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Graduate Student Papers on Advanced
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16. Abstract This document is the culmination of the eighth offering of an innovative transportation engineering graduate course at Texas A&M University entitled, "Advanced Surface Transportation Systems". The eighth offering of the course was presented during the summer 1998 term. As part of the course, a Mentors Program provides students with unique learning experiences. Six top-level transportation professionals from private enterprise and departments of transportation, who are leaders in their field and who have extensive experience with Intelligent Transportation Systems, were invited to Texas A&M University to present a 1½-day Symposium on Advanced Surface Transportation Systems at the beginning of the summer term. Immediately following the Symposium, the students enrolled in the course participated in a Forum and a Workshop with the transportation professionals and course instructor. Each student had discussions with the transportation professionals and the course instructor to identify a topic area for a term paper. Based on mutual interests, each student was assigned to one of the professionals who served as a mentor (along with the course instructor) for the remainder of the summer term. Each student worked with his/her mentor and course instructor to identify a topic area and objectives for a term paper. In addition to discussions with the course instructor, the students (communicating via telephone, fax, e-mail, and mail) worked directly with the mentors throughout the term while preparing their term papers. The mentors returned to the Texas A&M University campus near the end of the summer term to hear and critique the students' presentations.					
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AUGUST 1998



Class instructor and mentors (front row, from left) Conrad Dudek, Marsha Anderson, Ginger Gherardi, Colin Rayman; (back row) William Spreitzer, H. Douglas Robertson, Thomas Hicks.

PREFACE

This document is the culmination of the eighth offering of an innovative transportation engineering graduate course at Texas A&M University entitled, "Advanced Surface Transportation Systems," which was presented during the 1998 summer term. As part of the course, a Mentors Program provided the students with unique learning experiences. 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 at the beginning of the summer term. Immediately following the Symposium, the students enrolled in the course participated in a Forum and a Workshop with the transportation professionals and course instructor. Each student held numerous discussions with the transportation professionals and course instructor to identify a topic area for a term paper. Based on mutual interests, each student was assigned to one of the professionals who served as a mentor (along with the course instructor) for the remainder of the summer term. Each student worked with his/her mentor and course instructor to identify a topic area and objectives for a term paper. In addition to discussions with the course instructor, the students (communicating via telephone, fax and mail) worked directly with the mentors throughout the term while preparing their term papers. The mentors returned to the Texas A&M University campus near the end of the summer term to hear and critique the students' presentations.

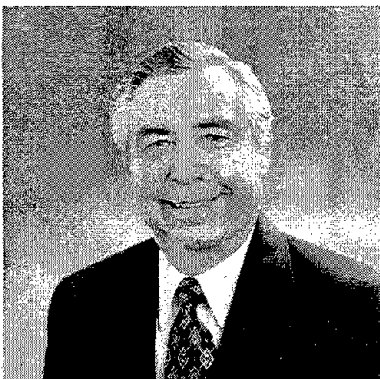
One important objective of the program was to develop rapport between the students and the transportation professionals. The opportunity for the students to communicate and interact with top transportation officials, who are recognized transportation engineering experts, was a key element to the students gaining 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.

Comparable to the previous years, this program was again extremely successful. The students had an excellent opportunity to interact directly for an extended period of time with top-level transportation professionals who are recognized for their knowledge and significant contributions both nationally and internationally.

Marsha Anderson, Ginger Gherardi, Thomas Hicks, Colin Rayman, H. Douglas Robertson and William Spreitzer devoted considerable time and energy to this program. We are extremely grateful for their valuable contributions to the educational program at Texas A&M University.

The opportunity to bring top-level transportation professionals to the campus was made possible through financial support provided by the "Advanced Institute" at Texas A&M University which is sponsored by the University Transportation Centers Program of the U.S. Department of Transportation, and from funds received from the Zachry Teaching Program from the College of Engineering at Texas A&M University.

Sandra Schoeneman and Sherry Burr, Senior Secretaries with the Texas Transportation Institute, coordinated the Symposium and Workshop in a very efficient and professional manner.



Congratulations are extended to the transportation engineering graduate students who participated in this course. Their papers are presented in this Compendium. Appendix A and B show the transportation professionals who graciously served as mentors in previous years and the students who participated in the Advanced Institute Program in previous. A listing of all the papers that were prepared since the first offering of the course in 1991 is shown in Appendix C of this Compendium.

*Conrad L. Dudek
Professor of Civil Engineering &
Associate Director, SWUTC*

1998 MENTORS

MARSHA D. ANDERSON

In 1990, Ms. Anderson 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. Anderson 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.

The range of technical projects for which Ms. Anderson has been responsible include: traffic impact and corridor studies, master transportation plans and studies, transportation demand management projects, parking studies and design analyses, freight studies, research, analysis, planning, management and administration of transportation and engineering projects. She has managed transportation planning projects employing microcomputer modeling, performed loading dock designs, freight terminal analysis, urban and over-the-road goods movement studies, area-wide studies, parking analyses and designs, expert witness testimony, site studies, and development of a methodology for routing hazardous materials movements. 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.



Ms. Anderson is past Chair of the Institute of Transportation Engineers' Technical Council Design Department, Policy Committee, Transportation Planners Council and is currently the Chair of the Goods Movement Council. She was a Director of the New Jersey Motor Truck Association, as well as the American Trucking Associations' Scholar-In-Residence. She has also been a special member of the Delaware Valley Regional Planning Commission's Urban Goods Movement Advisory Committee. Ms. Anderson chaired the Olympic Task Force on Goods Movement for the 1996 Games in Atlanta, Georgia and served as a venue Transportation Manager for the Paralympics. Other affiliations include the Transportation Research Board, Women's Transportation Seminar, Council for Quality Growth, Society of Women Engineers and the American Public Works Association.

Ms. Anderson 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. Anderson 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".



GINGER GHERARDI

In July of 1989, Ginger Gherardi became the first Executive Director of the Ventura County Transportation Commission (VCTC), which is also the Congestion Management Agency (CMA), the Airport Land Use Commission (ALUC), the Service Authority for Freeway Emergencies (SAFE), the Consolidated Transportation Service Authority (CTSA) and a member of the Southern California Regional Rail Authority (SCRRA). Under her leadership VCTC has adopted its Congestion Management Program, Airport Land Use Plan and implemented a centralized Transit Information System (Dial-A-Route). The Commission implemented Metrolink commuter rail service October 1992, including the construction of three rail stations (one of these as a result of the 1994 Northridge Earthquake) and two layover facilities. Recently VCTC purchased the Santa Paula Branch Railroad Line for development and use as a bicycle/trail/rail heritage corridor.

Ms. Gherardi was responsible for the expansion of the countywide call box system, including the development of a cellular phone program for physically challenged residents and the installation of TTY/TTD devices for the hearing impaired and the development and distribution of countywide bicycle maps. VCTC implemented a new countywide bus system, VISTA, linking municipal systems throughout the County that was selected as one of the outstanding examples of the use of Congestion Mitigation Air Quality (CMAQ) funds in the United States and received a 1997 Environmental Excellence Award from the Federal Highway Administration. VCTC is currently participating in a federal "Smart Card" demonstration project known as the Ventura County Passport. Most recently, VCTC implemented a website "Go Ventura" (<http://www.goventura.org>) that not only contains needed transportation information but provides personalized On-Line Transit Routing, a first in the United States.

Between September 1985 and July 1989, Ms. Gherardi was the Manager of the Highway/TSM Programs for the Los Angeles County Transportation Commission. Among other things, she was responsible for developing the 10 Year Highway Plan, "On the Road to the Year 2000"; the Los Angeles "Smart" Corridor Demonstration project; the implementation of a SAFE to upgrade the call box system and the development of a countywide bicycle map.

Prior to working at LACTC, Ms. Gherardi worked for the Southern California Association of Governments, managing the Transportation Development Act Programs. She is a former Simi Valley City Councilwoman, Mayor and teacher. Ms. Gherardi is a member of the Institute of Transportation Engineers (ITE), the Santa Paula Rotary and is on the Board of Directors of the Santa Paula Boys and Girls Club and Palmer Drug Abuse Program of Ventura County. She currently serves as the National Past President of the Women's Transportation Seminar (WTS). Ms. Gherardi received B.S. and M.S. degrees from Pratt Institute in Brooklyn, New York.

THOMAS HICKS

Thomas Hicks is presently the traffic engineer for the Maryland State Highway Administration (SHA) and one of the six Deputy Chief Engineers reporting to the Chief Engineer. He is responsible for coordinating the work of six Divisions - Traffic Safety, Traffic Engineering/Design, Traffic Operations (maintenance and operations), Traffic Development Support (studies and research), Motor Carrier, and Intelligent Transportation Systems (ITS/CHART). In addition he is responsible for the Highway Sign and Signal Shops.

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 as 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's position was elevated to Deputy Chief Engineer. In 1991, the Office of Traffic Engineering assumed control of the State's safety grant program and the Motor Carrier Program. The office then became known as the Office of Traffic & Safety. Maryland's traffic engineering program today is one of the largest and most comprehensive in the country.

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

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





COLIN RAYMAN

Colin Rayman is recognized as one of the premier practitioners in the field of Intelligent Transportation Systems (ITS) with special emphasis in advanced traffic management systems. He has over 24 years of professional and management experience with the Ontario Ministry of Transportation (MTO) and with the private sector. He has developed transportation policy and programs for the Ontario government and has also served as a senior technical advisor to foreign governments as well as managed transportation infrastructure projects in Ontario and internationally.

Mr. Rayman is the Manager of the Intelligent Transportation Systems Office of the Ontario Ministry of Transportation in Toronto. He is responsible for providing leadership in the development of a comprehensive ITS policy and strategy for the Province of Ontario.

Prior to his most recent assignment, Mr. Rayman served in a number of capacities with MTO. As Director of the Transportation Operations Branch, he was responsible for overall direction and administration of the MTO's highway maintenance and traffic operations sub-program and developed policy related to the Ministry's transportation corridor permitting function. As District Maintenance Engineer in Toronto, he was responsible for summer and winter maintenance in MTO's largest and most urbanized district. As Head of the Freeway Traffic Management Section, he was responsible for freeway traffic management systems implementation in the Province of Ontario. During this time, he successfully commissioned two new systems (including the COMPASS system).

During a two and a half year stint with the private sector, he managed a consulting practice in California. Project experience included Traffic Management Center Upgrades, Traffic Operations System designs and Fiber Optic Communication System designs in Los Angeles and Orange County for Caltrans. He also advised on the I-25 BUS/HOV Transportation Management System for the Regional Transportation District in Denver, CO and acted as a Specialist Consultant to the University of Minnesota for the development of an automatic incident detector.

He is the Vice-Chair of the ITS Society of Canada; Chair of the Research & Development Subcommittee of the ITS America ATMS Steering Committee; a Member of the Coordinating Council of ITS America; a Member of AASHTO's Advanced Transportation Systems Subcommittee; a Member of the NTCIP Joint Standards Committee; a Member of the Institute of Transportation Engineers; and a former member of TRB's Freeway Operations Committee. He is a registered professional engineer in Ontario.

H. DOUGLAS ROBERTSON

As a Vice President and Deputy Regional Manager for Transportation Planning and Engineering at TransCore, Dr. Robertson directs the operations of two area offices serving clients in Virginia, Maryland, Delaware, Pennsylvania, and the District of Columbia. He leads business development efforts and contributes to application projects in the areas of intelligent transportation systems, transportation planning/design, and traffic management/traveler information systems. Having worked in the public and private sectors and academia, he has a broad perspective of past, present, and future transportation needs and services.

Dr. Robertson also currently serves as TransCore's Senior Advisor for the Northeast Consultants (a joint venture with PB Farradyne Systems) who provide management support to the I-95 Corridor Coalition. The Coalition is made up of twenty-eight transportation agencies in twelve Eastern states. He is also the Responsible Manager for the Sydney, Australia Traffic Management Systems Project, a \$2.3 million effort to support the Roads and Traffic Authority of New South Wales as they prepare for the Year 2000 summer Olympics.



While Director of Plans and Programs at ITS America, he co-chaired a joint effort with U.S. DOT to develop the National ITS Program Plan. In other previous positions, Dr. Robertson was a professor of civil engineering at the University of North Carolina at Charlotte and prior to that served in both the National Highway Traffic Safety Administration and the Federal Highway Administration of the U.S. Department of Transportation.

He is a Fellow of the Institute of Transportation Engineers and a former Group 3 Council Chair of the Transportation Research Board. He was the senior editor and a principal author of the *Manual of Transportation Engineering Studies* for the Institute of Transportation Engineers and has published over 60 journal articles and reports.

Brigadier General Robertson serves in the U.S. Army Reserves as the Deputy Commanding General for the 108th Division (Institutional Training), a unit of over 3,200 soldiers with subordinate units located in the two Carolinas, Georgia, Florida, and Puerto Rico. He is a graduate of the U.S. Army War College. He has been selected to assume command of the Division next March with a subsequent promotion to Major General.

He received his Bachelor's degree in Civil Engineering from Clemson University, his Master's in Transportation Engineering from the University of South Carolina and his Doctorate in Civil Engineering from the University of Maryland. He is a registered professional engineer.

**WILLIAM M. SPREITZER**

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

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

of General Motors ITS Programs, corporate-wide and world-wide.

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

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IMPLEMENTATION OF A DYNAMIC HOV LANE

by

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Prepared for

CVEN 677

Advanced Surface Transportation Systems

Department of Civil Engineering

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SUMMARY

The research reported in this paper is an investigation of the implementation of a dynamic HOV lane. A dynamic HOV lane is an HOV lane that is converted to other uses at different times of the day or under special circumstances using ITS technologies and real-time data in order to make more efficient use of HOV facilities and improve the safety of motorists, incident responders, and HOV lane operations personnel.

The development of the concept included a literature review of HOV system planning and operations, incident management, and ITS research, as well as detailed interviews with agencies that oversee HOV lane operations in cities across the United States. Information from the literature and agency interviews was synthesized and analyzed to identify barriers to implementation and critical issues. Then a hypothetical dynamic HOV lane was designed to illustrate how the HOV lane and ITS components fit together and how the barriers might be overcome to preserve the benefits associated with a dynamic HOV lane.

The barriers identified were justifying the need for a dynamic HOV lane, ensuring motorists' safety, technical reliability, adequacy of data, implementation costs, public perceptions, legality, and the wide variety of contributing factors.

These barriers might be overcome by investigating potential applications carefully to ensure that there is a practical problem to solve, building a reliance on HOV system technologies, proper design and placement of system components, extensive public education, maximizing technical reliability with backup systems and good maintenance, archiving data for analysis and system improvements, using dynamic HOV lane technologies for other ATMS applications, and developing policies and laws to support dynamic HOV lanes.

Research findings showed a reluctance to depend on advanced technology for the accurate and safe operation of a dynamic HOV lane as described in this report. Because the fundamental difference between a dynamic HOV lane and a "normal" HOV lane is reliance upon a coordinated system of ITS technologies, it was therefore concluded that a dynamic HOV lane cannot be implemented until the dependability of its component technologies is successfully demonstrated.

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INTRODUCTION

In some cities, high-occupancy vehicle (HOV) lanes are converted daily to general-purpose lanes during off-peak hours to make more efficient use of available capacity. These are part-time HOV lanes. To reduce delay and secondary accident potential, some cities also allow general traffic to divert to HOV lanes during severe weather conditions or when major incidents occur. To date, Intelligent Transportation Systems (ITS) technologies, which provide advantages in immediate, remote response and communications, have not been fully utilized to facilitate such changes in HOV lane operations. Moreover, there are some HOV lane innovations that ITS technologies make possible which have not been investigated at all.

The research reported in this paper is an investigation of the implementation of a dynamic HOV lane. A *dynamic HOV lane* is an HOV lane that is converted to other uses at different times of the day or under special circumstances using ITS technologies and real-time data. This investigation included development of the concept of a dynamic HOV lane, examination of the actions that may be taken by agencies when dynamic HOV lanes are implemented, and assessment of the issues and concerns relevant to implementing such a system. It is hoped that this research will advance the state-of-the-art by applying existing ITS technologies in new ways to serve practical transportation needs.

Objectives

The objectives of this research were to:

- Define a new concept of a dynamic HOV lane and the environment in which it can be implemented
- Examine new ways in which ITS technologies and real-time information can be used to solve problems associated with HOV lane safety and efficiency
- Identify issues of concern and barriers that impede the implementation of a dynamic HOV lane
- Design a dynamic HOV lane

Scope

This research covered freeway applications of dynamic HOV lanes and focused on part-time HOV lanes and HOV lane operations during unplanned events such as major incidents on the mainlanes or severe weather conditions, when the dynamic nature of such an HOV lane may be most valuable. Seven agencies responsible for incident management or operations on a variety of established HOV lane networks were selected for detailed telephone interviews. These interviews, in conjunction with a literature review of HOV lane and incident management practices, were used to identify critical issues and barriers and design a hypothetical dynamic HOV lane.

Organization of Report

The Background section of this paper is a synopsis of relevant knowledge about HOV system planning and operations, incident management, and ITS research.

In the Concept Development section of this paper, the dynamic HOV lane concept is established in terms of structure, environment, and potential applications.

In the Agency Experience section, information gathered from agency interviews and agency publications is summarized. This information includes freeway HOV lane configuration, incident management policies and experience, existing ITS infrastructure, and agency concerns about dynamic HOV lanes and ITS technologies.

In the Identification of Barriers section, information from the literature and agency interviews is synthesized and analyzed to identify barriers to implementation and critical issues.

A dynamic HOV lane is designed for a hypothetical freeway in the Dynamic HOV Lane Design section to illustrate how the HOV lane and ITS components fit together and how the barriers might be overcome to preserve the benefits associated with a dynamic HOV lane.

The physical, operational, and environmental elements identified during the design process as necessary for overcoming the implementation barriers are summarized in the Conclusions section. Criteria for evaluating the appropriateness of a dynamic HOV lane for a freeway are developed, and the overall feasibility of the concept is assessed.

In the Recommendations section, a demonstration project is discussed and ideas for future research are proposed.

BACKGROUND

The concept of a dynamic HOV lane blends three areas of transportation knowledge and research: HOV system planning and operations, incident management, and the development and application of ITS technologies. Current, relevant practices in these areas are briefly described here.

HOV Lanes

HOV lanes are a congestion management strategy designed to provide benefits in the form of reduced, predictable travel times to travelers who choose to carpool or take the bus instead of driving alone (1). The provision of such benefits is most effective on heavily traveled roadways where breakdowns in traffic flow occur regularly or where incidents can impede traffic flow for significant periods of time. The goal of inducing travelers to use HOV facilities is to increase the average person-carrying capacity of the roadway without constructing new general-purpose lanes, thus ensuring mobility where roadway expansion is not possible (2). Three classes of HOV facilities are relevant to the subject of this paper: reversible flow lanes, concurrent flow lanes, and contraflow lanes.

Reversible flow HOV lanes serve inbound traffic during the morning peak and outbound traffic during the evening peak. To prevent collisions with opposing traffic and wrong-way entries, reversible flow HOV lanes are separated from general purpose lanes by concrete barriers and access is controlled by gates and/or pylons (2). Figure 1 shows a sketch of a barrier-separated, reversible flow lane.

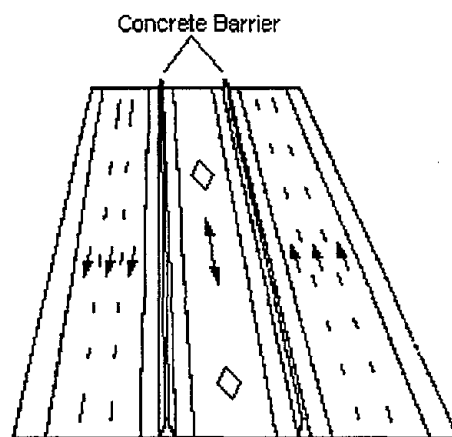


Figure 1. Reversible Flow HOV Lane (3).

Concurrent flow HOV lanes operate in the same direction as adjacent general-purpose lanes and are separated from them by painted stripes or buffer zones. Entries and exits may be limited to specific points or allowed continuously along the length of the lane (2). Concurrent flow facilities can be restricted to HOVs all day or only during portions of the day, in one direction or both directions, and they may be the inside lane, the outside lane, or a shoulder lane. This type of HOV lane is the most common because it is less expensive to implement than other types of HOV lanes, but it is also the most difficult to enforce (1). Figure 2 illustrates a concurrent flow lane.

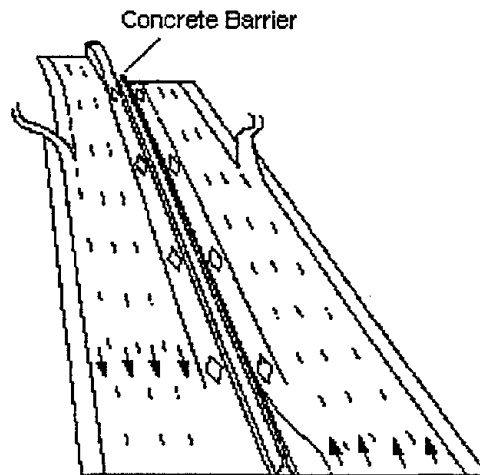


Figure 2. Concurrent Flow HOV Lane (3).

Contraflow HOV lanes are lanes taken from the non-peak direction and converted to HOV facilities serving the peak direction. They can operate only where a significant directional distribution exists on a freeway facility and excess capacity is available in the non-peak direction. The HOV lane is separated from the adjacent, opposing general-purpose lane by cones, pylons, or a moveable traffic barrier (2). These separators are moveable so that the contraflow lane can be converted back to a general purpose lane for the other peak period. Figure 3 depicts a contraflow lane. Figure 4 shows the reversal of a contraflow lane with a moveable barrier in Boston, Massachusetts.

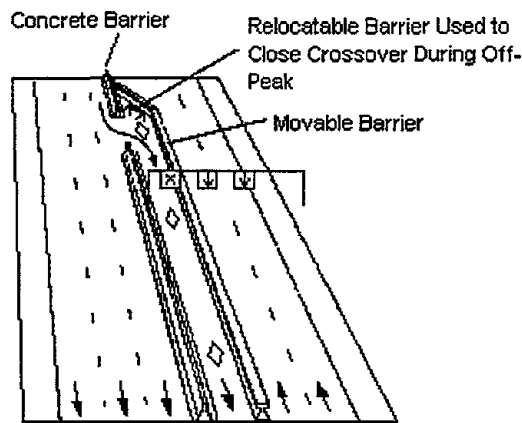


Figure 3. Contraflow HOV Lane (3).



Figure 4. Reversal of a Contraflow HOV Lane Using a Barrier Transfer Machine (4).

Incident Management

The National Highway Traffic Safety Administration defines a “major freeway incident” to include downed power lines, infrastructure failures, and crashes involving serious injuries, fatalities, vehicles on fire, spilled cargo, hazardous cargo, and overturned vehicles (5). Events that might also be classified as major incidents include flooding, icy roads, and other severe weather conditions (6). When such incidents occur, at least one freeway lane may be blocked. It has been estimated that, for every minute a freeway lane is blocked by an incident, it will take three to five minutes to restore the freeway to its original operating condition (1,5,6).

Each minute that roadway capacity is restricted results in longer queues, greater motorist delay, increased emissions, and a higher potential for secondary accidents (7). Secondary accidents result when drivers arrive at the end of an unexpected queue of slower-moving vehicles, such as the queue that forms when an incident blocks a lane (6). Secondary incidents may also result when cars overheat while waiting for the primary incident to clear, when motorists “gawk,” “gape,” or “rubberneck” as they pass the scene of an incident, or when motorists must merge with other traffic streams to bypass an incident. Few comprehensive studies of secondary accidents have been made, but, in one study, 17 percent of the crashes filmed on a limited-access roadway in Great Britain fit the definition of a secondary crash (8). It is estimated that the probability of a motorist being in an accident is 66 percent higher when an incident is already present (9). In addition to threatening motorists’ safety, secondary accidents exacerbate delay, driver frustration, and vehicle emissions (8,10).

To minimize incident duration and impacts, many metropolitan areas have implemented incident management programs. Such programs coordinate agency resources to reduce incident detection, verification, response, and clearance times. They also provide for proper traffic management so that incident responders are equipped with all necessary traffic control devices and motorists can be safely diverted to preplanned diversion routes (6,10). Involved agencies may include state departments of transportation (DOTs), transit agencies, police and fire departments, emergency medical services (EMS) teams, towing companies, and all levels of government (1).

Some agencies have made the use of HOV lanes a part of their incident management programs. There are two roles that HOV lanes have traditionally played in such programs. First, general traffic may be allowed

to divert to the HOV lane in order to bypass an incident (10,11). This is allowed in Houston and San Diego, among other cities. The diversion process depends on agency policy, the severity of the incident, and HOV lane configuration. Second, the HOV lane is kept free of general traffic and emergency vehicles are allowed to use it so that they might reach the scene of the incident quickly. In Seattle, for example, EMS units are legally allowed to use any route—including HOV lanes and shoulders—that will bring them to the incident scene. Theoretically, both procedures may be authorized for a given facility during a major incident: After emergency responders arrive at the scene via the HOV lane, the HOV lane can be opened up to general traffic. In this case, communicating changes in HOV lane use restrictions to motorists becomes very important.

ITS Technologies

In general, using ITS technologies means applying computers and advanced telecommunications to the transportation industry (12). One class of ITS technologies is Advanced Transportation Management Systems (ATMS). ATMS technologies are designed to make the most efficient use of available capacity so that congestion, travel times, and fuel usage are reduced (13).

Many urban areas that use advanced transportation technologies coordinate them through transportation management centers or traffic operations centers. Transportation management centers such as Houston's TranStar and Phoenix's Traffic Operations Center generally oversee freeway traffic surveillance and operations, incident management, and ITS programs. They may also be responsible for regional traffic signal systems, transit vehicle dispatching, ramp metering, emergency management, and the dissemination of traveler information (10,14,15).

Components of ATMS currently in use on freeways and relevant to the subject of this research include closed circuit television cameras, automatic vehicle identification, automatic vehicle location, lane control signals, variable message signs, highway advisory radio, detectors, and remotely operable gates and barriers (1).

Closed Circuit Television Cameras

Closed circuit television (CCTV) cameras are used to verify freeway conditions and the incidents identified by incident detection algorithms. They also provide information on the type of incident that has occurred so that the proper response can be initiated (16).

Automatic Vehicle Identification and Automatic Vehicle Location

Automatic vehicle identification (AVI) allows the location of vehicles such as ambulances and police cars to be monitored from a control center. A vehicle's identifying information is read from a transponder as the vehicle passes an AVI reader. Automatic vehicle location (AVL) systems can also identify vehicles, but AVL is used to place vehicles relative to specific times rather than specific locations. Vehicle location is determined through techniques such as dead reckoning, roadside beacons, and global positioning systems (13).

Lane Control Signals

Lane control signals can be located over individual lanes of travel or alongside the roadway. They display arrows in green or amber and "X"s in red to indicate if a specific lane is open, about to be closed, or closed downstream. Such signals are useful in providing advance warning of a lane blockage due to construction, incidents, or debris, as is the case in San Antonio (16), particularly if the arrows and "X"s are used in conjunction with other simple symbols, as in Figure 5. Lane control signals are used over reversible HOV

lanes in Houston to warn motorists if they are traveling in the wrong direction (10). European speed control signals have been used to display the advisory or regulatory speed over individual lanes of travel (17,18).



Figure 5. Lane Control Signals and Lane Use Signs in Europe (19).

Variable Message Signs

Variable message signs (VMSs) are larger and convey more information than lane control signals. A single alphanumeric message can be electronically displayed, or multiple messages can be displayed in sequence. A traffic management center might preconfigure messages for expected freeway incident scenarios (16).

Highway Advisory Radio

Highway advisory radio (HAR) is a portable, low-power means of broadcasting area-specific traffic information in the AM radio band to motorists. Portable signs announce the radio station to which motorists should tune their radios. Incident, construction, and airport parking information are examples of the types of transportation information that HAR has been used to provide (20). Incident information that HAR can provide includes advance notice of the incident location as well as diversion instructions.

In some areas of Europe, car radios are activated automatically as they pass an HAR station (18). This refinement of HAR is called automatic highway advisory radio (AHAR). AHAR is designed to keep motorists' visual attention on the roadway by making it unnecessary for them to read HAR information signs or tune their radios to the proper station while driving. A study was conducted in the early 1980s by the Federal Highway Administration (FHWA) to examine the feasibility of implementing AHAR in the United States. A receiver was installed in the cars of the study's volunteers, whose radios would operate normally until an "override" transmission was received from an AHAR transmitter. Most of the volunteers found AHAR to be quite useful in providing advisory highway information and would purchase a receiver if the cost was not exorbitant (21).

Hereafter, unless specifically noted, the acronym "HAR" will include both HAR and AHAR.

Detection Methods

Detection methods include inductance loop, radar, video, infrared, microwave, and audio detection. Accuracy, reliability, installation costs, and maintainability vary with each detection method and the environment in which it is applied (16).

Barriers and Gates

Remotely operable gates and barriers include arms that lower to block the HOV lane entrance and plastic poles or pylons that can be hydraulically raised or lowered to prevent or allow HOV lane access (22). Arms and pylons are illustrated in Figure 6 for the San Diego HOV lane system.

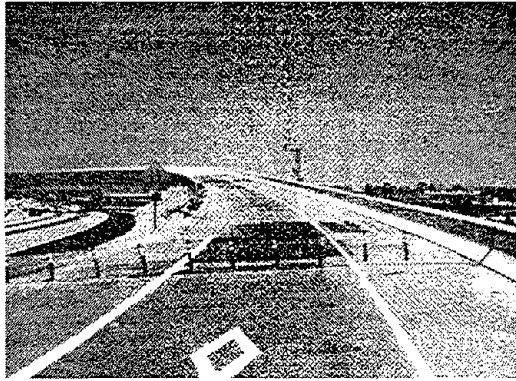


Figure 6. San Diego HOV Lane Barrier Arm and Pylons (23).

CONCEPT DEVELOPMENT

As defined previously, a dynamic HOV lane is an HOV lane that is converted to other uses at different times of the day or under special circumstances using ITS technologies and real-time data. In the first part of this section, the definition is applied to different HOV facility types and operating structures. Afterwards, the potential benefits of a dynamic HOV lane and related implementation issues are described in more detail.

Definition

When a freeway surveillance system is in place to monitor speeds and volumes, the agency that operates a dynamic HOV lane will ultimately be able to change the lane's hours of operation, occupancy requirements, location, and number of lanes immediately and electronically from a remote location such as a traffic management center through the manipulation of lane control signals, VMSs, and other ITS technologies. Changes in HOV lane operating status will be conveyed immediately to the public through VMSs, HAR, and lane control signals. The need to have personnel in the field to physically move barriers, open gates, or change signs will be lessened, if not eliminated, by automated barrier systems and electronic signing. Vehicle and crew locations will be tracked by AVI and AVL. Such a dynamic, flexible nature is practical when major incidents occur and a response is required as soon as possible. Figure 7 illustrates how a dynamic HOV lane might look.

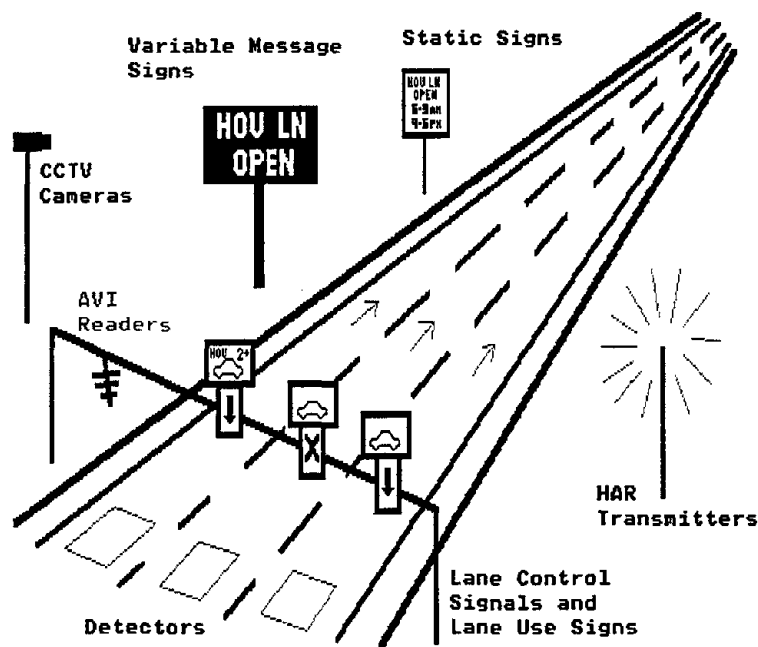


Figure 7. Theoretical Dynamic HOV Lane.

The dynamic HOV lane concept can also be applied to part-time HOV lanes and traffic routing during special events. The operating hours of a lane that is restricted to HOVs during peak commuting periods, for example, can be extended if HOV lane volumes remain high at the end of the period and mainline level of service (LOS) is low. Alternatively, if HOV lane volumes are unusually low and mainline LOS is high, the HOV restriction may be lifted early so that the entire freeway can be utilized more efficiently. Either way,

HOVs are guaranteed a reasonable travel time. During special events like Minnesota Vikings football games in Minneapolis, HOV restrictions can be initiated and maintained until traffic volumes—monitored by the traffic management center—decrease sufficiently.

In these cases, the agency that implements a dynamic HOV lane will be limited by driver expectancy and trip planning issues. Current HOV lane status must be clearly signed, and drivers must be adequately warned of imminent changes to lane status. For special events, the base hours of operation should be publicized in advance. For commuters, the HOV lane will be restricted to HOVs whenever mainline LOS is low. This restriction will occur regularly during the peak hours so that commuters can plan trips and arrange carpools accordingly.

The development of a dynamic HOV lane is governed by existing facility characteristics. A barrier-separated HOV lane, for example, would not benefit from dynamic characteristics to the extent that an unseparated lane would because the presence of the barrier limits access to the lane. Reversible lanes, in addition, must be periodically closed in order to reverse operations. Cities that currently have transportation management centers, freeway surveillance networks, AVI or AVL resources, and well-developed motorist information networks will find the concept more feasible in terms of implementation time and cost. Specific applications will also depend on local demand patterns, as cities that experience high off-peak traffic volumes, where nonrecurring congestion causes long delays, may find significant value in being able to dynamically change HOV lane operating conditions (24).

Benefits and Implementation Issues

The advantages that a dynamic HOV lane can provide, compared to HOV lanes that do not make full use of ITS technologies, are immediate response, more efficient use of existing ITS technologies, improved communication with motorists, improved safety for incident responders, and more efficient HOV lane usage. An increase in motorist safety is a result of each of these advantages. In this section, the characteristics of a dynamic HOV lane that make the concept worthy of investigation—as well as associated implementation issues—will be detailed.

Immediate Response

Remote operation means that changes in HOV lane operations can be affected quickly. Incident management actions, for example, can be taken as soon as the incident is detected and evaluated. Such actions include the raising of barriers, the lowering of pylon barricades, the changing of VMSs or lane control signals, and the broadcasting of incident information via HAR. General traffic can therefore begin diverting to the HOV lane immediately instead of waiting for incident responders to arrive on the scene. The quicker a response is initiated, the more delay, emissions, queue length, and secondary accidents are reduced.

In evaluating the efficacy of HOV lane diversion, an agency would be concerned with current HOV lane operating status, HOV lane volumes, mainline volumes, the time of day, and, if applicable, the direction in which the HOV lane is operating. These issues must be addressed before a response can be initiated. General questions that the agency might ask include:

- Is the HOV lane open at the time the incident occurs? If not, can the HOV lane be opened? How soon will it become available as a diversion route?
- How heavy are HOV lane volumes, and what effect will the diversion of general traffic to the HOV lane have on HOV lane LOS?
- Did the incident occur during a peak period? If the incident occurs just before the evening peak, for example, what will happen to the diversion strategy as traffic volumes increase in subsequent hours?

Questions specific to the operation of reversible and contraflow lanes are:

- If the incident occurs at the end of the morning peak, what effect will diverting traffic to the HOV lane have on the process for closing the lane so that the lane may be reversed for the evening peak?
- What if the incident occurs in the non-peak direction and the HOV lane is operating in the peak direction? Should the HOV lane be reversed for the diverting traffic? After the incident is cleared, is the lane reversed yet again?

New Application of Existing Technology

Dynamic HOV lanes allow more flexibility in making traffic diversion decisions. Traffic management centers already monitor freeway operations through the collection and analysis of surveillance data such as average speeds and detector occupancies. These real-time data are a vital part of incident detection algorithms. They can also potentially be used in conjunction with AVL information to quantify when a particular diversion scheme may be the most appropriate, based on minimization of motorist delay, emissions, queue length, and the probability of secondary accidents.

For example, an agency with access to such data can calculate the utility of allowing general traffic in the HOV lane and compare it to the utility of restricting the lane to emergency vehicles. The value of the first option is that queues will not build up so quickly and motorists are immediately able to bypass the incident. The value of the second option is that emergency vehicles can reach the incident sooner and may be able to clear it in less time. Injuries and fatalities must, of course, be considered in choosing a diversion scheme.

With the ability to dynamically change the hours of operation for the HOV lane, the HOV-only restriction could be lifted early if HOV lane volumes are low. Likewise, HOV lane operating hours could be extended if HOV lane volumes are particularly high (13). When the hours of operation are extended, HOVs will benefit from an ensured high LOS. When the hours are shortened, mainlane traffic will be free to make use of extra capacity. The real-time volumes would be measured as part of a freeway surveillance system and, after verification, would become the input for an algorithm or decision support system that would evaluate the benefits to be gained by altering HOV lane operating hours. The change in operating status would be immediately and clearly conveyed to motorists through VMSs, HAR, and lane control signals as conceptualized in Figure 7. Such a strategy would be appropriate for concurrent facilities or for reversible and contraflow lanes when there are no time conflicts with the lane reversal process, as long as local law allows SOVs to use the HOV lane outside of restricted hours.

In some facilities, particularly reversible facilities, overhead lane control signals are used to provide relevant operating information to HOV lane users at regular intervals, such as signaling the approaching end of the HOV lane. If lane control signals are present over both concurrent or contraflow HOV lanes and the mainlanes, however, it is then technically feasible to designate multiple lanes as HOV lanes. Such a feature would be useful during special events or for weekend traffic to popular destinations such as beaches and amusement parks. During these times, HOV volumes may be a higher percentage of total traffic than during commuting hours, although permanent HOV lane infrastructure to serve traffic for unique or seasonal events may not be justified. To take away more than one general-purpose lane during commuting periods, however, will not be feasible if the mainlanes become severely congested as a result and there is not a substantial existing volume of carpoolers to make good use of the HOV lane (25).

An example of the potential role of a dynamic HOV lane in mitigating seasonal traffic volumes is found on Cape Cod in Massachusetts. The Cape Cod Regional Transit Authority received funding from the Federal Transit Administration in late 1997 to demonstrate intelligent computer control systems that can be applied to improve the efficiency and performance of local transit services. It is hoped that this use of advanced technology will “lessen seasonal traffic congestion and improve air quality.” An alternative that might be

considered in such a situation is the provision of HOV facilities during the vacationing season only. Such a facility would not be necessary during the rest of the year. A dynamic HOV lane might be developed that would operate as a concurrent facility during the summer, either part-time or all day. If HOV lane volumes are high enough to justify it, a second lane may also be provided. Lane control signals would differentiate the facility from the other general-purpose lanes in lieu of pavement markings that would have to be removed at the end of every season. Lane operations would be supplemented with HAR—already used in many areas to provide tourist information—and portable VMSs to inform motorists of HOV lane operating hours and occupancy requirements. When the vacationing season concludes, the portable VMSs would be removed and the lanes would revert back to general-purpose lanes (26).

Communication with Motorists

Dynamic signing is a necessary component of a dynamic HOV lane because of the availability of real-time traffic information and the need to convey it to motorists as quickly and as clearly as possible. During incidents, dynamic HOV lane signing means that unambiguous, up-to-date incident information and diversion instructions can be provided to motorists as they need it in order to reduce motorist confusion and thereby smooth and calm the diversion process, making the incident scene safer for both drivers and incident responders.

Visual signing is capable of imparting necessary information to *all* motorists, independent of how they otherwise receive information in their vehicles, and therefore must be the primary element of a motorist information system in a dynamic HOV lane. Dynamic visual ITS communications technologies like VMSs and lane control signals display only the specific information that is needed by motorists at the time they are in the vicinity, such as a definitive statement that the HOV lane is currently open. Static signs, in contrast, must provide information about operating policies at all times of the day. A single sign might convey all required information, or a series of advance warning signs may present HOV lane operating policies in stages. Either static case could result in “information overload” or confusion (27,28). Static visual signs are also inflexible: changes in HOV policy require employees to physically replace signs in the field (27).

Audio signing and in-vehicle motorist information systems are supplemental information dissemination media. This is because some of the information provided to motorists in the implementation of a dynamic HOV lane, such as the operating status of a part-time HOV lane, is needed by every motorist on the roadway, and not all vehicles are equipped to receive such information. Moreover, motorists access these information systems voluntarily. To date, HAR and in-vehicle systems in the United States have provided purely advisory or general interest information to motorists. Unless AHAR specifically or in-vehicle displays become a federally mandated component of all motor vehicles, their inclusion in a dynamic HOV lane project must therefore be implemented in support of VMSs and lane control signals, not as primary information dissemination tools.

Safety

The freeway environment is not a safe place for unprotected police officers, DOT personnel, and incident responders. In 1989, 1990, and 1991, 20 percent of the fatalities on U. S. interstate highways were pedestrians or resulted from accidents involving vehicles stopped on the shoulder (6). Seven freeway construction workers were struck by vehicles and killed in Texas in 1995 (29). Four police officers were struck and killed at accident scenes in Texas between 1992 and 1996 (30).

With a dynamic HOV lane, some incident response tasks can be handled remotely using advanced electronics and telecommunications. These tasks include traffic diversion and the posting of incident information. The alternative is to send incident response personnel into the field where they will be in danger of being involved in a secondary accident. DOT personnel who physically move HOV lane barriers and gates when lanes open

and close or are reversed will also be removed from this dangerous environment if their tasks are automated and controlled from a remote location.

More Efficient HOV Lane Usage

The “empty lane syndrome” is the perception that the HOV lane is being underutilized, from the point of view of drivers who are not eligible to use the HOV lanes and view traffic volumes in terms of vehicles moved rather than persons moved (31). This perception is often a negative one. A dynamic HOV lane has the capability to mitigate the empty lane syndrome because HOV lane operating status can be modified as necessary. As described previously, for example, HOV lane restrictions can be terminated early when HOV lane volumes are unusually low, thereby mollifying those motorists who would object to an HOV lane that appears to be ineffective and inadequately used.

The operating hours and strategies of a dynamic HOV lane can also be modified for future traffic conditions more easily than those of a “normal” HOV lane can. This inflexibility is one disadvantage of fixed HOV lane infrastructure.

AGENCY EXPERIENCE

In order to evaluate the expected benefits, examine critical issues from the point of view of practical experience, and identify barriers to the implementation of a dynamic HOV lane, agencies responsible for operations or incident management on representative U. S. HOV facilities were interviewed by telephone, following a review of pertinent agency publications. Interview guideline questions, which were tailored for specific HOV system configurations and policies as necessary, can be found in the appendix. The appendix also contains a table summarizing HOV system information.

Dallas, Texas

The I-30 contraflow lane opened in 1991 as an interim HOV facility. The inside lane of the non-peak direction becomes a peak-direction lane using a moveable concrete barrier (3). This barrier is composed of hinged concrete sections that are each one meter long. There are no emergency access gates along the length of the barrier.

The reversal process, which involves changing signs and constructing a temporary barricade of pylons, takes approximately two hours to complete (32). Vehicles with two or more occupants may travel in the lane from 6 a.m. to 9 a.m. and from 4 p.m. to 7 p.m. in the peak direction (3). The lane is not available for use on weekends because there is no directional distribution that makes it possible for a lane to be safely removed from one side of the freeway.

Concurrent HOV facilities operate 24 hours a day on I-35E and I-635. These lanes are open to vehicles with at least two occupants and are separated from the general-purpose lanes by a double-wide stripe with two designated entrances and two designated exits. General traffic is not allowed to use these lanes outside the peak period because a 24-hour policy is believed to be less confusing for motorists and mainline off-peak volumes are not heavy enough to require the extra capacity.

The HOV system is operated by Dallas Area Rapid Transit (DART). A DART crew is stationed on I-30 whenever the lane is open. If a major incident significantly blocks the I-30 mainlanes, the superintendent of the operating crew recommends to DART administrators whether or not the HOV lane should be opened to general traffic. The contraflow facility cannot be reversed to divert non-peak mainlane traffic because there are no emergency access gates that can be opened on the non-peak side. Furthermore, only the barrier transfer machine can move the barrier to allow non-peak traffic into the HOV lane. To date, HOV lane diversion has been implemented only a couple of times on I-30. HOV lane diversion is also allowed on the concurrent facilities.

Dallas is currently expanding its ITS infrastructure. The first stage of an automated HOV lane enforcement demonstration project in Dallas has just been completed. A project demonstrating AVI toll tag applications on I-635 is in the planning stages (32).

Houston, Texas

The Houston Metropolitan Transit Authority (METRO) and the Texas Department of Transportation (TxDOT) operate five barrier-separated, reversible HOV lanes. All are one-lane facilities except for a short two-lane, two-way section of US 290. The I-45N, I-45S, US 59S, and US 290 HOV lanes are open to inbound vehicles from 5 a.m. to 11 a.m. and to outbound traffic from 2 p.m. to 8 p.m. on weekdays. The I-45S lane is, in addition, open to inbound HOVs from 3 p.m. to 9 p.m. on weekends in the summer. These HOV lanes restrict access to vehicles with a minimum of two occupants (33).

The I-10 HOV lane is one of three congestion pricing demonstration projects currently functioning in the United States. Unlike the other Houston HOV lanes, which restrict access to vehicles with a minimum of two occupants, 2+ vehicles pay a fixed toll to use the facility at certain times and are billed through transponders. This facility is open to inbound 2+ traffic from 5 a.m. to 6:45 a.m. and 8 a.m. to 11 a.m. Between 6:45 a.m. and 8 a.m., vehicles with three or more occupants travel the lane for free while vehicles with only two occupants must pay a toll. The lane is open to outbound 2+ traffic from 2 p.m. to 5 p.m. and 6 p.m. to 8 p.m. From 5 p.m. to 6 p.m., a toll is assessed in the manner described for inbound HOVs. On Saturdays, the I-10 HOV lane is open to outbound vehicles with two or more occupants from 5 a.m. to 8 p.m. On Sundays, the lane is open to inbound vehicles with two or more occupants during the same time period (34).

ITS infrastructure in Houston is coordinated through the TranStar traffic management center, which is jointly operated by Houston METRO, TxDOT, Harris County, and the City of Houston. This infrastructure includes loop detectors, AVI readers, VMSs, CCTV cameras, and overhead lane control signals. The overhead lane control signals are spaced two miles apart throughout the HOV lane network to notify drivers if they are traveling in the wrong direction (33). TranStar is currently investigating the deployment of remotely operable gates.

HOV lane diversion is implemented nine to ten times per year. This statistic has increased since the opening of TranStar and its attendant freeway surveillance network. There is no specific policy in place governing how many lanes must be blocked or how long incidents must last before HOV lane diversion is considered (35). METRO's police force will lift HOV restrictions if a major incident causes "prolonged closure" of the mainlanes, as evaluated in the field, regardless of whether or not the HOV lanes are open at the time (10). In particularly severe cases, the HOV lane may be closed to peak direction traffic, reversed, and opened to non-peak direction traffic (35). To provide incident and diversion information to motorists, VMSs upstream of the incident are changed by a METRO police officer stationed at TranStar (10).

In considering HOV lane diversion, METRO police must consider where HOV lane traffic will go once it enters the HOV lane. I-45S, for example, is a designated hurricane evacuation route for which the HOV lane feeds into downtown Houston, where the number of cars that can be accommodated by the street network is limited. Thus, to avoid creating downtown gridlock, the I-45S HOV lane may not be opened to general traffic during hurricane evacuations (35).

Maryland

The Maryland State Highway Administration (SHA) operates a pair of concurrent HOV lanes along I-270. They are separated from the general-purpose lanes by a two-foot buffer (36). The first segment of the facility commenced operating in 1993 (37). Figure 8 is a real-time image of this facility.

The southbound lane is open to vehicles with a minimum of two occupants from 6 a.m. to 9 a.m., and the northbound lane is open to HOVs from 3:30 p.m. to 6:30 p.m. Other traffic can use the lanes outside of these time periods (38). The lanes have not been used for special event traffic.

The decision to allow general traffic to divert to the HOV lane is made by the incident manager or the police officer in charge at the scene of the incident. A network of VMSs, HAR, and communications with local traffic reporters, coordinated through the Statewide Operations Center, informs motorists that the restriction is no longer in place. Emergency vehicles are able to make use of 14-foot shoulders along I-270 to reach incidents, so reserving the HOV lane for their use is not necessary. Diversion during severe weather has been tried at least once.

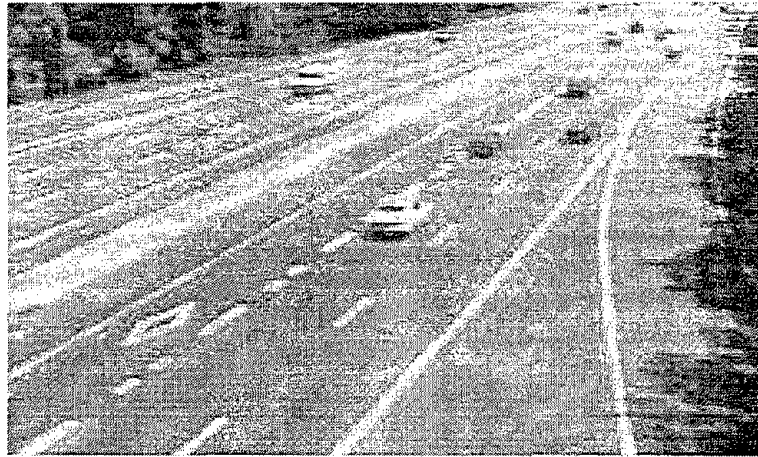


Figure 8. Concurrent HOV Lane Along the Inside of I-270 in Maryland (37).

When traffic is diverted to the HOV lane, the lane remains open to general traffic for the entire peak period because it is difficult to clear the lanes of general traffic once the restrictions have been lifted. It is also policy to have personnel in the field to set up arrow boards and direct the diversion process. This is because some existing technology, particularly the CCTV cameras, is deemed inadequate for safe remote operation.

Extending or curtailing HOV lane operating hours based on real-time volumes and speeds is not something that has been considered by SHA. The surveillance equipment for collecting such data is in place and SHA is looking at installing dynamic HOV lane signs, but concern about motorist confusion prevents the deployment of a dynamic HOV lane (36).

Minneapolis-St. Paul, Minnesota

The HOV system in Minneapolis-St. Paul, Minnesota, opened in 1992. It was preceded by an interim HOV lane that operated during the construction of I-394 in 1985 (39). It now includes three HOV facilities that operate within a freeway surveillance network that comprises detectors, VMSs, and CCTV cameras (40).

I-394 west of Highway 100 and I-35W are both concurrent facilities that are open from 6 a.m. to 9 a.m. and 3 p.m. to 6 p.m. The I-394 lane is open to eastbound traffic in the morning and westbound traffic in the evening, while the I-35W lanes are open to both directions during both peaks. The third facility, I-394 east of Highway 100, is a reversible, barrier-separated facility open to eastbound HOV traffic from 6 a.m. to 10:30 a.m. and to westbound HOV traffic from 2 p.m. to 12 a.m. It is also open for some special events. A section of this facility is depicted in Figure 9. During the restricted hours, vehicles must have two or more occupants. At other times, SOVs may use the concurrent facilities (41).

There is no set policy regarding when the HOV lanes may be used for the diversion of general traffic. The lanes have not been used for diversion to date because congestion has generally not been as high as in some other metropolitan areas. Furthermore, HOV systems decisions are based on HOV policy—providing a fast commute for HOV lane users—not maximizing freeway throughput (40).

The Minnesota Department of Transportation (MnDOT) is planning to extend the hours of operation on the reversible section of I-394 by two-and-a-half hours to account for increasing congestion levels. Dynamic restructuring of operating hours, based on real-time data, was not considered as an alternative because of the desire to maintain consistency in HOV lane policies. Without consistent hours, motorists may become confused and enforcement may be complicated (42).



