO program is planning to double in size over the next 3-4 years to cover the entire Atlanta metro area. When an incident occurs, the motorist must move their vehicle from travel lane immediately unless there is an serious injury or fatality according to state legislation. There are inter-agency agreements between GDOT and other respondents on how incidents are to be handled on the freeway along with manuals and after-incident debriefing meetings.

Washington DC / Baltimore, Maryland (4)

Once the traffic and roadway monitoring system has identified a problem, an immediate response is initiated to clear the incident and re-open lanes as quickly as possible, while protecting the safety of victims, travelers and emergency personnel. CHART operates a nationally recognized incident management program which depends heavily on the cooperation and teamwork developed among the State Highway Administration (SHA), the Maryland State Police (MSP) and the Maryland Transportation Administration (MDTA). The tools used for incident management include:

Emergency Traffic Patrols (ETP) used to provide emergency motorist assistance and to relocate disabled vehicles out of travel lanes and the Emergency Response Units (ERU) is used to set up overall traffic control at accident locations. (Figure 5) Freeway Incident Traffic Management (FITM) Trailers, pre-stocked with traffic control tools such as detour signs, cones, and trailblazers used to quickly set up pre-planned detour routes when incidents require full roadway closure.



Figure 5. CHART Vehicle

There are 18 full time employees and 18 part-time employees that patrols 180 miles of freeway in the Washington DC/ Baltimore/ Frederick Maryland area. Operating hours are each day from 5 am till 9 pm and on-call 24 hours a day. There are 21 vehicles in the fleet in which the operators drive home because of their on-call status.

A "Clear the Road" policy which provides for the rapid removal of vehicles from the travel lanes rather than waiting for a private tow service or time consuming off-loading of disabled trucks which are blocking traffic. There is an inter-agency agreement between the Maryland State Highway Administration

and Maryland State Police addressing how incidents are to be handled on the freeway. The freeway service program operates annually from a budget of approximately 3.8 million dollars.

Charleston, South Carolina (20)

Established in 1996, SCDOT Incident Response (formerly known as SHEP) now serves motorists traveling in the Beaufort, Charleston, Columbia, Florence, Grand Strand/Myrtle Beach, Rock Hill, and Greenville/Spartanburg urban areas. Prepared to handle a variety of situations, SCDOT Incident Response responders make minor repairs to disabled vehicles, assist with traffic control and incident management, and provide first aid until emergency medical service arrives.

The program started in Charleston on March 1999 and currently operating 24 hours a day. There are 3 service patrol vehicles that patrol 25 miles of freeway around the Charleston Area. The program has sixty employees with an annual budget of 6.5 million that operate the SCDOT Incident Response. This amount also includes the Traffic Operations statewide. (Figure 5)



Figure 6. SCDOT Incident Response Vehicle

At this time, state officials are working on legislation pertaining to the removal of disabled vehicles from freeway travel lane. There is no inter-agency agreement between SCDOT and others on how incidents are to be handled.

Knoxville, Tennessee (10)

The freeway service patrol in Knoxville serves 35 miles of roadway in the metro area using 10 FSP operators and one dispatcher. Their role in incident management consists of removing disabled vehicles from roadway and providing traffic control during an incident. The hours of operation are from 5:00 AM to 10:30 PM, Monday – Friday and 9:00 AM – 8:30 PM, Saturdays and Sundays. (Figure 7)



Figure 7. TDOT HELP Logo

In addition to the daily patrols in Knoxville and other areas in the state, the HELP units also responded to requests from local law enforcement agencies or the Tennessee Highway Patrol to assist with crashes and other emergencies outside of the normal patrol areas. HELP was also called on to assist with special events that created exceptional demands on the transportation system.

The annual operating budget for the HELP program in Knoxville is approximately 1 million dollars. Currently the regional TMC is under construction along with adding 75 cameras on the freeway system. Future plans, once construction is complete, is to begin 24 hour / 7 day patrols in the metro area. All legislation and agreements pertaining to disabled vehicles are being handled similar to the programs statewide.

Birmingham, Alabama (15)

On June 24, 1997, A.S.A.P began operation with 10 drivers and five yellow service trucks along five interstate routes, to minimize traffic incidents and overall congestion in the Birmingham Metropolitan Area. (Figure 8) The program is an effort of the Alabama Department of Transportation and the Alabama State Troopers with funding provided by the Federal Highway Administration. State Troopers dispatch the trucks in response to calls from the public to (*47) on cellular phone. In addition, video cameras placed along interstate routes permit the State Troopers and other traffic operation centers to monitor traffic flow at priority, high-traffic flow locations, which are more likely to have a traffic incident. A.S.A.P. operators are civilian employees of Alabama Department of Public Safety, with no law enforcement powers.

A.S.A.P is a component of an overall Congestion Management Program designed to reduce traffic congestion on the regions interstate system and to improve air quality in the Greater Birmingham Area. To achieve this goal, A.S.A.P service trucks offer a variety of free services to disabled motorist to get them on the road again. A.S.A.P has assisted Alabama drivers, as well as drivers from across the United States, Canada, and many other nations.

A.S.A.P. currently has 12 operators and 10 trucks that patrol approximately 112 miles of freeway in the Birmingham area on various interstate routes. The standard hours of operation are Monday - Friday from 6 a.m. to 10 p.m. Specific events or events or weekends with projected high interstate traffic my prompt additional A.S.A.P. services to be made available to the public. (Figure 9)

There is currently no state legislation pertaining to the removal of disabled vehicles from travel lanes on the interstate system. There is a state vehicle code that is displayed on signs around the interstate system in Birmingham that reads “Move Crash Vehicles From Travel Lane”, Title 32, Code of Alabama.

The Alabama State Troopers has an inter-agency agreement with local law enforcement groups in the Birmingham area to respond to incidents and patrol the interstate system in their particular jurisdiction.



Figure 8. Alabama Service & Assistance Patrol (ASAP) logo



Figure 9. ASAP Service Patrol Vehicle

SUMMARY

Many service patrol program coordinators interviewed who are having success in their efforts in combating obstacles during incidents on the freeway have similar practices. They are as follows:

- They have quick clearance campaigns or legislation in place to address moving disabled vehicles from travel lane;
- Inter-agency agreements are in place between State DOTs or Public Safety and other incident respondents on how to handle incidents on the freeway;
- They cite having supporting data that show decreased times in incident response and clearance that is available to present to decision makers;
- Studies performed on their programs to show benefits of cost, safety, mobility, etc. to present for funding or justification.

Table 3 provides a summary of the reviewed freeway programs showing number of personnel, vehicles, miles patrolled, hours of operation, quick clearance laws, inter-agency agreements and annual cost of programs. Table 4 lists the types and quantity of assists made by the reviewed service patrol programs along with the total number for 2003.

Table 3. Summary of FSP Information

Freeway Service Patrol Information									
	Birmingham ASAP	Raleigh IMAP	Salt Lake City IMT	Nashville HELP	Kansas City MAP	Atlanta HERO	Washington Baltimore ETP / ERU	Charleston SCDOT IR	Knoxville HELP
No. of Personnel	12	10	13	22	15	52	36	3	10
No. of Vehicles	10	10	15	22	8	45	50	Not available	12
No. of miles covered by service patrol	112.	72	125	70	164	220	180	25	35
Operating hours	M-F 6am-10pm	M-F 6am-8pm	M-F 6am-6pm	Mon-Sun 5am-10:30pm	M-F 5am-8pm	24 hour a day 7 days a week	5am-9pm 24 hr on call	24 hours	M-F, 5am- 10:30pm S-S, 9am- 8:30pm
Quick clearance legislation?	No	Yes	No	Yes	No	Yes	No	Currently Pending	Yes
Agreements with local law enforcement?	No	Yes	No	Yes	No	Yes	Yes	No	Yes
Annual operating budget	900,000	1 million	1.2 million	1.5 million	900,000	4.5 million	3.8 million	Not available	900,000 – 1 million

Table 4. FSP Assist Totals

2003 Freeway Service Patrol Assist Totals									
	Birmingham ASAP	Raleigh IMAP	Salt Lake City IMT	Nashville HELP	Kansas City MAP	Atlanta HERO	Washington Baltimore ETP / ERU	Charleston SCDOT IR	Knoxville HELP
Provided Traffic Control	2038	619	3552	6188	Not Available	Not Available	Not Available	556	3991
Removed Debris	1492	109	2412	1210	3060	1147	Not Available	514	1928
Pushed or Pulled Disabled Vehicle	199	1070	Not Available	117	481	Not Available	Not Available	142	102
Tire Changes	3582	Not Available	Not Available	3571	2430	Not Available	Not Available	1422	1883
Provided Fuel	1488	Not Available	Not Available	2017	1911	Not Available	Not Available	988	1583
Mechanical Assistance	1259	Not Available	Not Available	1816	1529	Not Available	Not Available	882	4306
Total Assists for 2003	23811	25112	8910	29145	16015	45240	38564	14880	30361

LOCAL INCIDENT RESPONDERS SURVEY

During the review of the freeway service patrol program, local incident responders were asked several questions about their agency's role and concerns about freeway incident response. (See Appendix B) A member from each of the following agencies was surveyed using questions such as:

- What services does your agency provide on highway incidents?
- What are your agency's safety concerns?
- What areas of training would your agency need?
- In what areas do highway departments seem to need more information or awareness?

A complete list of survey questions is located in Appendix B of this report. The following table contains the name of the responding agency, the service they provide and their issues and concerns.