Figure 9. Reversible HOV Lane in the Center of I-394 in Minneapolis (41).

Northern Virginia

The Shirley Highway HOV lanes in Northern Virginia are a part of I-95 and I-395 and serve commuters traveling to and from Washington, D. C. The facility is a two-lane, reversible, barrier-separated system. In the northbound direction from Monday through Thursday, it is open to HOVs from 6 a.m. to 9 a.m. and to all traffic from 9 a.m. to 11 a.m. and 10 p.m. to 6 a.m. In the southbound direction on the same days, it is open to HOVs from 3:30 p.m. to 6 p.m. and to all traffic from 1 p.m. to 3:30 p.m. and 6 p.m. to 8 p.m. On Fridays, the lanes are open to HOVs from 12 p.m. to 6 p.m. in the southbound direction. From 6 p.m. Friday to 8 a.m. Sunday, the lanes are open to all southbound traffic. From 10 a.m. Sunday to 6 a.m. Monday, the lanes are open to all northbound traffic (43). VDOT is currently studying the effects of permanently changing operating hours and occupancy requirements (44).

When an incident blocks 50 percent of the mainlanes in the peak direction and is expected to take one to two hours to clear, general traffic will be diverted to the HOV lane. This happens three to four times a year, and the decision to divert is made by the state police at the scene. Diverting traffic to the HOV lane is a very popular strategy with the local media, who will call the Virginia Department of Transportation (VDOT) whenever an incident occurs and ask if the restrictions will be lifted, but HOV lane volumes are so high that VDOT does not want to jeopardize those volumes by allowing general traffic to divert to the HOV lane often. The high HOV lane volumes have furthermore resulted in a policy that says, if an incident should occur in the non-peak direction, non-peak traffic will not be diverted to the HOV lane.

VDOT must also consider the potential for major queue build-up at the end of the HOV lanes, where HOVs merge with mainlane traffic or encounter downtown traffic signals. To minimize this queuing, traffic must be diverted to the HOV lanes to bypass the incident and then directed back to the mainlanes as soon as possible.

VDOT maintains a network of VMSs and freeway surveillance equipment and is able to remotely operate its HOV access gates. The agency would like to have accurate measures of delay and queue build-up during incidents, but does not think that such measures can be compared to similar measures calculated assuming that the HOV facility is reserved for emergency vehicles only (45).

San Diego, California

The Express Lanes in San Diego along I-15 make up a two-lane, reversible HOV facility that began operating in 1988. It is open from 5:45 a.m. to 9:15 a.m. for southbound HOV traffic and from 3 p.m. to 7 p.m. for northbound HOV traffic (11). If mainline speeds are less than 60 miles per hour at the end of the evening peak, HOV lane operating hours may be extended to provide premium service to HOVs until mainline speeds reach that threshold speed (22). Ten-foot shoulders parallel the lanes of travel, and there are no interchanges or exits except at the ends of the lane.

The Express Lanes are one of the few congestion pricing projects in the United States. The occupancy level is 2+ for free travel on the Express Lanes, and single-occupancy vehicles (SOVs) must pay a toll to use the lanes (23). The amount of the toll varies with the demand for the lane and is based on guaranteeing at least LOS C to HOV lane users. When Express Lane volumes are so high that the LOS worsens beyond C, SOVs are no longer allowed to use the lanes (18).

Reversing lane operations is handled manually. First, changeable message signs, located at both ends of the lane and prior to lane entries, indicate lane closure. Second, the lane is inspected for debris and abandoned vehicles. Pop-up pylons are hydraulically raised to form an obvious, but penetrable barrier. Crossing arms are lowered to block wrong-way entries, and changeable message signs then indicate that the lane is open in the opposite direction. Each step in this process is initiated manually in the field (11,18).

It has actually been possible since 1992 to coordinate the lane closure and reversal process on a fully automated, remote basis (22). CCTV cameras can visually monitor each stage of the reversal process, detectors measure gaps in the traffic stream so that the lane can be closed or opened without jeopardizing motorists, and the pylons and barriers can be controlled remotely. The California Department of Transportation (Caltrans) does not allow automated control, however, because there is no way to verify what the CCTV cameras are displaying except to have an employee physically on scene to ensure that all equipment is working properly. This desire for redundancy and double-checking is illustrated by the fact that the messages on the changeable message signs are viewed with a camera to verify that they are indeed displaying the correct information (18).

The Express Lanes are open to emergency vehicles at all times. Removable guardrails are spaced periodically in the concrete barrier to facilitate emergency vehicle access (23). The lanes are opened to the general public when two or more mainlanes are blocked for at least two hours (11). The two-hour time limit accounts for the time it takes to assemble the necessary employees to open the lanes. The lanes are only opened in the peak direction and are not opened to the general public if the incident occurs within approximately 30 minutes of the need to reverse lane operation for the other peak (22).

On average, this diversion strategy is implemented only once a year (22,23). This low number may be explained by the fact that San Diego's freeway service patrol monitors I-15 at a three-mile spacing during peak periods and is readily available to begin managing incidents. Furthermore, SOVs can effectively divert themselves by paying a toll to enter the Express Lanes if they become aware of a downstream incident before they reach the entry to the Express Lanes (18).

Seattle, Washington

The Seattle metropolitan area includes a number of different types of HOV lanes, all of which are operated by the Washington State Department of Transportation (WSDOT). Reversible and concurrent HOV lanes operate on both I-5 and I-90. Sections of these roadways are depicted in Figures 10 and 11. Concurrent facilities operate on I-405, SR 167, and SR 520.

The I-5 reversible lanes are open to HOVs with two or more occupants from 5 a.m. to 8:30 a.m. and 12 p.m. to 4 a.m. in the peak direction (46). The number of lanes provided varies from one to four (47). The I-90 reversible lanes are open to HOVs with two or more occupants 24 hours a day except for reversal periods (46). Some sections are either restricted to transit vehicles or open to both Mercer Island residents and HOVs. The concurrent sections of both freeways are open to HOVs containing two or more occupants 24 hours a day (47).

The concurrent lanes on I-405 and SR 167 operate 24 hours a day and require vehicles to contain at least two occupants. A shoulder lane on westbound SR 520 is reserved for vehicles with three or more occupants.

It is WSDOT policy to maintain an average HOV lane speed of 45 miles per hour at least 90 percent of the time during the peak hour (46). To reduce high demand levels and improve HOV lane LOS, WSDOT is currently looking at increasing occupancy requirements to three persons during peak periods (47).

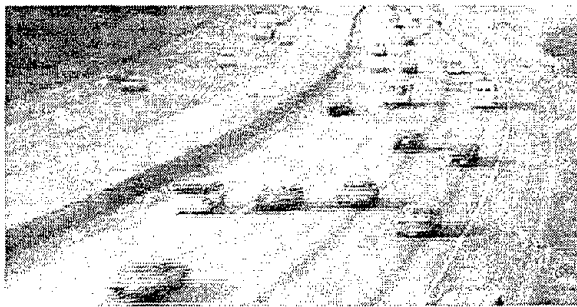


Figure 10. Concurrent HOV Lane Along Inside of I-5 (46).

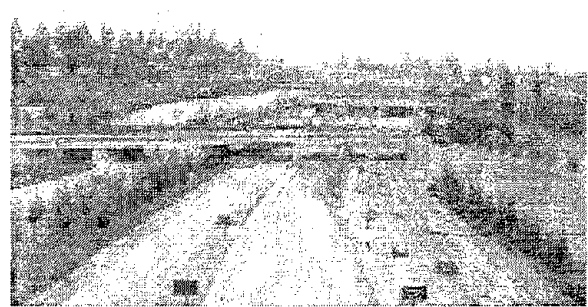


Figure 11. Reversible HOV Lane in Center of I-90 (46).

Approximately one-half of the concurrent HOV facilities in the United States allow SOVs to use the lanes outside of peak hours (1). WSDOT does not. The consistency of 24-hour operation is believed to minimize confusion, reduce accidents, and promote easier enforcement of occupancy requirements. Twenty-four-hour availability is also an incentive for drivers to use the HOV lanes for more trips as well as a means of keeping a traffic lane available for the use of emergency vehicles (46).

The decision to relax HOV lane restrictions is not made lightly. It is technically against the law for SOVs to use an HOV lane at any time, so the integrity and quality of the HOV system must be balanced against the needs of the situation. Assessing public tolerance is one component of this equation. HOV lane users, for example, were amenable to the HOV lane diversion strategy when a major incident closed the mainlanes on one Seattle freeway several months ago, but they were not happy when diversion was allowed in conjunction with construction activities without the permission of WSDOT.

The state police determine if an HOV lane will be opened to general traffic when a major incident occurs. Their decision depends on the time of day, the severity of the incident, and the availability of diversion routes other than the HOV lane. No set policy exists. Police officers at the scene, supported by VMSs and portable signs, will direct traffic around the incident (47).

IDENTIFICATION OF BARRIERS

From the literature and the agency interviews, a number of barriers to the deployment of a dynamic HOV lane were identified. These include justifying the need for such a facility, ensuring motorist safety, technical reliability, adequacy of data, implementation costs, funding restrictions, public perceptions, legality, and the wide variety of contributing factors.

Need

Before a dynamic HOV lane can be developed in a metropolitan area, there must exist a problem that the dynamic HOV lane can mitigate. This problem might be heavy traffic volumes, under- or overutilized HOV lanes, or a lack of alternate routes for mainlane diversion during major incidents.

In Minneapolis, for example, relatively low congestion levels imply that sufficient capacity exists in most corridors to handle daily demand. Making better use of that capacity is not such an urgent concern, so altering lane operating hours based on real-time volumes is not a concept that MnDOT can use. In addition, the number of major incidents that required diversion in past years is negligible, so the incident management advantages of a dynamic HOV lane serve no purpose.

In San Diego, congestion pricing provides SOVs the opportunity to “buy in” to the I-15 HOV lane and avoid congestion. This is an HOV demand management technique. The advantages that a dynamic HOV lane might provide in increasing the efficiency of the lane are superfluous when lane utilization can be controlled by changes in the toll paid by SOVs. In addition, the buy-in feature reduces the effectiveness of a dynamic HOV lane in the area of incident management. When a ready diversion alternative exists and drivers can decide individually whether or not they wish to use it, the transportation management center is limited to only providing incident information and deciding how many buy-ins are allowed.

In Maryland, 14-foot shoulders adequately serve the need of emergency vehicles to find an unobstructed path to the site of an incident. The advantage that a dynamic HOV lane would provide in offering a range of diversion options is thus restricted in this case.

The role of the dynamic HOV lane must also be identified within the existing HOV lane and freeway network because dynamic properties are better suited for some types of HOV lanes than for others. A contraflow lane, for example, requires a barrier to prevent high-speed, head-on collisions between opposing traffic streams. As noted in the Concept Development section, the presence of a barrier will limit the degree to which dynamic HOV lane properties can be utilized. Also, emergency access gates cannot be installed in contraflow barriers composed of continuous, hinged sections to allow mainlane traffic or emergency responders into the lane. Neither can these barriers be easily moved.

Motorist Safety

DART and WSDOT operate their concurrent HOV facilities 24 hours a day and do not allow general traffic to use these HOV lanes outside of peak periods. These policies were formulated to minimize motorist confusion over lane operating status, particularly for motorists who are infrequent users of the HOV facility, by minimizing the amount of HOV lane information that must be provided to motorists. One feature of a dynamic lane, however, is the ability to utilize real-time freeway data in making a decision about extending or curtailing HOV lane operating hours in order to make better use of the lane. With such a feature, a 24-hour HOV-only policy cannot exist, and so the issue of motorist confusion must be taken into consideration in designing the system and its operating rules.

Maryland SHA and MnDOT share the same fundamental belief. They allow SOVs on their lanes outside of restricted time periods, but they also express concerns about motorist confusion that may result when HOV lane operating hours are variable.

Technical Reliability

The dynamic HOV lane concept is untested in the field, so its technical feasibility must be assessed by the experiences of agencies with automated HOV lane features and with ATMS in general.

In San Diego, changes in HOV lane operations can be completed remotely, but remote operation is not allowed because the success or failure of the automated processes cannot be fully verified. In Maryland, as mentioned before, the existing ITS infrastructure is also not trusted enough to allow dynamic HOV lane operations. All interviewed agencies reported that the decision to allow HOV lane diversion during incidents is made by police officers in the field. It is not based on data obtained from CCTV cameras, loop detectors, or other surveillance media. Even on I-95 in Virginia, where HOV lane access is remotely controlled, a state policeman in the field makes the HOV lane diversion decision. This practice results from the general unpredictability of incidents and secondary accidents, which are best assessed by personnel at the incident scene, according to the interviews.

Overall, there is a reluctance to rely upon advanced technologies and incorporate them into current practices in the form of a dynamic HOV lane. Where advanced technologies and automation are used to detect incidents or open and close HOV lanes on a daily basis, their data and operation are generally verified by other technologies or by field personnel. The reluctance to trust advanced technologies is magnified in incident situations. No agency interviewed will authorize HOV lane diversion without the recommendation of field personnel. Waiting for field personnel to arrive prohibits immediate response and thus negates a major advantage of the dynamic HOV lane.

Adequacy of Data

Beyond stating that secondary accident probability increases with time, studies to date have not resulted in a means of estimating the number or severity of secondary accidents that may result from a major freeway incident. Therefore, including this measure of effectiveness in quantifying the utility of allowing general traffic to divert to the HOV lane based on real-time information may be very difficult, even when accurate delay and queue measures can be obtained through the freeway surveillance system. Nevertheless, should this inclusion be successfully accomplished, some agencies do not think that a comparative measure can be developed to evaluate the utility of restricting the HOV lane to emergency vehicles during incidents.

Incident duration estimates based on experience are sufficient for allocating incident response resources and approximating clearance time. However, inaccuracies in predicting incident duration may be a significant barrier to making full use of a dynamic HOV lane. In choosing between different diversion schemes, it is important to accurately calculate *total* delay, queuing, and secondary accident measures for all possible alternatives so that the alternative with the highest utility can be selected and implemented. These calculations must logically be made before a response is chosen and initiated. If total incident duration is incorrectly estimated, utility measures will be incorrect, and then the effectiveness of being able to choose from a range of diversion schemes will not be maximized.

Implementation

Developing and deploying the ATMS technologies necessary for a dynamic HOV lane may be prohibitively expensive if the infrastructure is not already in place, especially if the benefits cannot be easily quantified

or researched. Implementation is further impeded if there is little support for such a project or for advanced technologies in general.

Another implementation issue—one not necessarily restricted to dynamic HOV lanes—is adequate planning. HOV lane entries and exits must be designed to accommodate changing HOV lane policies. On I-95, for example, unusually high HOV lane volumes resulting from diversion or overutilization of the lane will create a bottleneck when the HOV lane ends. This does not result in travel time savings and can be as hazardous as congestion on the mainlanes.

VDOT's solution to this problem is to divert traffic back to the mainlanes as soon as possible. This may be possible on a barrier-separated facility such as the I-95 HOV lanes. This is not a practice on the concurrent HOV lane on I-270 in Maryland, however. When the HOV lane is opened to general traffic, it remains open for the entire peak period because it is very difficult to clear the HOV lane of general traffic once the incident has been bypassed. Ending HOV lane restrictions in this way results in a loss of HOV lane efficiency downstream of the incident.

Public Perceptions

Maintaining HOV lane integrity means, in the case of San Diego, operating the lane at LOS C. In Seattle, it means keeping the average HOV lane speed above 45 miles per hour. In all cases, it means operating the HOV lane in accordance with the reasons the lanes were constructed: the provision of reliable and predictable travel time savings to HOVs. To do otherwise can discourage carpoolers and kill the lane. HOV lane users may be justified in objecting to the use of their lane by vehicles that do not meet the occupancy requirements, even during major incidents. The general public, furthermore, may question why the lane was funded and restricted to HOVs in the first place if the restrictions are lifted too frequently. These two perceptions may result in loss of public support for the lane.

If restrictions are modified excessively, SOVs may also become so used to traveling in the HOV lane that the violation rate increases and enforcement becomes problematic. In addition, there will be little encouragement for SOVs to become HOVs if SOVs cannot see firsthand, in the field, a clear benefit to be gained by carpooling (48).

Legality

HOV lanes funded using environmental relief funding such as Congestion Mitigation and Air Quality (CMAQ) funds may not be allowed to become dynamic HOV lanes if SOVs are allowed to use the HOV lane at times and environmental benefits cannot be justified (32).

It is against HOV lane policy in Minnesota and against the law in Seattle to allow SOVs on the lanes. These legal restrictions will be ignored when incidents make it necessary, but liability issues must be considered when procedures are not followed exactly. Furthermore, these legal restrictions prohibit the implementation of a dynamic HOV lane whereby operating hours can be terminated early or extended as necessary to allow SOVs on the lane. Deployment will be hampered by the need to make changes to the HOV policies and state laws.

Liability issues in general must be thoroughly investigated whenever any new ITS technology or application is developed. High risk may make a project infeasible before it is ever demonstrated. Also, the accuracy of information provided to motorists must be guaranteed or else provided to such a degree that the agency cannot be held responsible for events that befall motorists who follow agency recommendations.

Wide Variety of Contributing Factors

There are so many factors and circumstances to consider in developing dynamic HOV lane diversion plans that “no amount of preplanning can be preprogrammed into the technology to account for all of the potential problems” (48). These factors and circumstances are unique to individual sites and situations. Agencies must consider weather conditions, traffic volumes, incident severity and location, incident response needs, secondary accidents, the availability and features of alternate diversion routes, and many other characteristics in deciding how to change HOV lane operating status.

DYNAMIC HOV LANE DESIGN

In this section, a hypothetical dynamic HOV lane is designed to show how the HOV lane and the ITS technologies are interrelated and how the barriers to implementation might be overcome. This illustration follows the development of the lane from the idea's inception to its full implementation. The final design is similar to Figure 7 in concept.

The Environment

A severe congestion problem is present during commuting hours on a typical interstate highway in a typical United States metropolis. Studies and traffic counts show that there are enough carpooling commuters to justify the construction of an HOV lane on the interstate. Moreover, an average of one major incident per month periodically shuts down significant portions of the freeway.

A desire to maximize the cost-effectiveness of providing the HOV lane in the present and in the future results in the decision to construct a dynamic HOV lane. This dynamic HOV lane will be controlled with currently-available ITS technologies, and it will provide incident management benefits in addition to improving freeway utilization. Implementation will not be easy because there are a number of barriers to overcome before success can be achieved.

Who Is Involved?

In planning this dynamic HOV lane, highly cooperative relationships must exist between the local government, the state DOT (the agency that will construct and operate the lane), enforcement personnel, incident responders, the local transit agency, the media, the future users of the lane, and the future non-users of the lane. Fortunately, most of these groups have developed strong working relationships with each other based on past joint projects. Each group has a role to play in directing its unique capabilities in support of the lane and in making sure that its needs will be met by the final product.

Four of these groups will work with the DOT to develop a construction plan. The local government is critical in the development of dynamic HOV lane policies and goals, based on researching the experiences of other facilities and the needs of the metropolis. Enforcement personnel must understand how the lane will operate and develop methods by which violators of lane policies can be safely apprehended within the dynamic HOV lane environment. Incident responders, likewise, must ascertain that their need to reach incident scenes quickly and safely can be met by the dynamic HOV lane. Finally, the transit agency must ensure that the HOV facility will accommodate its bus routes and schedules.

The DOT, in addition, will thoroughly train its maintenance staff in the use and upkeep of the ITS technologies. Good maintenance is required to ensure accuracy and reliability, without which the lane will be ineffective.

The DOT, the media, the local government, and the public will be part of an extensive public education campaign. The goals of this campaign are to gain public support, encourage lane use, minimize motorist confusion, and reduce the violation rate (49). Television broadcasts, newspaper stories, radio announcements, billboards, public meetings, an Internet web site, a telephone hotline, flyers, brochures, and an employer outreach program will be used to inform the public about the new dynamic HOV lane. The public education topics include explaining:

- Why an HOV lane is being built to ease congestion instead of another general-purpose lane
- How the lane will function daily, as it will function somewhat differently from HOV lanes for which motorists may have experience; some motorists may have no HOV lane experience at all

- How the lane will function during incidents
- The role of VMSs, HAR, and lane control signals in conveying traffic information
- Why motorists should respect the occupancy requirements and what the penalties for violation are
- How HOV lane utilization is measured in terms of the volume of *people* that use it, not the volume of *vehicles*

This campaign will be an ongoing process. The public will periodically be informed of HOV lane travel time savings as encouragement to use the lane. VMS use and partnerships with the media for the broadcasting of such information will be investigated, with care taken to let motorists know that the figure is average travel time savings, not guaranteed travel time savings.

Finally, funding sources will be secured in advance so that the project can be completed on time. Funding may be provided through joint development ventures between local entities or through grants from the federal government. In addition to qualifying for grants designated for environmental relief, the dynamic HOV lane may also qualify for demonstration project funding.

What Are the Physical Components of the Dynamic HOV Lane?

One of the biggest expenses in developing a dynamic HOV lane is installing the necessary technology as well as backup systems and methods of verifying the accuracy of collected data. The metropolis is fortunate that it already has a freeway surveillance network consisting of state-of-the-art detectors, CCTV cameras, and telecommunications lines. A traffic management center oversees that network as well as VMSs, AVI readers, HAR, and AVL. Each of these technologies play other roles in the transportation network of the metropolis; the dynamic HOV lane gives them an additional purpose.

One technology that the city lacks is lane control signals to provide information similar to the information provided by the lane control signals of Figure 5. These lane control signals will operate in conjunction with small, remotely changeable lane use signs that provide information on which vehicles are allowed to use the lane at the time. The signs that the city plans to install will show the 2+ designation over the dynamic HOV lane as depicted in Figure 12. These lane control signal assemblies are to be constructed across the interstate at key locations and at least one-half mile apart. With the lane control signals in place, the public education campaign to increase their regulatory force, and continuous access and egress, there is no need to permanently demarcate the concurrent facility with painted diamonds or special striping (50) and thereby confuse off-peak travelers who are unfamiliar with the facility.



Figure 12. Conceptual Overhead Lane Control Signals and Lane Use Sign for Hypothetical Dynamic HOV Lane.

The city also lacks a refined HAR system. Instead of setting up portable HAR transmitters when necessary, the city has decided to set up permanent transmitters along the interstate where VMSs can instruct motorists to tune in to the HAR station for traffic information. These transmitters are spaced so that their broadcast areas do not overlap. They can be controlled from the traffic management center like the VMSs and lane control signals. When not used to convey incident or construction information, select transmitters can broadcast HOV lane information to tourists.

If the city should decide to construct a contraflow or reversible HOV lane, automated gates and barriers will be required. The city would, in this case, like to install a system similar to San Diego's, where hydraulic pylons and gates are used in sequence to open and close HOV lane entries and exits while monitored by cameras and detectors. For safety reasons, a substantial barrier must separate opposing traffic streams (32).

The volume, speed, and detector occupancy data collected by the freeway surveillance network for the HOV lane and the mainlanes will be used in a decision support system developed at the traffic management center. This decision support system will consist of a method for predicting system measures of effectiveness, estimated by experience and calibrated (49), and an algorithm that quantifies the utility of different HOV lane operational strategies. These strategies will include both the day-to-day variation in HOV lane operating hours and the incident management schemes. The decision support system will also include a penalty factor to limit the frequency with which HOV lane diversion is allowed.

Where and When Would the Dynamic HOV Lane Operate?

The least expensive type of HOV lane to construct in the hypothetical city is a concurrent HOV lane. The interstate highway's shoulders are not adequate for carrying HOV traffic, so a concurrent HOV lane will operate on the inside lane of the freeway in the peak direction during the peak hours. The lane will also operate during special events. The perception of "taking away" a general purpose lane is an issue that has resulted in the failure of some HOV lane projects in the past (25), and so the importance of the public education campaign in gaining public support increases.

Access and egress will be allowed continuously along the length of the lane. Vehicles with two or more occupants will be allowed to use the lane because it has been determined that this occupancy level will result in an acceptable level of lane use.

In accordance with the capabilities of a dynamic HOV lane, the hours during which the lane is restricted to HOVs will be extended or shortened based on real-time lane usage data. San Diego's experiences in extending evening HOV lane operating hours will be studied for insight into this topic. The base operating hours are from 7:00 a.m. to 8:30 a.m. and 4:00 p.m. to 6:00 p.m. If HOV lane volumes are unusually high at 8:30 a.m. and the general-purpose lanes are congested, the operating hours will be extended until HOV lane volumes decrease or LOS on the mainlanes improves to LOS C—which is deemed acceptable—or better. VMSs will inform motorists that the HOV restriction remains in place, and the lane control signal assemblies will continue to designate the inside lane as reserved for 2+ HOVs. If HOV lane volumes are unusually low at 5:30 p.m. and the mainlanes operate at LOS C or better, then the restriction will be lifted without fear of worsening the LOS for HOVs. The "HOV 2+" lane use sign over the HOV lane will change from green to amber to indicate the imminent change, and then, after the "HOV 2+" lane use sign is switched off, VMSs will inform general traffic that the HOV lane is no longer restricted to HOVs. The guiding principle in altering HOV lane hours is that HOVs must always be provided with an acceptable base LOS under normal, incident-free conditions, whether the minimum LOS is provided in the HOV lane or in the mainlanes.

After an incident is detected by the freeway surveillance system, CCTV cameras are used to determine the type of response required. If the incident is "major" and there are no injuries, no fires, and no spilled

hazardous cargo, the dynamic HOV lane will be used as an incident management tool in the following possible ways:

- *Option 1.* The HOV lane will be opened to the general public as soon as a major incident occurs that significantly blocks the general-purpose lanes. “Significant” blockage is expected to close down at least 50 percent of the mainlanes for an expected duration of at least one hour.
- *Option 2.* So that emergency responders have an unobstructed path to the incident, the HOV lane is closed to general traffic at all times during the clearance of the incident and regardless of the severity of the incident. The HOV lane, in this hypothetical scenario, is closed to HOVs as well.
- *Option 3.* If AVI data show that incident responders are some distance away from the scene of the incident, the HOV lane will be opened to the general public as soon as the incident occurs, but only until the incident responders reach the interstate. Then the HOV lane will be closed to all traffic but incident responders.

After the diversion algorithms measure and weigh each option, VMSs upstream of the incident will inform motorists of the incident ahead and convey changes in HOV lane status. For each diversion option, the diversion process is illustrated in Table 1.

While the incident is present, VMSs far upstream warn approaching motorists of the incident and instruct them to tune in to an HAR station for further incident instructions. After the incident is cleared, the VMSs, lane use signs, and lane control signals are used to return the HOV lane to normal operating status. Green lane control arrows are once again displayed above all open lanes of travel.

In general, the lane control signals and lane use signs are used to warn specific groups of motorists—those who are currently using the lane over which the sign or signal is displayed—of upcoming changes in lane status. The VMSs are used to communicate with all users of the freeway. It is important that these three communication tools are used in a logical sequence so that freeway chaos after an incident can be minimized.

How Will Motorists’ Safety Be Ensured?

To ensure the safety of motorists using the dynamic HOV lane, component maintenance will be accorded a very high priority. Dynamic signing will be used effectively to provide clear, up-to-date information to motorists. Public education and awareness campaigns will also be employed, as described previously.

Testing of the dynamic HOV lane concept has not been extensive up to this point, so the city plans to implement its dynamic HOV lane in stages. As the HOV lane system progresses to full operability over time, the reliance on the technologies will grow as they are proven to be dependable and as guidelines are developed for their use in more circumstances. The first stage of the implementation process is to begin the public education campaign and introduce lane control signals and lane use signs to the public. The second stage is to initiate the variable hours system, using the existing VMSs, lane control signals, and lane use signs. Implementation of dynamic HOV lane diversion is the third stage. Within each stage, there will be a gradual transition from the use of the human presence as a backup system to the use of other technologies as the backup system. System capabilities will also be expanded and adapted to cover new operating scenarios and circumstances as required, learning from local experience and the experiences of other HOV lane projects.

Table 1. Steps in the Hypothetical HOV Lane Diversion Process.

Diversion Option	Process ¹
<p><i>Option 1</i></p> <p>General traffic diverts to the HOV lane immediately</p>	<ol style="list-style-type: none"> 1. The “HOV 2+” lane use sign over the HOV lane turns amber and flashes to indicate imminent termination of the HOV restriction. 2. The “HOV 2+” lane use sign is turned off. The HOV lane control signal remains a green arrow. 3. Meanwhile, VMSs display a message upstream of the incident, such as: MAJOR INCIDENT ONE MILE AHEAD 4. After the “HOV 2+” lane use sign is turned off, the VMSs also display: ALL TRAFFIC USE HOV LANE TO DIVERT
<p><i>Option 2</i></p> <p>HOV lane restricted to emergency vehicles at all times</p>	<ol style="list-style-type: none"> 1. The “HOV 2+” lane use sign over the HOV lane turns amber and flashes to indicate imminent termination of the HOV restriction. 2. The “HOV 2+” lane use sign is turned off. The HOV lane control signal changes from a green arrow to an amber arrow to a red X to indicate lane closure. 3. Meanwhile, VMSs display a message upstream of the incident, such as: MAJOR INCIDENT ONE MILE AHEAD 4. While the HOV lane control signal is changing, the VMSs also display: CLEAR HOV LANE FOR EMERGENCY VEHICLES
<p><i>Option 3</i></p> <p>HOV lane opened to general traffic until emergency responders need it; the HOV lane is then restricted to emergency vehicles</p>	<ol style="list-style-type: none"> 1. The “HOV 2+” lane use sign over the HOV lane turns amber and flashes to indicate imminent termination of the HOV restriction. 2. The “HOV 2+” lane use sign is turned off. The HOV lane control signal remains a green arrow. 3. Meanwhile, VMSs display a message upstream of the incident, such as: MAJOR INCIDENT ONE MILE AHEAD 4. After the “HOV 2+” lane use sign is turned off, the VMSs in the <i>immediate vicinity</i> of the incident also display: ALL TRAFFIC USE HOV LANE TO DIVERT 5. When emergency vehicles reach the interstate, the HOV lane control signal changes from a green arrow to an amber arrow to a red X, and the VMSs flash a new message: CLEAR HOV LANE FOR EMERGENCY VEHICLES

¹ These steps would be detailed further in an incident management plan.

CONCLUSIONS

This section summarizes the barriers that impede the implementation of a dynamic HOV lane and the elements that are critical in the success of such a lane. A flowchart describes the circumstances under which a dynamic HOV lane is appropriate, and the feasibility of the concept is assessed.

Summary of Barriers and Essential Elements

Issues of concern that inhibit the implementation of a dynamic HOV lane are:

- Justifying the need for a dynamic HOV lane
- Motorist safety
- Technical reliability
- Adequacy of data
- Implementation costs
- Public perceptions
- Legality and liability
- The wide range of contributing factors

To overcome these barriers, the following elements are necessary for the successful implementation of a dynamic HOV lane:

- *Need.* There must exist a problem that the dynamic HOV lane can mitigate. Figure 13 describes the environment in which a dynamic HOV lane is appropriate. If all of the conditions listed in Figure 13 are not met, the potential advantages of a dynamic HOV lane will be limited. The implementing agency must then decide if the benefits that can be achieved are considerable enough to proceed with implementation.
- *Reliance on the ATMS components.* These include VMSs spaced appropriately for the given freeway network and demand patterns, lane control signals and lane use signs over all lanes for the provision of simple lane status information, appropriate surveillance technology for data collection and verification, AVI and AVL systems to track vehicles and incident responders, and advanced telecommunications to link the ITS elements. While expensive to install and maintain, these components are often used for other freeway applications, thus improving their cost-effectiveness.
- *Extensive public education.* In addition to reducing motorist confusion, public education will lessen violation rates and help to minimize the “empty lane syndrome.”
- *An algorithm* to quantify diversion options, based on surveillance data, and *guidelines or rules* to assist in making decisions about the altering of HOV lane operating hours in real-time
- *Rigorous system maintenance* to maximize reliability and accuracy
- *Archiving capability* so that collected data can be analyzed and the dynamic HOV lane can be evaluated periodically. Secondary accident potential and incident duration predictors will be estimated, calibrated, and modified based on local experience and archived data. Archived data will also be used to adapt and expand the decision rules and algorithms.
- *HOV policies and laws* that support dynamic HOV lanes
- *Agency support.* Where the technological feasibility is in doubt, agency support may be obtained by demonstrating individual technologies to prove their reliability.
- *Backup systems and redundancies* for safety and the minimization of liability
- *A written HOV diversion policy* to minimize liability, provide procedural guidelines, and serve as a process evaluation tool
- *An understanding of the unique characteristics* of each implementation site and the ability to adapt the dynamic HOV lane to them over time. Building dynamic HOV lane operations in stages is recommended for identifying and managing the most important contributing factors and their effects on the system.

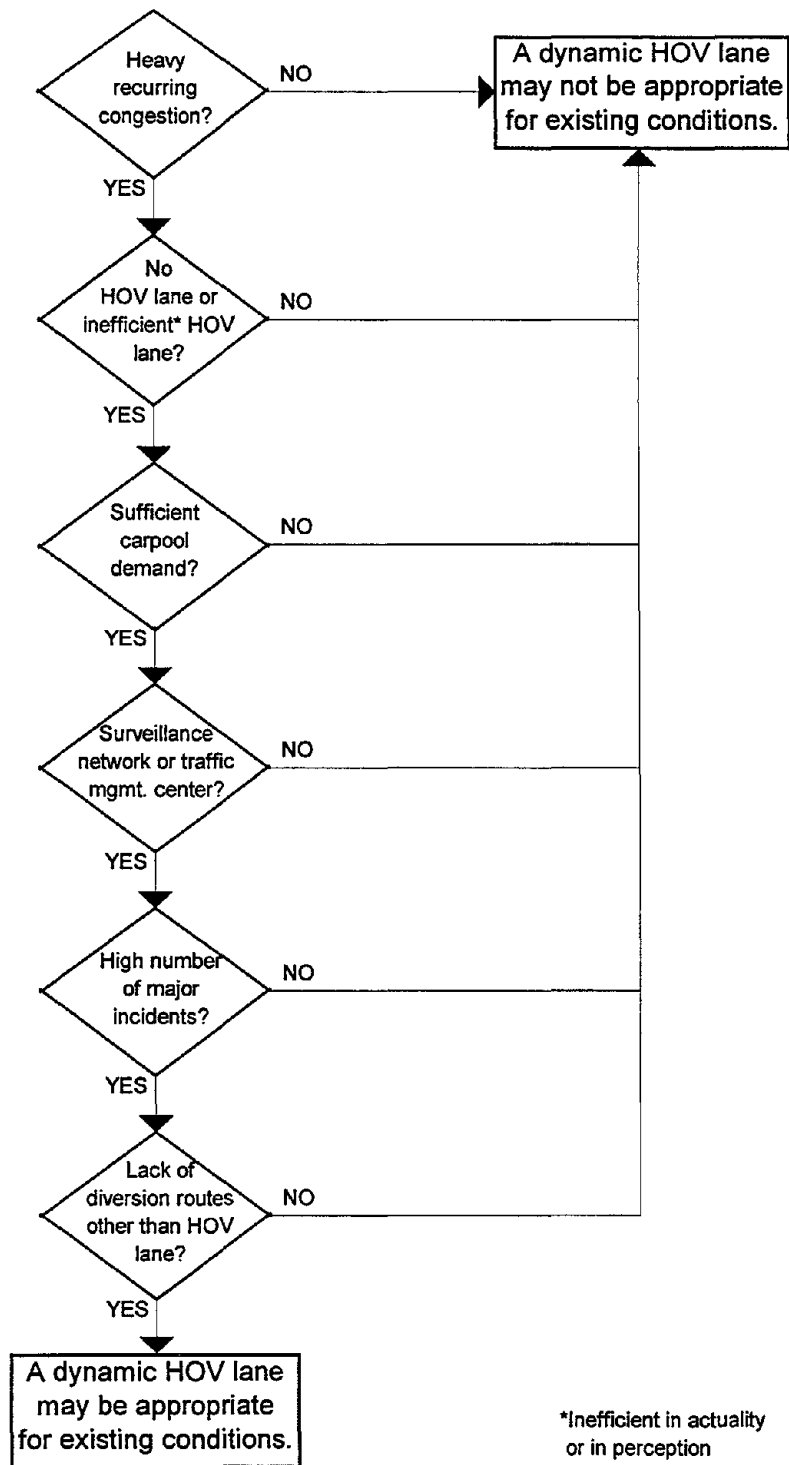


Figure 13. Under What Circumstances is a Dynamic HOV Lane Appropriate for Implementation?

Evaluation of Feasibility

Safety is the most important of all concerns and issues. The interviewed agencies are interested in innovative HOV lane practices to improve efficiency, but concerns about motorist safety result in a reluctance to experiment with ITS technologies in the ways described in this report. Because the fundamental difference between a dynamic HOV lane and a “normal” HOV lane is reliance upon a coordinated system of ITS technologies, a dynamic HOV lane cannot be implemented until the dependability of the component technologies—individually and cohesively—is successfully demonstrated.

RECOMMENDATIONS

The following sections address topics for future development and research that are related to the dynamic HOV lane concept.

Demonstration Project

The dynamic HOV lane concept is worthy of further research, particularly research that will quantify the dynamic HOV lane's benefits and demonstrate the dependability of the component technologies. This research could be funded by the United States DOT as an ATMS demonstration project. From the agency information gathered in the course of this research, a potential site for a demonstration project is on I-270 in Maryland. I-270 is appropriate because (36,49,51):

- Congestion is present during commuting hours and is expected to increase by 35 percent in the next fifteen years.
- It is an existing, concurrent facility. Upgrading an existing facility is less expensive than constructing a new lane, and a concurrent facility can make greater use of the component technologies.
- ITS infrastructure is in place, including a surveillance network, VMSs, and HAR, coordinated by the Chesapeake Highway Advisories Routing Traffic (CHART) system and its traffic management centers.
- The public views the lanes as underutilized.
- There is agency interest in efficiency improvements and expansion of the ITS network.
- There are no policies or laws that restrict the HOV facility to HOVs 24 hours a day.
- There are no frontage roads along I-270, so the only other diversion route is a parallel state highway. MD 355 is at-grade and is not access-controlled. These characteristics limit its usefulness as a diversion route.

The Maryland site is not perfect in the sense of meeting all of the criteria in Figure 13 because the existing HOV facility is successful and, while nonrecurring congestion is frequent (49), there are very few major incidents. However, the site has strong advantages in existing ITS infrastructure and HOV lane policies that support the development of a dynamic HOV lane. Therefore, for the purpose of demonstrating technical reliability and the operation of an HOV lane with variable hours, the site is more than adequate as a starting point in the implementation of a dynamic HOV lane.

Areas of Future Research

Both lane control signals and HAR (in the form of AHAR) are used extensively throughout Europe. European experience in the use of these technologies should be investigated and applied to the dynamic HOV lane concept. In particular, the regulatory power of lane control signals and public response to AHAR should be studied.

AHAR research should be applied to United States freeway operations in general to see if benefits might result from providing motorists with an involuntary audio means of receiving traffic information. This research would include a discussion of the technical, institutional, and social issues associated with both HAR and AHAR.

Likewise, the impacts and benefits of installing fixed HAR receivers and controlling them remotely should be analyzed further. In the United States, HAR is currently classified as a portable broadcast medium.

The issue of whether or not a 24-hour, HOV-only lane restriction policy reduces motorist confusion and, thereby, accidents would be of great interest to HOV lane operating agencies. Such an issue would have to be examined in the context of other HOV lane policies and influential environmental factors.

Another issue that requires further investigation is an analysis of how automated HOV lane enforcement can be improved and incorporated into a dynamic HOV lane. In any HOV lane project, good enforcement boosts the public's image of the HOV lane (49). A fully automated, dynamic HOV lane of necessity requires automated enforcement to remove police officers from the potentially hazardous enforcement environment. A study conducted in California in the early 1990s determined that the automated detection technology of the time was insufficient and inaccurate (52). An ongoing study in Dallas is investigating some aspects of the automated enforcement issue, but there is concern about both detection accuracy and the high costs of completing the research (32).

Finally, there are other environments in which a dynamic HOV lane may play a useful role. Dynamic HOV lanes could be applied to arterial streets, particularly arterial streets where one lane is a contraflow lane demarcated by complicated pavement markings and static signs. Dynamic HOV lanes might be developed to handle situations in which the freeway incident blocks the HOV lane and not the mainlanes. The use of dynamic HOV lanes in congestion pricing applications may also be worthy of research. As learned in the San Diego interview, congestion pricing projects can demonstrate unique incident management characteristics that should be analyzed in detail to see if new incident management techniques can be developed for application in other areas.

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APPENDIX

Guideline Questions for Interviews

1. Describe your HOV lane configuration and general operating policies, i.e., hours of operation and occupancy requirements.
2. What ITS infrastructure is currently in place in your jurisdiction?
3. Which agencies are responsible for incident management and HOV lane operation in your area, and how do you coordinate your actions in the event of a major incident or severe weather conditions?
4. Do you allow mixed traffic to divert to HOV lanes during major incidents, severe weather conditions, or other unplanned events?
5. Do you have policies in place governing the circumstances under which diversion is allowed? What are these policies?
6. How is diversion accomplished?
7. What is your experience with the success of your diversion strategy? What specific problems have you encountered?
8. Are you aware of any potential ITS solutions to those problems?
9. Have you investigated other diversion strategies or options, such as looking at when it might be more appropriate to maintain HOV lane restrictions (so that emergency vehicles can use the lane without impediments) than to allow mixed traffic to use the lane?
10. Have you heard of any innovative strategies in use in other HOV lane systems?
11. What information would you need in order to choose from a range of diversion options?
12. Is being able to choose from an array of diversion strategies something that would be beneficial?
13. Do you think that ITS technologies can make that choice feasible? What types of ITS technologies would be most useful? What else would be necessary?
14. What information do motorists need in order to successfully divert? How do you communicate this information to them?
15. ITS technologies can potentially provide instantaneous, clear instructions to motorists. If you were to use ITS technologies in this way, what issues would you be concerned about, and how would you alleviate those concerns?
16. What do you think of the viability of being able to dynamically alter HOV lane operating hours (within reason) to make more efficient use of the lane, based on real-time volume and speed data?
17. What other issues might arise if you were to implement a dynamic HOV lane with ITS technologies? Are there other significant barriers to surmount, such as politics, liability, and public acceptance?
18. What other problems do you see with the use of HOV lanes? With the use of ITS technologies?

HOV System Characteristics¹

Location	Facility	Number of Lanes; Type	Operating Hours	Occupancy	Diversion Policy ²
Dallas, Texas	I-30	1 lane; contraflow	Peak hours in peak direction	2+	No specific policy
	I-35E	1 lane each direction; concurrent; no buffer	24 hours	2+	
	I-635				
Houston, Texas	I-45, US 59, US 290	1 lane; reversible; barrier-separated (US 290 includes a short 2-way section)	Peak hours in peak direction; Weekends on I-45S inbound	2+	No specific policy
	I-10	1 lane; reversible; barrier-separated	Peak hours in peak direction; outbound on Saturdays; inbound on Sundays	2+	
			6:45 to 8 am and 5 to 6 pm in peak direction	Toll for 2+; free for 3+	
Maryland	I-270	1 lane each direction; concurrent; buffer-separated	Peak hours in peak direction	2+; SOVs at other times	No specific policy
Minneapolis-St. Paul, Minnesota	I-394	1 lane; reversible; barrier-separated	Peak hours in peak direction	2+	No specific policy
		1 lane each direction; concurrent; no buffer	Peak hours in peak direction	2+; SOVs at other times	
	I-35W	1 lane each direction; concurrent; no buffer	Peak hours in peak direction	2+; SOVs at other times	
Northern Virginia	I-395	2 lanes; reversible; barrier-separated	Peak hours in peak direction	3+; SOVs at other times, except reversal periods	50 percent of peak direction mainlanes blocked for 1-2 hours
San Diego, California	I-15	2 lanes; reversible; barrier-separated	Peak hours in peak direction	Toll for SOVs; free for 2+	2 or more lanes blocked for at least 2 hours
Seattle, Washington	I-5N, I-5S	1 lane each direction; concurrent; no buffer	24 hours	2+	No specific policy
	I-5N	1 to 4 lanes with ramps; reversible; barrier-separated	Peak hours in peak direction	2+	
	I-90	2 lanes; reversible; barrier-separated (includes a short 2-way section)	24 hours except for reversal times	Varies by location	
		1 lane each direction; concurrent; no buffer	24 hours	2+	
	SR 167	1 lane each direction; concurrent; no buffer	24 hours	2+	
	SR 520	WB shoulder lane; concurrent; no buffer	24 hours	3+	
	I-405	1 lane each direction; concurrent; no buffer	24 hours	2+	

¹ Summarized from interviews and the *HOV Systems Manual* (1)² For all agencies, personnel in the field make the decision to use the HOV lane for diversion.

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THE USE OF DYNAMIC MESSAGE SIGNS FOR DIVERTING TRAFFIC DURING FREEWAY INCIDENTS

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ABSTRACT

As metropolitan areas continue to develop incident management programs, the ability to provide reliable information for the diversion of traffic from freeway incidents becomes crucial. Drivers require complete and reliable information to make informed choices while traveling, and this is where the use of dynamic message signs becomes critical for the diversion of traffic during freeway incidents. The amount of information that can be provided through the use of dynamic message signs is greatly influenced by the short time period in which the motorist will be able to view the dynamic message sign.

The objectives of this research were to establish the current practices and messages for dynamic message signs when used for traffic diversion due to incidents and the rationale behind these messages. This information was then examined to develop guidelines regarding what steps need to be taken to allow for diversion. This was accomplished through the use of a survey. Six state Departments of Transportation were contacted to establish their use of dynamic message signs, and the obstacles faced with regards to diversion. Also, a literature review was completed to determine message content for the advisory messages provided for traffic diversion. This literature review found that the following components are necessary in an advisory message:

- a problem statement (incident description);
- location;
- an effect statement (major delay, etc.);
- an attention statement (addresses a certain group, not always necessary); and
- an action statement (what the motorist should do).

The analysis of the survey results showed that most agencies are not able to provide specific diversion information due to one or more of the following factors:

- a lack of available capacity on the roadways that will be used for diversion;
- a lack of real-time traffic information on the diversion roadways that would not allow the controlling agency to know if they were sending motorists to congested areas;
- a lack of available surveillance equipment for providing any traffic information to the controlling agency;
- a lack of alternative routes which would allow for convenient diversion of freeway traffic; or
- a lack of coordination between the local and state jurisdictions does not allow for the shifting of freeway traffic to roadways under local jurisdiction.

Using these issues as a foundation, the author established guidelines for the development of a diversion plan with emphasis given to how dynamic message signs will be applied in these situations. These guidelines were then applied to a case location in order to illustrate the application of a diversion plan.

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INTRODUCTION

As metropolitan areas throughout the nation advance in the development of incident management programs, the ability to provide reliable information to drivers becomes crucial. For programs that are diverting traffic from freeways, it is important to provide effective signing to both inform drivers of an incident and to successfully guide them around the incident. One way for agencies to distribute this information is through the use of dynamic message signs on the freeway system.

Incidents, and the resulting congestion on a freeway, create unexpected conditions for drivers and are therefore potential areas where safety hazards and excessive delay can result if drivers are not informed of the situation. The use of dynamic message signs for providing information to drivers when an incident disrupts the normal flow of traffic on a facility can alleviate many of the safety and delay problems associated with the disruption. Dynamic message sign messages can be presented in several different ways to provide a motorist with information regarding roadway conditions or diversion. The messages given during major freeway incidents can be divided into three classes based on whether the message provides:

1. A basic indication of congestion due to an incident;
2. An indication of an incident plus a recommendation to take a non-specific alternative route; and
3. An indication of congested conditions along with a specific alternate route.

The extent of the information to be provided for the diversion of traffic is often a point of inconsistency among agencies who operate dynamic message signs. Given that a driver desires to have as much accurate and useful information as possible, it is important to determine what information is currently being provided during major incidents on a freeway, and if there is any diversion information being included. Also, the rationale used when determining if traffic should be diverted from an urban freeway needs to be established to find a means of enhancing the use of dynamic message signs for this purpose.

Credibility must be considered in the use of dynamic message signs for the diversion of traffic during major freeway incidents. If messages become inconsistent or unreliable with regard to the information being provided, motorists are less likely to employ the information for diversion. For this reason, it is important to check the validity of an incident report before providing diversion information. Also, if traffic is being diverted, it is important to establish convenient and reliable routes so that motorists do not feel that they are being lead into worse conditions on the diversion routes or being taken a great distance out of their way. This feeling is greatly dependent on previous experiences that the motorist has had with the reliability and credibility of the information provided by dynamic message signs.

Problem Statement

Operating under the philosophy that drivers require complete and reliable information to make informed choices while traveling, it becomes necessary to provide the greatest amount of accurate information possible without confusing the driver. One way to accomplish this is to provide the information through the use of dynamic message signs. The amount of information that can be provided is greatly influenced by the short time period, approximately eight seconds, in which the motorist will be able to view the dynamic message sign (1). In order to provide the necessary information, one must understand the rationale behind the messages which are currently being used with dynamic message signs for diversion of traffic during incidents so that guidelines can be developed for the use of dynamic message signs under these conditions.

Objectives

The research contained in this report was conducted in order to achieve the following objectives:

- Establish the current practices and messages for dynamic message signs when used for traffic diversion due to incidents.
- Determine the rationale being used by operating agencies with regard to what diversion information is or is not being provided.
- Draw conclusions as to the obstacles which inhibit an agency's ability to provide diversion information based on the established practices and rationale of the providers.
- Develop guidelines regarding what steps need to be taken to allow for diversion information to be provided to drivers.
- Apply guidelines to a case location.

Report Organization

This report is divided into six sections. This section contains the objectives and study approach for the report. Following is a section which explains the method of study which was used during this research. The next part is the background section that includes a discussion of the content of advisory messages displayed on dynamic message signs.

Section 4 begins the summary of the research results. This portion includes information regarding how incidents are being detected, what type of messages each agency is employing during major freeway incidents, and the obstacles that stand in the way of displaying diversion information. Section 5 uses these data to establish guidelines for the use of dynamic message signs for diverting urban freeway traffic during major incidents. Section 6 continues this by taking these guidelines and relating them to a particular city as a case location. Finally, there is a summary section which highlights the main points developed in the research.

METHOD OF STUDY

Literature Review

A search of current literature was done in order to establish message content for dynamic message signs. The type of messages investigated were advisory message, which are the messages given for the diversion of traffic. The information gathered in this search is presented in the Background section of this report.

Data Collection

The data collection effort consisted of conducting a survey of several transportation management centers to establish the current practices for the use of dynamic message signs for the diversion of traffic during major freeway incidents. The survey was conducted by telephone using a survey form (see Appendix) designed to keep a consistent method of questioning. The individuals contacted have a direct connection to the operation of the dynamic message signs for their area. The individuals were asked several question to determine what type of messages are being provided and the rationale and/or policy used for the determination of the messages displayed using dynamic message signs. Questions were also asked with relation to the detection of incidents and obstacles which interfere with the diversion of traffic through the use of dynamic message signs. Table 1 is a list of the individuals contacted and the organization with which they are associated.

Table 1. Survey Contacts

Contact	Organization
Mark Demidovich	Georgia Department of Transportation
Glen Carlson	Minnesota Department of Transportation
Brian Dobbins	Washington Department of Transportation
Joe Contegni	New York State Department of Transportation
Gregory Damico	California Department of Transportation
Carlton Allen	Texas Department of Transportation

Data Analysis and Application

The information presented in the Study Results section was examined to determine the current practices of each of the organizations with regard to the use of dynamic message signs for the diversion of traffic during freeway incidents. The results of the analysis are found in the form of guidelines for the use of dynamic message signs in diverting traffic. A case study for the proposed guidelines is presented to illustrate the proposed process.

BACKGROUND

When dynamic message signs are used during urban freeway incidents, the types of messages which are displayed are categorized as advisory messages. This indicates that the sign is displaying real-time information about the freeway conditions and also suggesting a course of action to the driver. Such signs should be located on the freeway prior to critical decision points, at entrance ramps, or on arterial streets approaching the freeway (2). This use of dynamic message signs for incident information has the potential to either increase or decrease the performance of the system depending on the accuracy and timely use of the dynamic message. If the message is accurate and useful, the credibility will increase; but, the opposite is also true, if the information is not accurate it can decrease the credibility of the system (3).

The main purpose of advisory signs is to provide drivers with an adequate amount of information to allow for informed decisions to be made. Knowing this, the messages should contain the following elements to be effective: (2)

- a problem statement (incident description);
- location;
- an effect statement (major delay, etc.);
- an attention statement (addresses a certain group, not always necessary); and
- an action statement (what the motorist should do).

An example of this type of message is as follows:

ACCIDENT	(problem statement)
AT MILLER RD	(location)
MAJOR DELAY	(effect statement)
USE SECOND AVE	(action statement)

To allow for a driver to read, understand, and make decisions based on these messages, they must be short and concise due to the short period of time in which the driver will be able to read the message. With this in mind, trade-offs must sometimes be made as to the information which can be provided during this time period. The minimum components which can be provided and still be effective for decision making when trying to divert traffic are a problem statement, location, and an action statement (2). An example of this abbreviated message follows.

ACCIDENT
AT MILLER ROAD
TAKE SECOND AVE.

A second possible type of brief message would be to provide a problem statement and a generic indication to take an alternate route. This type of message would appear as follows.

ACCIDENT
AT MILLER ROAD
TAKE ALTERNATE ROUTE

The second type of brief message allows the driver to make the decision about if and how he/she is going to divert around the incident. This type of message would encourage diversion only by drivers who are familiar with the area and had enough knowledge about the local roadways to feel comfortable leaving the freeway.

SURVEY RESULTS

Agencies have determined independently how they feel dynamic message signs can best be used for providing information to drivers. This section outlines how the given metropolitan areas are currently handling the use of dynamic message signs for the diversion of traffic during major freeway incidents. A summary of the survey results can be found at the end of this section in Table 2.

Atlanta, Georgia

Incident Detection and Verification

As mentioned previously in the Background section of this report, credibility is a major issue when using dynamic message signs. With this in mind, it is important to have a reliable method for detecting and validating the occurrence of freeway incidents prior to displaying messages using dynamic message signs. The Georgia Department of Transportation uses several different methods for obtaining these facts. Primarily, detection is accomplished through the use of Autoscope video cameras, which are placed every one-third of a mile along a portion of the freeway system. The Autoscope video cameras are able to provide information regarding freeway speeds, traffic counts, and occupancy to the transportation management center. The traffic information is then processed to indicate where traffic is moving normally or where there is a problem. Once a problem has been detected using Autoscope, it is verified through the use of closed circuit television cameras which can be rotated to look at the section of road that is in question. The verification process allows the transportation management center to determine the cause of a slow down or the severity of an incident and road conditions. Also, incidents are detected by motorists on the freeway who call the transportation management centers or by the highway emergency response operators (HEROS) who work for the Department of Transportation patrolling the freeways to be able to help when a problem arises. Again, any accident which is reported is verified using closed circuit television cameras (4).

Dynamic Message Sign Usage

Once incidents have been identified and validated, the question of how best to provide information regarding the incident becomes crucial. In the Atlanta area, the Georgia Department of Transportation operates forty-one dynamic message signs. The following list contains the main locations for the dynamic message signs in the Atlanta area (4):

- On I-75 and I-85 inside of the I-285 loop. Located every five to six miles. Also, there is one sign on each of these interstates prior to I-285 headed towards downtown;
- On I-20 there are four signs, two approaching I-285 and two approaching I-75/85 downtown;
- Two signs on SR 400 SB inside the I-285 loop;
- One sign on SR 166 EB approaching I-75/85;

During approximately 80 percent of the incidents which are handled using dynamic message signs, the message contains:

- an indication of a problem; and
- a non-specific suggestion to use an alternative route.

An example of this type of message is as follows (4):

ACCIDENT ON I-85 NB
3 MILES AHEAD
USE ALT

The remaining 20 percent of the time, a message is given that contains:

- an indication of congested conditions; and
- a specific alternative route for the motorist to take.

An example of this type of message would be (4):

ACCIDENT ON I-75 NB
1 MI N OF MAIN ST
USE US 41 AS ALT

A specific route is only indicated when the traffic conditions of the alternative route are known. For the Atlanta area, this is possible for particular routes due to an extensive arterial detection system that is in place, this is not the case in many other metropolitan areas. The arterial detection system consists of closed circuit cameras that allow for an operator to manually look at the section of roadway that is in question. Even with this detection system though, specific routes are not always given for a couple of different reasons:

1. The layout of the Atlanta metropolitan area lacks convenient alternative routes available for diversion from the freeway system.
2. It is the feeling of the Georgia Department of Transportation that, because they can not be sure of the destination of the motorists, diverting them on a specific route may take a motorist out of their way or possibly get them lost (4).

One eyewitness account of an incident on an Atlanta freeway provided the following information regarding the use of dynamic message signs. This demonstrates that diversion information was not always provided on the dynamic message signs during this incident. The following are the messages which were provided by the dynamic message signs in that area (5):

Sign 1:
ACCIDENT AHEAD
4 MILES

Sign 2:
ACCIDENT AHEAD
2.5 MILES

Sign 3:
3 RIGHT LANES
BLOCKED

Obstacles for Diversion

In the Atlanta metropolitan area, the main obstacle faced for the diversion of traffic from the freeway system is a lack of convenient alternative routes. Also, the Georgia Department of Transportation considers the following factors to be obstacles to the use of dynamic message signs to divert traffic:

- a lack of real-time traffic information on the alternative routes;
- a need to coordinate the local and state agencies to make diversion from one jurisdiction to another possible.

The real-time information from the arterials for diversion purposes is not yet possible for the Department of Transportation. Although there are detection loops on the arterial roadways, this information is not being sent to the transportation management center for use in incident detection at this time. Without this information it is not always possible to know the conditions of the roadway which will be used as a diversion route. This limits the ability of the agency to divert traffic off the freeway (4).

The Georgia Department of Transportation has a good working partnership with the local agencies. Through the help of the state Department of Transportation, the local agencies were able to establish their own

transportation management centers. This has created a relationship of cooperation between the different agencies which created the working partnership among the agencies. Due to this partnership, the Department of Transportation is able to work with the county to be able to coordinate the signal timing for arterials to accommodate the addition traffic created through the diversion of freeway traffic due to an incident. Without this coordination, the benefits of diversion would be reduced for the freeway traffic (4).

Minneapolis, Minnesota

Incident Detection and Verification

Again, detection and verification of incidents is the first step to providing the valuable information possible via dynamic message signs. In Minneapolis, 90 percent of the incident detection is accomplished by way of cellular 911 calls from motorists. The calls are then verified through the use of closed circuit video cameras which are located on the freeway system. The Department of Transportation operates 210 of these cameras in the area. Also, there are loop detectors located throughout the freeway system that can show if there is a slow down in traffic speeds which may indicate that there has been an incident near that location. Again, the incident is verified through the use of the closed circuit cameras. The final method employed by the Minnesota Department of Transportation for incident detection is through the use of a Highway Helpers program. The Highway Helpers patrol the freeway system during critical hours of the day and are able to report an incident directly to the transportation management center (6).

Dynamic Message Sign Usage

Once the incident conditions are established, the Minnesota Department of Transportation then uses their dynamic message signs to provide information about an incident, and suggests the use of a non-specific alternate route. The dynamic message signs are ideally located a mile or two upstream of the major decision points such as freeway to freeway interchanges. The messages shown on the signs provide the following information:

- a problem statement;
- location of the problem; and
- an action statement that either indicates that the motorist should take a non-specific route or listen to the traffic radio station.

One specific example of the messages provided is as follows (6):

ACCIDENT
AT FRANCE AVE
USE OTHER ROUTES

Specific diversion information is never provided by the Minnesota Department of Transportation through the use of dynamic message signs. Specific alternate routes are provided using the traffic radio, but it is phrased as a suggestion and never as a mandatory action such as "consider taking...". Also, by using the radio, it is possible to provide several different suggestions for alternate routes. This lessens the possibility of overwhelming certain local streets by diverting all of the freeway traffic to that area (6).

The traffic radio broadcast is made possible through a partnership created between the Minnesota Department of Transportation and the public schools in Minneapolis which allows the transportation management center to use the radio station run by the public schools as a means of providing traffic information. These traffic reports are broadcast from the transportation management center every eight minutes during normal roadway conditions, and continuously if there is a major incident on the freeway system (6).

Obstacles for Diversion

The obstacles which face the Minnesota Department of Transportation for the diversion of traffic from the freeway system during incidents includes a lack of information about the traffic conditions on the roadways that will be used as diversion routes. Without this information, drivers could be sent towards worse conditions than they are experiencing on the freeway and the Department of Transportation would be unaware of this problem.

Another problem which was stated was that the dynamic message sign message must be very short. This does not always allow for enough room to clearly state the information necessary to divert traffic (6). As mentioned previously, a driver is only able to observe the sign for approximately eight seconds. All information necessary must be seen in this short period of time.

A final obstacle experienced by the Minnesota Department of Transportation is creating a diversion plan that encompasses all of the local and state agencies. This requires an integration of the transportation management centers for the cities and counties with the state. This plan is necessary to allow for the smooth diversion of traffic by including arterial signal timing plans as well as messages to the diverted traffic to allow for movement through the area with the least possible delay (6).

St. Paul, Minnesota

The DIVERT (During Incidents Vehicles Exit to Reduce Travel Time) project in St. Paul, Minnesota provides traffic guidance and control during freeway incidents. The main objectives of this test project are to increase freeway capacity during major freeway incidents, to manage traffic flow during freeway incidents, to apply new technologies, and to improve institutional interaction and cooperation. The project encompasses the area of I-94 & I-35E, which are intersecting freeways at this location, and the central business district of St. Paul, and uses three major arterials to divert freeway traffic. The diversion routes include: Kellogg Boulevard, a major signalized arterial providing diversion capability to the south and west sides of downtown St. Paul; and a pair of one-way arterials, 11th and 12th Streets, which provide additional capacity on the north side of St. Paul. Dynamic message signs are one component of the guidance sign system used to divert motorists around the incident. The system includes four dynamic message signs at locations prior to each major decision point for the traffic diversion from the freeways. The dynamic message signs for this plan are located at the four major decision points along the selected corridor (7):

- on I-35 on the east and west sides of town,
- on I-94 headed towards downtown from the west, and
- on US 10 going to downtown from the east.

Additionally, coordinated signal timing plans along the designated diversion routes in downtown St. Paul manage the diverted traffic to minimize congestion. Thus, the diverted traffic is accommodated in a planned fashion, as opposed to randomly entering the downtown area (7).

The information provided on the dynamic message signs used in the DIVERT project includes:

1. An indication that there has been an incident;
2. The freeway name where the incident is located, this is necessary since the two freeways are joined at this point, and
3. The exit that needs to be taken to bypass the incident.

This information is provided using two separate frames for the text on each dynamic message sign. This is the maximum recommended number of frames for this speed of traffic. An example of these messages is as follows (7).

Frame 1:
INCIDENT
AHEAD
94 EAST

Frame 2:
BYPASS
EXIT
241A

Seattle, Washington

Incident Detection and Verification

The policy of the Washington Department of Transportation indicates that dynamic message signs are only to be used during incidents if the incident can be visually confirmed by the controlling agency (3). The detection of incidents for the Washington Department of Transportation in the Seattle area is accomplished primarily through the aid of the state patrol computer aided dispatch system which receives cellular calls from motorists. The state patrol receives information regarding lane blockage, disabled vehicles, and accidents, and then prioritizes them by location and length of the affected traffic stream. The remainder of the incidents are identified using loop detectors which then feed information to a traffic flow map based on occupancy. Both information gathered by each method of detection is then verified using closed circuit video cameras located on the freeway system (8).

Dynamic Message Sign Usage

The Washington State Department of Transportation has published guidelines for the use of dynamic message signs in this state. Using these guidelines, it is established that the use of dynamic message signs during times of incidents are either third or fourth priority issues. The priority order for the use of the dynamic message signs is as follows (3):

1. Dedicated lane control and regulatory dynamic message signs.
2. Safety-related (example: flammable restrictions for tunnels).
3. Roadway closures.
4. Minor traffic impacts.
5. Public service announcements.
6. Test Messages.

When using dynamic message signs during times of incidents, the Washington Department of Transportation in the Seattle area generally provides the following information:

- incident location;
- type of incident, and
- where the congestion due to the incident begins.

Occasionally, a suggestion to take a non-specific alternate route will also be given. This is typically done only when the entire road is blocked due to the incident. Although, if diversion does become necessary, it is the policy of the Washington State Department of Transportation to divert traffic only to another state route, or with approval of the route operator (3). The Department of Transportation in this area considers it risky to routinely divert traffic around an incident due to the extreme amount of congestion already present on the local roads, and due to the limited number of alternative routes which are available to the motorist (8).

Although, the Department of Transportation does maintain a real time traffic map as part of their web page in order to allow people to obtain this information and decide on their own what is the best route to take. As well as providing the local media with incident information so that they can provide information to the motorists (8).

Obstacles for Diversion

The primary obstacle faced by the Washington Department of Transportation in the Seattle area is the lack of alternative roadways available for diversion. Seattle has a lake situated in the center of the metropolitan area which greatly reduces mobility in this area. The lake creates a natural obstacle to traffic and reduces the number of possible roadways across this area. Seattle has two main interstates running north to south which are separated by the lake, and two routes across the lake from the east to the west (8).

A second obstacle is that the local roadways which are available in Seattle already have a high level of congestion and would not be able to easily accommodate the additional traffic created by the diversion of freeway traffic onto the local arterials. Also, the Department of Transportation has made an agreement with the local agencies to avoid diverting traffic through these areas (8).

Due to the indicated obstacles for diversion, the Department of Transportation prefers to allow the state highway patrol to handle any necessary traffic diversion once they have established if it is necessary at the incident sight and the Department of Transportation is focused on the more efficient clearing of the incident from the roadways (8).

Long Island, New York

Incident Detection and Verification

The detection system being used by the New York State Department of Transportation includes the use of loop detectors as the primary form of detection. The problem areas which are detected through this method are then verified using closed circuit television cameras located on the freeway system. Also, they operate a roving patrol on the freeways during the weekday peak hours in order to help motorists as well as report incidents. Finally, the Department of Transportation is in contact with the state police and are given information from this agency on incidents that have occurred (9).

Dynamic Message Sign Usage

INFORM (Information for Motorists) is the advanced transportation management center which controls the operation of the dynamic message signs in the Long Island area. This area has 100 dynamic message signs under its supervision for use in traffic control. Once an incident is detected, these dynamic message signs are used to convey information to the driver. Depending on the situation, an indication of congestion is provided along with either a non-specific or a specific alternative route suggested. Alternative routes are only specified by INFORM when they are confident that the specific route is flowing freely. INFORM has chosen to provide these specific route recommendations because they believe that motorists are more likely to divert when given a specific diversion route, and this will help to alleviate the problems created on the freeway as a result of an incident (9).

INFORM estimates that delay savings due to increased motorist information reach as high as 1900 vehicle-hours for an incident during the peak period. It has been found that 5 - 10 percent of the drivers will divert when messages are displayed which only include an indication of an incident, and twice as often when messages include diversion information. Convenient alternate routes greatly impact the percentage of motorists who will use diversion routes (10).

Obstacles for Diversion

In Long Island, the INFORM system has already implemented a freeway traffic diversion plan, and therefore has overcome many of the obstacles which face areas that have not developed this plan. INFORM holds that area-wide transportation management can only be achieved through the coordinated efforts of a variety of agencies. Accordingly, the program places a strong emphasis on establishing inter-agency partnerships (10).

The major obstacle which was pointed out by the New York State Department of Transportation is that the dynamic message signs are not always functioning properly. In the INFORM system, there has been occasional communications problems between the transportation management center and the dynamic message signs which does not allow the displaying messages (2).

Los Angeles, California*Incident Detection and Verification*

Detection of freeway incidents in the Los Angeles, California area is accomplished remotely through the use of loop detectors and other sensors located on the freeway system. This allows for the California Department of Transportation to obtain traffic data from the transportation management center without having patrols at all locations. Verification of incident information is done using closed circuit video cameras which are controlled by the transportation management center when available, or by a field patrol. There are also observations of incidents reported from the field patrols who are in two-way communication with the transportation management center. These observations do not need to be verified (11).

Dynamic Message Sign Usage

In Los Angeles, the Department of Transportation uses dynamic message signs only as a way of providing information about (11) :

- the location of an incident; and
- the number of lanes which may be closed due to that incident.

It is the policy of the California Department of Transportation not to recommend alternative routes to motorists during incidents on the freeway for the following reasons (11):

- There is an absence of continuous one-way frontage roads adjacent to most freeway segments;
- No access to real-time traffic flow information on local streets;
- Diverted freeway traffic volumes could cause congestion on local streets;
- Motorists tend to get confused and lose their direction in unfamiliar local area;
- The number of motorists is extremely large and their ultimate destinations are unknown.

It is left as the job of the traffic reporting media to provide any available information with respect to possible diversion around an incident. This was decided due to the fact that the media are able to obtain real-time traffic conditions for the local streets, and can therefore provide better information with respect to diversion than is available to the Department of Transportation (11).

Obstacles for Diversion

Along with the policy problems stated above, the California Department of Transportation listed the following as the primary obstacles faced for the diversion of traffic during a freeway incident (11):

- coordination with local agencies;
- lack of real-time traffic information on parallel local agency facilities;
- lack of interconnection with local traffic control systems; and
- lack of closed circuit cameras or helicopter surveillance by the Department of Transportation on alternative routes.

With these problems in mind, the California Department of Transportation suggested that the steps necessary to allow for the diversion of freeway traffic would be to implement an integrated corridor management system. This would allow for a diversion plan to be carried out from one location with ease. Also, they suggested a need for real-time surveillance of city street traffic flow conditions.

Houston, Texas

Detection and Verification

The transportation management center in Houston, Texas has several different methods that are used for the detection and verification of incidents on the freeway system. The first method of detection is through the use of the automated vehicle identification system which can use the data gathered from vehicle tags to determine freeway speeds. Detection is also done using closed circuit television cameras which broadcast into the transportation management center. These cameras are also used in the verification of many reported incidents. Other methods of detection include alerts from the motorist assistance patrols, agency field personnel, public calls to the transportation management center, and law enforcement reports. Further verification of these reports can be done by either having multiple reports of the same incident, or by having other field personnel visually verify the incident (12).

Dynamic Message Sign Usage

The use of dynamic message signs in the Houston area greatly depends of the location of the incident in question. If the incident is located at a point where there is no alternative route available based on the location of the dynamic message sign, then the information provided via the dynamic message sign is only an indication that there is an incident ahead, and possibly the related road conditions. The following message is an example of this type of situation (12).

ACCIDENT AHEAD
AT AIRLINE
RIGHT LANE CLOSED

Another possible situation is that the incident has occurred where the alternate route which is available based on the location of the incident and the position of the dynamic message sign would take the motorist, but the available route would take the motorist off of the state operated freeway system and onto roadways that are under a different jurisdiction. By the policy of the Texas Department of Transportation, this type of diversion requires the permission of the agency who controls the diversion route. At this point, the transportation management center is most likely to give a message which provided information that there has been an incident and a non-specific indication to take an alternative route such as illustrated in the following message (12).

ACCIDENT AHEAD
AT AIRLINE
USE ALT. ROUTE

The final scenario presented by the Texas Department of Transportation for the possible diversion of traffic during a freeway incident is that the incident is located at such a point that the traffic can be diverted to another

state roadway. This is the best possible situation for the agency since it allows them to divert traffic with the least amount of difficulty. At this point, a message such as the following with two frames of information would appear on the dynamic message signs in the area (12).

Frame 1:
ACCIDENT AHEAD
AT AIRLINE
RT. LANE CLOSED

Frame 2:
EXPECT DELAYS
USE HARDY
TOLL ROAD

Obstacles for Diversion

The Texas Department of Transportation stated that the main obstacle which keeps the agency from diverting traffic from freeway incidents is a lack of dynamic message signs in the proper locations. In order to allow for freeway diversion, the dynamic message signs need to be located prior to each major decision point, such as exits and interchanges. The location to the signs to the accident is the main deciding factor in what type of message will be displayed by the transportation management center (12).

Also, it is the policy of Texas Department of Transportation that diversion from the state's right-of-way requires permission of the agency who has jurisdiction for that roadway (12). Due to this policy, diversion from freeways to local arterials requires a strong working relationship between the local and state agencies.

Table 2. Survey Results Summary

Survey Question		Georgia DOT	Minn. DOT	Wash. DOT	NYS DOT	Calif. DOT	Texas DOT
Incident Detection	Closed Circuit Cameras				X		X
	Autoscope	X					
	Loop Detectors		X	X	X	X	
	DOT Patrols	X	X		X	X	X
	Public Calls	X	X	X			X
	Police			X	X		X
	AVI Tags						X
Incident Verification	Closed Circuit Cameras	X	X	X	X	X	X
	DOT Patrols		X		X	X	X
	Multiple Public Calls						X
Message Content	No message						
	Basic Indication of Incident			X		X	X
	Suggest Non-specific Alternate Route	X	X	X	X		X
	Suggest Specific Alternate Route	X			X		X
Diversion Obstacles	Coordination of Agencies	X	X			X	X
	Lack of Real-Time Traffic Information on Diversion Route	X	X			X	
	Short DMS messages		X				
	Not always a Convenient Diversion Route	X		X			
	Location of DMS						X
	Lack of Diversion Route Capacity		X	X			
	Malfunctioning DMS				X		

Note: X indicates an affirmative answer from the survey

GUIDELINES FOR TRAFFIC DIVERSION

In order to achieve success in the use of dynamic message signs for the diversion of traffic around freeway incidents, there must first be a great deal of planning, discussion, and development. In the process of creating a diversion plan, a thorough process must be developed to coordinate the affected roadways. The messages displayed by dynamic message signs are only one part of this process. The guidelines will focus on the issues associated with the use of dynamic message signs, and will touch only briefly on the surrounding issues.

The guidelines that follow are recommendations of the author and are based on the experiences and recommendations of the transportation management centers which were contacted. Added consideration has been given to the experiences of the INFORM and DIVERT systems which already have diversion plans being tested that incorporate the use of dynamic message signs on the freeways. The guidelines given here will focus on the steps needed to allow for diversion and how dynamic message signs are factored into this process.

Stage 1: Preliminary Planning

This stage of the development for a diversion plan should rely heavily on the forming of partnerships among different agencies in the area. If these partnerships are not established at the beginning phases of the planning then there may be later conflicts over the objectives of the traffic diversion and the handling of the increased traffic on local roadways.

1. Define the Corridor for the Diversion Plan

When an urban area is looking at beginning a diversion plan, they must first look at what corridors within this area need to establish a plan for traffic diversion. A few characteristics of corridors where these plans may be effective are as follows:

- The corridor is a main travel route for the area. This would imply that an incident on this roadway would have a noticeable effect on a large number of motorists, and it would be worth the department's time and expense to ensure the efficient travel through this corridor.
- The corridor has a history of severe traffic problems due to frequent incidents. This may include congestion as well as residual accidents due to the unexpected freeway conditions.
- The corridor has convenient roadways to create an easy diversion route for the freeway traffic.

2. Forming Partnerships

Once the diversion corridor has been established, it is now necessary to determine what agencies will need to be involved in the diversion plans due to roadway jurisdictions and work to establishing the necessary partnerships among these agencies. If these partnerships are not possible, then continuing to plan for diversion in this area would not be recommended. Only through partnerships can a diversion from the roadways of one jurisdiction of another run smoothly. When traffic is being diverted from the freeway, through the use of dynamic message signs, to a roadway which is operated by another agency it is necessary to have cooperation among these bodies.

3. Funding

The funding for a diversion plan would have to be worked through the agencies that are involved with the diversion routes. This funding will need to come primarily from the jurisdiction who will be diverting the traffic since this is the agency who will be receiving the most benefit from the project. Also, if the roadway being diverted is an interstate, federal funds would be suggested for the diversion plan.

4. Design Diversion Routes

Once the preliminary selection has been established for the diversion corridor, it is necessary to evaluate what would be the “best” diversion route for the corridor. This will involve the examination of the major roadways in the area to determine which ones would be most able to handle the additional traffic, as well as determining where on the freeway system it is going to be most beneficial to begin traffic diversion, and where traffic is being generated. If there is an area which historically has a high incident rate, this will need to be factored into the decisions for the selection of possible routes. Also, if there are already existing dynamic message signs which are going to be utilized, the location of these existing signs will need to be considered in the selection of diversion routes.

A few characteristics of the roadways used in the diversion plan which should be considered at this point are as follows:

- the roadway has adequate capacity to accommodate the traffic which will be diverted to it during major incidents on the freeway. If there is already a congestion problem on the suggested arterial it may be wise to look for another possible route.
- The route does not take the freeway motorist excessively out of their way or on a complicated path before allowing the motorist to rejoin the freeway at some point beyond the incident.
- When possible, the diversion routes stay within the agency’s jurisdiction.

Once a route has been selected as a diversion route, it will be necessary to establish a system for the detection of traffic conditions on this roadway. If this system is already in place, then it will only be necessary to connect this system to the state transportation management center to allow this agency to check the conditions prior to diverting traffic.

Stage 2: Development of Route Signing

Once a path has been selected for the diversion route, it is necessary to create a signing plan for that route. This would include both dynamic message signs along the freeway system as well as guide signs on the diversion route which would need to be in place when an incident occurs and makes it necessary to use this diversion route.

1. Freeway Signing

The first indication which will be given to a motorist of an incident ahead and the need to take an alternate route will come from the signs located prior to the major decision points for the selected corridor. Major decision points for the corridor will include exits from the roadway and major entrances to the roadway. These signs need to be in the form of dynamic message signs in order to allow for enough information to be presented for the motorist to make informed decisions as to their route selection.

The messages provided using the dynamic message signs would need to be short and concise while still providing enough information for the driver to make informed decisions. An example of this type of message would be as follows:

ACCIDENT
4 MILES AHEAD
TAKE EXIT 215

The message provides information regarding the problem ahead, the location of the problem, and also the action which should be taken by the driver.

2. Guide Signs

Once the traffic has been diverted from the freeway to the other roadways by the dynamic message signs, the motorists will still require guidance signs on the diversion routes to allow them to travel easily to the point of reentry to the freeway system. This could be accomplished in many different fashions. The first would be typical guidance signs located all along the route which indicate the direction which needs to be taken by the diverted traffic to return to the freeway. An example of this type of sign is presented in Figure 1.



Figure 1: Guidance Sign

Although, there is a drawback to using the standard guide signs on diversion routes. The signs are visible to traffic even when the routes are not being used for diversion and may cause some confusion if they are inappropriate except in diversion situations. St. Paul has solved this problem in their DIVERT program by using a sign called a Blank-Out Sign which contains the same information as the typical guidance sign, except it is a light-emitting diode sign, which means that when the diversion route is not being used for this purpose these signs can be turned off and will not cause motorist confusion. The only change that was made in the layout of the sign from the guidance signs shown above is that the words "Bypass To" were added since the only time these signs were activated was during times when traffic was being diverted from the freeway (Z).

Stage 3: Final Implementation

Once the entire diversion plan has been developed and the necessary partnerships have been formed among the state and local agencies, the urban area is ready to start implementing diversion measures. Although, it should be noted that if the diversion route is experiencing congestion prior to the diversion of traffic, it would not be recommended to implement the plan at that time. This would overload the diversion route and possibly create worse condition for the diverted motorists.

Steps which may be taken before the first incident occurs would be to test each of the dynamic message signs being used in the system to ensure that they are in working order when a major incident occurs. Also, the state agency will want to create a catalog of the messages which will be displayed for any possible incident situation which might occur to ensure that the activation of these messages is efficient once an incident has been verified.

Finally, it would be beneficial to the safety and efficiency of the diversion plan if there were a continuous evaluation of the plan to ensure that the choice of diversion routes was accurate and continues to be the best alternative for the diversion of the freeway traffic. This evaluation should be done by the controlling agencies to ensure that all of the proposed objectives for this plan are being met. Driver safety should be the main factor in this evaluation.

CASE STUDY - RALEIGH, NORTH CAROLINA

The guidelines presented in the previous section will now be applied to Raleigh, North Carolina as a case study to illustrate how dynamic message signs can be used to divert traffic on urban freeways during major incidents. This area was selected because of available information on the traffic patterns of this location. Before the guidelines are applied, it is important to provide some background on the City of Raleigh and the major traffic patterns which will be affected by the proposed diversion plan.

City of Raleigh

The City of Raleigh is located in central North Carolina and was established as the state capital in 1792. From 1980 to 1990, the area had a population growth rate of 53 percent, and now stands as the 55th largest metropolitan area in the United States. The current population for the City of Raleigh, estimated in January of 1998, is 269,591 (13).

The most prominent center for industry in the Raleigh area is Research Triangle Park. This facility is a planned research park that was created in 1959. Research Triangle Park encompasses 6,900-acres and is home to 131 organizations. More than 37,000 people are employed in this facility. Research Triangle Park's overwhelming success is evident in the 15 million square feet of developed space, and the fact that the park maintains a vacancy rate of less than 1 percent. Research Triangle Park is home to companies such as IBM, Nortel, and GlaxoWellcome (13).

Stage 1: Preliminary Planning

1. Define the Corridor for the Diversion Plan

The need for a diversion plan becomes evident when examining the routes which lead to the Research Triangle Park facility. The major route to this area is Interstate 40, which can easily be overwhelmed if there is a major incident during the commuting hours for the facility. With this in mind, the Interstate 40 corridor from the west side of Raleigh to Research Triangle Park becomes a potential area for the creation of a diversion plan. Available alternative routes that could be used for this purpose would include US 70 and NC 54. It should be noted, that the primary focus of this diversion is for the commuter traffic generated by the Research Triangle Park facility. This means that the driver population being targeted is familiar with the Raleigh area.

2. Forming Partnerships

The agencies that would be involved in this diversion would be mainly state agencies due to the fact that the diversion routes selected are not local roadways. This provides a greater simplicity for the governing bodies because fewer agencies will be involved in the implementation of the diversion plan. Although, the county will be minimally involved due to the placement of one dynamic message sign on a county roadway to help with diversion. Even though the city is not directly involved, it would be advisable for the state agency to be in contact with both the City of Raleigh and Wake County to ensure that if there are future problems or needs which require coordination with these agencies, the partnerships are established.

3. Funding

The funding for the Raleigh diversion project should be primary the concern of the North Carolina Department of Transportation since it is a state route which is being diverted. Although, since it is an interstate section, the federal Department of Transportation should be contacted for a portion of the necessary funding.

4. Establish Diversion Routes

The corridor which was selected is a section of I-40 which runs between the beltline to the west of Raleigh and I-540 just prior to Research Triangle Park. This segment, along with the diversion routes which will be discussed, can be seen in Figure 2. Note that due to the selected diversion routes, many of the motorists will be diverted prior to entering I-40.

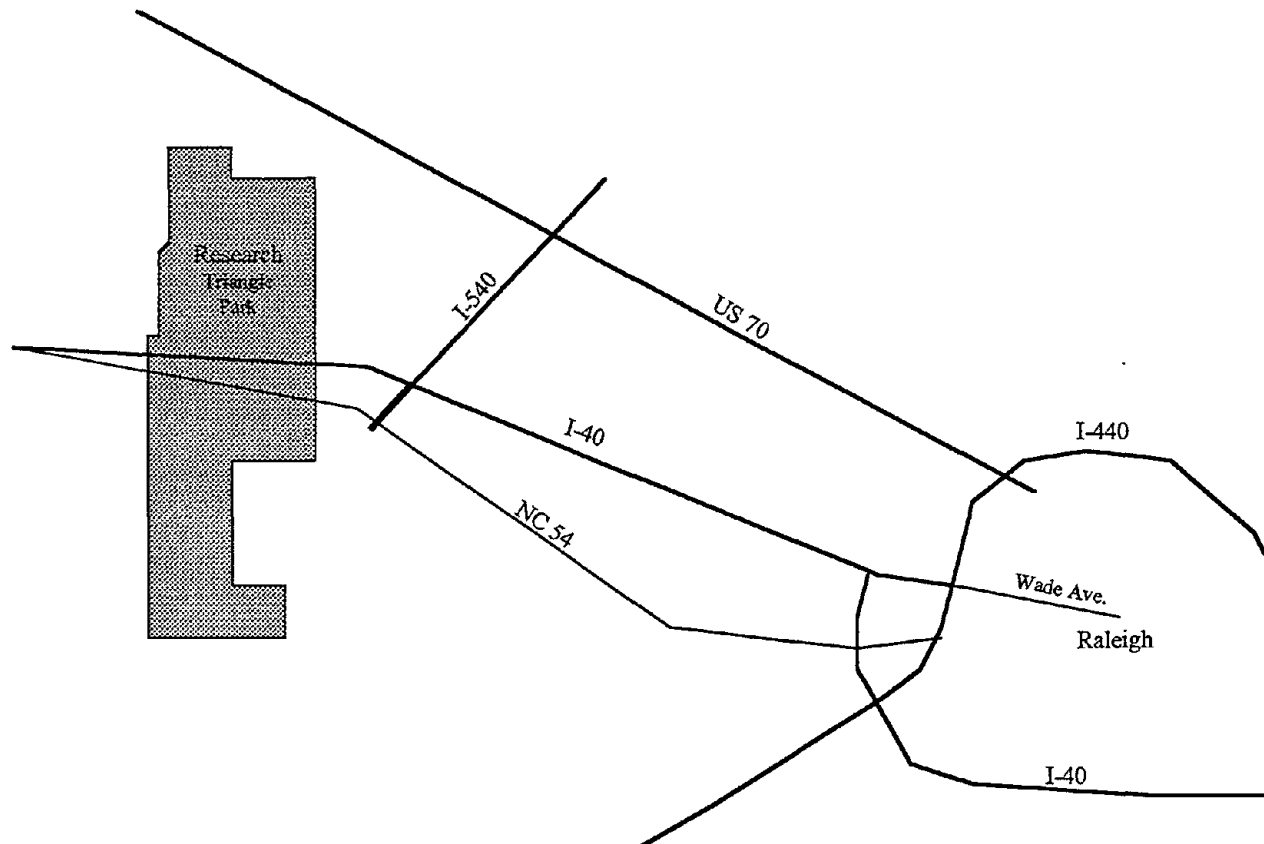


Figure 2: Case Study- Raleigh, North Carolina

In selecting the diversion routes, it was necessary to establish where the traffic was originating and determine what alternative routes would be convenient between these locations. Due to the location of the segment which was selected as the diversion corridor, the traffic could be approaching the segment from either the north portion of the I-440 beltline, or from the portion of I-40 that runs on the south side of Raleigh. For this reason, two different diversion paths were selected to best accommodate each direction of approaching traffic.

For the freeway traffic which will be approaching from the north side of Raleigh, it was decided that the best alternative route would be to divert the I-40 traffic to US 70 which runs parallel to I-40. Just prior to the Research Triangle Park, I-540 is available to allow traffic to move from US 70 back to I-40.

When the freeway traffic is approaching the diversion segment of I-40 from the south side of the City of Raleigh, it was determined that the best diversion option would be NC 54 that runs from I-40 near the beltline all the way to Research Triangle Park. For this route, if the traffic is headed for the research park, it would not have to return to the interstate, although this option is available by again using a segment of the newly constructed I-540 roadway just prior to the research park.

Stage 2: Development of Route Signing

1. Freeway Signing

For the plan which has been outlined above, there would be nine dynamic message signs needed to inform the approaching traffic of an incident on the selected segment of Interstate 40. They would be located at the following locations for the westbound traffic:

- On I-440 just prior to exit 7, this is the exit for US 70.
- On I-40 just prior to exit 290, this is the exit for NC 54.
- On Wade Avenue prior to the beltline. This would alert the traffic that enters I-40 from the downtown area. This installation would require the cooperation of the county because it is not located on a state route.
- On SH 54 prior to where it crosses I-40 so that traffic could be alerted to remain on NC 54.

For the eastbound traffic along this segment the following signs would need to be located on the freeway:

- On I-40 prior to Exit 281 for the traffic going to the south side of Raleigh using NC 54. This would also include motorists who would be remaining on I-40 continuing out of Raleigh to the east.
- On I-40 prior to exit 282 for the traffic headed to I-440 on the north side to Raleigh.

Also necessary for this plan are three dynamic message signs located on I-70 and I-540 to inform the motorist of the need to change interstates to follow the diversion route.

The locations of these dynamic message signs can be seen in Figure 3.

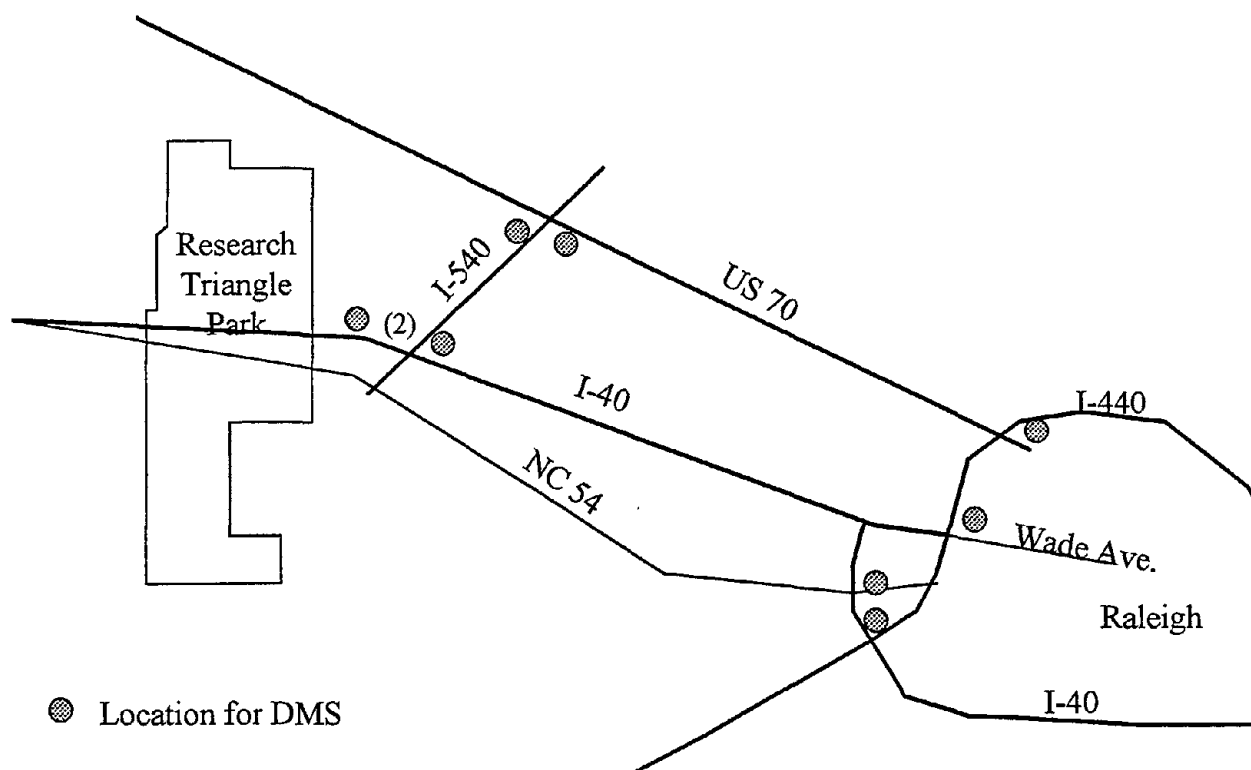


Figure 3: Dynamic Message Sign Locations

The messages placed on these signs would have to be carefully worded in order to be addressing the proper motorist destinations. The message would need to contain the following information as defined in the Background section of this report:

- a problem statement;
- location
- an attention statement; and
- an action statement.

An example of these messages would be as follows:

Frame 1:
ACCIDENT
2 MILES AHEAD

Frame 2:
BELTLINE TRAFFIC
TAKE EXIT 282

2. Guide Signs

The guide signs along the alternative routes could either be dynamic message signs or guidance signs located along the diversion routes. The best location for the dynamic message signs would be at the interchange of I-540 and US 70 for the traffic being diverted to the northern beltline. There would need to be guide signs located along the NC 54 route to ensure traffic that they were continuing on the proper path. These would serve best if they were the Blank-Out signs as explained in the Guidelines section of this report. It will also be advisable to place these along US 70 to avoid confusion for the motorist.

Stage 3: Final Implementation

Now that the routes have been set for the freeway diversion, and the dynamic message signs and guide signs are in place, it is critical that all of the components are tested prior to the first incident occurring that requires the use of the diversion routing. The signs should be able to be controlled from one central location such as the transportation management center. Also, the catalog of messages for the dynamic message signs should be programmed into the computer system. These messages should be available as soon as an incident has been detected and verified by the transportation management center. Once all of this equipment has been tested, the system is ready for use during a major freeway incident.

SUMMARY

The main obstacles that stand in the way of allowing for the diversion of freeway traffic around major incidents involve the following issues:

- lack of available capacity on the roadways that will be used for diversion;
- lack of real-time traffic information on the diversion roadways that would not allow the controlling agency to know if they were sending motorists to congested areas;
- lack of available surveillance equipment for providing any traffic information to the controlling agency;
- lack of alternative routes which would allow for convenient diversion of freeway traffic; or
- lack of coordination between the local and state jurisdictions does not allow for the shifting of freeway traffic to roadways under local jurisdiction.

Before an area can begin to divert traffic through the use of dynamic message signs, each of these issues must be addressed for that individual area. One of the main concerns when diverting traffic must be the credibility of the information provided. If a motorist is provided with consistent and accurate information through dynamic message signs, that person will be more likely to employ the recommendations given for diversion than if the information is frequently found to be inaccurate.

Once the above issues have been addressed, and it has been decided that the diversion of freeway traffic around major incidents is possible, message content must be considered. Some factors which will effect the message content include driver population (commuters vs. out-of-town traffic), location of available dynamic message signs with relation to the incident, and determining if a specific portion of the traffic needs to be singled out through the use of an attention statement. The consideration of these factors will allow for the most effective use of the available message space.

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APPENDIX

THE USE OF DYNAMIC MESSAGE SIGNS FOR DIVERTING TRAFFIC DURING FREEWAY INCIDENTS SURVEY

Name of Contact:

Name of Organization:

1. How are you detecting and validating freeway incidents?
2. a) What types of messages is your agency displaying on urban freeways for diverting traffic during incidents?
 - No message;
 - A basic indication of congestion due to an incident;
 - An indication of an incident plus a recommendation to take a non-specific alternative route; or
 - An indication of congested conditions along with a specific alternate route.

b) Why have you selected this type of message?
3. What are the primary problems or obstacles you face regarding the use of dynamic message signs for traffic diversion?
4. If you are not providing diversion information to motorists, what steps do you feel need to be taken in order to allow you to do this?

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ITS TECHNOLOGIES FOR EXPEDITING INTERNATIONAL BORDER CROSSING MOVEMENTS

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SUMMARY

The North American Free Trade Agreement has created a vast number of economic opportunities for the United States, Canada, and Mexico. These new economic opportunities have resulted in the increase of trading goods that need to be transported across national borders. Thus, the next step is to create an electronic environment that will eliminate paperwork, reduce errors, and speed clearance procedures in order to handle the increase in commercial traffic and squeeze extra capacity out of the existing border facilities. Various stakeholders of commercial traffic at international borders such as customs/immigration, custom brokers, shippers, carriers, and transportation agencies have moved towards the electronic environment by implementing the North American Trade Automation Prototype (NATAP). In addition, other border clearance programs are being examined to address other issues.

The objectives of this research were to evaluate the border clearance technology at the NATAP sites, recommend any changes that could improve conditions at these sites, and study the Pacific Northwest border crossings to determine if Intelligent Transportation Systems (ITS) technology is warranted.

To accomplish the objectives of the research, a literature review on border issues and the status of the border clearance initiatives was performed. In addition, a telephone survey of individuals in the public and private sector familiar with border crossing issues was conducted to obtain an insight from their personal experiences.

The evaluation showed that the border initiatives have taken the first steps towards an electronic environment. However, it is recommended that NATAP needs to become more user friendly, to move into a pilot stage, and to incorporate additional border clearance requirements in order to achieve its potential. Pre-clearance commuter programs were found to be successful and should be considered at more locations. After evaluating the NATAP sites and studying the Blaine, Washington/Douglas, British Columbia border crossing, it is recommended that the implementation of commercial vehicle clearance programs should not be made at the moment, but it is encouraged that ITS technologies should be looked into for performing commuter pre-clearance.

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INTRODUCTION

With the ratification of the North American Free Trade Agreement (NAFTA), an opportunity of easing the movement of goods and people across the borders of Canada, the United States (U.S.), and Mexico has been provided. Although the main objective of NAFTA was the reduction in tariff barriers, Article 512 of the treaty states that "to the extent possible the three Parties shall cooperate, for the purpose of the facilitation of the flow of trade, the harmonization of documentation, standardization of data elements, the acceptance of an international data syntax, and the exchange of information" (1). Studies show that U.S./Canadian trade is projected to increase by up to 25% by 2002, and U.S./Mexican trade is projected to increase by an estimated 170% by 2002 and continue to increase (2). Also, NAFTA will encourage industrial border zones which could lead to an increase in commuter travel through border crossings. As far as recreational travel, it is very difficult to predict because the exchange rate for the currencies of the three countries will determine the levels of such travel activity. However high passenger vehicle volume is still expected, so immigration clearance procedures for these commuters and tourists would need to be expedited to achieve efficient traffic operation. Thus, it is imperative that measures are taken to ensure smooth border crossing operations otherwise long queues, loss of valuable time, and higher costs of goods will result (3).

With this expected increase in traffic activity and the existing delays at border crossings being caused due to the high volume of trade, complexities of inspection requirements, and poor cargo clearance procedures, organizations involved in the three countries are investigating the role that Intelligent Transportation Systems (ITS) can play in expediting border crossing movements. At the moment, there are six border locations (two along the U.S./Canadian and four along the U.S./Mexican borders) where Automated Border Crossing Systems (ABCS) are being tested through the North American Trade Automation Prototype (NATAP) which is not intended to be a final, complete system but a proof-of-concept of how North American trade processes and systems could function. Thus, NATAP is a low-volume test of new concepts with a limited number of participants. As of now, NATAP is limited to land border truck and rail crossings; however, successful concepts are intended to be adapted for air and sea scenarios (1).

Because NATAP is a field demonstration, it began operating in parallel with the existing customs systems: Automated Customs System (ACS) – U.S., Cargo Control System (CCS) – Canada, and Sistema de Automatizacion Aduanera Intergral (SAAI) – Mexico. The extent to which each government extends the functionality of the system for testing other agency requirements or to experiment with other processing systems was determined by each customs administration (1).

In addition to NATAP, a number of other border clearance initiatives have been introduced to address other issues such as commuters and commercial vehicle safety.

Problem Statement

The NATAP program had to overcome a number of institutional barriers to even be implemented, so it is important to evaluate the program to assess whether the expected improvements in relation to border crossing efficiency have been accomplished. If the expectations have not been met, an analysis into the reasons why the expectations have not been met should be performed. Also, it is important to contact the parties that are involved at these border crossings such as carriers, brokers, toll collectors, and customs/immigration officials to see if they are all satisfied with NATAP. In addition, other border clearance initiatives existing at the NATAP sites should be examined to observe their effect on border operations. These issues are important to address in order to expedite the movement of goods and people across national borders.

Study Objectives

The primary objectives of this paper were to:

1. Evaluate the current operational performance of the six NATAP border crossings.
2. Analyze ABCS technology that has been implemented at the mentioned border crossings.
3. Recommend changes to improve conditions at these sites if warranted.
4. Recommend a border crossing plan with ABCS technologies, if warranted, as a case study for the border crossing which accommodates the Seattle, Washington – Vancouver, British Columbia area most directly.

Study Scope

This study focused on the six highway border crossings that are participating in NATAP. In addition, the U.S./Canadian border crossing in the Seattle/Vancouver area was studied in order to see if an ITS border crossing is warranted. The necessary data were collected by interviewing by telephone the appropriate individuals and by available literature.

Study Methodology

The following tasks were performed to fulfill the objectives of this research:

1. Review Literature

The review of literature was conducted to obtain a background on the type of electronic systems that have been used to perform various traffic operation functions at border crossings and information on the status of border crossing initiatives. A major source of literature was the Internet where the most recent information could be found. The literature review focused on the following topics:

- ABCS methods and expected benefits,
- Current evaluation of the methods in place, and
- Vehicle flow rates and traffic flow problems.

2. Conduct Telephone Interviews

Qualitative data were collected through a telephone survey. Individuals from private and public sector organizations were reached to obtain their opinions and comments regarding ITS technology. The questions attempted to obtain the professionals' opinions on:

- The traffic operation effectiveness of the current ITS technologies,
- The changes that would improve border crossing movements, and
- The various types of ITS technology developed specifically for border crossing movements and their advantages.

3. Case Study

Based on the findings from the NATAP sites, an analysis was completed to determine if ITS technologies can be used at border crossings in the Seattle/Vancouver area. As part of the analysis, the ABCS site selection criteria developed by a previous study were applied at the Pacific Northwest border crossings to determine if the criteria were applicable and ABCS technology is warranted (4).

Study Organization

This research report is composed of several sections which primarily deal with NATAP. However, other border initiatives are looked into, and a case study is presented to determine if ABCS would benefit the border crossing operations in the Pacific Northwest.

Following the Introduction, the Description of NATAP section presents the key elements, potential benefits, and the participant requirements of the prototype. The next section provides a description of other border clearance initiatives which explains the details and potential benefits of these programs that have been considered for implementation at the NATAP sites. It was considered important to obtain insight into these projects because they have the same goal as NATAP – expedite border crossing movements. The most recent and available information regarding the physical and traffic conditions of the NATAP sites is provided in the NATAP Sites section. The Evaluation of NATAP section is based on the survey responses of professionals familiar with NATAP and the review of status reports and news releases because these sources provided the latest information on the topic. Next, an evaluation of the other border clearance initiatives discussed in an earlier section was performed using the same approach as was used for the NATAP evaluation section. From the description and evaluation of NATAP and other border projects, conclusions and recommendations on these border issues are presented, respectively. In the Case Study section, a background on the Pacific Northwest border crossings is provided. The ABCS site selection criteria developed by a previous study are applied to the Pacific Northwest border to determine if ITS technology could benefit the border crossing process. By applying the criteria, an assessment on the quality of the criteria was also made. Finally, an acronym list, a border crossing site map, and the professional survey questions can be found in Appendices A through C, respectively.

DESCRIPTION OF NATAP

Elements of NATAP

It is important to understand the key elements of NATAP because the program will be extensively evaluated by the governments and trade community to determine its functionality and whether to move on to the next steps of system design. The key components to NATAP include the following (1):

1. Data standardization,
2. Electronic Data Interchange (EDI),
3. Pre-arrival processing,
4. Advanced technologies,
5. Treatment of trade, and
6. Integrated processes.

Data Standardization

NATAP uses standard commercial data agreed to by the three countries as the basis for government processing of imports, exports, and in-transit movement of goods. This standard set of data consists of common names, definitions, and codes, and is based upon normally occurring commercial and transportation data (core data) that are generally exchanged among the participants for normal business reasons. The core transportation and commercial data have been supplemented by some government specific data such as country of origin (1).

Electronic Data Interchange (EDI)

To promote electronic commerce, NATAP uses standard UN/EDIFACT messages as the only protocol. UN/EDIFACT which stands for United Nations Electronic Data Interchange for Administration, Commerce and Transport was established as a single international EDI standard flexible enough to meet the needs of government and private industry. Presently, UN/EDIFACT comprises an extensive set of internationally agreed-upon standards, directories, and guidelines whose purpose is to facilitate the electronic interchange of structured data (purchase orders, invoices, and payments) that relates to trade in goods and services between independent computerized information systems. It covers both batch EDI and interactive EDI and addresses security services and business information modeling (2).

The Trade Software Package (TSP), developed by Revenue Canada, is the tool for the transmission of data among the trading parties. The TSP contains the standard elements agreed upon by the three governments and is used by the trade community to transmit and receive data from the respective governments. Furthermore, the TSP contains all details of the transaction and is the record of the transaction. The set of data to be transmitted by NATAP participants has been divided into two UN/EDIFACT types: Customs Declaration (CUSDEC) message for commercial data and Customs Cargo Report (CUSCAR) message for transportation data. The trader (or agent) transmits the CUSDEC message and the carrier (or agent of the carrier) transmits the CUSCAR message. Upon receipt of an EDI message, the trader or carrier who transmitted the data receives a Customs Response (CUSRES) message acknowledging receipt of such information (1).