Table 5. Local Incident Responders

Name of Agency	Services Provided at Incident Scene	Issues and Concerns
ALDOT Maintenance	Traffic Control and Debris Removal	<ul style="list-style-type: none"> • Traffic Control • Lack of Communication • Emergency Management Training • Safe Passage of Motorist
Public Safety Department (ASAP)	Traffic Control and Debris Removal	<ul style="list-style-type: none"> • Motorist Safety Education • HAZMAT Awareness • CPR Training • Traffic Control
Birmingham Fire and Rescue	Fire and Medical Service	<ul style="list-style-type: none"> • Exposure of respondents on scene and en route • Lack of availability of resources • Lack of communication and coordination • Emergency access for responding vehicles • Apparatus positioning
Emergency Management Agency	HAZMAT and Environmental Support	<ul style="list-style-type: none"> • Environmental Awareness • Accurate information of incident location • HAZMAT training for DOT respondents • Lack of unified command on scene of incident

SUMMARY

All survey participants had concerns with safety at the incident scene in regard to the respondents and motorists. Lack of communication between agencies and understanding of protocol was cited to improve coordination at the incident scene.

RECOMMENDATIONS

As a result of the findings of this research, the recommendation will be presented to ALDOT and DPS to better improve the ASAP Program:

- Start a public information campaign with respect to incident management practices, in particular ASAP along with conducting motorist surveys and using comment cards to get user feedback;
- Evaluate and demonstrate the economic benefits of the A.S.A.P. program to travelers in the Birmingham region. These benefits include those associated directly with the motorist assistance rendered as a part of A.S.A.P., as well as indirect benefits associated with reduced delay, improved safety, and reduced environmental impacts. Conduct a cost-benefit analysis of the ASAP program along with identifying safety and capacity issues;
- Impress upon the decision makers the need for state legislation for the removal of disabled vehicles from travel lane;
- Develop an incident management responders handbook to be distributed among the agencies;
- Form an incident management task force to meet monthly to discuss concerns of the program and to meet shortly after major incidents for debriefing;
- Devise a monthly newsletter for distribution to ALDOT funding decision-makers and ITS committees;
- Strengthen the ASAP Program by requesting additional operators and vehicles to adequately cover the freeway in the Birmingham area. Perform analysis of assist data form previous years to determine locations where most incidents and assists are occurring.

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APPENDIX A: DRAFT SURVEY QUESTIONS

(State DOTs)

The following questions were used to interview State DOT contacts about their programs:

- What agencies operate the Freeway Service Patrol (FSP) in your area?
- What is the role of the freeway service patrol as a component of your incident management program?
- What is the annual operating cost for your freeway service patrol program?
- How many service patrol operators do you currently employ?
- How many vehicles are in your fleet?
- How many miles of freeway does the FSP serve?
- How many vehicles are operating during peak hour traffic?
- What are the operational hours of the FSP?
- How and who notifies the FSP of an incident?
- What are the average incident response times and incident clearance times for the FSP?
- What types of services are offered by your FSP?
- What types of equipment are on the FSP vehicles?
- Do you have any plans for expanding your program?
- What are the goals of your freeway service patrol program?
- Does the program in its current operations meet those goals?
- If not, what improvements need to be made?
- If you could start the program from the beginning, what would be done differently in its implementation?
- What do you think are the strengths and weaknesses of your program?

APPENDIX B: DRAFT SURVEY QUESTIONS

(Birmingham Area Incident Response Teams)

The questions below were used to interview the local incident response team members:

- What services does your agency provide on highway incidents?
- What are your agency's current safety concerns with the freeway incident response?
- What other concerns does your agency have with freeway incident response?
- Does your agency have standard protocols or procedures for on scene practices?
- What information would be most helpful to your agency en route and on scene of a freeway incident?
- Are you familiar with the Manual on Uniform Traffic Control Devices (MUTCD)?
- If yes, does your agency follow the traffic control principles provided by the MUTCD?
- In what areas do highway departments seem to need more information or awareness?
- What areas of training would your agency is most interested in?

- What are your most significant safety concerns with communication?
- Please give an example of your most significant concern(s) by sharing an experience your agency has had during a freeway incident response.

LIONEL HARBIN



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As the Assistant Traffic Engineer, Mr. Harbin is responsible for overseeing the ITS Operations and Maintenance activities performed by consultants for ALDOT. He is also tasked with inspecting work zone traffic control, supervising a division-wide maintenance crew that performs pavement markings and striping duties and interacting with various state construction personnel, contractors and local municipalities on construction issues involving ITS projects.

Mr. Harbin has been employed with the Alabama Department of Transportation since 1997 and prior to ALDOT, he was employed by the Georgia Department of Transportation from 1985 to 1997. He spent 5 years as a construction inspector and 7 years as a project engineer/manager.

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