Advanced Technologies

NATAP uses advanced technologies such as the Internet for the transmission of data and transponder technologies to electronically identify conveyances. Given the concern related to the transmission of data over the Internet, the security issue has been addressed by incorporating an encryption module in the NATAP processing procedure (1).

The Automatic Vehicle Identification (AVI) technology involves the two-way electronic communication between a transponder in a moving vehicle and a roadside reader. As a commercial vehicle approaches the primary inspection booth in the designated NATAP lane, the vehicle which has a transponder device on-board is identified electronically by a roadside reader. Based upon the computer processing of the data that came in advance, the reader then responds with a red (report to a secondary inspection facility) or green (proceed) light to inform the driver (1).

Pre-Arrival Processing

NATAP attempts to show that standard commercial data can be shared among businesses in the trade chain and submitted to and processed by the governments in advance of the vehicle arriving at the border. With a CUSDEC transmission, the merchandise data are submitted, and a North American transaction number is assigned to identify the transaction. The carrier, then, identifies the transportation movement by a trip/load number and transmits a CUSCAR message to customs. Also, the trip/load number is coded into the transponder of the vehicle. As the vehicle approaches the border, the ITS technology in place links the trip/load number with the North American transaction number, and the customs system is queried. If the data are present and no examination is required, the vehicle may proceed; otherwise, the vehicle must stop for inspection (1).

Treatment of Trade

Traditionally, imports and exports have been treated as different, unrelated processes. NATAP attempts to use the standard data record as the basis for all international trade processes (imports, exports, and transits) (1).

Integrated Processes

The international trade process is more than just the clearance of goods for customs purposes. NATAP attempts to incorporate the clearance of goods (for multiple federal trade agencies), the clearance of people (immigration), and conveyances (for safety and other inspections) into an integrated, comprehensive process (1).

Potential Benefits

Many view that automated systems will need to be installed to streamline border crossing procedures, and NATAP provides this opportunity. The NATAP Working Group which was created by the three customs administrations to oversee the project believes that participants and trade will benefit immensely if NATAP leads to the development of an operating system.

Participants

According to the NATAP Working Group, the following are benefits that NATAP participants can expect (1):

- NATAP will allow the trade participants to experiment with new concepts such as EDI and leading edge technologies without the expense associated with the design of a complete system.
- Participants will have the opportunity to influence and shape the future direction of a modern and simplified border clearance system by contributing to its design and development.
- Participants will gain a competitive and marketing edge by reaping the benefits of being the first to use those components deemed successful and incorporated into the mainstream systems of the three customs administrations.

Trade

NATAP is believed to benefit trade in the following ways (1):

- Significant processing and transmission cost reduction.
- Reduced congestion at border crossings through pre-arrival processing and a “seamless border”.
- Transmission of timely responses to trading partners as to the status of merchandise.
- Improved accuracy and timeliness of information due to the use of electronic commerce for the exchange of information between traders, carriers, brokers and customs.
- After NATAP, traders, carriers and brokers can continue to use the technology to conduct business with each other.

Participant Requirements

The NATAP Working Group has asked participants to abide by the following requirements (1):

- Develop and identify trading partnerships for participation in NATAP.
- Utilize the software package supplied by the customs administrations to receive, process, and transmit data to and from trading partners as well as the appropriate customs administration. However, participants are free to develop and utilize their own software package provided that the software meets the established prototype requirements.
- Participate in the start-up testing of NATAP.
- Attempt to conduct business electronically with all business partners (the Trade Software Package was developed to assist in this effort).
- Submit transactions during the test to enable all parties to perform a good evaluation.
- Give NATAP transactions sufficient processing priority so that trading partners and customs receive prompt responses.
- Assist in the evaluation stage.
- Communication links with customs must be through approved prototype Value Added Networks (VAN).
- Register and train personnel for participation in NATAP.
- Transmit all carrier data to customs prior to arrival of the commercial vehicle.
- Equip trucks with transponders.
- Acquire the following computer hardware and software:
 - ▶ IBM compatible workstation (minimum 486/33),
 - ▶ 100 MB free disk space,
 - ▶ 8 MB of RAM,
 - ▶ 14.4 modem, and
 - ▶ Windows 95 or Windows NT.

DESCRIPTION OF OTHER BORDER CLEARANCE INITIATIVES

NATAP is a joint customs program aimed to expedite the movement of goods. However, border crossings deal with other issues also which include commuter travel, recreational travel, and vehicle safety inspection. To make the border crossings efficient, ITS programs need to be adopted to expedite the clearance of these scenarios, also. At the moment, there are several operating and prototype programs that address these issues. Besides NATAP, other cargo clearance systems have also been examined by customs administrations. This section describes some of these other border initiatives that have been implemented at the NATAP sites.

The following border clearance initiatives are described in this section:

- In-Vehicle Voice Verification System (IVVVS),
- Secure Electronic Network for Traveler's Rapid Inspection (SENTRI),
- National Customs Automation Prototype (NCAP),
- Accelerated Commercial Release Operations Support System (ACROSS),
- Texas Regional International Border Expedited Crossings (TRIBEX), and
- Expedited Processing at International Crossings (EPIC).

IVVVS

At the moment, an automatic border crossing system is being tested called In-Vehicle Voice Verification System (IVVVS) to serve as a complement to SENTRI (6). This system developed under a partnership with the Rome Laboratory Intelligence Analysis Branch of the U.S. Air Force Rome Laboratory (AFRL), the U.S. Department of Justice Immigration and Naturalization Service (INS), and the New York State Technology Enterprise Corporation (NYSTEC) was ready for testing in early 1997. The partnership conducted a technology evaluation and demonstration to develop the initial components of a prototype, biometric-based voice verification system for automated border crossing.

IVVVS is based on the concept of biometrics which is the automated measuring of one or more specific attributes or features of a person, such as voice, fingerprint, infrared facial images, or hand geometry, with the intent of being able to distinguish that individual from all others. The goal of the program is to evaluate the potential of applying speech processing technology towards the development of a proof-of-concept IVVVS for automated border control. The system incorporates an infrared (IR) transmitter device for communicating from a moving vehicle with a fixed computer work station which receives the IR signal and performs voice verification. Voice data from the driver in a moving vehicle is collected using the IR transmitter device and then processed with unique algorithms that are able to successfully perform voice verification. To participate, individuals have to register their vehicles with INS and record a phrase of their speech to be stored in a computer at the border crossing. Each registered individual then receives a personal identification code and a portable IVVVS unit (Z).

Upon arriving at the border, individuals type in their personal code and speak their phrase into a telephone-like handset which IVVVS converts the sound into a digital signal and broadcasts it to a computer at the border facility. Special computer algorithms then check whether the speaker is the same as the person who originally recorded the phrase for that particular personal code and makes a decision in less than a second. The algorithms look for distinctive features of speech, such as the distribution of frequencies and the rate of speaking, thus the system cannot be easily tricked. For example, if an individual used a tape recording of a registered person's voice, the individual would not be able to proceed because of the distortion produced by even the best microphones. However, the system does not recognize someone if he/she have a bad cold or asthma.

SENTRI

The Secure Electronic Network for Traveler's Rapid Inspection (SENTRI) Project uses advanced technology such as electronic face recognition to accomplish the following goals: facilitate inspection of increasing border crossing traffic volume, reduce delays at land ports of entry, and ensure strict border integrity and security (8). The SENTRI system is designed for use by low-risk travelers who frequently cross the international borders of the U.S. People enrolled in this experiment are issued a radio frequency (RF) tag which is attached to their vehicle by INS and are allowed to use a SENTRI dedicated commuter lane. The tag codes a unique identification number for the authorized person/vehicle that is read by sensors. When the sensors detect a vehicle equipped with a tag, the records of the authorized person/vehicle, which include a photograph of the person, are retrieved. An advanced software package called FaceIt® developed by Visionics Corporation captures the face of the person as he/she drives through the border crossing and matches the face against the one authorized to drive the particular vehicle. If approval is confirmed, the driver is permitted to proceed without any delay; if not, the driver is requested to stop. It must be noted that this technology has the capability of finding the face of the driver anywhere in the field of view (9).

NCAP

The National Customs Automation Program (NCAP) is a prototype automated cargo processing project coordinated by U.S. Customs, Chrysler, Ford, General Motors, Levi Strauss, and Robert Bosch that is applicable to merchandise imported through the ports of Laredo, Texas (Columbia Solidarity Bridge only), Detroit, Michigan, and Port Huron, Michigan. NCAP which began operating in May 1998 is the first program of the new Automated Commercial Environment (ACE) to be implemented. The prototype which is expected to end sometime in 1999 will demonstrate concepts such as electronic support for examinations, periodic filing of post-release information, periodic payments of customs duties, and under certain conditions, permission to adjust declarations months after initial filing (10). Eventually, the parties of the new program hope that it will phase out the current U.S. cargo clearance system, ACS. According to U.S. Customs, the trade community can expect the following benefits (11):

- A single account number for each trade party to be used in all transactions will eliminate the current multiple identification numbering system.
- Carriers, brokers, and/or importers will transmit data directly to U.S. Customs.
- Ability of the trade community to easily determine their financial position with U.S. Customs without having to review potentially hundreds of individual documents.
- Transactions between participating ports will be combined and thus, reducing the number of individual payments to U.S. Customs.
- Payments will only be made to U.S. Customs twice monthly instead of daily.
- Filing of entry summary data is on a periodic basis rather than on a transaction basis.
- New import declaration format will result in the elimination of redundant data keying.

This program will only be available to importers who carry low-risk shipments from approved foreign suppliers (11).

ACROSS

The Accelerated Commercial Release Operations Support System (ACROSS) is an EDI-based customs clearing process program that entered full operation early 1996 by Canada Customs. According to Canada Customs, the benefits of ACROSS to the trade community are the following (12):

- Electronic exchange of release data.
- Electronic exchange of permit data including the Foreign Affairs Customs Automated permits.
- Exchange of information with no time constraints.
- Use of one system at a central office to process EDI releases for several ports of clearance.
- Improvement in accuracy of information by exchanging data without repeating input.
- Improvement in service delivery.
- Reduction in paper and handling costs by eliminating the photocopying and faxing of release packages.

However, a number of release situations are still dealt within the traditional manner to complement ACROSS because the system is not intended to accommodate all circumstances an importer may face. Some of these circumstances include the following (13):

- ACROSS transmissions must identify a contact person from whom information on the shipment can be obtained anytime.
- Shipments that enter Canada on a temporary basis only.
- Reliance on ACROSS alone may require importers to trace their own shipments and arrange their own on-line interfaces with carriers.

TRIBEX

The Texas Regional International Border Expedited Crossings (TRIBEX) program is an AVI/EDI prototype project carried out at Texan/Mexican border crossings by the Texas Department of Public Safety and the Federal Highway Administration (FHWA) to expedite commercial vehicle safety inspection. Commercial vehicle owners submit their vehicles for inspection once, and the information is placed into a database. Also, each vehicle receives a United States Department of Transportation (USDOT) license number which will help in verifying the vehicle. NATAP commercial vehicles can also use the same transponders for data transmission. In 1996, around 45% of Mexican commercial vehicles were placed out of service for serious safety violations that led to tighter inspection control of Mexican vehicles (14). The tighter safety inspection control but especially the U.S. Customs drug inspection techniques of Operation Brass Ring led to increased delays. The increased delay frustrated Mexican drivers, and they decided to protest by blockading all traffic leading into downtown Laredo in August 1996 (15). TRIBEX has the potential to reduce delays and prevent a repetition of such events.

EPIC

The Expedited Processing at International Crossings (EPIC) project is a public-private partnership field operational test (FOT) composed of the Arizona DOT, FHWA, Lockheed Martin, American Trucking Association, PB Farradyne, Hughes Electronics, and HELP, Inc. that involves ITS to expedite clearance of commercial vehicles for state licensing, permitting, and safety inspection reasons. Shipping companies can enroll after their federal and state motor carrier credentials are checked for safety and terminal inspections. Individual commercial vehicles are enrolled by submitting a valid registration, insurance, and current safety inspection certificate to be placed on file with the EPIC project. Transponder technology is being used to carry out this FOT for pre-trip processing of commercial vehicle data and real time processing of the transponder data. The transponders used in this project are compatible with the NATAP transponders.

In Figure 1, the EPIC process is explained with each number representing a step of the process. The following describes what occurs at each numbered location (17):

1. The vehicle crosses into the U.S., its transponder is read, and the information is registered in the system.
2. The driver is informed if Arizona requirements have been met or not via green or red Light Emitting Diode (LED) signals.

3. After exiting the U.S. Customs compound, the transponder is read again, and the information is processed by the system.
4. At the Mariposa Port of Entry (POE) Scale house, the vehicle is read for the final time, and motor vehicle inspectors visually verify the truck trailer combination as well as the driver.
5. The time that the commercial vehicle passes this point is recorded.
6. The time that the commercial vehicle passes this point is recorded as it leaves the United States.

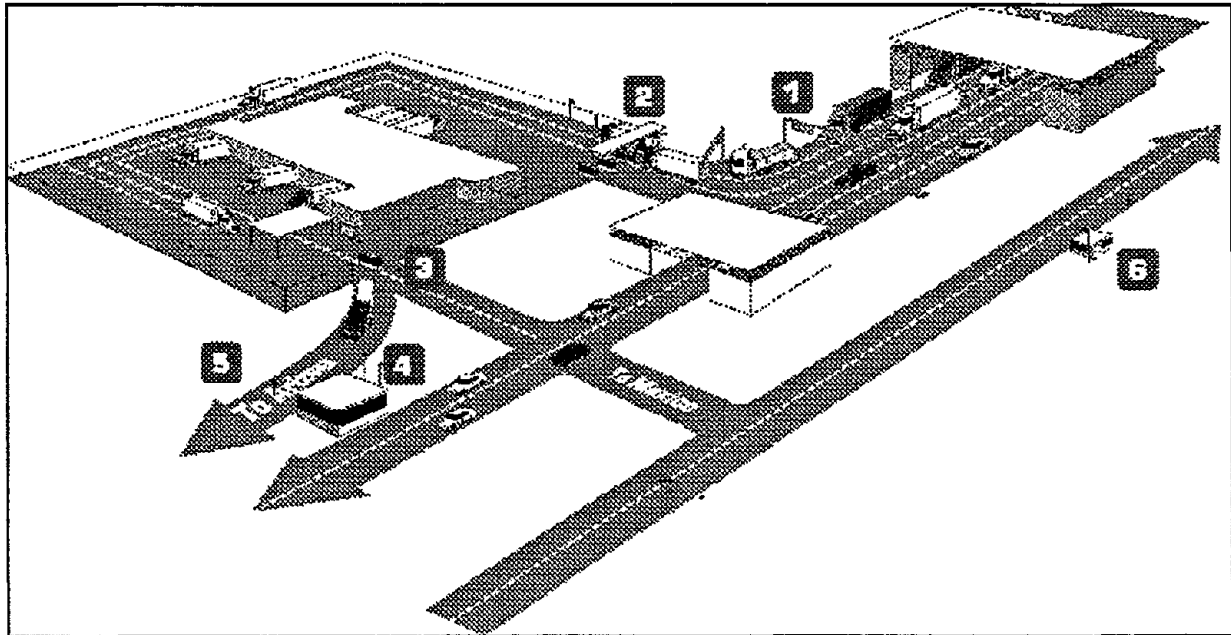


Figure 1: Mariposa Compound in Nogales, Arizona (17).

As part of the EPIC project, a software package called Management Information System for Transportation (MIST) has been developed to assist in reducing and monitoring delays at the border crossings. MIST will enable agencies to monitor traffic conditions, the status of field equipment, and to control traffic management devices. The potential benefits of MIST according to the organizations involved are as follows (16):

- Help border agency personnel to schedule the time of operation of different gates which in turn will help them in personnel scheduling.
- Provide carriers with information regarding the location of their vehicles in the customs compound, time it takes to clear different locations, and total clearance times.
- Track vehicle movement through the readers for individual vehicles equipped with transponders in real time.
- Provide individual clearance times for each vehicle and also provide average travel time for all vehicles.
- Provide historical travel time information.

However, the benefits of MIST can only be obtained for transponder equipped vehicles.

NATAP SITES

This section of the study provides some background on the NATAP sites in regards to physical and traffic conditions. Due to the institutional barriers unique to each site, NATAP began at different times. Table 1 provides some information on the NATAP sites.

Table 1. NATAP Site Information (1).

NATAP Site	Date of Initiation
Buffalo, New York / Fort Erie, Ontario	May 1997
Detroit, Michigan / Windsor, Ontario	May 1997
Laredo, Texas / Nuevo Laredo, Tamaulipas	July 1997
El Paso, Texas / Ciudad Juarez, Chihuahua	July 1997
Nogales, Arizona / Nogales, Sonora	May 1997
Otay Mesa, California / Tijuana, Baja California	November 1996

Buffalo/Fort Erie

The Peace Bridge which crosses the Niagara River and connects Queen Elizabeth Way with U.S. Interstate 190 and serves the downtown areas of Buffalo and Fort Erie is the NATAP site. At the present time, approximately 1.3 million heavy vehicles and 6.5 million passenger vehicles cross the Peace Bridge annually making it together with the Ambassador Bridge in the Detroit/Windsor areas the busiest crossings along the U.S./Canadian border. For the most part, delays have been primarily due to the peak hour physical capacity and operations of primary inspection lanes and plazas. Peak traffic volumes occur during the summer months with peak days occurring on holidays in the summer (18). AVI technology is being utilized at the Peace Bridge for toll collection since 1997 which has improved traffic operations (19).

Detroit/Windsor

The NATAP site in the Detroit/Windsor area is the four-lane, toll operated Ambassador Bridge which at the present time handles 2.1 million heavy vehicles per year and 7.0 million passenger vehicles per year. The Ambassador Bridge crosses the Detroit River and connects Provincial Highway 401 via a six-lane divided boulevard with U.S. Interstates 75 and 96 via poor city arterials. Truck traffic at the Ambassador Bridge has risen 10% annually for the past few years and is expected to continue (20). Most delays have occurred when too few primary inspection booths were open, and these delays have been attributed to shortages of staff and to inadequate systems and procedures for monitoring traffic on a minute-by-minute basis (18). Peak traffic volumes occur during the summer months with peak days occurring on holidays in the summer. A large proportion of the commercial traffic moves in a "just-in-time" mode in order to meet total order cycle times of as little as four hours with no surplus inventory in plants (18). AVI technology has also been installed at the Ambassador Bridge to accelerate toll collection and to improve traffic operations (2).

Laredo/Nuevo Laredo

NATAP has been fully implemented at the Colombia Solidarity Bridge and partially (southbound movements) at the Lincoln-Juarez Bridge which both cross the Rio Grande River. Both of these bridges handle primarily

commercial traffic. Specifically, the Colombia Solidarity Bridge, which is a toll facility, is located about 20 miles northwest of Laredo, and it links Dolores, Texas with Colombia, Nuevo Leon. Although it is an eight-lane bridge, the bridge has not been fully utilized since it was opened in 1991 for a number of reasons which include: inadequate road infrastructure on both sides of the border, scarcity of Mexican customs brokers, few brokers having licenses to operate in both Tamaulipas and Nuevo Leon, and the additional time and cost involved in using the facility (21).

However, in 1997, use of the bridge began to increase as it is evident by the 141% increase in northbound crossings since 1996, and since October 1997, the northbound volume has been higher across the Colombia Solidarity Bridge than the Lincoln-Juarez Bridge (22). A major reason for this change is attributed to the infrastructure improvements and the removal of some institutional barriers between the Mexican states of Tamaulipas and Nuevo Leon (23). If trends continue, approximately 720,000 commercial vehicles will cross the bridge into the U.S. in 1998.

The Lincoln-Juarez Bridge, also a toll facility, is a six-lane facility with three lanes in each direction, one of which is heavy vehicle exclusive. The bridge is connected directly to Interstate 35 on the U.S. side; however, there is very poor access to the crossing on the Mexican side. A major problem of the Lincoln-Juarez Bridge is that it suffers from delays because the vehicles using the bridge mix with the downtown traffic of Laredo and Nuevo Leon. If trends continue, approximately 600,000 commercial vehicles will enter the U.S. using this bridge in 1998.

Efforts are being made to begin the construction of a fourth bridge at the northern outskirts of Laredo and Nuevo Laredo which together with the Colombia Solidarity Bridge will handle all the commercial vehicle traffic. The Lincoln-Juarez Bridge and the Convent Street Bridge, which also serves the downtown areas and have heavy pedestrian traffic, will then handle only passenger vehicles. The City of Laredo is pushing this initiative because it believes border traffic will move quickly, efficiently, and safely through the area and allow recreational development in the downtown area (21).

Toll collection at both bridges is done manually, and no real concrete plans have been made to implement electronic toll collection.

El Paso/Ciudad Juarez

NATAP has been implemented at the toll operated Ysleta-Zaragoza Bridge which crosses the Rio Grande River and connects to U.S. Interstate 10 via State Highway 1375 and Mexican Interstate 45 via poor access roads. The bridge is located on the southeast edge of the city of El Paso and outside the city limits of Ciudad Juarez, so its traffic does not mix with extensive city traffic volumes like at the other two bridge locations (Paso Del Norte (PDN) and Bridge of the Americas (BOTA)) in the El Paso area. There are actually two separate four-lane bridges at this site with one bridge being for private vehicles and pedestrians and the other for commercial vehicles. Even at peak hours, congestion at the bridge has not been found to be a function of capacity. Instead it is a function of the number of personnel at inspection facilities (21).

In the New Mexico/West Texas area, the largest traffic volumes are generally crossing from Mexico into the United States over the three major bridges in the area: Paso Del Norte (PDN), Bridge of the Americas (BOTA), and Ysleta-Zaragoza. In general, BOTA is more congested than the other two bridges and a reason for this might be that it is not a toll bridge like the other two (21).

Recently, the northbound commercial vehicle volume at Ysleta-Zaragoza has dropped from approximately 1200 vehicles per day to approximately 900 vehicles per day. The lifting of vehicle weight restrictions at BOTA and the improvements to the Santa Teresa, New Mexico border crossing facilities are believed to be the main causes of this decreasing trend (24).

Nogales/Nogales

In 1997, over 240,000 commercial vehicles and over 9.5 million passenger vehicles entered the United States through this NATAP site. The easily accessible border crossing is served by U.S. Interstate 19 and Mexican Interstate 15. Nogales is a major entry point for the importation of produce that accounts for 50% of all winter produce consumed in the United States and Canada. During the height of the produce season, peak flows of 1300 commercial vehicles per day are reached resulting in physical plant overcapacity and inefficient inspection performance (25). The vast majority of commercial traffic is composed of Mexican commercial vehicles transporting goods from farms and factories along the border area to warehouses in the Nogales, Arizona area (26). In the past year, major infrastructure improvements through the Mariposa POE Cargo Redesign Project increased capacity and reduced waiting times dramatically include the following (25):

- Expansion of queuing area by constructing two dedicated lanes,
- Installation of four “superbooths” constructed off the ground that put inspectors at eye level with commercial vehicle drivers,
- Construction of two Rapid Enforcement Lanes for pre-determined low-risk conveyances, and
- Expansion of the X-ray compound.

Unlike some of the other border sites, the Nogales site does not have any land constraints.

Otay Mesa/Tijuana

The Otay Mesa border crossing connects California State Route 905 with Mexican Interstate 2. Otay Mesa is now the only commercial crossing between San Diego and Tijuana after the recent closure of the San Ysidro inspection facility and handles approximately 1.0 million commercial vehicles per year. Also, almost 9.0 million passenger vehicles per year enter the United States through this crossing. This passenger volume is composed by a large number of Mexican-Americans and Mexican nationals visiting their families and tourists. A major problem at the Otay Mesa crossing is that the U.S. POE facility is connected to State Route 905 by only a four-lane city street (Otay Mesa Road) that is currently operating at three times its designed capacity. If State Route 905 is fully constructed, it would unite the Otay Mesa border crossing with California's interstate highway system and alleviate congestion (27).

At the moment, construction has begun to widen Otay Mesa Road from four lanes to six lanes. This project which is expected to finish in early 1999 is believed will alleviate the current conditions. Another project plans for a “by pass” truck corridor which will provide a direct link from the federal POE facility to the state facility. This corridor will facilitate the processing of commercial vehicles by using weigh-in-motion (WIM) technology (28).

EVALUATION OF NATAP

As part of the study design, an evaluation of NATAP was performed. This was accomplished by contacting professionals who were familiar with NATAP and pertinent border crossing issues and by reviewing the latest information on such issues that is available in the Internet.

Survey Responses

This section contains the responses by the professionals to the survey. The responses are listed together with no reference to the professional in order to maintain the anonymity of each professional who participated. Table 2 lists the professionals that were contacted, their affiliation, and their NATAP site familiarity.

Table 2. Survey Respondents.

Organization Type	Professional	Affiliation	NATAP Site Familiarity
Associations	Neil Gray	International Bridge, Tunnel & Turnpike Association	Buffalo/Fort Erie; Detroit/Windsor
Bridge Authorities	Brent Gallagher	Niagara Falls Bridge Commission	Buffalo/Fort Erie
	Anthony Braunscheidel	Peace Bridge Authority	Buffalo/Fort Erie
Commercial Vehicle Operators	Enno Jacobson	Challenger Motor Freight	Detroit/Windsor
Consultants	Craig Fundling	Booz, Allen, & Hamilton	Buffalo/Fort Erie; Laredo/Nuevo Laredo
	Joe Elias	Calspan	Buffalo/Fort Erie
	Chris Buntine	CALSTART	Otay Mesa/Tijuana
	Pete Burns	HELP, Inc.	El Paso/Ciudad Juarez
	Pete Houser	SPS	All Sites
	John Hudson	Traffic Engineers, Inc.	Laredo/Nuevo Laredo; El Paso/Ciudad Juarez
Custom Brokers	Terry Harman	Livingston International	Buffalo/Fort Erie; Detroit/Windsor
Customs	Tim Hunt	Canada Customs	Buffalo/Fort Erie; Detroit/Windsor
	John Whillier	Canada Customs	Buffalo/Fort Erie
	Alan Dockter	U.S. Customs	Detroit/Windsor
	Roger Maier	U.S. Customs	Laredo/Nuevo Laredo

Table 2. Survey Respondents (Continued).

Organization Type	Professional	Affiliation	NATAP Site Familiarity
Customs	Brent Martin	U.S. Customs	Nogales/Nogales
	Eduardo Tijerina	U.S. Customs	Laredo/Nuevo Laredo
	Rick Walker	U.S. Customs	El Paso/Ciudad Juarez
	Denna Henry	U.S. Treasury	All Sites
Immigration	Tom Campbell	U.S. INS	Buffalo/Fort Erie; Detroit/Windsor; Otay Mesa/Tijuana
Manufacturers	Dana Fryxell	Lockheed Martin	All U.S./Mexican Sites
	Paul Manuel	Mark IV Industries	Buffalo/Fort Erie; Detroit/Windsor
Transportation Departments	David Hunt	Arizona DOT	Nogales/Nogales
	George Bays	Arizona DOT	Nogales/Nogales
	Jim Barnack	New York DOT	Buffalo/Fort Erie
	Sylvia Grijalva	FHWA	Otay Mesa/Tijuana
	Irene Rico	FHWA	Laredo/Nuevo Laredo; El Paso/Ciudad Juarez

In general, the responses of the professionals regarding NATAP can be grouped into the following categories (*19, 23, 24, 26, 29-51*):

- Potential benefits,
- Technology,
- Status, and
- Barriers.

Potential Benefits

For the most part, the respondents felt that NATAP should be continued because it can result in a “seamless border” and increased border facility capacity due to the pre-processing of electronically transmitted data. However, all claimed that it was difficult to measure any benefits because the project was just a prototype, and there was minimal market penetration due to some barriers.

Technology

Some respondents felt that the Trade Software Package was not user friendly and recommended a more user friendly version. An improvement according to the respondents would be if the transmitted data could be

downloaded from the host computer directly into the transponder rather than manually inputting the data because the high employee turnover rate in some industries does not allow time for an individual to become familiar with the technology.

The use of transponders was seen as the best method of technology to transmit, and some individuals commented that it is good that a standard (ASTM-6) transponder is being used. Some individuals stressed the ability of the transponders to be used with a broad range of other toll, automated roadway, and commercial vehicle systems. However, the transponders sometimes failed due to battery problems which resulted in the breakdown of the NATAP crossing process. Some respondents commented on alternative intelligent technologies that are being talked about in government and private industry such as Global Positioning Systems (GPS). The feeling was that GPS would be too costly and would not be appreciated by the carrier industry, but a continuation of efforts to improve the NATAP technology is encouraged to make the system more reliable. Some individuals also believe that X-ray units, not exactly ITS technology, should be encouraged to speed up secondary inspections of commercial vehicles.

Status

NATAP operations are ending at the sites, and evaluation of the project has begun. From the preliminary reports, most respondents believe that NATAP did accomplish its goal that it can be a tool to expedite border crossings. However, participation by the private sector was much lower than expected. At the U.S./Canadian sites, 500 transponders were made available for commercial vehicles; however, only 50 were requested. Low participation also occurred at the U.S./Mexican sites with the worst site being the El Paso/Ciudad Juarez site where no transponders were issued. Reasons given for the lack of participation included the following:

- Parallel processing discouraged many industries because participants were required to cross the border using both the NATAP and existing process.
- Fear of “big brother” plays an important role in discouraging participants especially along the U.S./Mexican border.
- The steps required for participants were deemed too complex, and it was recommended that they be re-analyzed.
- Some companies who wished to participate were unable to because other members of their trade chain were reluctant to be a part of NATAP.
- Additional customs commercial clearance programs have confused many people.

The general consensus was that the beginning of the pilot stage where parallel processing will not be required, and the reduction of customs commercial clearance programs being introduced will increase participation.

Barriers

All respondents believe that most of the problems that NATAP faces can be attributed to institutional barriers and lack of awareness of the program. The major barrier was seen to be the requirement of parallel processing of NATAP participants at the border. In the beginning of NATAP, there was a higher involvement because the private industry wanted to experiment with the technology. However, after a few test crossings, many stopped participating because of the double work that was required. Also, the introduction of customs programs such as NCAP has created more competition to obtain participants and funding for NATAP.

The lack of awareness was evident through all levels of the commercial border crossing process. For example, there have been instances that customs officials were not informed about NATAP and did not carry out the NATAP procedures. Also, the lack of awareness feeds the fear of “big brother” resulting in bad publicity for the prototype.

Literature on NATAP

This section contains a summary of the status reports written by the NATAP Working Group and press releases written on NATAP that were found in the Internet. For the most part, this literature reflected the same views as the survey respondents.

In general, the NATAP information found in the Internet can be grouped in the same categories as was the information obtained through the survey:

- Potential benefits,
- Technology,
- Status, and
- Barriers.

Potential Benefits

The various articles that were reviewed had the same general theme about the benefits of NATAP as the survey respondents (19, 52-54).

Technology

A number of shipping company representatives expressed opinions that the Trade Software Package was not user friendly (19, 52). For example, a number of SLH Transport drivers were required to stop because information was inputted incorrectly. Also, these individuals felt that NATAP does not seem to take into consideration how transport happens and that it makes a number of incorrect assumptions (52). For example, a commercial vehicle driver is required to always be where he/she is supposed to be, and the carrier needs to monitor over-the-border trade.

Also, the proximity of many companies to the border such as the Detroit-based auto industry makes NATAP difficult to use. Some commercial vehicles make trips almost daily across the border traveling to and from locations that are a few minutes away from the border crossing. Such a short period of time does not give customs officials enough time to receive and process the necessary data as a commercial vehicle using NATAP approaches the border expecting a green light (19).

During the NATAP testing phase, a number of flaws with the equipment have been discovered. For example, it was observed that if the bar code wand is plugged into the transponder when it is not in use, the electronics seem to lock up. The recommended solution is to leave them unplugged when not in use (53).

Status

Generally, the status reports reflected the views of the surveyed professionals regarding the reasons for lack of participation.

It was found that there is a feeling in the carrier industry that NATAP suits the needs for some sectors more than others. For example, NATAP does not work as well for commercial vehicles carrying a variety of goods because NATAP places a great burden on exporters by demanding a vast amount of data before a shipment leaves the country. A detailed registry of drivers is also essential to allow commercial vehicles to cross the border without stopping for inspection (19). The status reports also mentioned the problems of parallel processing and persuading everyone in a trade chain to participate in NATAP.

Representatives of the NATAP Working Group met on January 15, 1998 in Toronto, Ontario and reviewed the successes and problems of NATAP (54).

Successes that were seen in NATAP included:

- Data standardization appeared to meet the trade community and government expectations.
- Data can be used for multiple processes (toll, transportation, customs, immigration).
- NATAP did establish harmonized processes for trade at a high level (pre-arrival filing and processing; the use of ITS technology to support the NATAP border crossing process; driver registration process).
- The Internet proved to be a successful tool in transmitting data with no incidents of encryption software violation.
- The UN/EDIFACT protocol was successfully demonstrated as a means for sending standard electronic messages to the three governments.
- The transportation technologies such as transponders, readers, and antennae operated well.

Problem areas that the NATAP Working Group found included:

- Greater stability of transportation systems with back-up and diagnostic systems was needed.
- The burden of parallel processing was both costly and time consuming for participants.
- The TSP had no links to participants' internal systems proving to be labor intensive.
- The number of participants was lower than anticipated resulting in low NATAP volumes, especially because some participants felt that they had tested the concepts enough after only a few NATAP shipments.
- Several NATAP concepts were not demonstrated to the extent necessary for evaluation processes. These included in-transit processing, use and analysis of immigration and transportation data, calculation of duty liability, processing of specific commodities (agriculture, textiles, and alcohol), and Less Than Truckload (LTL) shipments.

On February 6, 1998, the NATAP Working Group met again to begin the development of the pilot study. Reports indicated that a pilot project would show more commitment to the concepts and would therefore make the project easier to promote. Also, it would result in increased motivation to address issues and a better evaluation (54).

Barriers

Many reports commented that institutional barriers are still playing an important role in hampering the efforts of NATAP. For example, the implementation of the Illegal Immigration Reform and Immigrant Responsibility Act of 1996 – Section 110 would have required the U.S. INS to document the entry and departure of every foreign national arriving and leaving the United States. If this law had not been overturned, it was believed that border crossing operations would have failed completely (55).

EVALUATION OF OTHER BORDER CLEARANCE INITIATIVES

As mentioned earlier, NATAP is not the only project that exists with the goal to expedite border crossing movements. An evaluation of these other initiatives is important in order to see if the goals have been achieved. One major difference between NATAP and these programs is that NATAP was designed by federal agencies from the three NAFTA countries whereas these programs involve federal and/or state agencies of one country. Information was obtained through the literature found in the Internet and by interviewing professionals. Once again, the responses are listed together with no reference to the professional in order to maintain the anonymity of each professional who was interviewed. Table 3 lists other border programs that exist at the NATAP sites.

Table 3. Site Information.

NATAP Site	Border Clearance Initiatives
Buffalo, New York / Fort Erie, Ontario	ACROSS, CANPASS, SENTRI
Detroit, Michigan / Windsor, Ontario	ACROSS, CANPASS, NCAP
Laredo, Texas / Nuevo Laredo, Tamaulipas	NCAP, TRIBEX
El Paso, Texas / Ciudad Juarez, Chihuahua	TRIBEX
Nogales, Arizona / Nogales, Sonora	EPIC
Otay Mesa, California / Tijuana, Baja California	IVVVS, SENTRI

An evaluation of the following border initiatives was performed:

- In-Vehicle Voice Verification System (IVVVS),
- Secure Electronic Network for Traveler's Rapid Inspection (SENTRI),
- National Customs Automation Prototype (NCAP),
- Accelerated Commercial Release Operations Support System (ACROSS),
- Texas Regional International Border Expedited Crossings (TRIBEX), and
- Expedited Processing at International Crossings (EPIC).

IVVVS

In December 1997 and January 1998, twenty commuters using a dedicated commuter lane performed tests on IVVVS at Otay Mesa. The project is still in the test phase, but the response from patrons and border inspectors has been positive. The next phase of the effort will involve more extensive testing of the system by hundreds of regular commuters. These commuters made use of a new device, also designed by NYSTEC, which combines the handset and transceiver into a single unit. NYSTEC and AFRL are refining the entire system and preparing for its full implementation. If immigration approves the system and it becomes an official border-crossing technology, the developers hope a manufacturer can mass-produce the handheld units to reduce the costs (56). The technologies, processes, and products developed at Otay Mesa could become the baseline system requirements for automated border crossing requirements at other federal and state government sites.

SENTRI

In April 1995, the Otay Mesa POE became the first testing site for SENTRI. The traffic operation impact of SENTRI has been so enormous that SENTRI now is in full operation at Otay Mesa. Before SENTRI, the

average waiting time at the border crossing was about 45 minutes. After SENTRI became available, the waiting time for individuals going through the designated SENTRI lane has never exceeded three minutes. SENTRI has also benefitted the non-SENTRI travelers because the quick clearance of low risk travelers has reduced the waiting time in the non-SENTRI lanes to less than 20 minutes (8). As of July 1998, there were 4000 participants in the SENTRI program at Otay Mesa. U.S. INS officials are satisfied with SENTRI because there have been no immigration violations and just three minor Customs violations. The success of the program has initiated plans to add a second dedicated commuter lane.

Due to the heavy passenger traffic at the Peace Bridge, one designated commuter lane has been installed to speed the flow of legal travelers as part of the U.S. INS PORTPASS Program using the SENTRI system. On the Canadian side, the same concept is being evaluated with one designated commuter lane as part of the CANPASS Program. A total number of 1500 SENTRI tags were made available to commuters by authorities and as of July 1998, 1000 of them are in use. Travelers and border officials are satisfied with this pre-clearance technology. Eventually, the U.S. INS hopes to issue about 10,000 tags.

The U.S. INS is planning to implement SENTRI at the Detroit border crossings in September 1998 by making available 2500 tags. Also, it is considering implementing the system at the El Paso border crossings in late 1998 (57).

NCAP

As mentioned earlier, NCAP was implemented in May 1998 but has not completed any transactions as of July 1998. At the moment, U.S. Customs personnel are still being trained on how to operate this electronic cargo clearance system.

ACROSS

ACROSS has received positive remarks from all stakeholders, and it has been implemented at almost all Canadian port of entries slowly phasing out Canada's previous cargo clearance system, CCS.

TRIBEX

TRIBEX has not be instituted because no real evaluation can be made due to a lack of participation. As of now, only four carriers with two vehicles each are participating. It is believed that the fear of "big brother" is the main reason for the low participation. However, the technical aspect of the project has met the expectations of the parties involved.

EPIC

To promote EPIC, a heavy advertising campaign was carried out by the Arizona DOT explaining the project and its potential benefits. Also to encourage participation, it was made clear that there would be no financial costs to participants. The advertising campaign was considered a success because in the first informational meeting over eighty individuals attended, and a number of them submitted applications for EPIC participation. However, most did not qualify because they did not meet the state and federal requirements. Most of the applicants were turned down because their vehicles did not pass state weight/safety requirements and/or the driver profiles were not satisfactory. Unfortunately, there were also a number of participants that expressed concern about EPIC violating their right of privacy. Thus, participation was not as high as expected. However, the parties involved with the project feel that EPIC has demonstrated that it can expedite the inspection process.

CONCLUSIONS

The test phase of NATAP is almost complete, and the three customs administrations together with other government agencies and the private sector participants are beginning to assess the prototype. By interviewing members of the various stakeholder groups and reviewing the latest literature on NATAP, the following can be concluded as is presented in Table 4.

Table 4. NATAP Conclusions.

Category	Comments
Potential benefits of NATAP	<ul style="list-style-type: none"> ▶ Paperless environment can be achieved. ▶ Data standardization will reduce mistakes. ▶ Pre-arrival processing will accelerate clearance process. ▶ Border facility capacity will increase. ▶ Time and cost savings to the trade community are attainable.
Technology evaluation	<ul style="list-style-type: none"> ▶ Proof-of-concept was achieved. ▶ Electronic data transmission via the Internet was praised. ▶ Standard transponder technology was considered the best option to expedite border crossing movements. ▶ Standard software package was not found to be user friendly.
Status	<ul style="list-style-type: none"> ▶ Participation by private sector was lower than expected. ▶ NATAP does not accommodate conveyances with a variety of goods. ▶ NATAP demands a vast amount of data from exporters. ▶ Several concepts have not been demonstrated. ▶ An evaluation by the customs administrations on the prototype has begun. ▶ Pilot studies have been set to begin in early 1999.
Barriers	<ul style="list-style-type: none"> ▶ Lack of awareness about the project was a problem. ▶ Privacy concerns hampered the project. ▶ Introduction of other cargo clearance programs is creating competition for participation and funding. ▶ Strict immigration legislation would limit the potential of NATAP.

In previous sections, other border clearance programs were examined to obtain an understanding on how they operate and their objectives. It was considered important to evaluate these programs because they have the same general goal – expedite border crossings through the use of advanced technology. Table 5 provides a summary in regards to these border initiatives.

Table 5. Conclusions for Other Border Clearance Initiatives.

Border Initiative	Issues Addressed	Main Government Participant(s)	Status	General Comments
IVVVS	Immigration clearance for frequent travelers	U.S. INS	FOT	Positive response shown by all stakeholders, and participation is steadily increasing.
SENTRI	Immigration clearance for frequent travelers	U.S. INS	Full Operation	Positive response shown by all stakeholders. Because of success in Otay Mesa, SENTRI is being introduced at other sites.
NCAP	Pre-arrival processing	U.S. Customs	Prototype	NCAP began in May 1998, so it is too soon to make any conclusions.
ACROSS	Pre-arrival processing	Canada Customs	Full Operation	ACROSS has been praised and is very close to be implemented at all Canadian ports of entry.
TRIBEX	Commercial vehicle permitting and safety inspection	FHWA, Texas Department of Public Safety	Prototype	No real evaluation can be made because of very low participation.
EPIC	Commercial vehicle permitting and safety inspection	FHWA, Arizona DOT	FOT	EPIC has provided proof-of-concept, but its potential has not been met due to lack of participation.

RECOMMENDATIONS

ABCS technologies have placed the groundwork for a bright future for all stakeholders – government, industry, and commuters. Government can hope to see more effective enforcement of customs, immigration, and commercial vehicle regulations. The carrier industry can expect faster delivery of goods and services and thus, increased revenue. Toll operators can anticipate a higher number of crossings per hour which will not only improve their profits but would also reduce the need for capacity upgrades. Reduction in commercial vehicles stopping at border crossings in conjunction with frequent traveler pre-clearance programs can result in reduced travel times for commuters.

However for ABCS projects to succeed, the following must be accomplished:

1. Support of ABCS,
2. Initiation of pilot studies,
3. Improvement to technology,
4. Consolidation of cargo clearance initiatives,
5. Incorporation of various clearance tasks, and
6. Elimination of institutional barriers.

Support of ABCS

To assist in the implementation of ABCS technologies, all stakeholders must place a greater effort in increasing the awareness of electronic commerce projects among their groups and need to increase cooperation among themselves. There were cases in which individuals who were directly involved in commercial vehicle border crossing procedures were not informed with NATAP resulting in unnecessary delay for NATAP vehicles. Incidents like these create a credibility problem and detract participants. Also, an increase in promoting the benefits of ABCS can possibly change the minds of people that are concerned about violation of privacy when they realize that the benefits outweigh the costs. Furthermore, commuter pre-clearance programs are encouraged to be implemented and developed because they have reduced the waiting times for travelers and relieved the workload for inspection officials at the test sites.

Initiation of Pilot Studies

NATAP and other prototype border projects have suffered from a lack of participation because there is no incentive for individuals to participate due to the requirement of double processing. Although prototypes are important in providing proof that the technology is capable of achieving its tasks, pilot studies which do not require double processing should begin as soon as possible in order to increase participation that will lead to a better evaluation.

Improvement to Technology

During the NATAP test phase, the Trade Software Package was found to be confusing to the users at times. An improvement to the software package and more hands on training would be beneficial.

Consolidation of Cargo Clearance Initiatives

NATAP is an AVI/EDI project that was developed by all three NAFTA countries. Unfortunately, Canada and the U.S. have recently introduced new cargo clearance systems which has led to confusion and uncertainty among individuals in the various stakeholder groups. Because NATAP is the only joint-developed cargo clearance program, it is recommended that NATAP should not be interfered with national initiatives. However, NATAP should be applied only at sites where the benefits outweigh the costs.

Incorporation of Various Clearance Tasks

NATAP was not very successful in achieving to integrate other clearance processes such as state licensing, permitting, and vehicle safety inspections as it was envisioned. It would be beneficial to incorporate these tasks into one program; however, this would be a challenging task due to the need of total cooperation among stakeholders.

Elimination of Institutional Barriers

Although many institutional barriers have been eliminated, barriers are still hampering the potential of ABCS technologies. However, the most serious barrier could potentially have been the Illegal Immigration Reform and Responsibility Act – Section 110 which was fortunately repealed by the U.S. Congress. It is highly recommended that such legislation is never passed because not only will it cause huge delays at the border, but it will also create an atmosphere of mistrust between the NAFTA partners.

CASE STUDY: ABCS IN THE PACIFIC NORTHWEST

Together, the border crossings of the Pacific Northwest form the fourth largest trade frontier along the U.S./Canadian border in terms of both volume and monetary value (3). The Pacific Northwest also serves as a major port for both the U.S. and Canada to conduct trade with other Pacific Rim countries. Thus, it is very important to investigate if the application of ABCS systems in the region could achieve greater economic benefits for both countries.

Background

Based on the traffic flows entering the United States at the Pacific Northwest, the Blaine/Douglas crossing is experiencing the vast amount of the regional border crossing activity (58). The Blaine crossing is actually composed of two crossings: 1) the Peace Arch Crossing which connects U.S. Interstate 5 with Provincial Highway 99 that handles only passenger vehicles; and 2) State Highway 543 connecting with Provincial Highway 15 that handles both commercial and passenger vehicles. Recent infrastructure improvements have increased capacity and improved accessibility; however, half of the inspection booths are not being utilized due to lack of staff (59).

At this border station in 1997, 440,000 commercial and 4.4 million passenger vehicles entered the U.S. representing a difference in volume since 1995 of +23% and -9.1%. The increase in commercial traffic more than likely can be attributed to NAFTA. However, the decrease in passenger traffic cannot be explained as easily. A possible reason could be that the value of the Canadian dollar which has dropped versus the U.S. dollar caused Canadians to cut down on recreational activities to the U.S. Another reason could be that travelers are not encouraged to travel across the international border because the waiting times for entering the U.S. has increased dramatically recently. The delay to enter the U.S. is attributed to a combination of a shortage of U.S. Customs/INS staff and the increased inspection for the smuggling of British Columbia-grown marijuana (60).

Unlike the NATAP sites, the trade at Blaine/Douglas for the most part is not associated with the adjacent border area and thus, does not involve "just-in-time" cycles or warehouse-bound goods such as agricultural products like along the U.S./Mexican borders. Instead, it involves the movement of a wide variety of goods from the western regions of Canada and many different regions of the western and eastern United States and vice versa. This means that there are few commercial vehicles crossing the border back and forth in a short time span. As of now, NATAP has not been pushed in the area; however, the Blaine crossing is very close to becoming a NCAP test site (61).

Current Border Crossing Operations

At the moment, there are no ITS applications being used at the Blaine/Douglas crossing. For commercial vehicles, ACROSS was implemented recently, and for passenger vehicles, two commuter pre-clearance programs are operating. The commuter programs are CANPASS-Highway and Peace Arch Crossing Entry (PACE), and a brief description is provided.

CANPASS-Highway

At a number of Washington/British Columbia land border crossings including the Blaine/Douglas crossing, a program called CANPASS-Highway, launched by Revenue Canada in cooperation with Citizenship and Immigration Canada, has been implemented to streamline customs and immigration clearance of low-risk frequent travelers. The technology used at these crossings is called Optical Character Recognition (OCR) which involves the infrared reading of license plates. Canadian and American citizens including Canadian permanent residents who have passed a rigorous security check can participate. Participants are able to enter Canada

through special CANPASS express lanes and to bypass the standard interview with a customs officer. Canadian participants bringing goods into Canada; however, have to fill in a traveler declaration card and deposit it as they drive through the express lane. Based on the information on the card, any duties and taxes are charged to their credit card account. The program which has 50,000 participants has been considered a success by the public and border officials.

PACE

The Peace Arch Crossing Entry (PACE) is a U.S. Customs/INS pre-clearance program that began in 1986 that allows for low risk travelers to use dedicated lanes at the Peace Arch. After a successful background check, these travelers receive a decal to place on the front windshield of their vehicles in order for border officials to identify them while they cross the border. Secondary inspection occurs if a border official in his/her judgement feels that is warranted. There are about 50,000 participants in the PACE program.

Application of ABCS Site Selection Criteria

The Blaine/Douglas border crossing was considered as a case study to apply the ABCS site selection criteria developed in a previous study (4). The criteria have been applied to the Peace Bridge border crossing; however, it would be interesting to apply them at a site that is not one of the busiest in North America. The site selection criteria are as follows (4):

1. An identifiable problem must exist at the border crossing.
2. A commercial vehicle volume greater than 100,000 vehicles per year must occur.
3. A high commuter volume must be present.
4. Physical expansion is not an option due to site specific constraints.
5. The potential for dedicating a lane or lanes for ABCS participants must exist.
6. The geometric site characteristics must be able to accommodate the technology needed.
7. Interagency cooperation is needed at the border crossing.
8. Market-share remains undisturbed between border crossings within an area.
9. High participation is necessary.

A portion of this information was provided by professionals familiar with the Blaine/Douglas crossing. The responses are listed together with no reference to the professional in order to maintain the anonymity of each professional who participated (59,61,62).

1. The major problem at this border crossing is the lack of staff to perform the border clearance procedures which has led to high increases in waiting times especially at the Peace Arch Crossing. This problem is compounded during the spring and summer due to a surge of recreational travel and due to the strict inspection procedures for the crackdown on drug trafficking.
2. The Blaine crossing does experience a commercial vehicle volume greater than 100,000 vehicles per year. The commercial vehicle volume entering the U.S. alone was over 440,000 vehicles in 1997. Based on data from the past two years, it is expected that 23% increase in commercial traffic entering the U.S. through the Blaine crossing will occur in 1998.
3. A high commuter volume does exist as it is evident from the 700,000 PACE vehicle entries into the U.S. alone in 1997 which accounts for about 16% of all passenger vehicle crossings into the U.S.
4. The Blaine crossing has adequate facilities, but half of them are not used because of lack of staff to operate them.

5. At the Blaine crossing, a dedicated lane for the commuter pre-clearance programs is present. The potential for adding more dedicated lanes exists considering that half of the existing lanes are not being used at the present time.
6. Geometric constraints do not pose a problem to ABCS deployment because this area has level terrain and minimal urban development.
7. The level of interagency cooperation at this crossing that can be expected is difficult to predict. There is indication that there has been adequate cooperation between Canadian and U.S. authorities in operating the pre-clearance commuter programs that have existed since 1986. However, the same cannot be said in regards to commercial vehicle programs. There seemed to be a lack of communication between the different agencies which has resulted in the development of different initiatives, lack of awareness about the different initiatives, and conflicting trade evaluation.
8. At the NATAP sites, market-share issues are very important because “just-in-time” deliveries are commonplace which means that predictable travel times are very valuable. The concern is that if a site realizes considerable benefits from ABCS, the market-share between the ABCS site and other crossings in the area may be interrupted (4). However, market-share issues will not play a major factor because there are no toll bridges in the Pacific Northwest.
9. As mentioned earlier, there are 50,000 participants in the current commuter programs at the Blaine/Douglas crossing. Commuter participation in an ABCS program such as SENTRI or IVVVS can be expected because these programs would not require manual identification of qualified individuals as is done in the PACE program. The information gathered from different sources on commercial vehicle operations in the area has been very contradicting. Thus, it is difficult to determine the level of participation in commercial vehicle ABCS programs.

Evaluation of ABCS Site Selection Criteria

The ABCS site selection criteria developed by Jonathan Bean were found to be applicable and very useful in evaluating a border crossing. A recommended addition to the list of criteria would be that conflicting border clearance programs should not be introduced at the same time at a particular site. The possibility of confusion among the stakeholders is greatly increased if this occurs as it was observed during the evaluation of the border clearance initiatives at the NATAP sites.

Recommendations for Pacific Northwest

After evaluating the NATAP sites and applying the ABCS site selection criteria to the Blaine/Douglas border crossing, the following are recommended for the near future:

- ABCS commuter pre-clearance programs should be considered.
- Commercial vehicle ABCS programs should not be implemented in the near future.

Commuter Clearance

The Blaine/Douglas crossing met all the ABCS site selection criteria that were applicable to commuter traffic which makes an ABCS program like SENTRI a very attractive option. SENTRI uses AVI technology to identify pre-registered vehicles whereas PACE requires for inspectors to identify vehicles with decals manually. Thus, the staffing problem faced at this site could be alleviated with SENTRI. Also, SENTRI uses face recognition technology to identify if the driver is actually registered. PACE, on the other hand, depends on the

inspector's judgement to verify drivers. Although CANPASS-Highway uses infrared technology to identify registered vehicles, it also cannot determine if a registered vehicle is driven by its authorized individual. The driver verification of SENTRI would benefit inspection officials because it would give them a more reliable method in determining secondary inspection. Also, the possibility for unauthorized individuals driving registered vehicles would be greatly reduced.

Although the Otay Mesa tests of IVVVS have pleased both commuters and inspection officials, IVVVS should not be considered before SENTRI is at Blaine because IVVVS does have some technical problems that need to be solved.

Commercial Vehicle Clearance

Based on U.S. Customs data, a high commercial vehicle volume exists at the Blaine border crossing, and if trends continue, it is expected to increase by 23% in the near future. ABCS technology can assist border officials to process these vehicles and prevent a deterioration in operational performance. However, it was found that a lack of interagency communication exists in the Pacific Northwest. This lack of communication has resulted in different evaluations of the conditions at the Blaine crossing. It was found that information regarding the characteristics of trade and expected levels of private sector participation in clearance initiatives was conflicting among the different agencies. Also, the lack of communication has created an awareness problem about the different commercial vehicle clearance initiatives that are being studied by the different agencies in the Pacific Northwest. Until this problem is resolved, it would be difficult to expect a successful ABCS program, thus at this time, ABCS for commercial vehicle clearance is not recommended.

FUTURE RESEARCH

The ratification of NAFTA has created a great need for research to find solutions to the problems that will arise with the increase in trade and traffic across the common borders of the NAFTA nations. ABCS technologies can play a major role in accommodating the traffic flows across the international borders. Some topics that are recommended for further research in this subject area include the following:

- An evaluation of the NATAP pilot study that will begin in 1999 to determine the impact to traffic operation and the cost/benefit ratio of the project.
- An analysis of the Santa Teresa, New Mexico/Ciudad Juarez, Chihuahua border crossing to determine the reasons for the increase in volume, but most importantly, to examine the ABCS technology that has been implemented since 1994. This ABCS project developed by Sandia National Laboratories with funding from the New Mexico DOT and FHWA is known as the Advanced Technologies for International Intermodal Ports of Entry (ATIFE) System. ATIFE incorporates an automated satellite tracking system which provides the status of the cargo container but not the vehicle, an intelligent information system which notifies stakeholders whenever data are needed, and a process map which shows the entire shipment process (63).
- NATAP was also designed to expedite commercial rail traffic, so it is important to evaluate the rail aspect of NATAP.
- Although the European Union is composed of fifteen countries with different languages, cultures and economic systems, these nations have eliminated institutional trade barriers since the early 1990's. The examination of the European Union's "seamless border" practices and possible implementation in North America should be investigated.

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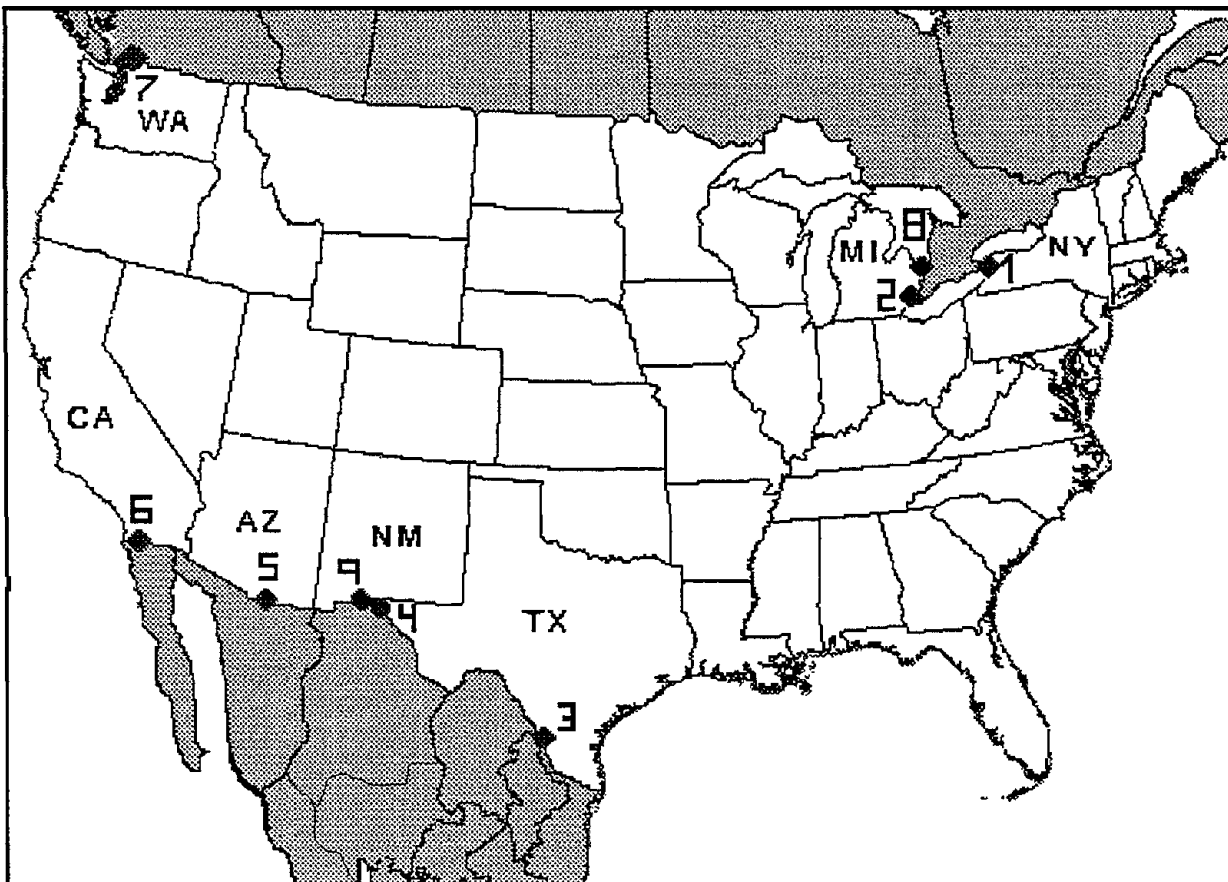
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APPENDIX A**ACRONYM LIST**

ABCS	Automated Border Crossing Systems
ACE	Automated Commercial Environment
ACROSS	Accelerated Commercial Release Operation Support System
ACS	Automated Customs System
AFRL	United States Air Force Rome Laboratory
ASTM	American Society for Testing and Materials
ATIPE	Advanced Technologies for International Intermodal Ports of Entry
AVI	Automatic Vehicle Identification
BOTA	Bridge of the Americas
CUSCAR	Customs Cargo Release
CUSDEC	Customs Declaration
CUSRES	Customs Response
DOT	Department of Transportation
EDI	Electronic Data Interchange
EPIC	Expedite Processing at International Crossings
FHWA	Federal Highway Administration
GPS	Global Positioning System
INS	Immigration & Naturalization Service
IR	Infrared
ITS	Intelligent Transportation Systems
IVVVS	In-Vehicle Voice Verification System

LED	Light Emitting Diode
LTL	Less Than Truckload
MIST	Management Information System for Transportation
NAFTA	North American Free Trade Agreement
NATAP	North American Trade Automation Prototype
NCAP	National Customs Automation Program
NYSTEC	New York State Technology Enterprise Corporation
OCR	Optical Character Recognition
PACE	Peace Arch Crossing Entry
PDN	Paso del Norte Bridge
POE	Port of Entry
RF	Radio Frequency
SAAI	Sistema de Automatizacion Aduanera Integral
SENTRI	Secure Electronic Network for Traveler's Rapid Inspection
TRIBEX	Texas Regional International Border Expedited Crossings
TSP	Trade Software Package
UN/EDIFACT	United Nations Electronic Data Interchange for Administration, Commerce and Transport
VAN	Value Added Network
WIM	Weigh-in-Motion

APPENDIX B
BORDER CROSSING SITE MAP



LEGEND:

NATAP Sites

1. Buffalo, New York / Fort Erie, Ontario
2. Detroit, Michigan / Windsor, Ontario
3. Laredo, Texas / Nuevo Laredo, Tamaulipas
4. El Paso, Texas / Ciudad Juarez, Chihuahua
5. Nogales, Arizona / Nogales, Sonora
6. Otay Mesa, California / Tijuana, Baja California

Case Study Site

7. Blaine, Washington / Douglas, British Columbia

Other Border Sites Mentioned

8. Port Huron, Michigan / Point Edward, Ontario
9. Santa Teresa, New Mexico / Ciudad Juarez, Chihuahua

APPENDIX C**ADVANCED BORDER CROSSING SYSTEMS
SURVEY**

After introductions, a brief description of the research being conducted will be given to the contact. The following questions will be asked at a minimum.

1. Of the following NATAP sites, which ones are you more familiar with?
 - a. Buffalo, New York
 - b. Detroit, Michigan
 - c. Otay Mesa, California
 - d. Nogales, Arizona
 - e. El Paso, Texas
 - f. Laredo, Texas
2. What types of traffic flows is this crossing experiencing in terms of volume?
3. What type of ITS application is being currently used at the particular border crossing?
 - a. Which technology is most beneficial? Why?
 - b. Which technology is least beneficial? Why?
4. What is your attitude towards the ITS technology in place at the particular border crossing?
5. What would you like to see changed to make the crossing more efficient?

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TRAVEL TIME ESTIMATION ON FREEWAYS USING LOOP DETECTORS AND AVI TECHNOLOGIES

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SUMMARY

Travel time information is useful to a wide variety of audiences, including transportation engineers and planners, business persons, administrators, and drivers. For traffic management centers, travel time data are commonly used for the measurement of traffic conditions and levels of congestion. As Advanced Traveler Information Systems (ATIS) become more prevalent, the importance of accurately measuring and estimating link travel time grows. Two travel time data collection technologies, inductance loop detectors and Automatic Vehicle Identification (AVI), are used to measure travel time in most traffic systems.

The objectives of this paper are to investigate the current application of loop detectors and AVI technologies used for travel time estimation on freeways and determine which technology is the better investment. A literature review, phone interviews and a questionnaire were used to help identify the current state-of-the-practice and the advantages and disadvantages for each system. This would include installation and maintenance issues, accuracy, spacing, additional benefits and costs of each system.

It was found that many state agencies are familiar with installing and maintaining loop detectors and that the cost of a loop detector system to measure travel time is relatively low. When detectors are properly maintained, they produce volume and occupancy data that can be used to calculate travel time on freeways. However, the travel time data is subject to errors in high speed or congested conditions. Loop detectors are also prone to failure and often require maintenance, which often leads to lane closures and the interruption of traffic.

Travel time can be accurately estimated with minimal roadway equipment by using AVI technology. Radio frequency antennas are often mounted on existing structures and spaced up to 10.8 km between reader stations. AVI technology is ideal for traffic management and ATIS due to their numerous uses of accurate travel time data. However, the biggest drawback of AVI is the capital and installation cost. AVI is a new technology in traffic management and requires skilled personnel for the installation, software development, and operations of such a system.

AVI technology is recommended for agencies and cities using Advanced Traffic Management Systems (ATMS) and ATIS. AVI can also extend the coverage area of ATMS beyond other data sources in use. Due to the high initial cost, areas with existing AVI systems (i.e. electronic toll collection (ETC), electronic parking) are ideal for an AVI travel time system. AVI travel time collection systems are clearly more reliable and accurate than loop detectors; however, the cost of AVI may be prohibitive. Properly installed and maintained loop detectors can be used as a low cost alternative to collect travel time data. If possible, loop detector should be installed during construction of freeway lanes.

A hypothetical AVI travel time data collection system was implemented on 16 km (10 mi) of the LBJ Freeway in Dallas, Texas. The system will provide travel time information to motorists and transportation agencies. An AVI system is ideal in the area since other AVI systems, such as toll collection and parking systems, exist and have a substantial number of vehicles equipped with electronic tags. The cost of installing and maintaining the recommended system is addressed as well as possible methods for processing travel time data.

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INTRODUCTION

Background

Travel time information is exceedingly useful to drivers, as they can estimate the time required to get to their destination. The same information is also important to transportation professionals operating traffic management centers and planning facilities. It is used for numerous applications ranging from congestion measurement to providing travel information.

The predominant source of highway traffic information comes from single-loop detectors which do not directly measure vehicle speed. The conventional method of estimating speed, and hence travel time, is from the single-loop data and an assumed vehicle length to relate density, flow, and speed (1). Two loop detectors acting together can produce the speed between them thus giving travel time between loops. A drawback to this method is that the detectors might produce inaccurate results since loops have difficulty in detecting congestion between loop locations (2). Also, single loop detectors can give less accurate results at slower speeds. Loop detectors can become unreliable by wear and tear of the road surface above them.

Automatic Vehicle Identification (AVI) technologies offer an improvement over the current travel time estimation methodologies. AVI technology has been used by electronic toll facilities across the world and is being implemented as a travel time measurement tool. The technique involves equipping probe vehicles with transponders that transmit the vehicles identification numbers. Receiving units are placed along the roadway to detect the vehicle's transponder and transmit the signal to a central computer or communications center. By monitoring several receivers, travel time can be determined by noting the time it takes a vehicle to pass two sequential receivers (3). AVI systems give accurate results since the vehicle's identification number is used to calculate travel times.

Currently, traffic information is available to motorists for some cities. Major metropolitan areas such as Houston, Minneapolis/St. Paul, San Antonio, and Seattle use loop detectors and/or AVI readers to provide travel time information. Travel time data can be passed on to the public by the use of the Internet, highway advisory radio, variable message signs, kiosks, and other Intelligent Transportation Systems (ITS) applications.

Research Objectives

To drivers, one of the most important and useful information is the time required for them to travel from one point to another on any roadway, national highway, and expressway. With this information, drivers can plan and choose a route that will take them to their destination safe and efficiently. Two systems, loop detectors and AVI, are used to measure the travel time so that travel time information can be provided to motorists.

The primary goal of this research was to investigate the current application of loop detectors and AVI technologies used for travel time estimation on freeways and to determine which is the better investment. The objectives of this study are as follows:

- Identify cities or transportation systems that utilize loop detectors and/or AVI technologies to measure travel time on freeways.
- Identify the advantages/disadvantages of loop detectors and AVI systems. This would include uses, accuracy, reliability, benefits and potential benefits of each system.
- Investigate current probe density and optimal spacing of AVI technologies in relation to loop detectors.
- Compare costs (installation, maintenance, and other costs) of AVI systems and loop detectors to measure freeway travel time.
- Investigate how the systems display travel time data for conversion to traffic information.

- Recommend which technology should be implemented to measure travel time on freeways.
- Investigate how the results could be applied to a freeway section in the city of Dallas.

Study Approach and Scope

In this paper, the author presents a detailed comparison of loop detectors and AVI technologies used by current transportation systems for measuring travel time on urban freeways. The current technology and cost of each system along with the method of how each system relays traffic information was compared.

The information presented in this paper was obtained from a literature search and contacts with of transportation professionals. Phone interviews and a questionnaire were used to help identify the current state-of-the-practice and the advantages and disadvantages for each system. From the results, a technology is recommended to be used for the measurement of travel time on freeways. This conclusion was reached by comparing loop detector and AVI technology accuracy, reliability, benefits, potential benefits, and current problems. The associated costs of the system were also compared to determine which system is the most cost effective.

These results were applied to a segment of freeway in the city of Dallas. The recommended system provides travel time information to motorists and transportation agencies. The example demonstrates the benefits of implementing the system to measure freeway travel time. The cost and feasibility of installing and maintaining the recommended system for Dallas is addressed, as well as the system's overall performance.

DISPLAY OF TRAVEL TIME INFORMATION

Benefits of Travel Time Information

Travel time information is useful to a wide variety of audiences, including transportation engineers and planners, business persons, consumers, media representatives, administrators, and drivers. Many transportation agencies have already adopted travel time measures for congestion measurement. Congestion management systems, mandated by the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, commonly use travel time-based performance measures to evaluate and monitor traffic congestion (4). Travel time data are needed to evaluate existing traffic conditions in transportation planning and for determining benefits for benefit-cost ratio calculations in transportation economic studies. In addition to providing a measurement of travel time or congestion, automated travel time estimates provide a useful measure of throughput and could possibly be employed to detect incidents.

As Advanced Travel Information Systems (ATIS) become more prevalent, the importance of accurately measuring and estimating link travel time grows. ATIS are able to disseminate traffic and travel information to individual drivers in their homes, offices, and vehicles. Different media, including variable message signs, commercial radio broadcasts, telephone systems, electronic mail, kiosks, and Internet sites, relay traffic and travel information to drivers. Using traffic information from these systems, drivers make decisions about what routes to travel, which mode to use, and what time they should depart to reach their destinations. Also, travel information is becoming important for on-board vehicle navigation/guidance systems, and accurate prediction could provide valuable information for scheduling in commercial industries, such as trucking and transit operations.

Travel Time Information Systems

Travelers make a number of choices before and during a trip, including the choice of time of travel, mode, route, and destination. The culmination of such choices gives rise to travel demand and travel time information. An individual is only able to minimize the cost or disutility of a trip based on this information if it is available. For example, if a variable message sign relays information concerning an incident to drivers, then this information allows drivers to select new routes that offer potentially shorter travel times.

In recent years, traffic management centers began using or plan to use new technologies, such as the World Wide Web (WWW) and electronic mail, to inform motorists about traffic conditions. The Internet has the potential to be the most widely used technology for an ATIS (5). The WWW is an information retrieval system that provides users with straightforward access to information in the form of text, graphics, and sound via the Internet. The number of traffic and traveler information sites on the WWW is increasing. However, many sites either are at the development stage or in a cycle of continual refinement and expansion. By using travel time data, most traffic information sites provide information on specified metropolitan areas and are helpful to the traveler in planning their route.

In a study by the Texas Transportation Institute (TTI), researchers found that accurate travel time information was useful to the traffic management efforts in Houston, Texas (6). The travel time data significantly increased the use of variable message signs on the freeway system which displays traffic information to motorists. Participants in the study indicated that accurate and believable information provided by the system directly affected their travel behavior by causing them to change routes or adjust departure times. Further analysis suggested that reliable travel time information could result in fuel savings benefits by the drivers in the system. Given that accurate and timely information is provided to motorists, the annual fuel savings benefits for the system were estimated to range between 33,800 and 67,000 liters/year (8,923 and 17,848 gal./year) (6).

LOOP DETECTOR OPERATION FOR TRAVEL TIME MEASUREMENTS

Loop Detector Theory of Operation

The predominant and most popular highway detection system comes from inductance loop detectors (Z). An inductance loop detector operates on the principle of inductance, the property of a wire or circuit element to “induce” currents in isolated but adjacent conductive media. A detector consists of an insulated electrical wire, placed on or below the road surface, attached to a signal amplifier, a power source, and other electronics. Driving an alternating current through the wire generates an electromagnetic field around the loop. Any conductor, such as the engine of a car, which passes through the field will absorb electromagnetic energy and simultaneously decrease the inductance and frequency of the loop. For most conventional installations, when the inductance and frequency changes a preset threshold in the actuate detector electronics, this indicates that a vehicle has been detected. Many factors determine loop inductance, including wire size, wire length, the number of turns, lead length, and insulation (Z).

Loop Detector Configuration

The inductive loop is an insulated electrical wire, usually several meters to a side, with several turns. Loops are installed in a variety of shapes such as square, rectangle, diamond, circular and octagonal, though each configuration produces a different electromagnetic field. The pull-box, usually located adjacent to the road, houses the splices between the lead-in cable from the controller and the lead-in wires from the loop. The controller electronics, usually housed in a cabinet detect, amplify, and process loop signals (Z).

Detectors operate in either the pulse or presence mode. Presence operation implies that detector output will remain “on” while a vehicle is over the loop. This allows the controller to measure the amount of time that a vehicle was on top of the loop. Pulsed detection requires the detector to generate a short pulse every time a vehicle enters the loop, regardless of the actual departure of the detected vehicle.

Travel Time Calculation

Loop detectors supply several pieces of information about prevailing traffic conditions, including vehicle presence, flow, occupancy and speed. Flow and occupancy may be extracted directly from loop data; however, algorithms must be developed and used to calculate point speed and travel time.

The extrapolation method is an algorithm that estimates average travel time by assuming that spot speeds can be applied for freeway sections between loop detectors (4). Using the estimated spot speeds and the known distance between detectors, the travel time is estimated. An example of the extrapolation method is shown in Figure 1.

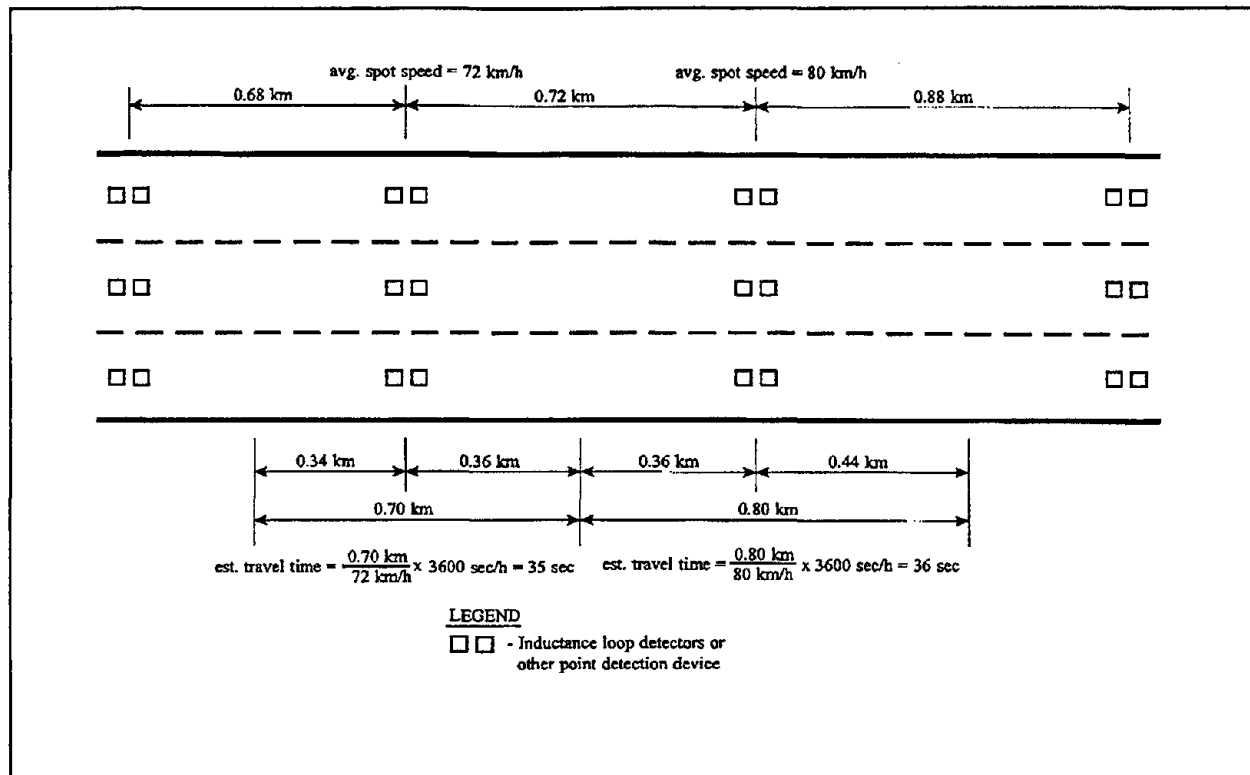


Figure 1. Example of Extrapolating Link Travel Times from Spot Speeds (4)

Speed may be approximated from the data of a single detector using the fundamental theory of traffic flow:

$$\text{flow} = \text{speed} \times \text{density} \quad (1)$$

The following equation has been used to estimate speeds from single loop detectors (4):

$$\text{speed} = \frac{\text{volume}}{\text{occupancy} \times g} \quad (2)$$

where: g = speed correction factor (based upon assumed vehicle length, detector configuration, and traffic conditions).

The Chicago Traffic Systems Center uses the typical formulation for calculating speeds by assuming an average vehicle length of 6.55 meters (21.5 feet) and a speed correction factor of 40.9 (2). Speeds are determined using the following equation (2):

$$\text{speed} = \frac{\text{volume} \times 21.5 \text{ feet}}{\text{occupancy} \times 40.9} \quad (3)$$

From the estimated speed and the known distance between detectors, estimated travel time can be computed as follows (4):

$$\text{travel time (sec)} = \frac{\text{distance (km)}}{\text{speed (km/h)}} \times 3600 \text{ sec/h} \quad (4)$$

While it is possible to obtain reasonable travel time estimates with single loop data, paired loops offer a more accurate approach. When using a “speed trap”, travel time is measured directly between two loop detectors which are separated by a known distance. This time is measured from when the vehicle crosses the leading edge of each detector. There are several considerations in the “speed trap” design. For one, loop inductance is a strong function of vehicle speed. As the freeway speeds increase, the percentages of the inductance shift decreases. Sensitivity settings may have to be adjusted when loop detectors are used in high-speed freeway environments (8).

The results of a TTI study indicated that the accuracy of the “speed trap” design was dependent upon the separation between loops, inductance loop wire type, and consistency in design and use (8). The study found that the optimal distance between inductance loops was 9 meters. In practice, California Partners for Advanced Transit and Highways (PATH) researchers found that inductive loops are spaced anywhere from 2 meters to more than 20 meters. However, if detectors are too closely spaced, cross-talk may occur, while detectors spaced too far apart may be susceptible to vehicle lane changes. The researchers also suggest an optimal spacing of 9 meters (9).

AVI OPERATION FOR TRAVEL TIME MEASUREMENTS

AVI Theory of Operation

Automatic vehicle identification provides operators with the ability to track probe vehicles by wireless communication to the transportation centers. The probe vehicle technique utilizes passive instrumented vehicles in the traffic stream and remote sensing devices to collect travel times. There are several types of AVI technologies available to read the information from the tags of passing vehicles. These include infrared scanners, video cameras, inductive loops that read tags, and radio frequency (RF)/microwave technology (2). The most common type of AVI technology used is the RF/microwave system. This system is in widespread use throughout the United States for a variety of purposes: electronic toll collection, incident management, performance measure data collection, traveler information, and traffic monitoring.

AVI Configuration

The system design of an AVI system is represented by the system architecture and software design (10). The system architecture defines the framework of the major hardware and software components of the AVI system and the methods used to communicate between components. The software design focuses on the software components of the AVI system using data flow analysis and structure charts. Less attention is usually paid to the hardware components while more attention is paid to the software components because they have to be custom-developed for each system.

Figure 2 illustrates the AVI components and the data collection process. Travel time can be computed by using a basic AVI system that has four primary components (4):

- probe vehicles equipped with electronic tags;
- roadside antenna that detect the presence of electronic transponders;
- roadside readers which bundle data; and
- a central computer facility to collect and interpret all data and compute travel time.

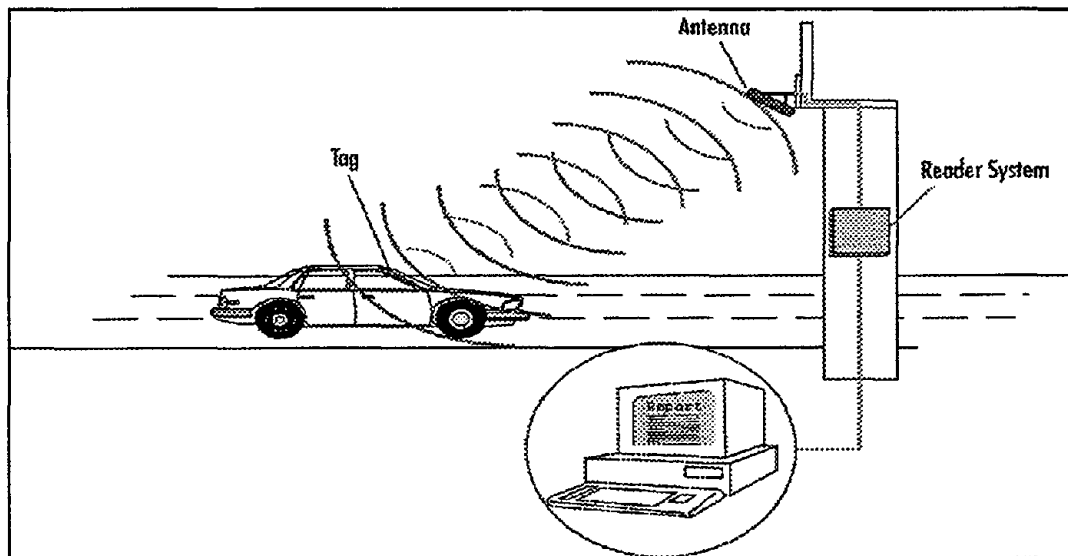


Figure 2. Typical AVI Reader Station

Electronic tags, also known as transponders, are encoded with unique identification (ID) numbers. Roadside antennas are located on the roadside or overhead structures (e.g., bridges, guide signs), or as part of an electronic toll collection booth. The roadside antenna broadcasts radio frequency energy over one or more freeway lanes called the read zone or reader footprint. The antenna's radio frequency source is either integrated or a separate component (10).

When the probe vehicle is in the read zone, the tag reflects a small part of this radio frequency energy back to the antenna. The reflected radio waves denote the tag's unique ID number and other stored data. The antenna relays the signal to the reader system, which can add information such as date/time to the tag's identification code and stores it in a buffer. These bundled data are then transmitted to a central computer facility via telephone line where they are processed and stored.

Travel Time Calculation

AVI calculates travel time from probe vehicles equipped with electronic tags. The travel time information is obtained by subtracting the time a vehicle enters a freeway section, location A, from the time a vehicle leaves the freeway section, location B. This is expressed mathematically as shown in the following equation (2):

$$TT_i = T_{bi} - T_{ai} \quad (5)$$

where:

TT_i	=	travel time of vehicle i from location A to location B,
T_{bi}	=	time vehicle i passes location B, and
T_{ai}	=	time vehicle i passes location A.

Travel times vary from vehicle to vehicle and the mean travel time values on the freeway sections are much more meaningful to traffic managers. Mean travel times for specific periods can detect patterns and congestion problems on a freeway section. By maintaining both a rolling average of travel times and a historical record of the previous time period, the system can determine both current conditions and when those conditions become congested (4).

FINDINGS FROM LITERATURE REVIEW

Introduction

The literature review yielded information on existing loop detector and AVI systems that collect travel time data. Spacing of the loop detectors and AVI readers along with the data collection techniques used by traffic management centers were reviewed. How these systems use and display the travel time data for conversion to traffic information was also investigated.

Loop Detector Systems

Seattle Smart Trek System

The travel information system in Seattle, Washington is one of the most extensive systems in the United States. The system is called Smart Trek and utilizes numerous technologies to provide travel information to travelers and public/private agencies. Smart Trek utilizes travel time data collected from loop detectors to provide a more comprehensive picture of traffic.

The Washington State Department of Transportation (WSDOT) uses a network of loop detectors embedded in the highway. The loop detectors are located every half-mile on major Seattle area freeways, and the data from the loops is transmitted every 20 seconds to the WSDOT Traffic Systems Management Center (TSMC) (11).

The loops used in the Seattle system are six foot square and are connected to Type 170 micro-computers located in roadside cabinets. Each cabinet is equipped with a type Bell 202 1200 bit-per-second modem that is connected to a communication hub (11). From the communication hub, fiber optic cables transmit loop data along with video surveillance to the TSMC. Computers at the TSMC then compute travel times and speeds and plot the results on monitors in the TSMC control room. The TSMC uses variable message signs, dial-up phone service, broadcast on the highway advisory radio, and a WWW traffic page to display the results.

The results are displayed on the WSDOT FLOW Map, an Internet based map of traffic speeds and incidents. Interest in the travel map has been a success with almost 300,000 hits a day (12). The Smart Trek system includes TrafficView, which provides views of area highways, traffic speeds and incident locations, and advises which route to take between selected highway access points. Customized traffic reports are sent via electronic mail to your computer at the times you select.

Another system of Smart Trek delivers customized traffic reports for the road segments you select at the times you need updates. The traffic reports are being made available to message watches, pagers, desktop and portable computers, hand-held devices, TV, radio, kiosks, and in-vehicle navigation units. Other systems include bus, ferry, and airport information, variable messages signs, cable television channels devoted to traffic information and commercial radio reports (12).

San Francisco Bay Area TravInfo System

TravInfo, the San Francisco Bay Area's ATIS, is a public/private partnership that provides traffic information to Bay Area travelers. TravInfo gathers travel time data from loop detectors to produce information on traffic speed and congestion. Similar information comes from a fleet of tow trucks equipped with automatic vehicle location (AVL) system and closed-circuit television cameras.

Traffic information is available by telephone hotline, highway advisory radio, and three separate WWW sites. Public sector partners furnish a multimodal, database on the operating conditions of freeways, transit systems

and major arterials (13). Private sector partners use the database to archive, analyze and provide travel information to the public. The public and private partnership is essential in the development of this system.

Minnesota System

Roadway loop detectors are a main element of Minnesota Department of Transportation's Traffic Management Center (TMC). The TMC helps Twin Cities metropolitan area motorists reach their destinations safely and efficiently by managing traffic on the metro area freeway system. Loop detectors are spaced about every half-mile along the freeway system and the data of the loops are transmitted to the TMC every 30 seconds (14). The data are used by TMC computers to estimate the average speed and travel time for freeway sections. The speed and travel time data are then used to generate map displays of traffic conditions. They are also used by TMC computers to determine ramp metering rates and help detect congestion. The traffic condition information is displayed on the Twin Cities Sidewalk site on the WWW (15) and broadcast on a traffic radio and cable television station.

San Antonio System

The San Antonio Advanced Traffic Management System (ATMS)/Intelligent Vehicle Highway System (IVHS) TransGuide utilizes inductive loop detectors in a "speed trap" configuration to accumulate travel time data. These detectors are placed in each lane of the entire system, 26 miles for the completed Phase I project, at a maximum of one half mile spacings (16).

Each inductive loop is six feet square and consists of one conductor 14 AWG grade loop of wire buried approximately one inch between loops. Each loop detector is interfaced with a local control unit (LCU) microprocessor which connects a group of detectors at a station. Software algorithms running on the LCU microprocessor accumulate speed, occupancy, and volume rates in memory. The LCU keeps a moving average of these rates for a period of between 10 and 60 seconds and sends the accumulated average speed and occupancy data to TransGuide mainframe. The LCU also performs diagnostic monitoring of each detector to test for failure and will report any non-activity or maximum presence conditions (16).

At TransGuide, the mainframe software system is responsible for providing detection, routing, analysis, display, storage, and archiving. The software analyzes the roadway data by the LCU and uses a rolling average technique to compare the incoming data to preset thresholds. The system uses variable message signs, a low powered television station, and a traffic map on the WWW to display average travel times. Table 1 summarizes the existing loop detector systems acquired from the literature review.

Table 1. Summary of Loop Detector Systems

Loop Detector Systems	Spacing	Use of Travel Time Data	Other Information
Seattle Smart Trek	0.9 km (0.5 mi)	Variable Message Signs Phone Service Highway Advisory Radio WWW	Extensive ATIS Planned
San Francisco Bay Area TravInfo	N/A	Phone Service Highway Advisory Radio WWW	Public/Private Partnership
Minnesota Twin Cities System	0.9 km (0.5 mi)	Congestion Detection Ramp Metering Traffic Radio WWW	
San Antonio TransGuide	0.9 km (0.5 mi)	Congestion Detection Variable Message Signs WWW	Addition to AVI System

AVI Systems

The primary application for AVI technology is for electronic toll collection. Currently, about 18 U.S. toll collection agencies use AVI to electronically collect tolls (4) and an additional 10 toll agencies are planning to use AVI for electronic toll collection by the end of 1998. Electronic toll collection (ETC) systems can provide useful travel time data, particularly on systems with a large percentage of motorists using electronic tolling. The combination of an electronic toll collection system and a traffic information and management system can be referred to as an electronic toll and traffic management (ETTM) system. A few large metropolitan areas collect travel time data and monitor traffic operation with AVI technology.

Houston System

The TranStar Traffic Monitoring System in Houston, Texas is the first AVI system installed in the U.S. to implement the traffic management aspect of ETTM technology. The system monitors traffic conditions, detects incidents, distributes travel information, and archives travel time data. With the help of the Texas Department of Transportation (TxDOT), the Houston AVI system required four to six months per phase for installation and used the above-the-road sensors to avoid the roadway closures and the attendant traffic control costs of roadway closures (17).

Antennas are mounted above traffic on existing roadway overpasses, overhead sign structures, or side-mount sign structures. The Houston system uses two general antenna types: a type that emits a directional, narrow, and long RF capture range and a type that emits a broader and shorter RF capture range. Each type is designed for certain lanes and traffic conditions.

The antenna spacing depends on the availability of existing structures, and spacings are typically 2.0 km (1.2 mi). The actual range of spacings is between 1.4 km (0.9 mi) and 10.8 km (6.7 mi) with an average range of about 4.6 km (2.85 mi).

Motorists traveling during the peak period were targeted to receive tags; however, the system relied upon vehicles equipped with ETC tags. Over 200,000 tags have been distributed through the local automated toll collection system to date. Approximately five percent of the total volume passing antenna locations yield tag reads (4). This corresponds to approximately four tag reads per minute during peak periods and about three tag reads per minute during off-peak periods.

There are several agencies, in addition to the TxDOT, that are installing AVI systems in Houston. The Harris County Toll Road Authority has installed an AVI system for toll collection and the city of Houston Aviation Department is preparing to install AVI at their two airports for the automatic fare collection of commercial vehicles using the airport facilities. These AVI systems should be compatible and will help aid in the collection of travel time data. For trip planning purposes, this travel information is available through the WWW, through media reports, and through roadside variable message signs.

New York/New Jersey TRANSMIT System

The TRANSCOM System for Managing Incidents and Traffic (TRANSMIT) system operates on 29 km (18 mi) of the New York State Thruway and Garden State Parkway in New York and New Jersey. The system is part of an ETTM system which utilizes vehicles equipped with electronic toll tags to serve as vehicle probes within the traffic stream. The primary system function is the processing of traffic flow data for detection of incidents and the identification of unusual congestion conditions (18).

Twenty-three antennas are used on the TRANSMIT system and one antenna is used to cover all lanes in one direction. Mountings utilize existing overhead structures. Antenna spacing of 2.4 km (1.5 mi) is used for a maximum incident detection time of five minutes. The probe vehicle density specified by the system is 0.9 percent of total volume for two-lane highways and 2.1 percent for three- and four-lane highways.

Seattle's Puget Sound System

The Washington State Transportation Center (TRAC) performed a study to investigate the use of an AVI system to collect travel time data in Seattle's Puget Sound Region (19). This system used an AVI loop detection type system with 50 in-vehicle transmitters and 10 antenna units. The study checked AVI data for consistency and found that 17 percent of the vehicles (buses) went undetected. TRAC concluded that there were potential applications for loop-based AVI technology; however, a AVI system would require a significant investment by the transportation agency.

The receivers were connected to ten inductive loops located in high occupancy vehicle (HOV) lanes along the north Seattle I-5 corridor. Sequential antenna spacing was between 1 and 4 km (0.62 to 2.5 mi) with an average distance of 2.6 km (1.61 mi) (19). Forty-nine transmitters were installed on the underside of buses, while one transmitter was installed on a Washington State Department of Transportation vehicle.

San Antonio System

As part of a nationwide initiative to implement new applications for ITS, the Federal Highway Administration selected San Antonio, Texas as one of the four sites in the United States to receive funding under a federal program called the Model Deployment Initiative (MDI). One part of the TransGuide system is to integrate AVI technology to monitor traffic conditions. Tagged vehicles act as traffic probes to provide actual travel time and the average speed along key sections of the highway. With the travel time and speed data, the system also provides comprehensive data used for traveler information systems, traffic diversion messages, and incident reporting (20). The cost for the AVI systems in San Antonio is approximately \$3,500,000.

To reduce installation costs, AVI antennas were mounted on existing overhead structures. Antennas are spaced at 1.6 km (1 mi) to 3.2 km (2 mi) intervals. Site selection for antennas was based partly on an analysis of volume to capacity ratios to determine the most congested areas of the freeway system (4). The plan to distribute AVI tags through the vehicle registration process is behind schedule, and tags are now being distributed on a volunteer basis. Approximately 30,000 tags are in use and 48,000 more tags are planned to be distributed, based upon budgetary constraints. San Antonio does not have any ETC systems to contribute to the data collection; however, toll tags and other electronic tags from other cities and states can be read by the reader sites.

Oslo AVI System

The AVI system in Oslo, Norway calculates travel times from over 400,000 probe vehicles (18). The Oslo AVI system tracks vehicles and averages travel times every five minutes for each section within the roadside reader units. The averaged travel time data are transmitted every five minutes to a traffic control center. The number of probe vehicles is high, since one-third of the total traffic population is equipped with electronic tags and these tags are used on numerous toll roads in and around Oslo. About 20 vehicles pass test sites every five minutes on average (21).

Gary-Chicago-Milwaukee Corridor Transportation Information Center

The Illinois Department of Transportation (IDOT) and the Illinois State Toll Highway Authority are jointly working on a project to use the I-PASS electronic toll collection system to generate travel time information. The toll way authority is currently expanding the installation of the AVI technology to cover the entire toll way and will use anonymous information from the I-PASS system to calculate travel times between interchanges (22). Table 2 summarizes the existing AVI systems acquired from the literature review.

Table 2. Summary of AVI Systems

AVI Systems	Spacing	Probe Density	Use of Travel Time Data	Other Information
Houston TranStar	1.4 km - 10.8 km (0.9 mi - 6.7 mi)	200,000 5% Volume	Variable Message Signs Media Reports WWW	Existing ETC First ETTM
New York/ New Jersey TRANSMIT	2.4 km (1.5 mi)	0.9-2.1% Volume	Congestion Detection Incident Detection	Existing ETC
Seattle's Puget Sound Study	2.6 km (1.6 mi)	50	Test Accuracy	Loop-base AVI Significant investment
San Antonio TransGuide	1.6 km - 3.2 (1.0 mi - 2.0 mi)	15,000	Congestion Detection Variable Message Signs WWW	Addition to loop detector system
Oslo, Norway	N/A	400,000 33% Volume	N/A	Existing ETC
Gary/Chicago/ Milwaukee Corridor	N/A	N/A	N/A	Existing ETC Planned System

FINDINGS FROM SURVEY

Introduction

Various transportation professionals were surveyed to help identify the current state-of-the-practice and the advantages and disadvantages for loop detector and AVI systems. A questionnaire was developed and administered to individuals with knowledge of or involved in these systems that are used for travel time data collection (see Appendix). The questionnaire included questions on spacing, accuracy, and benefits of loop detector and AVI systems and also asked the participant about problems and costs associated with each system.

The survey was sent to one professional and phone surveys were conducted on 8 individuals. The majority of the participants were from Texas and one was from Minnesota. Amtech Transportation Systems Group and TxDOT were contacted for cost information.

Loop Detector Systems

Minnesota Department of Transportation

There are approximately 3,000 loop detectors in place on the Twin Cities metro area freeways. The system covers 328 miles of freeway and provides volume and occupancy data, and estimated travel time and speed information (23). Travel time information is used by TMC to monitor and evaluate their system. This information is also displayed on a traffic map viewable from the WWW. Construction and paving projects on the loop detector system are seen as a major problem. Loops are placed 25 mm (1 in) to 38 mm (1.5 in) below the road surface and are often milled out. The cost of one loop detector in the system is approximately \$1,500. Other uses that the data from loop detectors provide are for ramp metering and volume manuals used for planning construction (23).

San Antonio TransGuide

It was found through the survey that San Antonio has over 650 detection stations which are placed 0.8 km (0.5 mi) apart. San Antonio's TransGuide system places loop detector stations near entrance and exit ramps and are spaced for queue detection (24). According to TransGuide, ten percent of the loops are malfunctioning or need service. A problem associated with the loop detector system is that loop sensitivity settings often need to be reset. Also, during congested periods, data is often verified by surveillance cameras. Travel time data from loop detectors are used for incident detection and the presentation of traveler information on the WWW (24).

AVI Systems

Dallas Planned AVI System

The Texas Transportation Institute (TTI) in Dallas and TxDOT are in a preliminary design stage of implementing a small scaled AVI system in North Dallas (25). They are in the process of installing three reader stations on the LBJ Freeway (I-635) approximately spaced one mile apart. Detection cameras are going to be used in addition to the AVI system for data verification. Each detection camera has a 0.8 km (0.5 mi) range and will cover the AVI coverage area. Travel time data will be transmitted through telephone lines to the TTI office for evaluation and analysis. Travel time data will be tested for accuracy and reliability in various traffic conditions.

San Antonio TransGuide

The AVI system in San Antonio consists of 53 reader stations placed in freeway sections not covered by loop detectors or camera surveillance (24). According to TransGuide, the system has proven to be reliable and very accurate. The problem associated with AVI systems, is malfunctioning modems located in the reader. Travel time data is used as part of their ATIS and data will be available to a planned in-vehicle navigation system.

Researchers from the Center for Transportation Research at Virginia Tech are currently evaluating the AVI and loop detector system in San Antonio as part of the MDI. The overall objective of the MDI evaluation project is to evaluate the throughput, safety, environmental, and integration benefits of ITS. Part of the evaluation consists of analyzing San Antonio AVI and loop detector travel time measurements (26). Global Positioning Systems (GPS) are being used to evaluate the accuracy and reliability of travel time measurements of the two systems.

Costs

Amtech Transportation Systems Group AVI systems are used in Dallas, San Antonio, and Houston. For a three station AVI system in Dallas, the cost of a three site system is \$160,000. The cost of an AVI system depends on the accuracy and size of system (27). Cost is a main concern for transportation agencies (28, 29). The typical cost for TxDOT to install one loop detector is approximately \$2250 (25). This price includes the loop detector, LCU, cabinet, and electrical equipment. In order to measure speed at the greatest accuracy, two detectors (\$4500) would be required. This does not include the costs of road closures and the delay to motorists. Table 3 summarizes the data acquired from the survey.

Table 3. Summary of Findings from Survey

	Loop Detector Systems	AVI Systems
Spacing	0.8 km (0.5 mi)	1.6 km - 16.0 km (1.0 mi - 10.0 mi)
Accuracy	Reliable Verified with Other Data Source	Very Accurate
Problems	Malfunctions Sensitivity	Costs Modems
Travel Time Information	Incident Detection Freeway Link Monitoring	System Evaluation ATIS
Costs	\$1500 - 2250/loop - cabinet, equipment, and LCU	\$160,000/3 site system

COMPARISON OF LOOP DETECTOR AND AVI TECHNOLOGIES FOR TRAVEL TIME MEASUREMENT

Installation and Maintenance

Any installation and maintenance of loop detectors requires road closures. Road closures cause delay to traffic and present safety concerns to drivers and the installation crew. A loop detector must be installed for each lane and requires a lengthy process to install, especially on a high-volume, multi-lane freeway. A typical traffic monitoring project using loop sensors requires two to three years to construct and requires numerous lane closures during installations (17). Loops are often restricted to access and egress points for maintenance and inspection. Along with other factors, poor installation procedures is a common source of loop failure. For a loop to be effective and long lasting, care must be taken in the installation process. Saw cuts should be uniform, clean, and properly sealed, and inductance settings should be set accordingly to speed.

All inductance loops are subject to malfunction, and such malfunctions can dramatically and adversely affect detection. Many factors such as pavement and sealant failure are commonly identified as the main causes for failure. Pavement failure or deformation causes loop wires to be strained resulting in breakage, wire insulation wear, or the infiltration of foreign materials. Sealant failure causes the loop to be exposed and in many cases the loop was found to have floated to the top of the cut (30).

Other common sources of loop failure include poor installation and maintenance procedures, damage from utility repair, construction, or snow removal, lightning surges, malfunctioned amplifiers, and corroded splices or wires. Failure rates vary significantly, ranging anywhere from three to fifteen percent per year (30). In practice, loop inspection procedures vary substantially among state agencies.

AVI antennas are not exposed to extreme traffic conditions like loop detectors. AVI antennas are usually installed on existing structures such as bridges and guide signs. An AVI system can be installed and maintained without significantly interfering with the traffic flow. Antennas have the ability to be installed at locations that restrict loop detector installation, and one antenna can collect data from multiple lanes. Very few personnel are needed to maintain the system and process data which results in the reduction of risk of injury in the field (4).

Accuracy

For loop detector systems, travel time is measured by two detectors spaced at the beginning and end of the section. However, loop detectors are not very accurate for detecting congestion, which affects actual travel time on the section. This is due to the fact that loop detectors only estimate speeds immediately upstream and downstream of the detector. When spacing of detectors is greater than 0.8 km (0.5 mi), significant changes in speed can occur between the detectors without being noticed at the detector locations (2). Being slow to detect reduced speeds, the detectors cannot determine how the delays between them relate to total travel time within the section.

According to California PATH researchers (9), accurately calibrated speed traps with loops of individual wire can expect to achieve measurement errors of 5 to 8 km/h (3 to 5 mph) at low speeds and 16 to 19 km/h (10 to 12 mph) at high speeds. Multi-conductor cable loops average errors about of 0.3 km/h (0.2 mph) at low speeds and 5 to 8 km/h (3 to 5 mph) at high speeds. Hall and Persaud (31) and Pushkar et al. (32) show that speed estimates by loop detectors are flawed and that the accuracy of equation used to estimate travel time is a function of many factors, including location, weather, and systematic bias with respect to lane occupancy.

Based on results of the Advanced Driver and Vehicle Advisory Navigation Concept (ADVANCE) project evaluation (33), the estimates of link travel time produced by loop detectors appear to be accurate except when

highly congested conditions exist over long periods of time. During highly congested periods, loop detectors do not provide reliable information on changes in traffic flow. Freeway loop detectors may provide reasonable estimates in light traffic, but using detector estimates in heavy congestion can provide inaccurate results. Many urban traffic control centers are planning for more accurate measures of sectional travel times using AVI and GPS receivers.

The AVI technology used to measure travel time is based on Electronic Toll Collection (ETC) that is used to automate toll collection. Agencies using AVI technology have experienced detection accuracy rates of between 85 to 99 percent (4). An AVI system can be designed to meet accuracy needs

Probe Density

Loop detectors do not require specific probes for data collection while AVI requires a minimum probe density to maintain accurate travel times. AVI probes can be personal, public transit, or commercial vehicles and are usually not being driven just to collect travel time information. Probe vehicle sample sizes vary depending on many factors such as existing AVI systems, road networks and traffic patterns. The probe density requirement for an AVI system is based on desired levels of accuracy and the location of readers.

AVI probe density varies depending on location and the existence of other AVI systems. For example, the Oslo AVI system calculates travel times from 33 percent of total volume, over 400,000 tags, while the New York/New Jersey system only collects data from 0.9 percent of total volume (18, 21). Over 200,000 tags have been distributed in Houston and approximately five percent of the total volume give travel time measurement (17). In a study by TTI, researchers found that a greater number of probe vehicles are needed on congested freeways than on less congested freeways (17).

Spacing

Loop detectors are often placed at 0.4 to 0.8 km (0.25 to 0.5 mi) spacings on freeways for incident detection. For the loop detector systems investigated in this report (the Twin Cities, San Antonio, and Seattle), detectors are spaced at every half-mile and are used for incident detection and travel time measurement. If the spacing of the detectors increases to more than 0.8 km, inaccurate speed estimation could occur in heavily congested areas or where there is significant vehicle lane changing (34). Since point speeds are used for the estimation of travel time, inaccurate speed estimation leads to erroneous travel time information. The relative short spacing requirements can also adversely impact costs of the installation and maintenance of a loop detector system.

Typical AVI antenna spacings range between 2 km (1.2 mi) to 5 km (3.1 mi). The Houston system uses spacings between 1.4 km (0.9 mi) and 10.8 km (6.7 mi). The level of congestion is often considered in the placement of antennas. In areas with greater expected congestion, antennas are placed more closely. An AVI system designer for the TRANSMIT project recommends that antennas be spaced no greater than two minutes apart in sections where speeds are less than 48 km/h (30 mph) during recurring congestion (18).

Costs

Loop detectors have numerous costs associated with them. Table 4 shows the cost of just the communications equipment. Frequent loop failures tend to increase maintenance costs along with lane closures. A lane closure can cost up to \$4000 depending on location and time required for installation. Also, loop maintenance costs are high due to the fact that the majority of malfunctioning loops are replaced without any diagnosis of the cause of failure.

Table 4. Loop Detector Hardware Costs for Point Speed Detection (2)

Equipment/Personnel	Unit Cost
25 pair 22 AWG communications cable	\$4.92/meter
6 pair 22 AWG communications cable	\$3.28/meter
T-1 Digital Multiplexer	\$12,000
Data Transceiver	\$2,400
Fiber Optic Cable	\$11.48/meter

The cost of AVI technology depends on the system being developed and implemented. A big factor in the cost of hardware and software is the required accuracy of the system. Other systems which utilize AVI and allow partnerships can greatly reduce costs and can benefit the overall system. Table 5 summarizes AVI equipment and costs. Depending on location, freeway lanes might be closed for a period of time. According to Amtech Transportation Systems Group (27), the cost for a 3 site system would be \$160,500. With a coverage of 3 sites and 12 antennas, the approximate cost per point detection is \$13,000.

Table 5. Estimated AVI Hardware Costs

Equipment	Unit Cost
Electronic Tag	\$20 - \$50
Roadside Antenna	\$1,500
Roadside Reader	\$10,000 - \$30,000
Cable Connection	\$100/meter
Telephone Communications	Varies

Both loop detector and AVI systems consist of a central computer that collects, stores, and processes the travel time data. Each computer has specialized software installed or developed and require trained personnel operating the computer. These costs must be considered when developing a system. Table 6 shows the costs that are associated with data collection and the storage system.

Table 6. Estimated Software and Personnel Costs (4)

Equipment/Personnel	Unit Cost
Control Facility Computer	\$2,000 - \$5,000
Computer Data Storage	\$100 - \$200/gigabyte
Specialized Software	Varies
Analysis Software	\$150 - \$300
Data Reduction Personnel	Varies

Additional Benefits

Since the 1960s, the inductive loop detector has become the most popular form of detection. Loop detectors are used for signalized intersection control, ramp metering control, and freeway surveillance and control. Loop detectors detect the presence of vehicles and have the ability to produce volume and occupancy data. Algorithms are continually being developed to accurately estimate travel time and speed. Loop detectors are limited in use, however, in comparison with AVI technology.

The AVI has a number of uses and the potential to collect data that are difficult to obtain, such as origin/destination (OD) data. The AVI traffic probe concept has the potential to yield OD data that are accurate and extremely useful. OD information can be used for improving the accuracy of traffic simulation models and as basic data for traffic control planning. This information is useful under both normal conditions and special events.

AVI can provide the benefits associated with preempting signals to improve the travel times of emergency vehicles and buses. With AVI systems, businesses and communities can control access, authorize security, and administer monthly parking fees automatically.

With AVI, commercial and government fleets can collect, track, monitor and report data for operations and maintenance. AVI technology can automatically identify and monitor rail and intermodal equipment. Other potential applications include performance monitoring of HOV lanes and regulation of HOV lane use. These AVI benefits may complement emerging ITS, ATMS, and ATIS.

Summary of Findings

Two types of travel time collection technologies, loop detector and AVI, have been presented and discussed. Based on this research, the advantages and disadvantages are summarized in Table 7.

Table 7. Advantages and Disadvantages of Loop Detector and AVI Systems for Travel Time Data Collection

Data Collection Technology	Advantages	Disadvantages
Loop Detector System	<ul style="list-style-type: none"> • Detectors count useful volume data. • Required skill and knowledge level is low. • Reasonable estimates of travel time can be obtained in light traffic (point speed errors of 5 to 8 km/h from which travel time is calculated). • Capital, installation, data collection, and data reduction costs are low (\$8,670 cost per station). 	<ul style="list-style-type: none"> • Installation and maintenance of loops requires lane closures. • Loop detectors frequently malfunction and need a high degree of maintenance. • Travel time is not directly measured. • Travel time estimation is considered inaccurate especially for congested freeways. • For large systems, the short spacing requirement can increase the number of detector stations and cost.
AVI Systems	<ul style="list-style-type: none"> • Very accurate (up to 99%) travel time information is collected and distributed by ATMS and ATIS. • Travel time data are collected for entire 24-hour periods for each day since personnel are not required for field data collection. • Operating and maintenance costs of each station are low. • Hardware can be installed on existing structures and where loop detectors are not feasible. • Installation on existing structures reduce the disruption of traffic. • AVI technology is used in toll collection and fleet management and can provide abundant travel time data. 	<ul style="list-style-type: none"> • High capital and installation costs (up to \$50,000 per station). • Data collection is limited to the probe density, i.e., the number of tags in use within the study area. • Privacy is a main concern and issue among motorists. • Travel times are limited to fixed routes and reader stations. • Technology is new and unfamiliar to most transportation agencies. • No Volume Data

For an 8-lane, 16 km (10 mi) freeway segment, a loop detector system requires 42 stations for 0.8 km (0.5 mi) intervals. Each station includes 8 loop detectors (2 per lane), a cabinet, LCU and communication equipment. The cost of a station is \$18,000 and the total cost of 42 stations are approximately \$756,000.

For a comparable AVI system, 10 reader stations are spaced at 3.2 km (2 mi) intervals. At a cost of \$13,000 per lane, the cost of a station is \$52,000. The total cost of 10 reader stations is \$520,000. If the operating agency must buy electronic tags, the cost of 50,000 tags at \$20 per tag would be \$1,000,000. The cost of the system is \$1,520,000, double that of loop detectors. Table 8 provides a summary comparison of loop detector and AVI technologies.

Table 8. Comparison of Travel Time Collection Technologies

Data Collection Technology	Costs			Data Accuracy	Constraints
	Capital	Installation	Data Collection		
Loop Detector Systems	Low	Moderate	Low	Low	High failure rate and inaccurate estimations
AVI Systems	High	High	Low	High	Probe density and antenna sites

CONCLUSIONS

Loop detector and automatic vehicle identification (AVI) systems have been studied to determine the current installation and operating procedures, accuracy, and cost factors of each system. Loop detector systems are commonly used by traffic management centers for travel time data collection in the U.S.. Many state agencies are familiar with the loop detector installation and maintenance and the cost of a loop detector is relatively low. When detectors are properly maintained, they can produce volume and occupancy data that can be used to calculate travel time on freeways. However, this information can only be estimated and is subject to errors in high speed or congested conditions. Loop detectors are prone to failure and often require maintenance. Also, when loop detectors are installed or require maintenance, lanes of the freeway are often shut down, potentially causing congestion and accidents.

Travel time can be estimated with minimal roadway equipment by using AVI technology. Since individual vehicles can actually be tracked from one reading site to the next, average travel times can be accurately determined. Accurate information also can be collected without covering all lanes at each reading site. AVI technology is ideal for traffic management and Advanced Traveler Information Systems (ATIS) due to their numerous uses of accurate travel time data. However, the biggest drawback of AVI is the cost. AVI is a new technology in traffic management and requires skilled personnel for the installation, software development, and operations of such a system. The capital costs of reader stations and electronic tagged vehicles is significant when compared to loop detectors.

AVI technology is recommended for agencies and cities using Advanced Traffic Management Systems (ATMS) and ATIS. Accurate and reliable travel time information is vital to ATIS since there are many users that rely on the information. If the information is inaccurate or irrelevant, motorist will dismiss the information and the extensive efforts and money put into ATMS and ATIS will be wasted. AVI can also extend the coverage area of ATMS beyond other data sources in use; i.e. automatic vehicle location (AVL), loop detectors, cameras. Due to the high initial cost, areas with existing AVI systems are ideal for an AVI travel time system. The system can benefit from vehicles equipped with compatible electronic tags so that purchase of additional tags is kept to a minimum. AVI systems may require a significant investment in communications infrastructure, but they can provide accurate and reliable travel time data.

AVI travel time collection systems are clearly more reliable and accurate than loop detectors; however, the cost of AVI may be prohibitive. Properly installed and maintained loop detectors can be used as a low cost alternative to collect travel time data. If possible, loop detector should be installed during construction of freeway lanes to reduce errors in the installation and lane closures. Attention must be directed to factors affecting the accuracy of travel time data; location of detectors, distance between detectors, traffic conditions, and accuracy of each detector.

IMPLEMENTATION OF RESULTS

Introduction

The findings in this report were used to implement a hypothetical travel time data collection system for the city of Dallas, Texas. The data collection system will collect travel time information on a specified freeway section and will be collected for several purposes. Transportation agencies in Dallas can use the travel time data for performance measures to evaluate and monitor congestion. The main objective of the data collection is to establish a database of current roadway operating conditions. This travel time data will be available through ATIS; therefore, accurate and reliable information is needed. ATIS will be able to distribute traffic information to travelers using or planning to use the system.

Three steps were used to determine which system should be implemented for travel time data collection. These steps include the following:

1. Investigate any existing sources that measure or provide assistance in measuring travel time;
2. Determine the needs and potential users for the travel time data; and
3. Determine the financial resources and expertise available for the travel time measurement system.

The first step in selecting a travel time collection technology is to investigate any existing sources that measure or provide assistance in measuring travel time. The North Dallas Tollway uses Amtech Transportation Systems Group AVI system for toll collection and 200,000 Amtech electronic tags are currently in use. Garages in the Central Dallas Association (CDA) parking network will be equipped with Amtech's AVI system to control parking access and fees. Amtech will also provide its AVI system to manage financial transactions at the Dallas/Forth Worth International Airport (DFW). Patrons will be able to use the same tags for all three AVI applications. Loop detectors are used on 11 miles of the North Central Expressway (U.S. 75) to collect freeway speed and travel time. Loop detectors were installed with the reconstruction of the freeway.

The next step in considering a technology is to consider all needs and potential users for the travel time data. Travel time data are needed by agencies to evaluate existing traffic conditions in transportation planning, conducting transportation economic studies, and has the potential to detect incidents. Travel time will be used to disseminate traffic information through existing variable messages signs, radio broadcasts, telephone systems, and the Internet. Since the travel time data will be used for several purposes, the data must be accurate and reliable.

The last step is to consider the resources available for implementing a travel time collection system. Financial resources are needed for the planning, implementing, and continuation of a system. Funds can possibly be obtained from Federal and state programs that encourage traffic management. If seen as a benefit for the public, public and private agencies can contribute financially or with their expertise. Experienced and trained personnel are also needed for the complex processing of the data and for the maintenance of the system.

An AVI system was determined to be the best data collection system to be implemented. The major factor in the decision is the existence of a large number of vehicles using electronic tags which will significantly reduce the capital costs. Also, AVI systems provide the most accurate and reliable systems which are vital to the success of ATMS and ATIS. Finally, the system can be used for other purposes such as origin and destination studies and the management of transit and commercial fleets.

System Design Considerations

Adequate planning and design are vital to the success of such a system. AVI systems prove to have high capital and installation costs, and care must be taken to ensure the system is implemented correctly so it can operate efficiently and accurately. Coordination is necessary between agencies operating and using other AVI systems and the agencies that utilize the design system for travel time data collection. Partnerships are encouraged between public and private agencies to share the travel time data and reduce redundant activity. Business and residential leaders should be involved in the planning process to answer questions and concerns the public might have about privacy and benefits of the system.

The AVI system requires hardware that is compatible with the other systems in the area. Therefore, Amtech equipment and communications will be used for the project. The following AVI equipment is necessary for travel time data collection:

- Electronic tags,
- Antennas and roadside reader for each station,
- Communications for reader station, and
- Computer and control center for processing tag data..

Geographic Locations

The geographic scope of the AVI system will consist of the LBJ Freeway in north Dallas. The LBJ Freeway is heavily congested in peak periods and traffic volumes are expected to increase. Business and residential growth is booming in this area and continued growth is expected in the future. The area also consists of hotels and shopping malls, such as the Galleria which attract out-of-town tourists. Since the area is heavily congested and is used frequently, an AVI system in this area will be able to collect travel time data for performance measures and traffic conditions that can be distributed to the public.

These sections are in proximity of the North Dallas Tollway and electronic toll tags from the system can be used for travel time measurement. Vehicles with tags for the AVI systems that control parking at CDA and DFW networks will also be detected for travel information. The Dallas North Tollway intersects I-635 and provides timely access to downtown Dallas. The Tollway utilizes AVI technology for toll collection and the tags from this system will also be used on I-635 to collect travel time data. The AVI system will be installed on approximately 16 km (10 mi) of I-635 between I-35E and U.S. 75.

Electronic Tags and Tag Distribution

The existing probe vehicle systems include three AVI systems operating in the Dallas area. These systems currently use over 200,000 electronic tags which are manufactured by Amtech Transportation Systems Group. These tags will be used to collect travel time data by the implemented AVI system. Along with the tags from other AVI systems, it is desirable to distribute as many tags as to other users as well. With existing HOV lanes and planned High Occupancy Toll (HOT) lanes in Dallas, priority passage through these lanes can be used as an incentive for using an electronic tag. AVI tags will also be distributed to city and state agencies to install on their fleet vehicles; however, the tags must be bought by the collection program. These distribution plans will be used to increase the sample size and travel time accuracy.

Antenna Spacing and Installation Specifications

Typical antenna spacing range from 2 km to 5 km and adequate spacing varies with variations in mean travel time data. Antenna spacings and reader stations are presented in Figure 3. Sixteen reader stations, two stations per site (Site 1,4,5, and 8) will be installed on I-635 with an average spacing of 2.5 km (1.6 mi). Sites 4 and

5 will cover both directions entering and exiting the Dallas North Tollway. Sites 1 will measure probe vehicles west of I-35E and station 8 will measure probe vehicles east of U.S. 75. Sites 2 and 3 will be placed north and south of the I-635 and I-35E interchange. Readers at sites 6 and 7 will be placed north and south of the I-635 and U.S. 75 interchange.

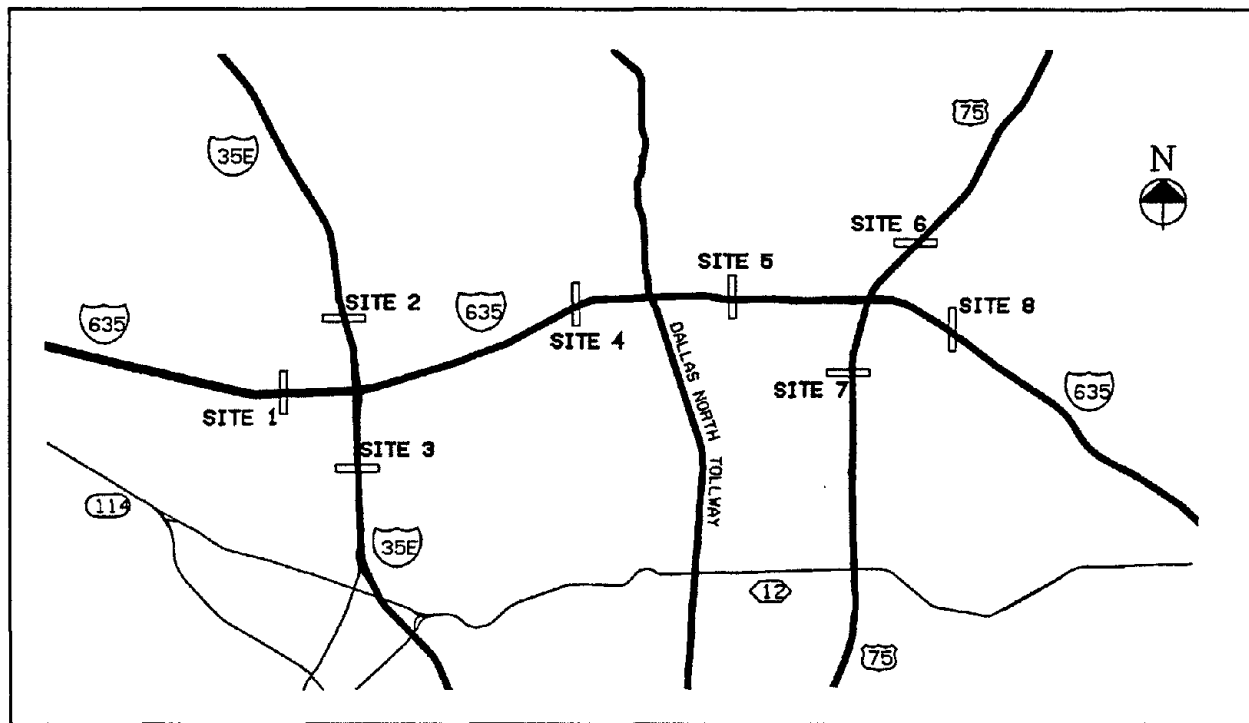


Figure 3. AVI Site Selection Map, Dallas, Texas

Antennas will be mounted on existing overpass and sign structures and the exact antenna spacing depends on structure locations. The number of antennas at each station depend on the number of lanes at the station and how accurately one antenna can measure multiple lanes.

Roadside Reader Station

The RF signal AVI technology will be used as the primary communications media. The AVI roadside reader consists of a number of components including an automatic data processor, reader modules, RF modules, antennas, a cabinet, and a modem. Once the data are collected by the reader, they are sent to a central computer for data reduction.

Data Reduction

The data from the reader station are obtained by the central computer via telephone lines. The central computer will be located in a TMC or transportation agency directly involved with the travel time data. The central computer then stores the data with specialized software to perform travel time processing. The AVI system software must be custom developed by the AVI equipment vendor or agency operating the system. From the *Travel Time Data Collection Handbook* (4), the basic steps in the AVI data reduction process include:

1. Store tag read data.
2. Match sequential tag reads.
3. Filter erroneous data.
4. Archive travel time data.
5. Access archived travel time data.
6. Create anonymous data file.

The data can now be stored or be made available to agencies to provide traffic information. Once the process is implemented and calibrated, accurate travel time data can be obtained quickly and efficiently.

Costs

The cost of a roadside reader station is costs about \$31,000 on average and goes up as high as \$50,000. Maintenance costs are reported to be \$256 per lane per site per month. The AVI system in Dallas will consist of eight sites, two reader stations per site. Using the average cost per station, 16 reader stations cost \$496,000. The maintenance costs for the system will be \$196,608 per year.

Travel Time Information

Travel time information will be available to travelers on a WWW traffic page. This will be accomplished by the TMC or another agency. The agency's personal computer will log on the central computer by a modem and request travel time at two minute intervals. With the travel time data, traffic maps are plotted in memory and saved as a graphic file. Then the WWW traffic page links to the graphic file and shows them to Internet users using standard HTML and HTTP services.

With increased emphasis on traffic management, accurate traffic information can be used to detect incidents and measure current traffic conditions. Traffic information then can be available to motorist through the network of variable message signs operating in Dallas. This same information can be used by emerging ITS technologies such as in-vehicle navigation systems, kiosks, and electronic mail.

Summary

An AVI travel time data collection system was implemented on 16 km (10 mi) of the LBJ Freeway in Dallas, Texas. The system consists of 16 reader stations spaced approximately 2.5 km (1.6 mi) apart. The system will cost \$496,000 without the need to purchase electronic tags. The maintenance costs for the system will be \$196,608 per year.

Travel time data from this corridor will be used to monitor and evaluate congestion and will be collected primarily from vehicles equipped with electronic tags for the North Dallas Tollway. With data produced by the AVI system and existing loop detectors on the North Central Expressway (U.S. 75), travel time information will be used for the management of traffic and ATIS in Dallas. The AVI system should be expanded in Dallas to cover freeways around the central business district and those which experience heavy congested.

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APPENDIX

QUESTIONNAIRE

Name _____

Title _____

Organization _____

Address _____

Phone # _____

Fax # _____

35. Does your organization utilize *loop detectors*?☐ Yes☐ No → go to #102. Does your organization utilize *loop detectors* to measure freeway travel time?☐ Yes☐ No → go to #103. What is the optimal spacing of *loop detectors* to give a representation of travel time?_____
_____4. How accurate is the *loop detector* method for calculating travel times?_____
_____5. What are the inaccuracies (if any) with using *loop detectors* to measure travel time?_____
_____6. What other uses do *loop detectors* provide for your organization?_____
_____7. What potential uses will *loop detectors* provide for your organization in the future?_____
_____8. What problems do you associate with *loop detectors*?_____
_____9. What is the approximate cost (planning, installation, maintenance, other) per mile per lane to operate a *loop detector* system?_____

10. Does your organization utilize Automatic Vehicle Identification (AVI) technology?
☐ Yes
☐ No -> go to #20
11. Does your organization utilize AVI technology to measure freeway travel time?
☐ Yes
☐ No -> go to #20
12. What AVI technology does your organization use? (manufacturers, name, model)

13. What is the optimal spacing of AVI roadside readers to give a representation of travel time?

14. How accurate is the AVI method for calculating travel times?

15. What are the inaccuracies (if any) with using AVI to measure travel time?

16. What other uses does AVI provide for your organization?

17. What potential uses will AVI technology provide for your organization in the future?

18. What problems do you associate with AVI technology?

19. What is the approximate cost (planning, installation, maintenance, other) per mile per lane to operate an AVI system?

20. Does your organization utilize and/or store travel time information?
☐ Yes
☐ No -> go to #27
21. What does your organization do with the travel time information?

22. Does your organization provide motorists with this information?

☐ Yes

☐ No -> go to #27

In real-time?

☐ Yes

☐ No

23. How does your organization provide motorist with travel time information?

24. In what other ways does your organization plan to provide travel time information to motorists?

25. Does your organization predict freeway travel times?

☐ Yes

☐ No -> go to #27

26. What is your organization's methodology for predicting freeway travel times?

27. Could you provide a list of resources, contacts, or other organizations that may be using AVI and/or loop detectors to estimate travel time on freeways?

STOP... Thank you for your time and cooperation.

**GARRY L. FORD, JR.**

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AN EVALUATION OF PUBLIC-PRIVATE PARTNERSHIP STRATEGIES WITHIN THE TRAVELER INFORMATION SERVICES MARKET

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SUMMARY

Recently, key agencies involved with traveler information systems in the United States have begun to examine the potential of introducing traveler information services to the consumer market, with the hopes of creating a system that can sustain itself financially after its federal funding expires. There is a significant opportunity for public sector agencies to offset the operational and maintenance costs within a traveler information system by selling real-time traffic information to information service providers and value-added resellers, who can in turn, provide subscription-based services to the public. In this regard, there are a variety of partnership strategies that could be formed between public and private sector parties for such an arrangement.

Through this research, the author sought to examine the current state of the consumer market for traveler information services; evaluate the public-private partnership strategies that can be employed in the design, operation, and maintenance of a traveler information system; identify non-technical barriers encountered by both sectors throughout the public-private partnership process; develop guidelines to assist the public and private sectors in developing effective partnerships that can minimize the impact of these barriers; and demonstrate the effectiveness of the implementation guidelines by applying them to a case study in Houston, Texas.

A literature review was conducted to assess the current state of the consumer market for traveler information services, concentrating on the potential market segments, available technologies, and revenue generation strategies. The author concluded that, because the traveler information services market is still relatively new, its future success is dependent on overcoming a number of barriers, including the lack of geographic coverage, the lack of technical standards, the need for greatly improved information, and the need to raise public awareness of traveler information technologies.

In addition to the literature review, a telephone survey was conducted with public and private sector transportation professionals involved with selected Model Deployment Initiative programs, ITS Corridor programs, ATIS field operational tests, and Showcase projects in the US. This provided insight into the various public-private relationships that can be employed for the design, operation, and maintenance of a traveler information system, as well as the various organizational, financial, and legal barriers that can potentially inhibit the success of these relationships.

Based on the lessons learned from the research, guidelines were formulated to assist public and private sector agencies in developing effective partnerships that can overcome the barriers previously identified. These guidelines included the following:

- Develop a foundation for the traveler information system;
- Select private sector partners;
- Negotiate the details of the contract;
- Ameliorate differences between and within public and private sector partners; and
- Develop the traveler information products and services.

The recommended guidelines for developing public-private partnerships were applied as a case study to the hypothetical implementation of a personalized paging service in the city of Houston, Texas.

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INTRODUCTION

Advanced traveler information systems (ATIS) provide information to travelers either prior to or during a trip, allowing them to make better informed decisions regarding route planning, travel mode, and time of day to travel. Traveler information services provide travelers with real-time information such as traffic congestion, highway incidents, and weather conditions. These services can be expanded to provide travelers with other kinds of transportation information, including public transit routes and schedules, intermodal connections, parking availability, and airline departures. Non-transportation information such as lodging, restaurants, automobile services, and points of interest can also be featured. Traveler information can be conveyed to individuals in their homes, offices, and vehicles, as well as at transportation terminals, public places, and along roadways via a wide variety of communications devices and mediums. (1)

Problem Statement

Recently, key agencies involved with ATIS projects in the United States have begun to examine the potential for introducing traveler information services to the consumer market, with the hopes of creating a long-term ATIS program that can sustain itself financially after its federal funding expires. There is a significant opportunity for the public sector agencies to offset the operational and maintenance costs within these ATIS projects by selling real-time traffic information to information service providers and value-added resellers, who can in turn, provide subscription-based services to the public (2). In this regard, there are a variety of partnership strategies that could be formed between public and private sector parties for such an arrangement. However, there is little documentation regarding the advantages and disadvantages of each particular strategy. In addition, it is not certain whether consumers are even willing to pay for real-time traffic information (3). An examination of the current state of the consumer market for traveler information services is therefore needed in order to assess potential market segments and the traveler information products which these parties would find useful. The development of implementation guidelines is also needed to assist public and private sector agencies in developing effective partnerships in order to expedite the delivery of dynamic traveler information to the public.

Research Objectives

The primary objective of this research is to develop a set of guidelines to assist public and private sector agencies in developing effective partnerships while minimizing the impact of common barriers that may exist between and within the two sectors. The specific objectives of this research were to:

- Examine the current state of the consumer market for traveler information services;
- Evaluate the public-private partnership strategies that can be employed in the design, operation, and maintenance of a traveler information system;
- Identify non-technical barriers encountered by both sectors throughout the public-private partnership process;
- Develop guidelines to assist the public and private sectors in developing effective partnerships that can minimize the impact of these barriers; and
- Demonstrate the implementation guidelines by applying them to a case study in Houston, Texas.

Organization of Report

This report is organized into eight sections. In the second section, the methodology used to conduct this research will be presented. In the third section, a discussion will be provided regarding the current state of the consumer market for traveler information services. The various partnership strategies that can be formed between public and private sector agencies will be addressed in Section 4. The author presents a summary of

the survey results in Section 5. The significant findings regarding the market potential for traveler information will be presented. In addition, a discussion of the common organizational, financial, and regulatory barriers that can arise between public and private sector entities through the partnership process will be provided. In Section 6, an approach to developing successful partnerships in such a way as to minimize inter- and intra-agency differences will be formulated. These strategies will be applied to a case study in Houston, Texas in Section 7. Finally, conclusions will be presented based on the results of the survey and the guidelines formulated in this report.

STUDY DESIGN

To accomplish the objectives of this report, the research methodology consisted of three primary tasks. First, a literature review was conducted to establish the state-of-the-art in the consumer market for traveler information products and services. Data was then collected in the form of telephone surveys to obtain insight from transportation professionals regarding their experiences with the consumer market and public-private partnerships. This information provided a framework for the formulation of guidelines to assist public and private sector agencies in developing successful partnerships. These tasks will be discussed in further detail in this section.

Literature Review

To assess the consumer market for traveler information services, a literature search was conducted using the California PATH Database, the WinSPIRS Transport Database, and the Texas A&M University Library database. The search provided background information on the following issues:

- Potential consumer market segments;
- Traveler information products and services;
- Revenue generation strategies;
- Limitations of current traveler information products and services;
- Opportunities for private sector participation in a traveler information system; and
- Public-private partnership strategies.

Data Collection

To fill voids that were present in the existing literature, a survey of public and private sector transportation professionals involved with selected Model Deployment Initiative programs, ITS Corridor programs, ATIS field operational tests, and Showcase projects was conducted. The survey was completed through telephone interviews. Throughout the interview process, the public and private sector representatives of the selected ATIS projects were asked to provide insight regarding the current state of the consumer market for traveler information. In addition, the representatives were questioned about any non-technical barriers encountered throughout their involvement in public-private partnerships, as well as the strategies employed to overcome these problems. The telephone interviews were based on a survey to ensure consistency throughout the interview process. The survey included the following questions:

1. What traveler information services will be provided as part of this project?
2. What kinds of technology will be used to disseminate this information?
3. Who are the value-added resellers and/or information service providers who have been involved in disseminating this information?
4. Was a marketing study completed throughout the planning process to examine the potential for commercialization of the traveler information? If yes, what were the key findings regarding the present and future consumer market for traveler information?
5. What strategies are being used to generate revenue (both present and future)? (For example, advertising sponsors, selling hardware or software).
6. Are there any additional marketing or public acceptance issues you have encountered regarding privatization?
7. Have there been any 'lessons learned' from your privatization efforts?
8. Describe the partnership arrangements between the public and private sector parties involved in this project. Who performs data gathering, data fusion, data dissemination?
9. Has this arrangement worked well? What were the advantages and disadvantages?

10. What are some of the organizational, financial, or regulatory differences that you have encountered during the partnership? How were these differences overcome?
11. Have there been any 'lessons learned' from entering into the partnership?

Data Analysis and Application

The results of the literature review and data collection effort were used to formulate an approach to developing effective public-private partnerships while minimizing the effects of organizational, financial, and regulatory differences that may exist between and within the two sectors. The guidelines incorporate existing strategies used by public and private agencies to overcome these differences, and new strategies were developed to address additional concerns of both the public and private sectors. To test the validity of the guidelines, they were applied as a case study to the development of a personalized paging system in the city of Houston, Texas.

THE CONSUMER MARKET FOR TRAVELER INFORMATION SERVICES

The consumer market for ITS is expected to grow dramatically over the next 20 years, with growth driven primarily by consumers' needs for personal safety, security, and comfort. As consumers become increasingly frustrated with congestion on urban streets and freeways, they will have a greater need for information regarding efficient transportation options. It is also expected that, over time, advertising will raise consumer awareness of ITS products and services, further supporting the growth of the commercial ITS market (4). However, this growth can occur only if the public sector develops the technical standards necessary to determine how dynamic information should be configured and transmitted; this will encourage large-scale investment in the ITS market on the part of the private sector. There is, therefore, a valid argument that as technical standards are adopted within the ITS community, and as users adopt the necessary behavioral changes, the market for traveler information services and products has the potential to evolve into a large and profitable industry. It also follows that once a consumer audience is established, advertisers will not be far behind, creating additional opportunities to generate revenue within this market (5).

The current state of the consumer market for traveler information services is described in this section of the report. An overview of the potential consumer market segments is presented, as well as a discussion of the various traveler information products and services available within this market.

Consumer Market Segments

Within the commercial market for traveler information, there are several potential market segments for traveler information products and services. These include the traveling public, rental car companies, public service agencies, commercial and fleet operations, corporations, and commercial developers.

The Traveling Public

With approximately 122 million privately-owned vehicles in the United States, there is an enormous potential to market traveler information services and products to commuters who may have long daily commutes or who have schedule-driven jobs. The market potential among drivers of recreational vehicles is also substantial, as these drivers often travel long distances to destinations where they are unfamiliar with the local transportation network. (6, 7, 8)

Rental Car Companies

Rental car companies have already displayed a strong interest in certain traveler information products. Avis began experimenting with in-vehicle navigation systems in 1992 and now has units in 1200 cars in the Southeast and the West. Hertz and National offer similar options in their vehicles in selected cities. Additional features that car rental customers may find valuable include services/attractions directories, route guidance, and real-time traffic information. These features are invaluable to customers who may be unfamiliar with the transportation network of the city in which they are visiting. Through the provision of these systems in their fleets, rental car companies can capitalize on business expansion and customer loyalty. (6, 9, 10)

Public Service Agencies

Public service agencies responsible for emergency response and transit fleet operations comprise another potential segment within the traveler information services market. Emergency service agencies such as police, fire, and ambulance are forecast to be significant end-user markets of these services. Particularly in congested urban areas, traveler information systems can safely and efficiently direct emergency vehicles to the scenes of accidents and other emergencies by providing drivers or dispatchers with real-time traffic information and

corresponding shortest-distance recommendations. Drivers and dispatchers of transit fleets can also use such systems to navigate around congestion, accidents, and road construction on streets and freeways, allowing them to remain on schedule. (6 7)

Commercial Fleet Operations

Commercial enterprises and fleet operators comprise a fourth market segment who have a strong economic need for traffic information, particularly among commercial vehicles, package delivery services, sales and service forces, taxicab companies, and limousines. Within these particular businesses, it is economically beneficial to the company if a driver can pick up one more fare, make one more delivery, or deliver a package or load on time. (7 8)

Corporations

A fifth market segment consists of corporations that are interested in providing their employees with traveler information services through their internal telephone or computer systems. In this manner, employees without a cellular phone in their car could access traffic information from their desk to determine whether they should depart early, remain at work longer, or take an alternative route to avoid delays. (8)

Commercial Developers

A final market segment consists of developers, landlords, and hotel operators who are interested in providing the service to their clients, tenants, and guests as an amenity, giving them a competitive edge within their particular industry. (8)

Traveler Information Products and Services

There are a variety of communications devices and mediums either used presently or projected for use in the traveler information services market.

Commercial Radio and Television Broadcasts

Since the mid-1950s, commercial radio stations have been broadcasting traffic reports to the traveling public. Today, the commercial traffic information industry is nationwide, with traffic information being broadcasted commercially on over 860 radio and television stations in 54 cities to an estimated listening audience of 120 to 150 million nationwide. The radio, however, is the most dominant communications medium for traffic information. According to a 1995 University of California study, 98% of motorists obtain traffic information from the radio. In a Seattle survey, 80% of commuters preferred receiving traffic information from the radio over any other communications medium. Its dominance can be attributed to several factors: the radio is easily available from home, in vehicles, and in the workplace; radio-based traffic reports can be easily accessed during commute hours; and listeners perceive the information over the radio to be cost-free. (6 7 11 12 13)

Most of the traffic reports broadcast over radio and television come from private traffic reporting companies. Two of the most prominent traffic reporting companies are Shadow Broadcast Services and Metro Traffic Networks, who serve in 10 and 51 metropolitan markets, respectively. These companies collect roadway information through a variety of information sources, including state-of-the-art technologies, aerial surveillance, incident and construction reports from state and local police agencies, and on-the-scene reports solicited from cellular callers. The companies process this information into concise traffic reports which are provided to radio and TV stations as either a voice or text-based data feed. Private traffic reporting companies rarely charge these stations directly for the traffic reports. Rather, they barter them in exchange for advertising

air time, which is subsequently sold to advertising sponsors. National organizations such as Shadow and Metro can accumulate air time on radio and TV stations across the country, allowing them to provide a nationwide network of advertising media to large sponsors. This strategy has allowed the commercial traffic reporting industry to be the largest revenue producer within the current traveler information services market. (12, 13)

The effectiveness of traffic information over radio and television is limited, however, by the willingness of traffic reporting companies to broadcast all the relevant incident data for area freeways. Often the time slots for broadcasting the traffic reports are limited to one or two minutes. This forces the traffic reporting agencies to limit the broadcast to include only selected incident information, which is then delivered in a quick, albeit entertaining, manner. After an incident has been broadcasted, typically no follow-up information is provided as to when the accident was cleared. For tourists and other travelers who are unfamiliar with the local area, these broadcasts can have limited value. In the case of regular commuters, the frequency of the broadcast (e.g., every 15 or 20 minutes) can significantly impact the perceived utility of the traffic information. (14)

The quality of commercial radio and television broadcasts can benefit from public agency investment in intelligent transportation infrastructure and traffic surveillance technologies. This will enable traffic reporting agencies to provide live video shots of traffic conditions and longer, more detailed traffic reports. However, this will be largely dependent on the willingness of public agencies to share data with these companies. (7, 11, 14, 15)

Telephone Information Systems

Telephone information systems are a relatively low-tech, low-cost approach to providing travelers with updated traffic reports. These systems allow callers to obtain current roadway conditions for a particular region or roadway in a recorded voice form. This is advantageous over traditional radio broadcasts because callers can obtain route-specific information on-demand, rather than having to wait for the next traffic report to be broadcast over the radio. Telephone information systems do not require any sort of expensive and dedicated equipment on the part of the caller - all that is needed is a touch-tone telephone. However, the minimal effort necessary for people to access a telephone information system may be considered burdensome over more passive methods of simply turning on the radio or television to obtain information. Another disadvantage is that users must remember the telephone number in order to access the system. People also have a concern that information obtained prior to traveling could be stale by the time the trip was being made. However, the increasing popularity of cellular telephones provides a means by which travelers can access the system while en route. If the provider of a telephone information system works with cellular providers to adopt a two-digit dialing system for cellular phone users (e.g., dial *1 to access the system), these problems can be overcome. (13, 14, 16, 17)

Operators of telephone information systems have attempted to generate revenue from these systems in several ways. One early strategy involved charging users on a per-call basis using 1-900 or 1-976 numbers. However, this was largely unsuccessful, implying that users are sensitive to paying for information, especially when they perceive it to be similar to that obtained from traditional radio and television broadcasts. In the case of cellular users, the number of calls has increased dramatically when air time charges are waived. Programs designed to attract users or even corporations to subscribe to a telephone information service on a monthly basis have also been unsuccessful. (13, 18, 19)

Another strategy to generate revenue within this market is through the sale of advertising time on the telephone information system. This has also met limited success in that, once accustomed to the system, users often want to skip to the section of the menu in which they are interested, without having to listen to advertisements. Another problem associated with advertising is that sponsors often want to see historical data for the system such as user demographics and access rates per day before committing their advertising dollars. (13, 16)

Personalized Paging Systems

Paging devices are a popular communications medium widely used by the public today. Pagers are becoming increasingly versatile as they incorporate digital technologies and as competition in the industry leads to the development of a variety of specialized services. Such services include the ability to forward e-mail messages to pagers, acknowledgment paging that allows users to confirm receipt of a page, answer-back paging that allows users to respond to a page with preprogrammed messages, two-way text messaging, and voice paging that sends brief digitized voice messages to specially-equipped pagers. (1, 20, 21)

The future of paging will likely evolve beyond traditional short message capabilities and expand to become a mobile information service. For example, at some point the pager could be connected to dynamic message signs along highways or to transportation management centers to provide drivers with real-time information such as traffic conditions or construction activities within an urban area. Large paging displays installed on automobile dashboards could provide drivers with similar information. (1, 21)

Revenue can be generated within this market through the development of personalized paging services, in which users would pay a subscription-based fee to receive information concerning traffic problems specific to the route and time of their commute. A more customized approach would involve a service that could recommend alternate routes that would allow the traveler to bypass major congestion points and accidents. However, the success of such a service will be dependent on the value that consumers place on receiving such information and their willingness to pay for it. (15)

Internet World Wide Web Systems

The World Wide Web, a part of the Internet, is capable of providing up-to-date information to an extremely large and diverse audience at minimal cost. As depicted in Figure 1, the growth in the number of computers connected to the Internet has increased at an exponential rate since 1993. (22)

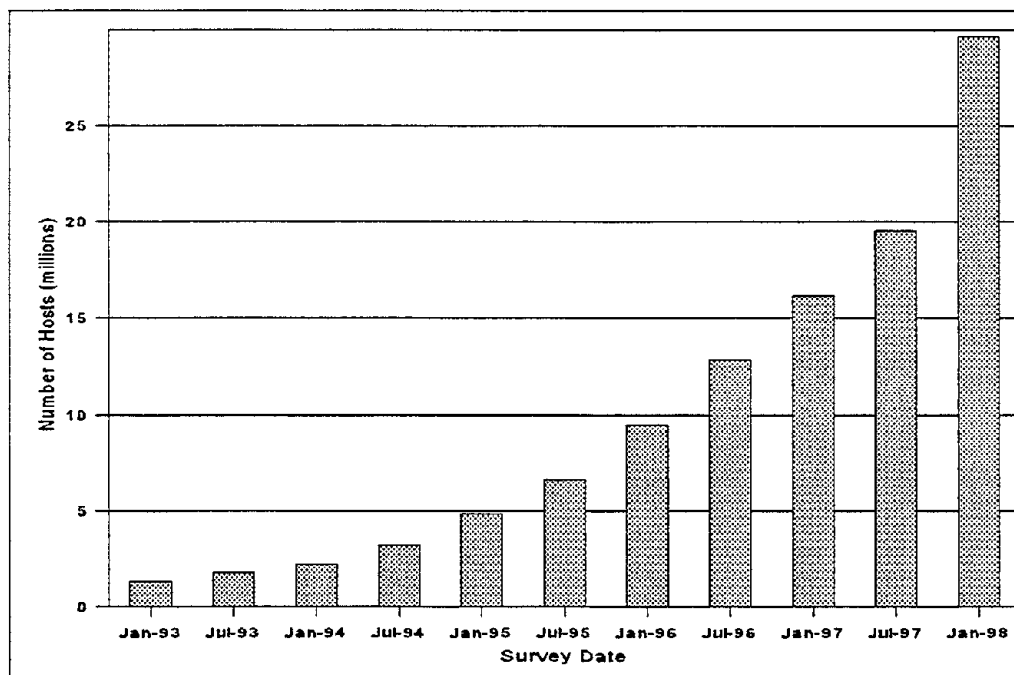


Figure 1. Growth in Internet Use (Number of Hosts). (23)

The World Wide Web is characterized by several features that make it an ideal medium for providing transportation-related information to the public. The interactive and colorful interface of the World Wide Web allows commuters to view graphics and video images of traffic conditions at major interchanges and congestion points along roadways. The Web provides 24 hour access to information such as weather forecasts, maps and directional information, construction and road closure advisories, airport and flight information, and information concerning public transportation options. (24, 25)

Web sites depicting real-time traffic conditions in metropolitan areas have been set up by numerous state and local transportation agencies in the US. The costs associated with developing and maintaining a Web site includes initial development (\$2,000 - \$3,000 for professional development), registration of the domain name (\$100 for first two years, \$50 for each additional year), hosting by an internet service provider (\$20 to \$50 per month), and subsequent maintenance of the Web site (\$25 to \$75 per hour). Users are not charged directly to access these sites, but they must pay monthly access charges imposed by their internet service providers. (24)

Microsoft has also recently become involved in providing traveler information on the World Wide Web. Named *Trafficview*, this transportation service is provided as part of Microsoft's *Sidewalk* sites for the cities of Seattle, Minneapolis/St. Paul, and Boston (*Traffic*). *Trafficview* offers several unique features that are typically not available on public agency Web sites. For example, users can obtain estimates of freeway driving times by clicking on an origin and destination from the *Trafficview* map. The system can also provide personalized commute reports, and, upon request, can send a daily e-mail message to users to inform them of estimated trip times. The decision to include *Trafficview* on individual *Sidewalk* sites is made by Microsoft on a city-by-city basis, depending on Microsoft's understanding of the potential audience for and value of traffic information, the availability of a comprehensive data infrastructure, and ease of access to that data. Microsoft absorbs the costs of developing the software to analyze the traffic data, predict travel times, and host the Web and e-mail servers. (26, 27)

Revenue may potentially be generated within this medium through the sales of advertisements on Web sites that have a high daily access rate. The revenue generated through these sales may eventually provide funds for sustainability and perhaps even become profitable ventures. However, the World Wide Web advertising model has yet to be proven as a substantial, long-term mechanism to generate revenue for any type of Web site. (13)

Intranet Systems

Intranet and Local Area Network (LAN) systems are another development within the field of traveler information technologies. Intranets are commonly used to communicate information to employees within a single organization, but one of the more inventive uses of a company Intranet is to communicate real-time traffic information to employees. A pioneering example of this is at the Chrysler Technology Center in Auburn Hills, Michigan. The Chrysler Technology Center Employee Network is an internal cable system that displays current traffic conditions on over 500 TV monitors located throughout the facility. Real-time congestion maps are obtained from the Road Commission of Oakland County's traffic management center, providing departing employees with up-to-the-minute reports on traffic conditions throughout the region. This information enables them to make efficient decisions as to whether they should postpone their departure or find a different route for their commute home. Employees will eventually be able to access this information directly from their desktop computers. (1, 12)

Interactive Multimedia Kiosks

Interactive multimedia kiosks are another means of providing traveler information and other services to the general public. Kiosks can be placed in airports, bus terminals, train stations, parking garages, car rental agencies, and at rest areas along highways. Similar to the World Wide Web, kiosks can provide travelers with

specific information through the use of text, colorful graphics, still images, and live video. In addition, travelers can obtain maps, personalized directions, and information on local attractions in printed form from kiosks equipped with printers. Kiosks installed with card and bill readers can provide transaction-related services such as fare collection, coupon distribution, travel reservations and ticketing, and banking services. (13, 28)

Many of the kiosk systems that provide dynamic traffic information have been deployed as part of ITS programs with public funding. These projects have demonstrated several of the limitations associated with kiosk deployment. For example, the cost of an individual kiosk unit may range from \$8,000 to \$20,000, with additional expenses required for installation, software purchases, and network connections (13). These costs may limit the number of kiosks that can be deployed in the field. The presence of environmental factors such as wind and rain can also limit the location and placement of kiosks.

Widespread kiosk deployment may require the use of innovative ways in which to generate additional revenue. For example, a sponsorship program could be employed, in which sponsors pay a monthly or annual fee and are allowed limited advertising on the kiosk user interface. Another strategy is to attract site location partners who would pay an annual fee to have a kiosk on their property. (29)

Handheld Computing Devices

Handheld computing devices, often referred to as personal digital assistants (PDAs), provide travelers with a variety of information in a mobile environment. This information could include roadway congestion and incident reports, construction activities, static and dynamic transit information, maps, turn-by-turn instructions, optional location detection using GPS, event information, and yellow pages information. PDAs obtain dynamic information through the use of wireless communications and some form of client-server relationship. Most PDAs feature built-in capabilities such as a daily planner, telephone directory, note-taking capabilities, and access to e-mail and other on-line services. These features are attractive to local commuters, tourists, and business travelers who may be unfamiliar with a particular region. Figure 2 illustrates a typical user interface of a PDA. (13, 30)

Revenue can be generated within the PDA market through various consumer costs associated with owning and operating such a device. The first of these is the initial retail cost of the PDA hardware, which may range anywhere from \$300 to \$1,500 depending on the desired features (32). The purchase of application software is necessary to access dynamic traveler information, the cost of which is unknown. Access to dynamic information also requires that the PDA be equipped with wireless communications capabilities. The most cost effective approach is to receive information as a one-way broadcast through an FM subcarrier broadcast. Two-way communications is another, albeit more expensive, method, in which the PDA is integrated with either a wireless packet-radio modem, a cellular modem, or a switched-circuit landline fax/data modem. (30)

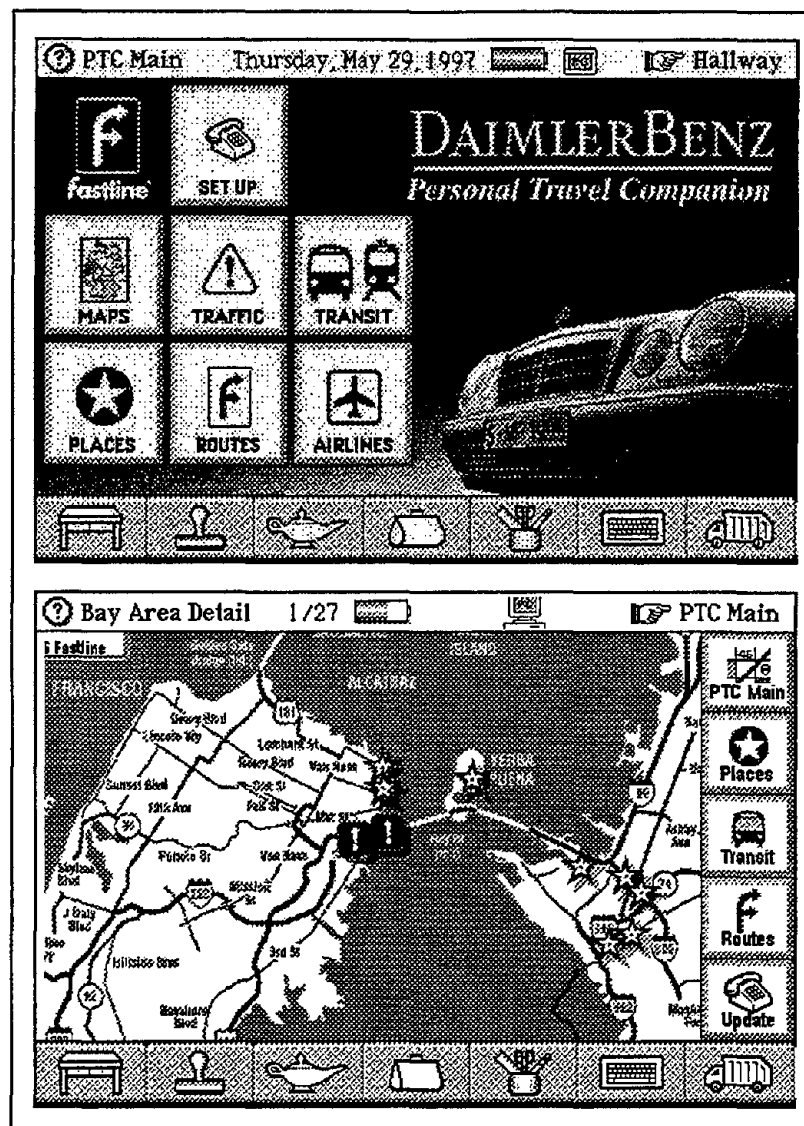


Figure 2. User Interface of a Personal Digital Assistant. (31)

PDAs manufactured by Motorola, Sony, Apple, and Hewlett-Packard have been used in federally-funded field operational tests and Showcase programs around the country, including Northern and Southern California, Houston, Minnesota, Detroit, Seattle, and Atlanta. Although the commercial market for PDAs has been quite limited to date, the emergence of more powerful, less expensive devices with longer battery life and usability enhancements such as backlighting will improve their marketability. Also, as technical standards are adopted by the ITS community for access and formatting of dynamic information, and as users adopt the necessary behavioral changes, mobile computing products have the potential to evolve into a large and profitable market. (13, 30)

In-Vehicle Navigation Systems

In-vehicle navigation systems can help drivers in unfamiliar territory increase their personal safety while decreasing the travel time and anxiety associated with driving. Navigation systems typically incorporate a global positioning satellite (GPS) system with dead-reckoning and map-matching technology, allowing the

system to know the location of the vehicle and provide visual and/or verbal turn-by-turn directions to the specified destination. Navigation systems can also provide comprehensive maps and point-of-interest information. However, the majority of navigation systems on the market are autonomous and have no communications technology with which to obtain dynamic traffic information for a region. (13, 33)

In Japan, approximately 1.2 million in-vehicle navigation systems have been sold to consumers over the last decade. The US market has been significantly slower, with an estimated 6,000 navigation systems sold in the US last year. According to a study prepared for the US Department of Transportation, route-specific information alone does not have enough value to be marketable to individual motorists. Regular commuters seem to prefer relying on their own ability to determine the best alternate route as long as they know the nature, location and extent of any delays. However, as mentioned previously, many rental car agencies in the US are recognizing the value of navigation systems and are incorporating them into their fleets in selected cities. Additional markets for in-vehicle navigation systems include taxicab companies, commercial fleets, delivery services, and motorists who often drive in unfamiliar territory. (7, 11, 15, 17, 34, 35)

Navigation systems are gaining popularity in the US market, but they are still relatively expensive due to low production rates, with prices ranging from \$2,000 to \$3,000 (33). Within the rental car market, companies can generate revenue by charging customers an additional daily usage fee for a vehicle equipped with a navigation system. In Hertz's Neverlost System, for example, customers are charged a daily usage fee of \$6.00 for the navigation system. Revenue can also be generated through the periodic sales of map updates or maps of other geographic regions. However, without communications technology to obtain dynamic traveler information, in-vehicle navigation systems cannot provide an ongoing means to generate revenue. It is expected that once this technology is established, a significant amount of revenue can be generated through per-access fees or monthly subscription fees. (13, 35)

Mayday Systems

Mayday systems allow drivers to summon an emergency dispatch center in the event of a mechanical breakdown or accident (11). The majority of mayday systems are comprised of two in-vehicle components: cellular communications and a global positioning system (GPS) locating device. These components work in tandem such that, when an accident or other emergency occurs, the GPS coordinates of the vehicle are relayed to the emergency dispatch center via the cellular telephone. The system can be activated either manually, in which case the driver must press a button to dial the center, or through automated sensors, in which the system is interfaced directly with vehicle systems such as airbag deployment. Mayday systems are particularly advantageous in accident situations because detection is nearly instantaneous, the location of the accident is known, motorists can remain in their vehicles, and they can relay additional information about the accident to help expedite the appropriate response. Systems featuring additional capabilities such as remote car unlock, stolen vehicle tracking, and traveler information, are also attractive among motorists. (13, 36)

Revenue can be generated within this market by charging the consumer directly for the system hardware and the service. The initial cost for a mayday system includes purchase and installation of the system, which can range anywhere from \$500 to \$2,000. Mayday system providers can also charge a monthly service fee in addition to normal monthly cellular telephone charges. (36)

Although mayday systems are not typically considered to be a traveler *information* service, basic consumers' needs for safety, security, and comfort have created a demand for mayday systems that is currently greater than in-vehicle navigation and route-guidance systems. In fact, mayday systems may eventually help open the market for traveler information services by incorporating the advanced features available in other technologies and communication mediums as previously described within this section of the report. (11, 13)

Summary of Traveler Information Products and Services

Table 1 summarizes various features of the traveler information services and products described in this section of the report.

Table 1. Summary of Traveler Information Products and Services

Traveler Information Product	Potential Consumer Markets	Revenue Potential	Revenue Generation Strategies	Limitations
Radio/TV Broadcasts	Traveling public Commercial fleets	High	Advertising	<ul style="list-style-type: none"> • Limited content • Quick broadcasts • Frequency of broadcasts • Limited utility by tourists and other travelers
Telephone Systems	Traveling public Commercial fleets Corporations	Low	Pay-per-call Advertising Partner w/cellular providers	<ul style="list-style-type: none"> • User recall of phone # • Timeliness of information
Paging Systems	Traveling public Commercial fleets	Low - Medium	System hardware Monthly subscription	<ul style="list-style-type: none"> • Timeliness of information • Value of information
World Wide Web	Traveling public Commercial fleets Corporations	Low - Medium	Advertising	<ul style="list-style-type: none"> • Site development and maintenance costs • Timeliness of information
Intranet/LAN Systems	Corporations Developers	Low	Advertising sponsors Monthly subscription	<ul style="list-style-type: none"> • Willingness of corporations to subscribe
Kiosks	Traveling public Rental car companies Corporations Developers	Medium	Pay-per-use fee Advertising sponsors Site location fees	<ul style="list-style-type: none"> • Expensive installation & maintenance • Environmental limitations • Limited public access • Low usage rates
Handheld Computers	Traveling public Rental car companies Commercial fleets	Medium - High	System hardware Software Communications	<ul style="list-style-type: none"> • Expensive • Cumbersome to carry • Limited geographic coverage
In-vehicle Navigation	Traveling public Rental car companies Public agencies Commercial fleets	Medium - High	System hardware Software Communications Monthly subscription	<ul style="list-style-type: none"> • Expensive • Most are autonomous • Limited utility by regular commuters
Mayday Systems	Traveling public Rental car companies Commercial fleets	High	System hardware Installation Monthly subscription	<ul style="list-style-type: none"> • Expensive • No dynamic information

Opportunities to Develop Public-Private Partnerships

As mentioned previously, the commercial traffic reporting industry has been the most profitable within the ATIS market to date. Although the information collected by these private companies is sufficient for general dissemination on the radio, the quality and detail of these reports have not been enough to inspire independent payment by consumers. Radio and TV broadcasts of traffic reports have, over the years, conditioned consumers into perceiving that this information is free, which has had a marked effect on the remainder of the market for traveler information products and services. There is a need to improve the accuracy, timeliness, and comprehensiveness of the information in order to make it marketable. This is possible, however, only through government spending to place sensors in the roads and cameras overhead, and other methods for gathering information. Transportation agencies in cities such as Atlanta, Houston, Seattle, San Francisco, Los Angeles, Chicago, Detroit, and Minneapolis/St. Paul have been monitoring traffic and collecting traffic data as part of their freeway incident and traffic management programs for several years. The information collected through these systems will be a core resource for the provision of dynamic, real-time data in traveler information products and services (2). The private sector can play a key role in expanding the market for traveler information products by using their expertise to add value to the packaging and presentation of real-time information obtained from the public sector (13). This illustrates why the formation of partnerships between these public and private agencies will be invaluable to the future success of the traveler information services market. The next section of the report will focus on the various partnership mechanisms that can be employed between the two sectors.

PUBLIC-PRIVATE PARTNERSHIPS

Transportation agencies in the US are facing funding reductions at the federal, state, and local levels. With additional political pressures to reduce the size of their operations, these agencies are forced to operate in a resource-constrained environment with smaller staffs, posing a serious dilemma for transportation managers. In light of these pressures, public sector agencies are beginning to look to the private sector for additional funding of ITS projects, as well as for staffing and operational support. In the case of traveler information systems, the development of public-private partnerships has the potential to generate revenue from consumers and value-added resellers who would use the traffic information provided by the system. A portion of this revenue could be returned to the public sector to offset maintenance and operational costs. Public-private partnerships within the traveler information services benefit all parties involved - public agencies make the most of their resources, private companies obtain a larger market for their goods and services, and users get more complex services than either group could provide alone. (37, 38)

This section of the report will examine the various public-private partnership strategies that can be employed for the purposes of developing, operating, and maintaining a traveler information system. The strategies can range from one that utilizes heavy public sector operation and control to one that is an entirely private operation. Each strategy will be discussed in terms of which sector collects the raw data, transforms the data into a useful format, and disseminates the data to the public.

The Public Model

The public model is characterized by one or more public agencies having exclusive responsibility for developing, operating, and maintaining the traveler information system. A publicly-funded data collection infrastructure is used to collect raw data, which is then converted into a form that is useful for dissemination, a process referred to as 'fusing' the data. In the public model, large quantities of information are provided to the public free of charge. (39)

An example of a public model would be a transportation network equipped with a publicly-funded data collection infrastructure and a transportation management center, both financed with public funds and operated by public employees. Information would be disseminated to the public through a comprehensive distribution network consisting of roadside variable message signs, highway advisory radio, kiosks in public places, a telephone dial-in service, a public access cable TV channel, and a Web site. (27)

Contracting Mechanisms

When more than one public agency is involved in a traveler information system, it is referred to as a public-public partnership. Each agency can have different levels of involvement regarding resource-sharing, roles, and responsibilities. This is usually established in the form of a legal agreement, examples of which can include inter-local service agreements, interagency agreements, memorandums of understanding, and memorandums of agreement. However, when a large number of agencies are involved in a public-public partnership, a single interagency agreement may be difficult to obtain. In this case, it might be practical to have each agency submit a non-legal, nonbinding letter of participation that recognizes their participation in the partnership but allows them to leave at any time. (40, 41)

Pros and Cons

Public-public partnerships are beneficial to the overall traveler information system in that they enable agencies to develop an integrated system in which current traffic conditions can be merged with travel advisories, construction information, and transit information. However, the public sector is often limited in that they may

not have sufficient resources to cover a regional road network. Coverage is usually limited to freeways immediate to a city's urban centers, and little to no coverage is provided on outlying freeways and major arterials. Also, the public sector often cannot respond effectively to consumer market needs, especially those pertaining to personal and commercial travel, as this goes beyond their scope of traditional responsibility. Because so much information is given away to the general public, there is little incentive for the private sector to get involved. The public model allows the public sector to retain a high level of control over its operations, but there is little opportunity to generate revenue that could offset maintenance and operational costs. (39, 42)

Contracting for Services

Contracting involves a public agency hiring a private firm to perform a specified task. In the case of operating a traveler information system, the fusion process would most likely be the task contracted out to the private sector. The task or service is defined in a set of technical specifications and presented to interested parties in a 'request for proposal' process. Private agencies interested in performing the task submit a bid to the public agency, who then reviews and evaluates all the bids received. The winning bidder enters into a contract agreement with the public agency to perform the task or service. (40)

Contracting Mechanisms

There are three variations of contracts: (1) low-bid contracting; (2) life cycle contracting; and (3) performance contracting. The low-bid contracting process involves selecting the lowest bid among those competitors who are determined to be technically competent to perform the task. Life cycle contracting is a design-build contract which includes the long-term operating costs of the system. Performance contracting involves selecting a firm to perform a service based on their ability to meet certain performance specifications. A contract can be structured as a fixed price, cost plus fixed fee, cost plus award fee, or another alternative. (40)

Variations of contracting could also be achieved by changing the contracting process used to hire a private firm. For example, a basic fee-for-service contract could involve a private firm writing and operating software that meets the specifications established by the public agency. The contract could vary in the establishment of the ownership rights of the software program. The more expensive, but less risky approach would specify that, at the end of the contract, the public agency owns the software. Granting ownership to the private firm would be less expensive, but involves considerably greater risk. (5, 39)

Pros and Cons

Contracting is useful when a public agency lacks experience in a particular area, lacks staff who are technically qualified to perform a task, or simply does not have enough staff to perform a task. Contracting allows the public sector to maintain control over the service while taking advantage of the technical expertise of private sector personnel. However, the public sector must have a good understanding of the desired finished product in order to write an effective request for proposal and to efficiently manage the contract and performance of the private firm. (40)

Franchising

In a franchise, the public sector is responsible for traffic data collection, but gives a private sector firm the exclusive right to fuse, market, and sell the data for a given period of time. The private firm is selected competitively based on what they are willing to pay to obtain exclusive control of the public agencies' data. Payment could be in the form of a fixed price, revenue sharing, or through the purchase and installation of new infrastructure. In return, the private firm is allowed to sell the data to other information service providers and to consumers. (39)

Pros and Cons

A franchise is a good alternative when the public sector wants to provide a service to the public, but has no interest in either providing the service itself or in retaining close control of the service. The franchise model allows the private sector to provide information that is tailored to meet the needs of the various end-users. The traveler information service then becomes market-driven, utilizing the latest technologies while maintaining optimal performance. In a franchise, however, the public sector loses control of the data and, because the private sector sells the information, people who cannot afford to pay for the service are unable to receive traffic information, creating a problem regarding social equity. The public sector also runs the risk of financial failure on the part of the private firm. If this occurs, the private firm would either leave the market entirely or they would force the public sector to renegotiate the terms of the initial agreement, in which case the public sector would have to pay to keep the fusion process operating. The public sector can minimize this risk by purchasing the rights to any hardware or software used in the traveler information system, making it easier to change contractors at a later date in the event of such problems. (39)

Competitive Licensing

A variation of the franchise is competitive licensing, in which the public sector allows two or more private firms to market traffic information for sale to consumers in a given service area.

Pros and Cons

Competitive licensing is beneficial in that it creates a competitive market in which consumers can access information of high quality at lower costs. The public sector also stands to benefit from competitive licensing, as the loss of any one vendor does not harm the operation of the overall traveler information system. Competitive licensing should be employed with caution, however, in regions where opportunities to sell data are small to begin with. This is because fragmenting the market early may prevent any of the private partners from making a profit. (27, 39)

Asset Management

Asset management is similar to the strategy of competitive licensing. Instead of providing the information directly to private firms for dissemination, however, the public sector employs the services of an outside broker to manage its traffic data and to broker the sale of this information to wholesalers and retailers in exchange for a commission. In this regard, the public sector maintains control of the data while relying on the expertise of the outside broker to open new markets. (5)

Pros and Cons

The strategy of asset management provides a means to accelerate the creation of a competitive, robust market for traveler information services and products. Asset management also provides a means for the public agency to generate supplemental revenue, allowing it to expand, operate, and maintain its data collection system. (5)

Outsourcing

With outsourcing, a public agency owns the traveler information system but contracts its operation to a private firm. The private contractor provides the equipment and operates the system, while the public sector finances the system and designates functional and technical standards. This allows the public agency to benefit from the marketing, management, and organization skills of the private sector while maintaining control over the system. (27, 43)

Pros and Cons

One of the primary advantages of outsourcing is in the area of human resources. A private firm not subject to civil service regulations has greater flexibility to hire and train qualified staff and to discipline and dismiss employees when necessary. A private firm can also attract and retain highly skilled operators, traffic systems engineers, computer systems analysts, and hardware engineers necessary to operate a complex traffic operations center. (38)

Cost Sharing

Cost sharing involves a public-private partnership in which both sectors share the financial burden of the design, construction, operation, and maintenance of the traveler information system. The revenue generated from the system (from both consumers and taxpayers) can be applied to the capital and/or operating costs of the traveler information system. Cost sharing is used when both the public and private sector stand to benefit from a given system. (40)

Contracting Mechanisms

The contracting mechanism for a cost sharing relationship may take the form of direct payments, indirect payments, in-kind contributions, or revenue sharing. In the form of direct payment, each agency agrees to pay a share of the total cost of the system in dollars. In the form of indirect payment, each agency contributes to their share of costs by providing indirect payments in the form of subsidies, vouchers for end-users, or by providing favorable tax treatments to private firms. In-kind contributions are when agencies donate staff time, equipment, and other resources to a traveler information system in place of cash contributions. In revenue sharing, the agencies agree to meet cost obligations by sharing the revenue that is generated by the various end-user products and services. (40)

Pros and Cons

Cost sharing is advantageous in that public and private sector agencies can leverage one another to undertake a business opportunity that may otherwise involve a great deal of risk. However, the problem with combining resources to operate a traveler information system is that ownership and intellectual property rights become unclear. This can be solved by defining ownership rights in the legal documents that govern the partnership. (40)

Joint Ownership

In the joint ownership model, a public agency enters into a cooperative agreement with one or more private sector firms to develop and jointly operate a traveler information system. Typically, the public and private sector firms share joint responsibility for data collection, and one of the partners operates the traveler information center where the publicly and privately-collected data is merged. Both parties have access to the enhanced database, although contractual terms may govern the sale of the enhanced information and the division of resulting revenue (27).

Pros and Cons

Joint ownership provides both partners significant savings in terms of money, time, and personnel. However, when resources are merged through this type of partnership, issues regarding rights of ownership, access to and use of public resources, and style of procurement can arise, potentially overshadowing any savings. In addition, an agency may face difficulties leaving a joint ownership partnership in the event of problems.

The Private Model

In the private model, private traffic reporting companies own and operate their own traveler information system, performing all the data collection, fusion, and dissemination functions. These companies collect roadway information through state-of-the-art technologies and a variety of other information sources, including aerial surveillance from aircraft within the region, incident and construction reports from state and local police agencies, real-time traffic information from local traffic operations centers, and on-the-scene reports of current roadway and accident conditions solicited from cellular callers. The information is then processed and translated into concise traffic reports which are provided to subscribing radio and TV stations either as a broadcast-quality voice feed or through a text-based data feed of incident and congestion descriptions. (12, 13)

Pros and Cons

In this model, the private sector owns and operates the data collection system. This provides a high level of private sector control and gives them greater incentive to produce consumer products and services that are likely to generate a revenue. Thus, the implementation and growth of the information system becomes market-driven, often taking advantage of the latest in technological advances. However, a disadvantage of the private model is that it may not provide enough revenue for the operation, maintenance, and future expansion of the transportation data collection and management system. (5, 42)

Summary

This section has provided insight into the various partnerships that can be developed between public and private sector agencies in the context of the traveler information services market. Table 2 highlights the characteristics of each of these partnership strategies, identifying the roles of each sector with respect to data collection, data fusion, and data dissemination.

Table 2. Public and Private Sector Roles Within Various Partnerships

Partnership Strategy	Data Collection	Data Fusion	Data Dissemination
The Public Model	Public	Public	Public/Private
Contracting	Public	Private	Public
Franchise	Public	Private	Private
Competitive Licensing	Public	Private	Private
Asset Management	Public	Public	Private
Outsourcing	Private	Private	Public/Private
Cost Sharing	Public/Private	Public/Private	Public/Private
Joint Ownership	Public/Private	Private	Public/Private
The Private Model	Private	Private	Private

SUMMARY OF FINDINGS

There are many potential barriers to the development of a comprehensive, self-sustaining traveler information system. The consumer market for traveler information is itself still relatively new, and its future success will be dependent on overcoming a number of uncertainties. Involving the private sector in a portion of the development, operation, and maintenance of a traveler information system can alleviate some of these uncertainties, but this introduces a new set of problems due to the differences that exist between and within the public and private sectors. In this section, a summary of the major findings with respect to these issues will be presented. The findings are derived from information obtained during the literature review and through telephone interviews with public and private sector transportation professionals involved with selected ATIS projects in the US.

The Consumer Market for Traveler Information

Lack of Geographic Coverage

One of the major problems with current real-time traffic information is that, in the majority of metropolitan areas, coverage is limited to major freeways, with little information available for arterials within the region. The private sector is concerned that, in order to better market real-time traffic information, the geographic distribution of coverage must be improved. They would prefer to have small amounts of information covering a broad transportation network. The public sector, on the other hand, is very facility-oriented, collecting large amounts of data for particular freeway corridors. Although such large amounts of data provide the public sector with an effective traffic management system, the data collected may or may not be useful to the consumer. (44)

Another issue is that of providing regional versus national coverage. When a consumer invests in the technology necessary to receive dynamic information, that device is generally limited to one particular geographic region. In the event that the consumer relocates to another city, or even simply visits for a short time, his or her device is not compatible with the infrastructure in the new city to receive similar dynamic information. Metro Networks and Etak have recently joined forces to counteract this problem. Etak has developed a traffic workstation that consolidates traffic information and puts it in standard data formats for uniform transmission anywhere in the United States. Metro Networks is responsible for entering the traffic data into the workstation. The data is transmitted using FM subcarrier broadcasts and other media, allowing any device that receives information from Metro Networks in one city to be able to receive information in any other city covered. The goal is to provide coverage in 75 urban areas within the next two years. (44, 45)

Need for Technical Standards

Another way to solve the issue of regional versus national coverage will be through the development of technical standards. Without guidelines to determine how equipment should be configured and how information should be transmitted, the private sector will be reluctant to invest in the traveler information services market. Currently, the majority of ATIS projects in the United States have their own distinct architecture. These conditions would force private sector vendors who ventured into the market to design separate systems for every city. Interoperability should be a requirement of future standards so that end-user devices will operate on any state-wide infrastructure. The development of technical standards will encourage large-scale private investment, which will also help drive down prices for consumers. (9)

Consumers' Willingness to Pay

Previous studies suggest that consumers are unwilling to pay for traveler information services in their current state, as they perceive the information to be comparable to that received from the broadcast media. And, as access to perceived 'free' information available through radio, television, and the Internet expands, there will be even less incentive for consumers to pay for this information in the future. To compound this, many within the transportation industry believe that it is good policy for public agencies to keep motorists informed of traffic conditions, especially when this information has been collected with traffic management systems that were paid for by tax dollars. On the other hand, there is also broad agreement that the traveler information market can benefit from the technological and market research experience of the private sector, which will help pave the way for the sustainability of traveler information services within the marketplace. All of these factors are mutually exclusive, however, in that it is difficult for the private sector to sell information if it is available elsewhere for free. Further, if there is no market in which to sell information, the private sector cannot provide the public sector with a portion of revenue that could defray the taxpayer cost of providing this information. (11, 27, 39, 42, 46)

'Value-Added' Traveler Information

Many professionals in the information service provider and value-added reseller industries believe that traveler information in itself does not have enough value to be a marketable commodity. There have already been many examples of highly specialized companies who have been unsuccessful at marketing single-purpose, closed-system technologies. To become marketable, traveler information must provide value to the consumer while requiring minimal engagement. This can be accomplished by enhancing the scope, detail, and quality of traffic information so that it is substantially better than that currently available from the broadcast media. Possible enhancements include personalizing the information to individual travelers' needs and bundling traffic information with other information and services. (17)

Personalized Information

One way to enhance traffic information as we know it is to provide consumers with a personalized information service. In this manner, consumers could obtain timely and detailed information about the conditions prevailing on their particular routes at their intended times of travel. This service could be accessed by the consumer either on demand, or, in the case of regular commuters, the information could be sent automatically through telephone, fax, e-mail, or pager. The advantage of automatic notification is that the service becomes passive in that it reaches out to, as opposed to waiting to be accessed by, the subscriber. Travelers who subscribe to the service would register in advance with the information provider their personal preferences as to their travel times, days of the week they wish to receive the information, their travel routes, the desired communication medium through which they wish to obtain the information, and billing information. (27, 47).

This service could be further customized by providing travelers with not only route-specific traffic advisories, but to also recommend alternate routes that would allow them to bypass major congestion and traffic accidents. A potential problem with this, however, is that the geographic and topographic features of some metropolitan areas may limit a commuter's choice of travel routes. Commuters may also be reluctant to divert from their normal routes because of area neighborhood traffic restrictions, safety concerns, or fear of getting lost. If this more customized service is to be offered, travelers could register both their preferred travel routes and the alternate routes they would be willing to travel at the time of their commute with their information provider. (11, 12, 47)

Bundled Information

The current format of traffic information could be further enhanced by 'bundling' this information with other types of information or services. For example, within the vehicle, traffic information would gain value in the eyes of the consumer if it could be tied to other components of the car, such as the stereo, cellular phone, and navigation system. When packaged as a general or multi-purpose device, the price for the traffic information could be spread over all the other services. (9, 27)

Public Education and Awareness

Public education and awareness will play a large part in gaining consumer acceptance of traveler information products. It has been seen that, although people complain bitterly about travel delays, expected or unexpected, they are not strongly motivated to seek out better information regarding current traffic conditions. People do listen to traffic reports on the radio, but they also regard this information to be incorrect, outdated, insufficiently specific, or too limited in geographic coverage. However, they also perceive the small amount of extra time and effort necessary to place a telephone call, boot up a computer, or access a web page as being too troublesome. Consumer awareness and acceptance of ATIS technologies can be raised through promotional or educational activities emphasizing that the few minutes of extra time and effort spent before a trip can be compensated by greater time savings while traveling. (17)

Barriers to Developing Effective Public-Private Partnerships

Throughout the process of forming and developing a partnership, a number of problems can arise between and within the public and private sector firms involved, posing a potential threat to the success of the venture. The problems identified throughout this research effort can be classified as organizational, financial, or regulatory/legal.

Organizational

Organizational barriers result from intra-agency and interagency differences that may arise throughout the project. These include the following:

Differing Cultures, Goals, and Objectives

Public-private partnerships can be challenging due to the differing cultures, goals, and responsibilities between and within the two sectors. For example, the public sector seeks to provide the public with real-time traffic information at the lowest possible cost. This is partly because the information was collected with traffic management systems that were paid for by tax dollars; but more importantly, the public sector seeks to minimize the negative effects of traffic congestion while improving safety, economic efficiency, and regional air quality (39). The private sector, on the other hand, seeks to make a profit by repackaging the information so that it has value, selling this information to the public through subscription-based services, and selling advertising time that is packaged with the information. These differences can present a barrier to a public-private partnership if either side does not clearly understand the objectives of the other. However, by working towards a common cause, public and private sectors can cooperate amidst their differences. (41, 42)

Clarification of Roles

One of the biggest obstacles to developing a traveler information system can be the successful coordination of the efforts and resources of the players involved. To do this, the roles and expectations of each of the partners should be established early in the partnership. The functional components of the traveler information system

can be partitioned among the different partners, depending on their interests and capabilities. This allows each participant to perform tasks which focus on their respective strengths while letting the other partners focus on the remaining tasks. When a partnership lacks role clarity, it may slow down the overall system development process. (40, 48)

'Turf' Mentality

Coordination between and within public agencies can also be a potential barrier to the development of public-private partnerships. According to the experiences of some agencies, the development of public-public partnerships is seen as an integral step in the development of a traveler information system, and a necessary first step before public-private partnerships can be formed. However, each agency involved in a partnership has a unique set of operational policies and agendas. This can create 'turf wars,' allowing institutional problems to stand in the way of progress. One reason for tension between agencies is that, to some extent, local jurisdictions compete in a 'zero sum' environment, in which they compete against one another for the same scarce funding resources. Other reasons for tension can include an unwillingness of one agency to contribute to system costs; the desire of one agency to maintain control over the use and dissemination of data; and issues regarding equity, leadership, and ego. (40, 49)

Project Champion

When developing public-private partnerships, the importance of having a project champion cannot be overstated. The champion, usually a member of a public sector agency, must have the creative, energetic leadership required to break new ground and effectively gain support from all sides. This person must spend a large amount of time educating legislators and senior staff about the value of ITS and how it can provide a cost-effective means to meet the traffic management objectives of the public sector. (41)

Financial

Liability Issues

Liability associated with any new technology that becomes part of a traveler information system or traffic management system is of concern to both the public and private sectors and may create a potential barrier to developing an effective partnership.

Project Risks and Benefits

When both public and private sector partners share in the costs and ownership of a traveler information system, they also share in the potential risks and benefits. For example, the private sector partners risk not receiving the expected return for their investment. The public sector risks losing the investment of public funds and possibly receiving negative publicity and loss of public confidence in the department of transportation. If the traveler information system is successful, the private sector partners will be rewarded with a profitable business venture, which will open doors for those firms to participate in similar projects in other markets. The public sector will benefit from a more comprehensive transportation management system in which travelers are better informed. In addition, the public sector may receive a percentage of the revenue generated from the system that can be used to offset operational and maintenance costs. (48, 50)

Regulatory/Legal

Enabling Legislation

Even when public and private sector agencies recognize the need for and potential benefit of working together, many state governments lack the authority to establish a new way of doing business. Thus, new legislation may need to be passed to allow a state department of transportation to enter into non-traditional relationships with private sector firms. This barrier creates an insurmountable risk for the private sector because without the proper legislation, the public sector will not be able to enter into public-private partnerships. (51)

Contracting Mechanisms

The contracting procedures involved in public-private partnerships is another potential barrier. Traditional public sector contracting requirements can be difficult to understand, requiring many signatures that can significantly delay the start of the project. In addition, intellectual property, indemnification, and liability clauses can be difficult to negotiate. When there are a large number of partners involved in a traveler information system, a single memorandum of understanding is often difficult to obtain. The solution is to use non-legal, nonbinding letters of participation from each agency that allow the agencies to pull out at any time. These letters can recognize the lead public agency as a procurement agency on behalf of the region and state that the enhanced information is for internal public agency use only. The contracting process can cause development trade-offs in that money is spent resolving contracting issues rather than development issues. (41, 48, 49)

Intellectual Property Rights

When public and private resources are combined to develop the operating components of a traveler information system, intellectual property rights can become an issue. This is especially true with the development of software. In many states, government regulations (Federal Acquisition Rules) specify that the government shall retain ownership rights to all developed software. The private firm that developed the software must rescind their proprietary interest in and or control over it once developed. Therefore, throughout contract negotiations, both public and private sector partners must ensure that their interests are protected. For example, the public sector can insert 'escape clause' procedures into the contract to ensure that if a private firm leaves the partnership, they do not take crucial software with it, leaving the system inoperable. Another method is to provide participants with legal 'sole use' rights to jointly developed software. (40, 48)

GUIDELINES FOR DEVELOPING EFFECTIVE PUBLIC-PRIVATE PARTNERSHIPS

Outlined in this section are guidelines that can be used by public sector agencies when entering into partnerships with private sector firms for the development, operation, or maintenance of a dynamic traveler information system. These guidelines provide a means by which public and private sector firms can develop an effective partnership while resolving potential organizational, financial, and regulatory issues that may arise throughout the process. The guidelines incorporate existing strategies being used by public and private sector agencies to overcome these issues, and new strategies are incorporated into the guidelines to address additional concerns identified through this research. The guidelines are summarized in Table 3, followed by a detailed description of each guideline.

Table 3. Guidelines for Developing Effective Public-Private Partnerships

Guidelines
Stage 1: Develop a foundation for the traveler information system.
Stage 2: Select private sector partners.
Stage 3: Negotiate the details of the contract.
Stage 4: Ameliorate differences between and within public and private sector partners.
Stage 5: Develop the traveler information products and services.

STAGE 1: Develop a foundation for the traveler information system.

Because a successful traveler information system is dependent on merging a variety of information (e.g., real-time traffic, transit, and regional information), the development of public-public partnerships is an integral first step in developing the foundation for a comprehensive traveler information system. The public-public partnership could potentially involve the following agencies: state Department of Transportation, city and county jurisdictions, regional/local transportation authorities, regional/local police departments, emergency management groups, tollroad authorities, turnpike authorities, and port authorities.

A single public agency must assume a strong leadership role to ensure effective participation on the part of all the partners. The lead public agency will be responsible for the facilitation and coordination of the efforts of both the public and private sector partners. Within this lead agency, there must be a project champion who represents the project and its benefits to upper management and legislators. In addition, this person must have the organizational and interpersonal savvy necessary to reach out to and develop relationships with both public and private sector agencies.

Finally, in developing a foundation for the traveler information system, the lead agency must define the requirements of the product or service to be developed by private sector firms. If the product is intended for consumer use, the basic features of the traveler information product should satisfy the information needs of travelers in the region as determined by market research. The lead agency should then issue either technical or functional specifications for the development of these products or services. In either case, the lead agency must clearly understand what is needed, what traveler information is available, and what can be achieved based on financial, political, and managerial limitations. However, functional specifications would provide private sector firms greater flexibility in developing the product or service while utilizing a variety of technologies and strategies.

STAGE 2: Select private sector partners.

Private sector partners should be selected based on their compatibility with the objectives of the overall project. Any firm that can add net value to the traveler information system should be considered. These private sector partners are valuable to the project in that they have market experience and can quickly adapt to changing technologies. It is important to remember, however, that private sector interest will most likely be based on the benefits to be gained compared to the costs of participation (46). Thus, the project champion must reach out to these private sector firms to educate them about the benefits and opportunities to be gained from participation in the project.

STAGE 3: Negotiate the details of the contract.

In this stage, the functional components of the traveler information system should be partitioned among the different partners based on their respective interests and capabilities. The contract between public and private sector firms can be in the form of an informal agreement, written contracts, or other legislation, depending on the partnership strategy that is most appropriate for the project. However, the specifics of the contract should identify: operational responsibilities, ownership of intellectual property rights or other assets, policy-making procedures, and how revenue generated from the system will be shared among the partners. The terms of the contract should have some degree of flexibility, allowing partners to leave the partnership gracefully.

STAGE 4: Ameliorate differences between and within public and private sector partners.

Throughout the contract negotiations and the ensuing project, significant interagency and intra-agency problems can manifest themselves as partners begin to interact and attempt to communicate. Therefore, a crucial stage in partnership development involves developing mechanisms to overcome or lessen the problems of partner-to-partner interactions. A key success component involves each partner taking the time to understand the cultural differences, objectives, and operating goals of the other. This involves the development of personal relationships between key members of each partnering firm. Relationship development can provide a medium for communication through formal and informal channels at all times, potentially alleviating future problems. A second strategy is for the public and private sector firms to participate in personnel exchanges. In the case of a traveler information system, the exchange can occur between both the public-public and public-private partners. A personnel exchange is beneficial in that it allows participating employees to gain first-hand insight into the internal operating complexities of the other agency. This can further contribute to both improved communications and the development of personal relationships between key personnel. A final strategy is to obtain a third-party mediator to represent the values and concerns of each participating organization. The mediator is a person who has insight into the cultures of both sectors and is therefore trusted by all parties. The mediator can be instrumental in helping the partners ameliorate their differences and work towards a resolution. (46)

STAGE 5: Develop the traveler information products and services.

Throughout the development of the product or service, the private sector should form end-user advisory councils to test various prototypes. These councils are beneficial in that vendors gain knowledge of the particular features and functionality that consumers desire in a traveler information product or service before introducing that product or service to the market. This process allows the development of the product to be market-driven, rather than driven by what the transportation industry feels is best for the market. A product that is tailored to meet the needs of consumers will have greater long-term success in the marketplace.

Another important element in developing a successful traveler information product is creating a public education and awareness campaign. Because this market is relatively new, many consumers are unaware of

the benefits that real-time traffic information and other ATIS features provide over conventional radio broadcasts. Consumer awareness and acceptance of traveler information products can be raised through promotional marketing that emphasizes that the few minutes of extra time and effort spent before a trip can be compensated by greater time savings en route.

Summary

The guidelines formulated in this section of the report are summarized in the flowchart in Figure 3. These guidelines provide a starting point for developing innovative public-private partnerships while minimizing the potentially negative effects of certain institutional, financial, and legal issues. Although the guidelines are flexible enough to accommodate a variety of the public-private partnership strategies described in this paper, it is important to realize that these guidelines may not be applicable to all regions due to various factors such as the availability of existing or planned intelligent transportation infrastructure, the political environment, and public and political opposition to the sale of information collected with public funds.

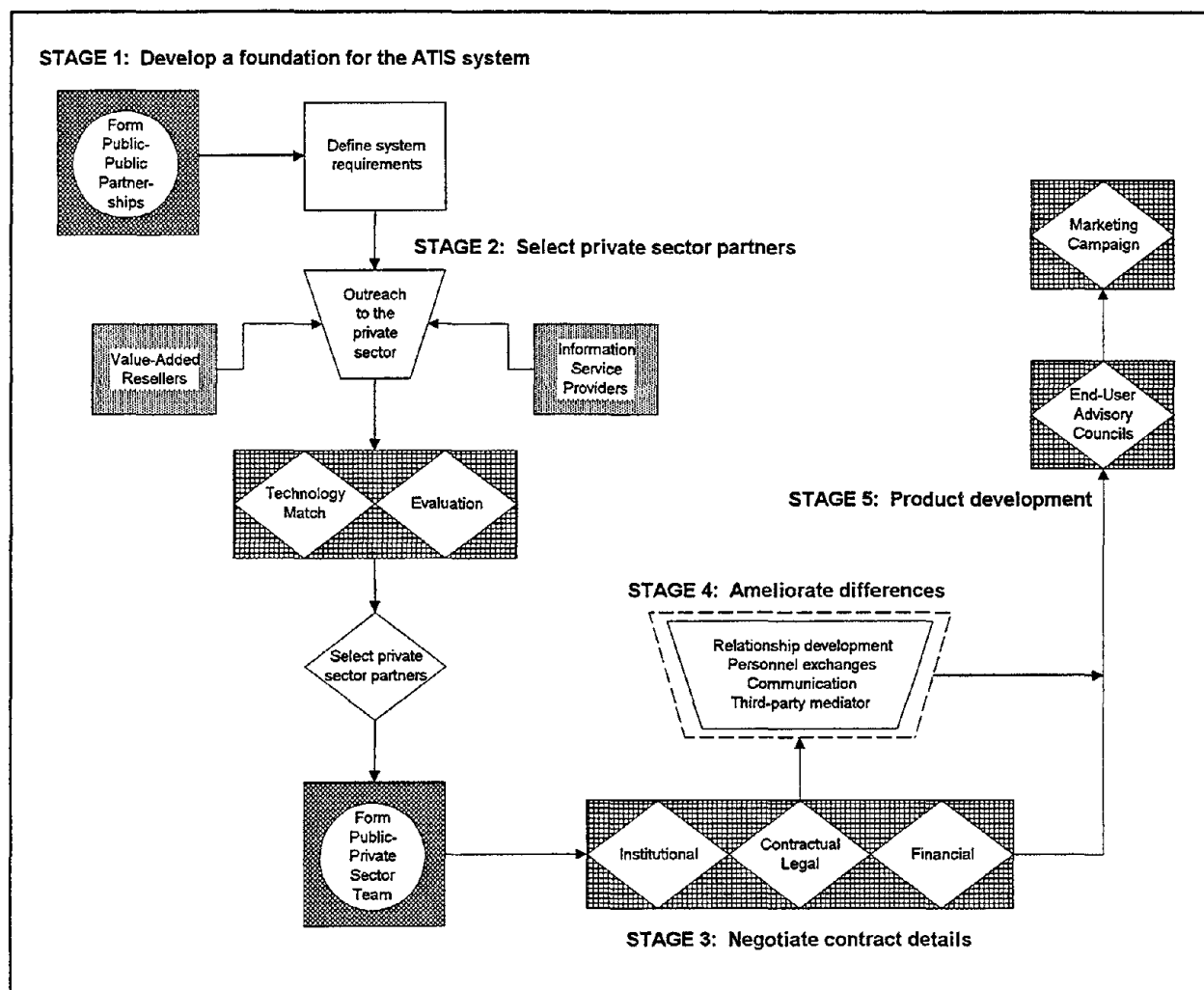


Figure 3. The Public-Private Partnership Process

CASE STUDY: HOUSTON, TEXAS

Houston is a large metropolitan area located in Southeast Texas. Presently, the city limits cover the majority of Harris County, with extensions into both Fort Bend and Montgomery counties. Recent census data show Houston to be the fourth largest city in the United States, with a population of nearly 1.8 million. (41)

TranStar is a partnership comprised of the transportation and emergency management agencies in the Houston area, including the Texas Department of Transportation, the Metropolitan Transit Authority of Harris County (METRO), the City of Houston, and Harris County. Together, these agencies are responsible for the design, operation, and maintenance of facilities to provide transportation and emergency management services within the greater Houston area. TranStar is housed in a 52,000 square foot transportation management center located on Old Katy Road near I-610 West. The building is equipped with facilities for traffic control, communications, METRO police and bus dispatch, telephone switching, office space, and briefing rooms for use during special events and emergencies. The building also contains viewing rooms so the public and news media can monitor operations during public tours, special events, and emergency situations. Each member agency contributes to the annual operating budget of the transportation management center on a prorated basis relative to its occupancy and utilization of building components. (41)

Application of Guidelines for Developing Effective Public-Private Partnerships

This section provides an application of the guidelines developed to assist public and private sector agencies in developing effective partnerships while minimizing the effects of common organizational, financial, and legal barriers. The strategies will be applied to the hypothetical implementation of a personalized paging service as an extension of the Houston Smart Commuter project. The case study will not focus on the technical details associated with the paging service; rather, it will examine the partnership that would be developed between Houston TranStar and the involved private information service providers.

STAGE 1: Develop a foundation for the traveler information system.

Houston TranStar is unique from other transportation management centers in that it is comprised of a strong public-public partnership that includes regional transportation agencies as well as emergency management groups. The TranStar building is staffed with professionals from all four member agencies, as well as representatives from the Harris County Sheriff's Department, Houston Police Department, and local emergency management groups. This integrated structure creates an opportunity to eliminate the 'turf' problems typically associated with public-public relationships. By pooling their financial, personnel, and equipment resources, the potential problems traditionally associated with public sector administrative and bureaucratic processes are reduced. The presence of multiple agencies in the TranStar building also provides a means for improved responsiveness when performing transportation and emergency management responsibilities.

TranStar places a strong emphasis on providing effective transportation management services in the Houston region. The region already has a significant intelligent transportation infrastructure in place, comprising of closed circuit television cameras (CCTV), changeable message signs, automatic vehicle location detectors, flow signals at freeway entrance ramps, high occupancy vehicle (HOV) lanes, and a fiber optic communications network. This infrastructure, combined with the solid relationship that exists among the TranStar partners, provides a strong foundation for merging a variety of information into a comprehensive traveler information system.

Real-time traffic information is currently disseminated to the public through TranStar's Internet Web site. In addition, the public receives traffic updates through traditional broadcasts on local radio and television media by private traffic reporting companies. Representatives from two of these companies are stationed on

TranStar's control room floor and are provided access to the CCTV system and real-time traffic information. To avoid issues of social equity, TranStar should continue to provide traffic information over these traditional mediums. However, to provide a more personalized service to commuters, TranStar could develop a personalized paging system as an extension of the federally-funded Smart Commuter project.

The Smart Commuter project involves disseminating traffic and incident information to selected commuters via a handheld computer and through a telephone-based information system. The coverage area of the Smart Commuter project is currently limited to North Houston along the I-45 and Hardy Tollroad corridors. As real-time traffic information is available for the majority of Houston's freeways, the personalized paging service could be offered on a city-wide basis to alert commuters of traffic problems, construction activities, and estimated travel times along their regular routes. An additional feature could be to provide automated carpool matching services. The desired requirements of the personalized paging service should be established in the form of functional specifications so that private sector firms have greater flexibility in designing the technical aspects of the service.

Either the Texas Department of Transportation or Houston METRO could serve as the lead public agency for this project. Houston METRO has previous experience in that they currently provide project management services for the Smart Commuter project. This experience can extend naturally into the development of a personalized paging service. However, either agency would be appropriate as they are both actively involved in the ITS efforts in the Houston area.

STAGE 2: Select private sector partners

TranStar could use the evaluation results of the Smart Commuter project to assess the value that participants place on receiving real-time traffic conditions for area freeways and HOV lanes. This information could be presented to information service providers in the Houston area to educate them regarding the market potential for a personalized paging service. In addition, potential vendors could be educated as to the benefits of ITS and could be shown the progress of ITS activities in the Houston area to date.

STAGE 3: Negotiate the details of the contract.

In this stage, the functional components of the paging service are to be partitioned among the different partners. Members of the TranStar partnership would retain their primary responsibility of collecting traffic data and providing emergency management services. As part of the Smart Commuter project, members of METRO Police currently monitor traffic incidents from TranStar's control room floor and enter incident details into a central computer database. This responsibility should be retained so that detailed incident information can be included as a feature of the paging service. The information service providers would be responsible for developing the technical details of the service, including any necessary algorithms and computer software. All traffic, incident, and construction information can be obtained directly from TranStar. However, the paging system should be capable of transmitting customized information to subscribers based on their individual traveler profiles.

These responsibilities will strongly influence the contracting mechanism used in the case of a personalized paging service. Because the TranStar partners will want to retain strong ownership and control over the data collection functions, appropriate partnership strategies between TranStar and the information service providers include the public model, competitive licensing, and cost sharing. Intellectual property rights may become an issue, depending on the methodology used by the private sector firm to fuse the data so that it can be customized for individual travelers. Another issue to be established in the contract is revenue sharing. Initially, revenue generated from the paging service may not be enough to offset the operational and maintenance costs on the part of the information service provider. Therefore, for an initial start-up period, TranStar should not

charge the private firm for the dynamic information. Once a market is established and more information service providers are attracted to the service, TranStar can begin to charge for the information. Payment can be made through a percentage of the revenue or through direct payment for the dynamic information.

STAGE 4: Ameliorate differences between and within public and private sector partners.

A potential source of conflict between the TranStar partner agencies and the private sector firms may be the organizational differences that exist between the two sectors, particularly with respect to their goals and internal operating policies. The project managers within each sector must therefore seek to develop strategies to overcome these issues. A key component will be the development of a personal relationship between the two project managers. This will provide an environment of open communication in which each manager can learn about the goals, objectives, and policies of the other. The two managers can further bridge differences by participating in a personnel exchange. Although this is not practical for TranStar personnel, a representative from the private sector firm can be assigned to work at the TranStar building, allowing an open channel for communication with TranStar personnel at all times. If these strategies prove to be ineffective in overcoming differences, the two project managers can employ the services of a third-party mediator to assist in negotiating a resolution.

STAGE 5: Develop the traveler information products and services.

During the development stage of the paging service, the information service providers should organize end-user advisory councils to test the service before widespread introduction to the Houston market. These councils can provide valuable input regarding the format and length of the various pager messages. In addition, the councils can provide feedback regarding additional features or traveler information they would find useful.

Traditional marketing strategies can be employed to increase public awareness of the personalized paging service. These strategies should focus on informing consumers of the availability of the service, describing the advantages of the various features available through the paging service, and educating them about the benefits of real-time traffic information over traditional radio and television broadcasts. The marketing efforts should be deployed through various means of advertising, including radio, television, promotional flyers, newspapers, Internet Web sites, and billboards.

CONCLUSIONS

When developing the services and products for a regional traveler information system, it is important realize that the consumer market is still relatively new. As such, its future success is dependent on overcoming a number of barriers, including the current lack of geographical coverage, the lack of technical standards, the need for greatly improved information, and the need to raise consumer awareness of traveler information technologies. Amidst these barriers, the future holds significant opportunities to generate revenue within the traveler information market. These opportunities may only be realized, however, through public sector partnerships with private sector firms. The private sector has the marketing expertise to package traffic information to consumers in such a way that it holds significantly more value than currently realized.

The guidelines developed in this report provide a starting point for developing innovative public-private partnerships with regards to developing, operating, and maintaining a traveler information system. These guidelines serve as a framework for overcoming the institutional, financial, and legal barriers that can potentially inhibit the success of a public-private partnership. The guidelines are flexible enough to accommodate a variety of the public-private partnerships described in the report. However, it is important to realize that these guidelines may differ by geographic regions due to the availability of existing or planned intelligent transportation infrastructure, the political environment, and opposition to the sale of information collected with public funds.

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**EXTENSION OF THE DEDICATED SHORT RANGE
COMMUNICATIONS STANDARD FOR APPLICATION TO TRANSIT
MANAGEMENT SYSTEMS**

by

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SUMMARY

Communication between vehicles and the roadside is an integral part of the Intelligent Transportation System (ITS) architecture. Reliable, accurate, and efficient two-way communication is necessary for optimal use of almost all ITS user services. While these applications often require different types of information to be sent between the vehicle and the roadway, the vehicle cannot be equipped with a different device for each application. Standardization and consolidation are needed to ensure the resulting system is as efficient and seamless as possible.

Evolving primarily from automatic vehicle identification (AVI) technology, Dedicated Short Range Communications (DSRC) is the title given to the standardized vehicle-roadway communications system now under development. The standard is being developed in North America by an organized coalition of professional societies, government departments, and private firms, using an Open Systems Interconnection (OSI) 7-layer reference model to describe each part of the standard. The purpose of the DSRC standard is to define the basic form and function of the technology, while allowing a wide range of applications to be accommodated. However due to the need for boundaries, the main applications that the DSRC standard is designed around are electronic tolling, commercial vehicle operations, and non-stop border crossing. While these functions are currently the most common, the ITS field is constantly expanding and thus developing new uses for DSRC. In order for the DSRC standard to be useful in the long term, it must be comprehensive and accommodating of new technologies and applications which may not be much more than theories at this time.

This research paper examines each part of the DSRC standard and describes the current proposed standard. The DSRC standardization effort is progressing quickly and should yield a very workable set of standards for future development. The open architecture and flexible configurations will allow private developers to market products that best meet the needs of the customers. The standardization should also increase the availability of ITS around North America, because proposed projects would no longer have to determine the basic technologies to deploy.

The standards examined are also applied to transit management, an ITS application that has not yet been implemented with the DSRC standard. This application shows that the hardware and software of DSRC is being standardized with a large amount of flexibility built in, beyond the current applications the standard was designed around.

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INTRODUCTION

Communication between vehicles and the roadside is an integral part of the Intelligent Transportation System (ITS) architecture. Reliable, accurate, and efficient two-way communication is necessary for optimal use of electronic toll and traffic management (ETTM), automatic vehicle identification (AVI), automatic vehicle location (AVL), advanced traveler information systems (ATIS), and most other ITS applications (1,2). While these applications often require different types of information to be sent between the vehicle and the roadway, realistically the vehicle cannot be equipped with a different device for each application. Besides space in the vehicle and on the roadside, space in the radio frequency spectrum is at a premium. Additionally, vehicles attempting to use ITS in several geographic areas could have to use separate transponders and frequencies for the same function, depending on the operator and manufacturer. Standardization and consolidation are needed to ensure the resulting system is as efficient and seamless as possible. Many systems operating with the same equipment also allow many groups of customers to share the cost of the necessary infrastructure, reducing the cost per user and per application (3).

Evolving primarily from AVI technology, Dedicated Short Range Communications (DSRC) is the title given to the standardized vehicle-roadway communications system now under development. The standard is being developed in North America by an organized coalition of professional societies, government departments, and private firms, using an Open Systems Interconnection (OSI) 7-layer reference model to describe each part of the standard. The American Society for Testing and Materials (ASTM) subcommittee E17.51 is producing the standard for Layer 1, the physical layer, and Layer 2, the data link control layer. The Institute of Electrical and Electronic Engineers (IEEE) SCC32 committee is producing the standard for Layer 7, the processing and applications. The other layers are not considered important for standardization as part of DSRC (4,5).

The purpose of the DSRC standard is to establish the basic form and function of the technology, while allowing a wide range of applications to be accommodated. However due to the need for boundaries, the main applications that the DSRC standard is designed around are ETTM, commercial vehicle operations (CVO), and non-stop border crossing. While these functions are currently the most common, the ITS field is constantly expanding and thus developing new uses for DSRC. In order for the DSRC standard to be useful in the long term, it must be comprehensive and accommodating of new technologies and applications which may not be much more than theories at this time. Too much time, money and credibility would be lost if a standard was adopted, then promptly bypassed by events and ignored (3).

Problem Statement

DSRC is a vital component of current and future ITS initiatives. A comprehensive international standard is urgently required to ensure compatibility of varied systems and focus development efforts on the uses of the technology rather than the form. The proposed standard must be examined closely to determine its suitability for use with all foreseeable ITS needs.

Research Objectives

The following is a list of the primary research objectives of this study:

- Evaluate proposed DSRC standard for meeting current and future ITS requirements, and
- Develop enhancements to proposed DSRC standard to meet current and future ITS requirements. Text describing proposed enhancements will be written in appropriate language for direct insertion into DSRC standard.

Scope

This research addresses all aspects of the DSRC standard, but focuses primarily on the OSI Layer 7 portion. This applications layer specifies the format of the information passed between the roadside and the mobile transponder mounted in the vehicle. The narrowing of the scope is warranted, as the Layer 1 and 2 standards are approaching completion, while some work still remains to be done on the Layer 7 effort, and this research may further that effort.

Methodology

Information to develop this report was gathered from a review of the current literature and an informal survey of professionals involved in the DSRC standardization effort. Reviewed literature included drafts of standards, research reports, and minutes and supporting documents from meetings of standard-developing groups. The general steps involved in the research effort were as follows:

- Identify the DSRC standard as proposed,
- Examine DSRC standard for deficiencies,
- Identify ITS applications not addressed in proposed DSRC standard, and
- Expand proposed DSRC standard to include identified application.

DSRC INTRODUCTION

This section of the paper will provide the background to aid in understanding of the DSRC standardization effort. The first section describes the National ITS Architecture, of which DSRC will be shown to be a small but essential part. The layers and subsections of the Architecture are separated down to the DSRC level. The physical components of the DSRC environment are described and an example is provided.

National ITS Architecture

Prompted by the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), the United States Department of Transportation (USDOT) began to develop a set of standards and protocols to encourage the development and use of ITS technology. To coordinate the effort, the USDOT first defined the National ITS Architecture, in concert with many nationwide organizations and corporations. This framework was needed to channel research and development efforts towards the seamless, multimodal system described in ISTEA. The National ITS Architecture project also identified 30 user services the ITS could be used to support (6).

The National ITS Architecture is intended to direct ITS development on two layers, the Transportation Layer and the Communications Layer. The Transportation Layer is the physical ITS infrastructure, defined as the travelers, vehicles, management centers, and roadside equipment. The Communications Layer is the connections between segments of the Transportation Layer. A third layer, the Institutional Layer, reflects the static environment in which ITS development must function, including the political, social, and economic systems (6).

Flexibility is an essential part of the National ITS Architecture. The Architecture does not detail any specific technique or technology, it only provides the framework to ensure that separate ITS systems will work efficiently together where needed. Users will be able to choose from a selection of specific technologies according to their needs and resources (7).

Communications Layer of National ITS Architecture

The Communications Layer of the National ITS Architecture coordinates the connections between parts of the Transportation Layer. Each solution for a user service will require items of the Transportation Layer to exchange data in some form. The Communications Layer performs these data transfers. Figure 1 shows the Communications Layer connections between Transportation Layer subsystems.

Loral Federal Systems and Rockwell International designed the Communications Layer to have two components to address all connectivity requirements. These are:

- Wireline Communications, and
- Wireless Communications.

Wireline Communications

Wireline, physical connections by wires or fiber optic cable, is typically used for connections between nonmoving parts of the Transportation Layer infrastructure. In Figure 1 the wireline wide area communications is shown as the links between the roadside subsystems and the management center subsystems that administer the ITS applications. The wireline communications also handles data transfers between management centers and most other communications between fixed sites. For these static, continuous applications the wireline link is the most precise and economical (9).

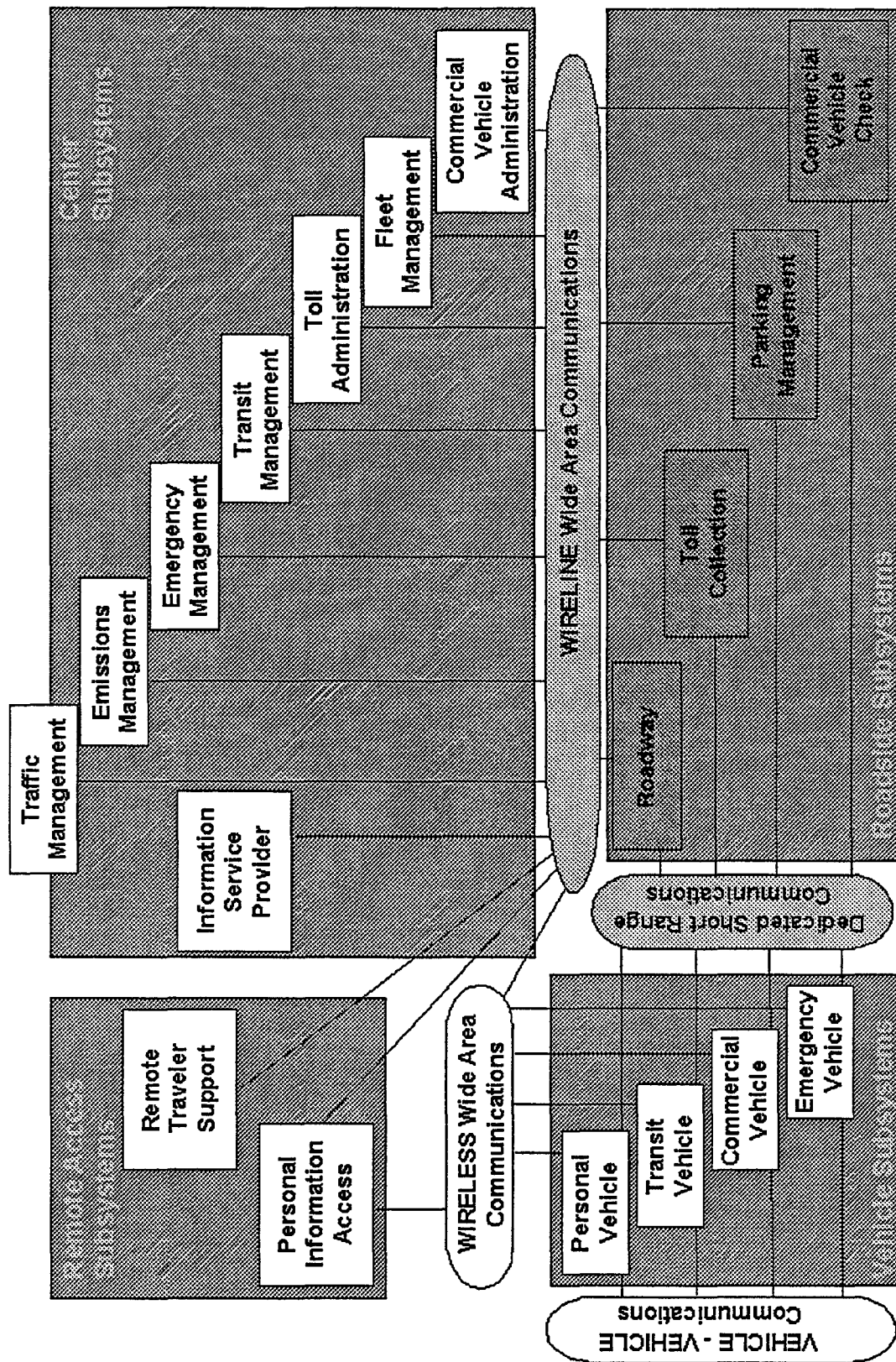


Figure 1. National ITS Architecture (8).

Wireless Communications

The wireless component of the Communications Layer accommodates connections between mobile components of the Transportation Layer. The wireless portion is divided into three general categories: wide-area wireless, vehicle-vehicle, and Dedicated Short Range Communications (DSRC), each specialized for meeting an ITS requirement. Wide-area and vehicle-vehicle wireless communications are briefly described below.

Wide-Area Wireless Communications. Wide-area wireless is used to connect mobile units to base stations over distances greater than 1 kilometer. Examples of wide-area wireless technology currently in use are cellular telephones and anti-theft tracking devices. Systems of this type can have two-way data transmissions or one-way only transmission. The system can also be broadcast to all receivers within range, or directed at once specific unit.

Vehicle-Vehicle Communications. Vehicle-vehicle data transfers connect mobile units as necessary for applications such as automated highways or emergency vehicle warnings. The range and precision of such systems are highly dependent on the needs of the application (2).

Dedicated Short Range Communications

DSRC is the link between the mobile unit and the roadside subsystems as shown in Figure 1. DSRC can be one-way or two-way links by radio frequency (RF) transmitters and receivers. The range of DSRC extends up to 100 meters. Figure 2 shows the overall DSRC environment, an expansion of the Figure 1 vehicle subsystem to roadside subsystem link.

On Board Unit

The equipment on the vehicle is known as the On Board Unit (OBU), or 'tag' or 'transponder'. This equipment consists of a transponder and optional on board devices. The transponder sends and receives data from the roadside equipment, shown as interface 4 on Figure 2, as well as storing information. Transponders can be connected to and exchange data with other devices in the vehicle to meet specific needs. Examples of this would be an electronic logbook for a commercial vehicle, or connections to the vehicle's engine computer to monitor performance measures (2).

Road Side Unit

The equipment located on the side of the roadway is known as the Road Side unit (RSU), or 'reader'. This equipment communicates with the OBU and also with the back office equipment. The antenna physically transmits and receives the signal from the OBU. The reader sends and receives messages from the OBU via the antenna. RSU operation is under control of the VRC controller, which directs the transmissions to the OBU. The VRC controller also exchanges data with the back office equipment, usually by wireline communication (11). The back office to RSU communication is shown as interface 1 in Figure 2.

Back Office Equipment

The back office equipment is the electronic administrator of whatever ITS application that the DSRC system is supporting. The back office equipment stores and processes any information needed by the ITS application, as well as directing the RSU's transmissions to the OBU. Each ITS application runs on specialized equipment according to its technical requirements. For most efficient operation, groups of ITS applications with similar customer bases or geographic areas could be located at a central facility, connected to the same sets of DSRC stations. Such traffic management centers would reduce administrative and overhead costs while improving coordination between human operators (11).

The interface between the RSU and the back office equipment is not technically DSRC, because the physical connection is generally by wireline wide area communications. However, the messages sent by the back office equipment must be of the proper form for transmission to the OBU, so the RSU to back office interface is addressed by the DSRC standard.

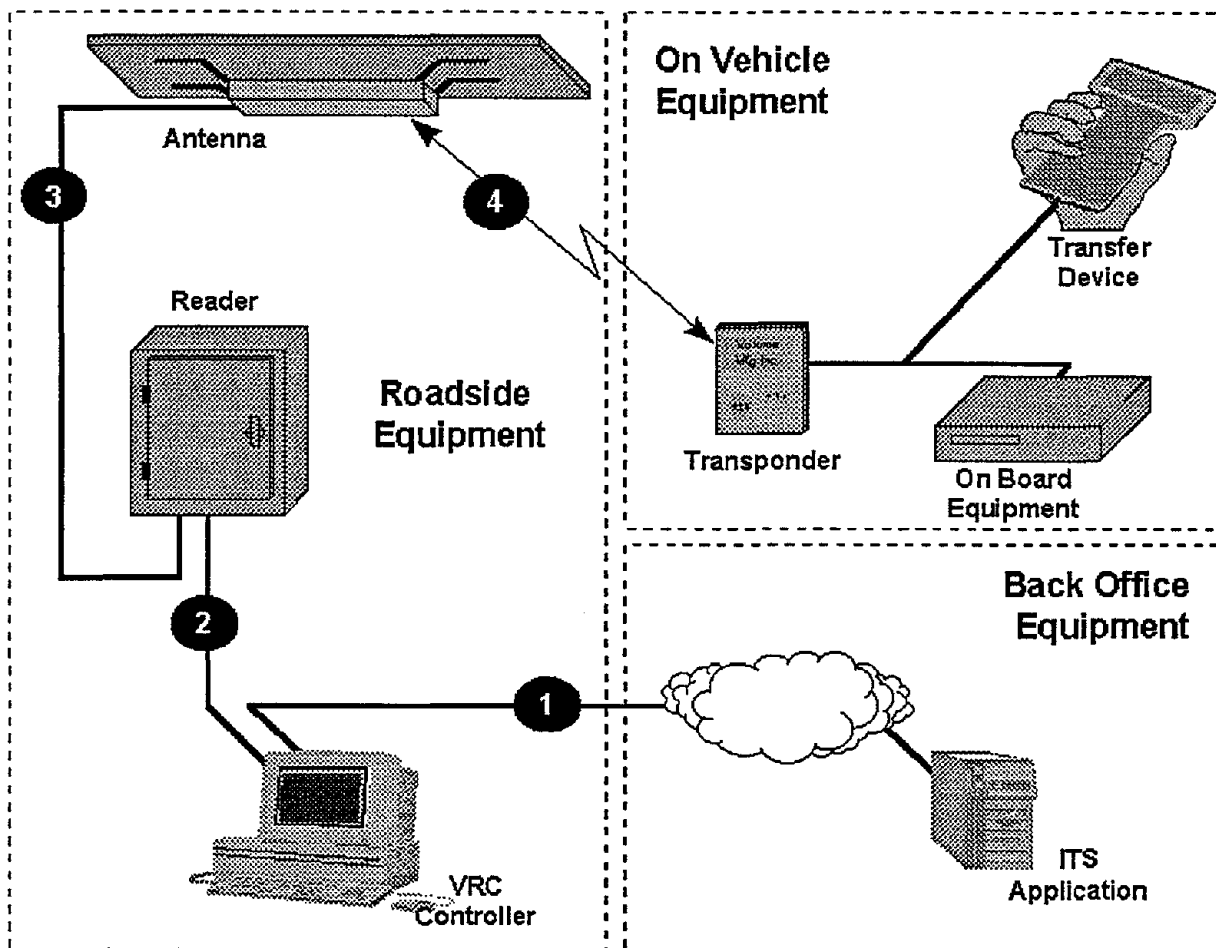


Figure 2. Overall DSRC Environment (10).

RSU Field Installation Example

As the range of DSRC is purposefully kept short, the vehicles may be able to communicate with the RSU for a few seconds. The ITS application may also require processing time to correctly respond to a query from the OBU, or to select the proper message from a list of queued messages waiting for delivery. Thus most DSRC installations employ multiple RSUs, so that several exchanges of information can be made. Figure 3 shows a configuration for commercial vehicle check station, utilizing weigh-in-motion (WIM) devices to allow drivers to bypass the time-consuming check station.

In this slightly simplified representation, traffic passes from left to right in Figure 3 and the advanced DSRC reader interrogates each OBU to find the identity of the vehicle. If the OBU belongs to a commercial vehicle, the information and the WIM results are passed to the back office equipment. If the OBU is not on a commercial vehicle, the process ends. By the time a commercial vehicle reaches the clearance reader, the back office equipment has analyzed the information it has on the vehicle, including the agreement with the fleet operator and any prior checks of the vehicle, and passed instructions to the RSU for the vehicle to stop at the station or bypass it. When the vehicle passes the clearance reader, the queued information is transmitted to the proper OBU, which then displays to the driver the results of the clearance.

If the vehicle must stop for a check, the driver decelerates and enters the roadside check facility. If the vehicle can bypass the station, the driver remains at speed and continues as normal. The compliance reader interrogates each OBU again as the vehicles pass the check station, to ensure that bypassing vehicles were properly cleared. The exit reader passes information to the OBU of each checked vehicle, so that the information stored on the tag is properly updated with the inspection results. Checked vehicles then reenter the roadway and proceed as normal. The back office equipment may exchange its data with other check stations to provide a body of information on each vehicle's condition (11).

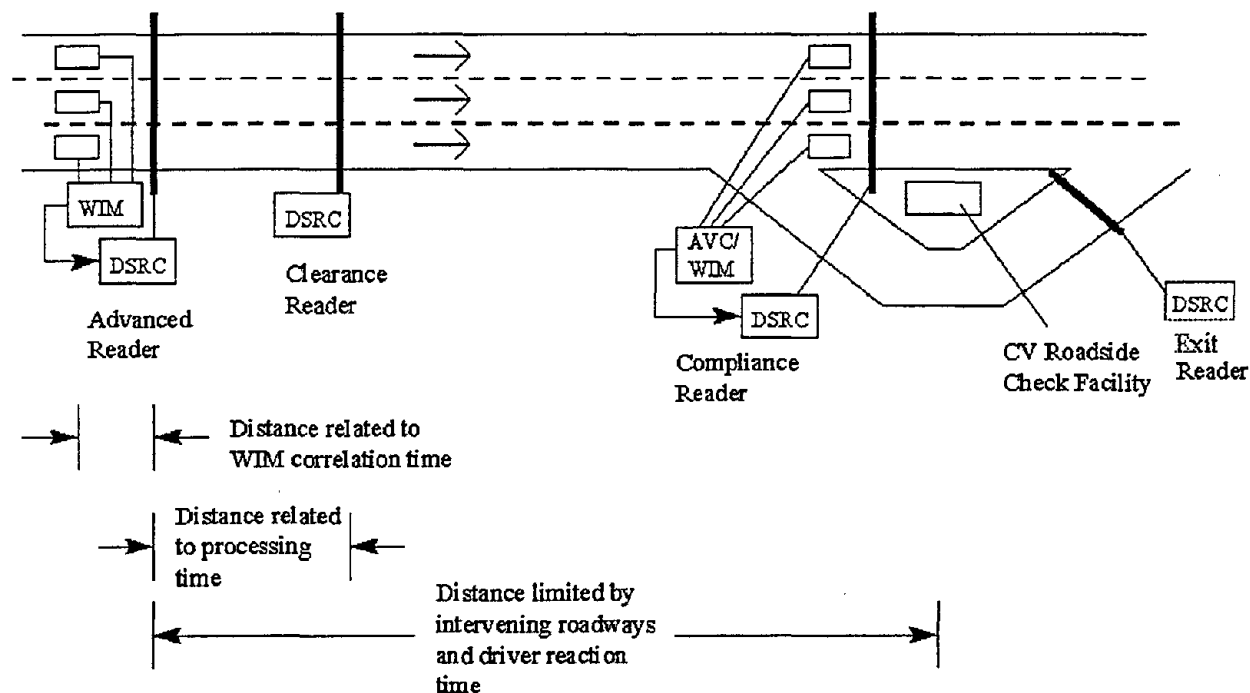


Figure 3. CVO Check Station (2).

PROPOSED DSRC STANDARDIZATION MODEL

This section of the report details the model of DSRC standardization that is being jointly developed. The OSI 7-Layer model is applied to the DSRC standards. The assumed transponder is described and an example transmission demonstrated.

Objectives of DSRC Standards

Recognizing the need for standardization of equipment and technology, the USDOT and interested parties from the ITS industry began the process of adopting ITS standards in the early 1990s. The goal of the program is to “accelerate ITS deployment and foster national interoperability and efficiency” (12). Communication between OBU, RSU, and the back office is an important area for standardization because of limited space in road vehicles, on the roadside, and within the electromagnetic spectrum. Developing the standards known as DSRC will allow compliant OBUs to communicate with any compliant RSU. The standard will also allow research to focus on the uses of the technology rather than the specific technology used for communication. When the standard is fully implemented, the OBU will become simply a generic communications device, able to interface with and gain the benefits of ITS from any RSU. The development of ITS applications can be specialized to meet the requirements of each specific application. Systems could be designed by organizations to implement desirable features, such as fleet management for commercial vehicle operators. The OBU manufacturer can then tailor the design of the transponder to meet the demands of the customer, with the corresponding variance in cost and capability (11).

7-Layer OSI Model

The DSRC standard is being developed in accordance with the International Standards Organizations (ISO) Open Systems Interconnect (OSI) 7-layer model. The seven layers break any communications system into more manageable subsections and are defined as follows (4,5,13):

- Layer 1 - Physical. Describes the physical medium of transmission. Includes operating frequencies and modulation for wireless applications.
- Layer 2 - Data Link. Describes the format of data and the operating modes.
- Layer 3 - Network. Describes the process by which data are addressed and routed between the various parts of the system.
- Layer 4 - Transport. Describes the process for moving messages from point to point, including breaking data into transmittable pieces, and error-checking mechanisms.
- Layer 5 - Session. Describes the methods of control over parts of the network.
- Layer 6 - Presentation. Describes any syntax changes or data transformations.
- Layer 7 - Application. Describes specific functions and message formats.

OSI Layers 1 and 2 are being developed by ASTM Subcommittee E17.51, the current version is Draft 7. OSI Layer 7 is being developed by IEEE Working Group P1455. Portions of other layers are specified where necessary under the broader standards of Layer 1 and 2 or Layer 7.

Figure 4 shows the DSRC OSI 7-Layer architecture. The left side of the figure represents the RSU and back office ITS Applications, while the right side of the figure represents the OBU. The IEEE Data Dictionary Standard, in the development process by IEEE P1489, will provide the fundamental definitions and formats to the DSRC messages. Thus DSRC applications will draw from a standardized set of data elements to form the message sets regarding specific topics (14).

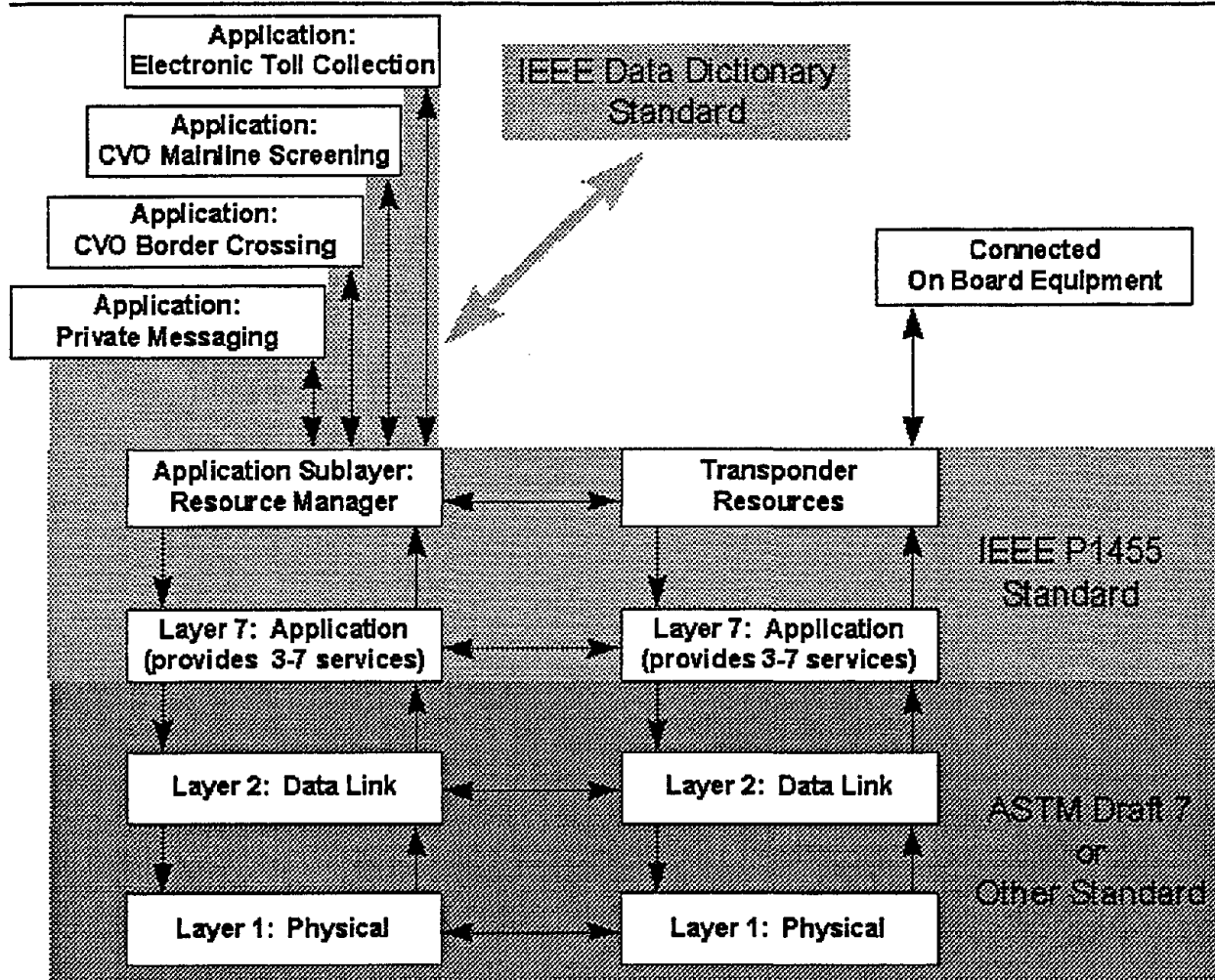


Figure 4. DSRC Architecture (10).

Transponder

The transponder is the heart of the OBU. It sends and receives messages from the RSU, as well as storing information. The transponder can also communicate to the driver of the vehicle with lights, sounds, or readouts, and receive information via keypad. The transponder may also be connected to on board equipment to record input from a variety of sources. While the features of transponders from different manufacturers will vary, the basic transponder template is shown below in Figure 5.

The purpose of each transponder part is defined as follows:

- **RF Interface:** communicates with the RSU.
- **Controller:** controls the memory and input/output functions of the transponder in response to RSU commands.
- **Digital Interface:** channel for sending and receiving data from vehicle equipment.
- **Read/Only Memory:** stores permanent transponder identification and specifications; uses fixed binary allocation rather than messages.
- **Read/Write Memory:** message based general memory
- **Extended R/W Memory:** message based memory organized as separate pages; size variable by manufacturer; accessible from digital interface for both input and output
- **Output Mechanisms:** provide information directly to driver by visual or audible signals installed on transponder.

Transponders vary primarily by the amount of extended read/write memory installed, the devices hooked to the digital interface, and the output mechanisms present. The minimal transponder has only read/only memory and no external output or digital interface. This corresponds to some current "toll tag" transponders used in ETTM and AVI systems. Adding the basic read/write memory, then extended R/W memory, expands the capabilities of the transponder (9,10,11).

Read/Only Memory

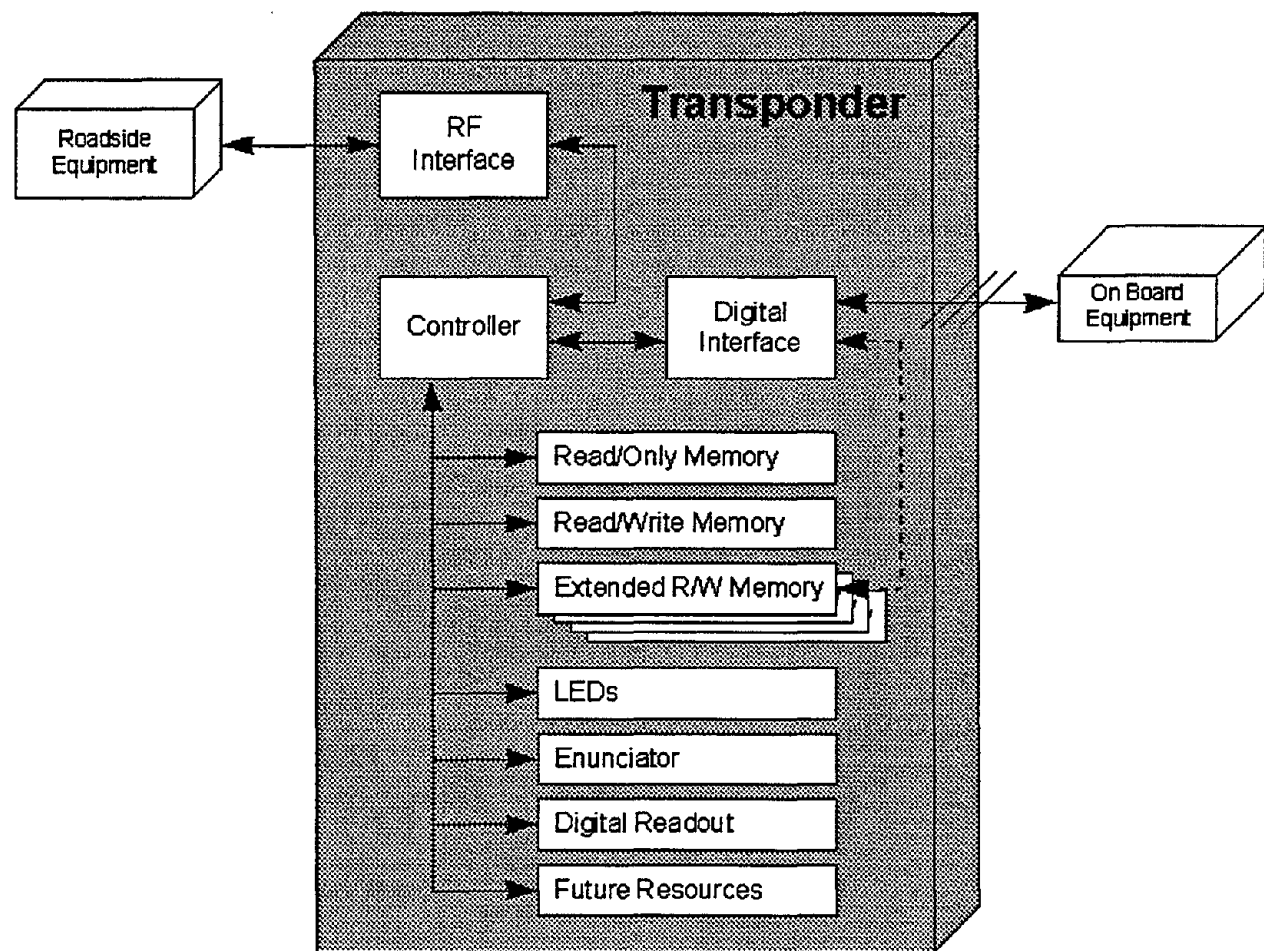


Figure 5. Typical Transponder (10).

The read/only memory contains permanent information about the transponder and its capabilities. In concise format the R/O stores information identifying:

- transponder unique ID and serial number
- manufacturer
- standard and revision level
- size of R/O memory
- number and size of extended R/W memory pages
- output mechanisms
- billing agency

This information is transmitted to the RSU in response to the initial query of the transponder. The RSU and back office equipment uses this information to tailor the requests and information transfers to the capabilities of the transponder (10).

Read/Write Memory

The read/write memory areas are available for use as data storage in the long- or short-term. The basic read/write area serves to both hold messages and to indicate the location of longer messages in the extended R/W memory. If a message is sent to be stored in the extended read/write memory, a new image of the basic R/W area will be sent as well, to serve as a signpost to the location of the message. Messages stored in the basic R/W area will have a header with identifier, date, and message length (10).

Extended Read/Write Memory

The extended R/W memory areas consist of pages of 64, 256, or 1024 bytes space each, depending on the planned capabilities of the transponder. The information stored in these pages is dependent on the ITS application being used. This memory is transmitted in whole or part to the RSU following a specific request. The RSU can also send messages to be stored in the extended R/W. Each message will have a header with an identifier, the ITS application, the date, and the message length. Transmission of large areas of the extended R/W memory may require breaking the message into parts (4,10).

Typical DSRC Exchanges

The following are examples of characteristic exchanges between the roadside and the vehicle transponder. Each is initiated as the transponder enters the area of RSU transmission (10).

Identification

RSU: Transmit query of transponder R/O memory
OBU: Transmit image of R/O memory
RSU: Analyze R/O image for ID and capabilities, forward to back office equipment

Commercial Vehicle Clearance

RSU: Transmit query of transponder R/O and R/W
OBU: Transmit images of R/O and R/W memory
RSU: Analyze R/O image for ID and capabilities
Check R/W image for message identifiers
Transmit query of extended R/W memory messages
OBU: Transmit image of specified messages, in fragments if necessary
RSU: Assemble fragments, analyze messages
Generate updated R/W memory image
Generate updated image of extended R/W memory message
Transmit updated R/W and extended R/W images
OBU: Store R/W and extended R/W images

DSRC LAYERS 1 AND 2: DATA MOVEMENT HARDWARE AND SOFTWARE

This section describes the proposed specifications for the physical hardware and the movement of data through the DSRC system. The OSI Layers 1 and 2 standards are the primary definers of the data movement, however most of the standards are broadly defined to encourage a wide range of potential solutions.

Frequency

Current short range communications systems in North America use frequencies around 915 MHz, in the Location Monitoring Service (LMS) band. The ASTM DSRC proposal uses this frequency in order to preserve backwards compatibility. Due to the congestion of the electromagnetic spectrum, efforts are in progress to adopt another frequency band in addition to the 915 MHz band. ITS America petitioned the Federal Communications Commission (FCC) in 1997 with a request for allocation of the 5.850-5.925 GHz band to ITS applications. After a public comment period, the FCC published the proposal for the allocation in the Federal Record on June 30, 1998, and is accepting comments until September 14, 1998 (15).

The 5.8 GHz band is successfully in operation for DSRC in Asia and Europe, however the characteristics of the band are not as favorable to DSRC operations as is 915 MHz. The higher frequency has problems with range, error rate, and infrastructure cost (16).

Range

The loss of power of a signal is a function of distance and frequency. As distance and frequency increase the signal arriving at the receiver will decrease. Because the power of the transmission, and thus the strength of the signal, is limited by statute and safety concerns, the range for successful transmissions will decrease using 5.8 GHz versus 915 MHz. The associated losses from the signal having to pass through windscreens or aerial moisture are also higher for 5.8 GHz. The range problem is doubled for backscatter tags, which reflect the signal back to the roadside unit using the transponder, because the signal must overcome the losses across twice the physical distance between RSU and vehicle (16).

Error Rates

Multi-path fading causes errors to occur in transmissions when multiple copies of the same signal arrive at the receiver and cancel each other out. The extra signals can be reflections from the roadway or other object. The fade rate is inversely proportional to wavelength, thus the errors will increase with the 5.8 GHz band as the higher frequency means a shorter wavelength. The fade rate also restricts the time available for data transmissions. The exchange time is limited to less than one-half to one-quarter of the fade rate, to minimize the chance of a fade occurring in the middle of a transmission. The length between fades is about 5 times higher using 915 MHz than with 5.8 GHz, reducing the time available for 5.8 GHz transmission to between 4.5 and 9 ms. While large amounts of data can still be transferred, there is less of a margin than at 915 MHz (16).

Infrastructure Cost

The 915 MHz band is close enough to the cellular telephone frequencies that many components are being produced in volume, while 5.8 GHz equipment is more exotic and expensive until production can be increased. Due to a greatly increased amount of RF cable loss during 5.8 GHz operation, the RF antenna may have to be equipped with an amplifier and frequency converter, so that transmissions between the roadside reader and antenna can be accomplished at a lower frequency with less loss. 915 MHz operation does not require extra equipment at the antenna due to acceptable cable losses. Besides the extra equipment necessary, the 5.8 GHz equipment may have higher maintenance costs due to the location of the equipment above the roadway instead of in the roadside installation (16).

Despite the technical disadvantages of the 5.8 GHz band, it has been chosen to supplement the 915 MHz band in North American operation. The disadvantages are not insurmountable and the opportunities of a relatively uncluttered frequency are important to future development. ITS America promotes the 5.8 GHz band as a good compromise between the congestion and competition on lower frequencies with the technical problems of higher frequencies (15).

Transponder

Both active and backscatter tags are defined under the ASTM Layer 1 Draft 7 standard. Active tags contain a power source that allows them to transmit the requested information back to the RSU. They also contain the processing power and memory areas to store and retrieve information beyond basic identification. Backscatter tags reflect the incoming signal back to the RSU, while modifying it to hold the requested information. Backscatter tags can also use the energy from the incoming signal to perform read/write operations. DSRC system manufacturer Amtech is highly committed to backscatter tags, saying they provide high performance for the least cost and longest life. Amtech also says that backscatter tags can respond properly to frequencies within a range of the design frequency, and thus are better equipped to handle local frequency variations (5.17,18).

Roadside Equipment

Under ASTM Draft 7, the roadside equipment initiates and controls all transactions with the OBU. The transmissions occur as the mobile OBU passes through the range of the RSU. The antenna equipment can be configured to discriminate between different transponders in close proximity, as in closely packed automobile platoons (5.11).

Data Transformations

As the size of messages to be passed to and from the OBU varies by application, the DSRC system must be able to convert large messages to smaller pieces for proper transmittal. The maximum Frame size used by the actual wireless transmission will be 512 bits. Figure 6 shows how data are transformed as they pass through the DSRC system from the ITS Application to storage in an advanced OBU.

1. The ITS Application produces Messages and then forms a Message Package which is destined for a specific transponder.
2. The Message Package is transmitted to the VRC Controller. The VRC Controller breaks the Message Package into Transponder Memory Images, each sized to fit exactly into the memory page of the transponder.
3. The TMIs are sent to the Reader, which breaks down the TMIs further into Frames, groups of bits to be transmitted together.
4. The RF Interface of the transponder receives the Frames and arranges them back in to TAI format, then sends the TMIs to the Controller.
5. The transponder Controller converts the TMIs back into the Message Package, then breaks out the specific Messages, which are written to the extended R/W memory area (4).

Multiple Applications on One Transponder

The ability to support many ITS applications with only one transponder per vehicle is one goal of DSRC standardization. Before the VRC Controller sends data to be written to the transponder memory, the VRC Controller must check the planned destination to ensure that messages from other ITS Applications are not lost. This interrogation takes place during the initial reading of the transponder's R/O and basic R/W memory. If the header messages in the basic R/W memory indicate that the planned destination is occupied, the VRC Controller will select the next available memory location with sufficient space for the message being transferred (5).

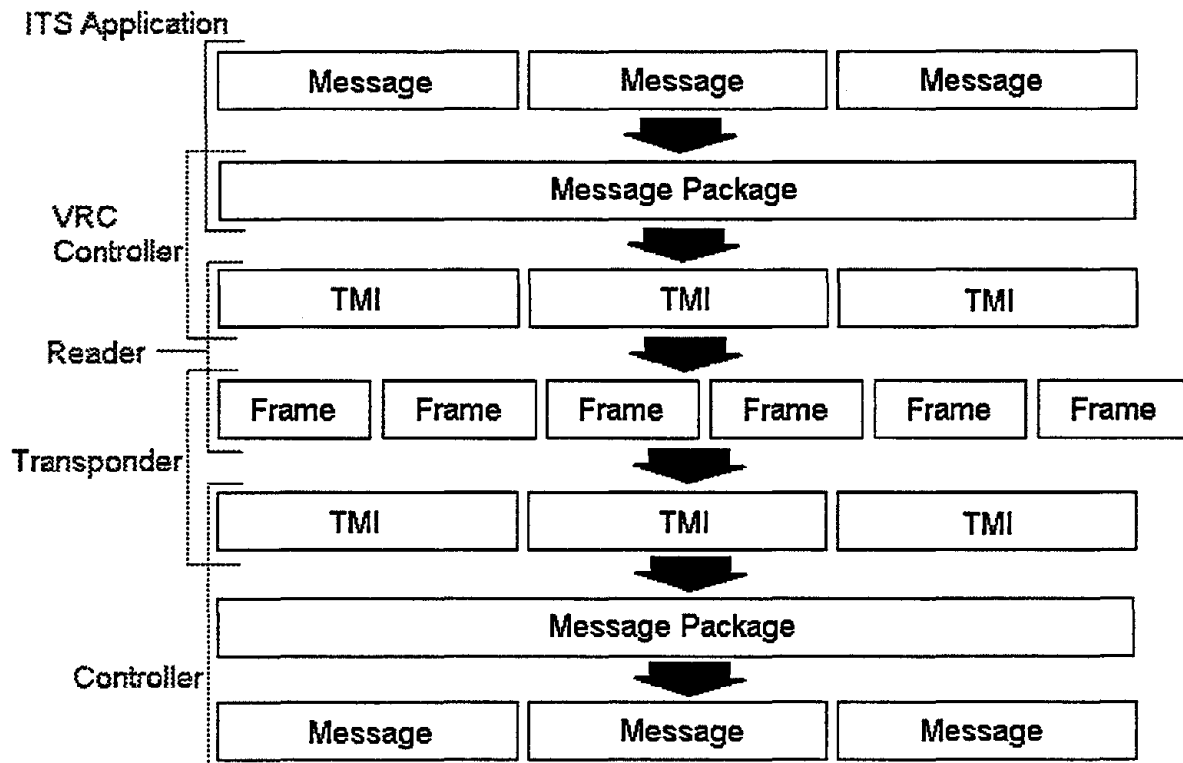


Figure 6. DSRC Data Formatting and Control (4).

DSRC LAYER 7: APPLICATIONS AND MESSAGE SETS

This section describes the message sets used to organize the data used by ITS applications to provide User Services. Layer 7 of the DSRC standard is primarily concerned with organizing the format of the message sets. The message sets must be flexible enough to handle all contingencies that can arise within an application. The procedure for developing message sets must be robust yet simple, so that applications developed in the future can be quickly implemented using the existing DSRC system.

Transponder Control

A set of commands is necessary to direct the various functions of the transponder and OBU as a whole. These commands are sent by the RSU to the OBU to instruct the transponder Controller. Instructions include querying the main R/O and R/W memory, reading specified memory regions, and writing to specified memory locations. To assist the multiple users of the transponders, extended memory pages can be reserved for specific agencies, or released to open use when no longer required. The RF capability of the transponder can be disabled for a time period, and the internal diagnostics can be checked.

Set User Interface

By using commands to set the user interfaces, information can be transmitted visually and audibly to the driver of the vehicle. Most advanced transponders have red, yellow, and green LEDs, as well as a speaker. Each LED can be commanded to activate permanently, for a certain period, or flash for a number of repetitions. The 8 bit user interface field also has 4 empty spaces available to other user interface elements, for use by manufacturer development (10).

On Board Equipment

Other electronic devices can be connected and accessed through the transponder as part of the OBU. Each piece of on board equipment will have space in the extended R/W memory to store messages. The on board equipment will store a message on the transponder, then the RSU will retrieve the message and analyze. If a response is warranted by the ITS Application, the RSU will write a response to the transponder memory, which will be read in turn by the on board equipment. The on board equipment will then be able to respond to instructions or send more data to the transponder for retrieval (10).

Message Header

The message header is used for identification purposes in both the basic read/write memory and the extended read/write memory areas of the transponder. Each message to be stored in the transponder's memory must have a header for identification purposes.

Short Form

The short form of the header is used in the basic read/write area, to indicate during the initial transaction with the RSU that a message is present in the extended R/W area. Designed to conserve space, the short form header takes only 2 bytes of space. The header contains the message identifier, the message date in half-years since the last decade, and the message length in byte pairs. This information allows the VRC Controller in the RSU to select the appropriate message for the ITS Application it is trying to satisfy, to find the message within the extended memory area, and to know how much of the memory area to retrieve.

Long Form

The long form of the header is used only in the extended R/W area, directly before the actual message. The long form header takes 4 bytes of space. The header contains an identifier by both ITS Application and within that Application. The header also contains a more precise date of days since the last decade, as well as the message length in bytes. This header allows the VRC to more precisely date the message, and identify exactly which ITS Application and process within the Application it belongs with (10).

Message Sets

Message sets are the instructions which tell the VRC Controller what information to send and retrieve when communicating with the OBU. Each ITS Application will have a message set, although some Applications may require some identical messages. The standardization of message sets is being performed by writing groups within IEEE SCC32.

Data Elements

Each message in a message set in a well defined ITS Application standard is made up of data elements, which are the names for the various pieces of data that the ITS manager is collecting or distributing. Each data element is described by its name, a description, the number of bits it occupies, the range of values expected to be assigned, the use of the data, and the direction of data flow. A well defined set of data elements will make the message set construction flow smoothly. The draft data elements for ETTM, developed by the ETTM Writing Group, are included as Table 1 (19).

Table 1. Data Elements for ETTM Messages (19)

Data Element Name	Description	Bits	Range of Values	Cat. ¹	Use of Data	Data Flow ²
Transaction Type Code	Message type	16	Lookup table (tbd)	1	Control	Down
Transponder Control	Control instructions (tbd)	24	Variable	1	Control	Down
CRC	Error detection code	16	Variable	1	Control	Up/Down
Status Code	Error diagnostic	16	Lookup Table (tbd)	1	Control	Up
Transponder ID	Unique ID number (includes Agency Code, Group/Agency, State/Region as subfields tbd)	48	Variable	1	Read-Only	Up/Down
Transponder Features	Defines tag feature set (display, ports, etc.)	8	Lookup table (tbd)	1	Read-Only	Up
Vehicle Characteristics	Vehicle description (includes Vehicle Profile, Vehicle Axles, Vehicle Tires, Vehicle Class as subfields tbd)	16	Lookup table (tbd)	1	Read-Only	Down
Time	Date and time	32	Variable	1	Read/Write	Up/Down
Plaza ID	Plaza location	8	Lookup table (tbd)	1	Read/Write	Up/Down
Lane ID	Lane location	8	Lookup table (tbd)	1	Read/Write	Up/Down
Agency/Org Specific	Available for agency/organization use	??	Variable	1	Read/Write	Up/Down
Password	Provides password if required	32	Variable	2	Control	Down
Encryption Seed	For use with encryption	32	Variable	2	Control	Down
Transaction Number	Sequential number of transaction event	8	Variable	2	Read/Write	Up/Down
Reader ID	Unique ID number	32	Variable	3	Read/Write	Up/Down
Toll Pricing Data	Toll amount or info at entry (e.g., congestion)	16	Variable	3	Read/Write	Up/Down
HOV Status	Defines HOV Status	2	Lookup table (tbd)	4	Read-Only	Up

¹Category: 1 = Part of the core messages

2 = Not sure of placement

3 = Not part of the core messages

4 = No need in current messages, but retained in list for future consideration

²Down = Data flow from Reader to Transponder. Up = Data flow from Transponder to Reader. Up/Down = Data flow both directions.

Messages

The message has a standardized form that contains all elements necessary for proper data exchange. Each message within a message set is designed to perform a single action. Thus an ITS Application must draw from the message set the proper messages to perform its functions. These procedures are dependent on the ITS Application programmer, but careful planning can make the data exchange efficient and complete. The message form defines the message, however it is only for reference by the programmer or administrator. Each message must be defined in the programming in accordance with its form.

Each message is designated by the following factors:

- **Definition:** Identifies the purpose of the message,
- **Fields:** Identifies the data elements used by the message, in the order they are to be stored,
- **Generated By:** Identifies where the data to fill the data elements are to be found,
- **Stored In:** Identifies where the message is to be stored until retrieved,
- **Received By:** Identifies which element of the DSRC system is to retrieve the message, and
- **Comments or Special:** Identifies any special handling necessary.

The Fields entry can be a simple list of data elements if the data elements were defined explicitly. If the data elements are not standardized, the Fields entry should include the name, purpose, size, usage, and data direction similar to the data element description (19,20). The following are two ETTM messages taken directly from the message set developed by the ETTM Writing Group. Each message is built from the data elements defined earlier in Table 1 (19):

- **Name:** **Transponder Identifier**
 - **Definition:** Contains information to uniquely identify the transponder and describe its features
 - **Fields:** Transponder ID
 Transponder Features
 - **Generated By:** Transponder (programmed by agency at time of issue)
 - **Stored In:** Transponder read-only memory
 - **Received By:** All readers
 - **Comments:** Transponder ID contains agency ID data, etc
- **Name:** **Toll System Entry**
 - **Definition:** Contains information to identify where and when a vehicle entered the system (e.g. closed road tolling)
 - **Fields:** Time
 Plaza ID
 Lane ID
 - **Generated By:** Entry reader
 - **Stored In:** Transponder scratchpad memory
 - **Received By:** Exit reader
 - **Comments:** Could also be used for TM probing

FINDINGS

After intense effort over the past four years, the Dedicated Short Range Communications standard is progressing quickly. The form and fundamental issues affecting DSRC have mostly been decided, leaving only the minor details remaining under discussion. The voting by standards making organizations on OSI Layers 1, 2, and 7 is imminent.

The foundation of the standard rests on relatively firm, tested technologies, and experience is gained daily in the operation of the many ITS applications nationwide. The simplified 7-Layer OSI model allows the vital parts of the system to be standardized, while remaining as open as possible to innovation and development in the application of those parts.

Consultation with professionals involved in the standardization effort indicates that there is general enthusiasm for the direction and progress of the DSRC standards effort. The majority of contacts think that the DSRC standards are appropriate for each layer. There is some concern that the standard should emphasize backwards compatibility more than at present, to protect customers served by legacy systems of previous technical generations.

While the standard does not explicitly satisfy every respondent, there were no major deficiencies identified as unsolvable. The one deficiency identified by this author is the use of a 32-bit integer to define the time in seconds since January 1, 1970. Although this is a standard mechanism for managing time, it will "roll over" in 2038 and reset to zero, probably causing problems with any system still in use at that time. Of course, one would hope that the DSRC standard and equipment will have been updated by that time, however this has not been the case in similar situations involving computer programs using two digit integers for the year. Such systems, designed decades ago with hardware constraints or little thought for the future, may cause problems as the year changes from 1999 to 2000.

Due to the open, expandable nature of the DSRC transponder, use with future ITS Applications should not be a problem. The correct on board equipment, back office programs, and message sets for communication should allow almost unlimited applications. The competition among manufacturers to better meet the needs of the customer through customization of transponders and services should make ITS more available to all potential users.

APPLICATION OF DSRC STANDARD: TRANSIT MANAGEMENT MESSAGE SET

As the proposed DSRC standard is nearly finalized, increasing the number of ITS Applications supported by the new standard is the most important step remaining before the standard can be considered complete. Transit operation is an area where DSRC can easily be used to provide more effective service to customers. While a transit agency may not use the geographic flexibility and interoperability offered by DSRC, the communications needs of many vehicle-based services can be supported by the DSRC system, eliminating the need for separate communications systems. Currently the typical DSRC application is serving by highway travelers, but the expansion of DSRC to secondary streets will increase as ITS becomes more prevalent. The use of DSRC by transit vehicles on secondary streets will also provide the RSU infrastructure to encourage development of ITS applications aimed at personal automobiles and commercial vehicles.

Formation of the transit management message set by the author followed these steps:

- Identification of transit management tasks to be accomplished,
- Development of data elements, and
- Development of individual messages.

Identification of Tasks

The mechanics of transit management systems can vary widely according to the sophistication and resources of the transit agency. While the final message set must contain messages to accommodate all possible transit management tasks, due to the limitations of this research only the most common needs have been addressed. The functions to be accommodated by this part of the transit management message set were found in literature and are as follows:

- Signal prioritization and preemption,
- Fare collection, and
- Passenger and agency information transfer.

Signal Prioritization and Preemption

Signal priority and preemption is the management of traffic signals to reduce or eliminate delay to transit vehicles and emergency vehicles. While many cities have already installed single-purpose signal priority systems, the use of ITS through DSRC could yield other time savers such as route and traffic information. Nottinghamshire, UK, is currently operating a bus priority system using inductive loops to interrogate the transponder on the transit vehicle. The loops are connected to the local Urban Traffic Control Centre, which optimizes the traffic signal timings using the SCOOT system (22). Figure 7 shows a signal priority system where the bus transmits a message to the signal controller, which adjusts the traffic signal settings to accommodate the bus. In this case the bus has a bus lane which maximizes its advantage over the normal vehicles by allowing it to bypass queues.

Signal preemption by emergency vehicles is similar to signal priority systems, only the signal is usually set to all-red. This allows the vehicle to bypass intersections at near normal speed and by driving in the opposing lanes of traffic if necessary.

Signal prioritization and preemption requires the roadside to be notified when the vehicle approaches the traffic signal, so that the signal controller can modify the signal timings to accommodate the vehicle. More sophisticated systems will require a means to set the priority level of the vehicle, so that the priority system gives an appropriate level of consideration to the vehicle (21)

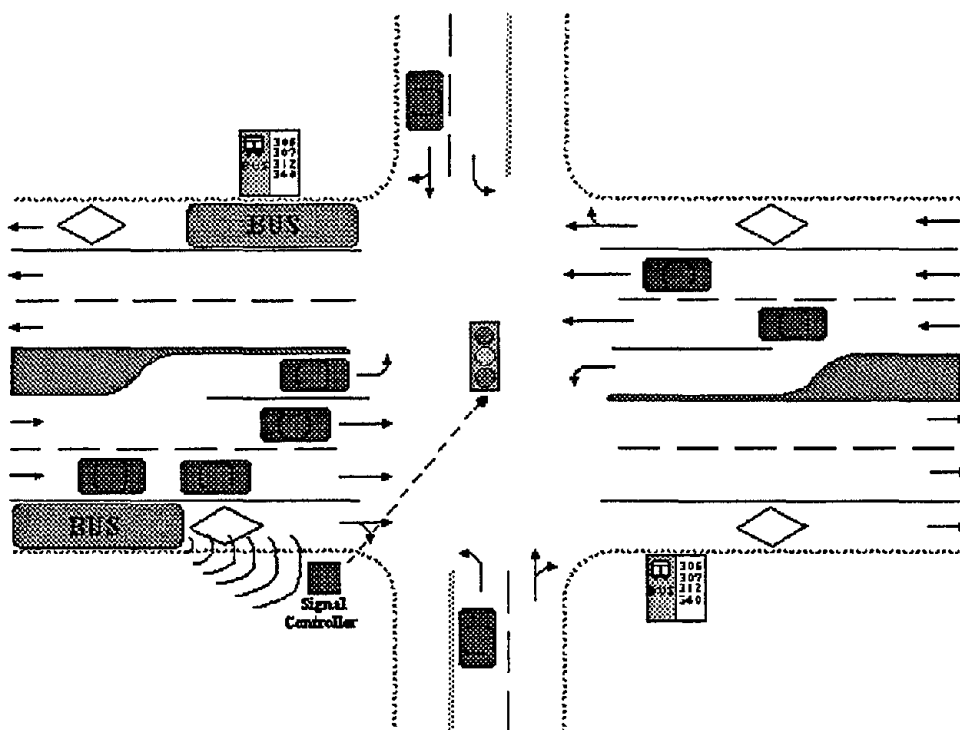


Figure 7. Transit Signal Priority (23).

Fare Collection

Efficiently managing the payment of fares is a priority among transit agencies. Fare collection on transit vehicles must progress quickly to minimize loading time. Advanced fare collection using magnetic swipe cards or other transfer devices can improve service to customers by eliminating the need for money or tokens. Such systems also reduce costs for the transit agency. Smart cards are being developed that could link together the financial accounts from many separate agencies, so that any charges made by an individual are debited from a common account. The transit agency can use the DSRC system to support the use of smart cards for fare collection, increasing the attractiveness of transit to customers who may already have a smart card for other uses. More equitable fare structures such as area-based fares could also be instituted, because DSRC operation would make the more complex schemes transparent to the customer. Farebox management requires messages to record the entry of a customer to the transit vehicle and the recording of that customer's billing information (24).

Passenger and Agency Information Transfer

The flexibility offered by DSRC can be used to provide a variety of information about the performance of the transit system to both customers and administrators. Passenger information could include displaying realtime arrival times at transit stops and displaying current location inside transit vehicles. Management information could include vehicle location, deviance from schedule, and passenger counting. The information transfers require messages to move the relevant pieces of data to and from the transit vehicle.

Data Elements

Table 2 summarizes the data elements developed by the author that are required by the proposed signal priority/preemption message set. Each data element may be used within different messages, so there is no reason to separate the elements in to groups according to their usual task.

Table 2. Data Elements for Transit Management Messages

Data Element Name	Description	Bits	Range of Values	Use of Data	Data Flow¹
Transponder ID	Unique ID Number, including Agency Code	40	Variable	Read/Only	Up
Transponder Features	Defines tag feature set, includes memory size, peripherals	22	as IEEE Layer 7	Read/Only	Up
Vehicle Characteristics	Vehicle description, includes class (fire, EMT, police, transit, maint) and type	16	Lookup table ex: 01=standard bus 02=lift-equipped 11=ladder truck 12=pumper truck 21=ambulance etc.	Read/Only	Up
Time	Date and Time	32	Variable	Read/Write	Up/Down
Reader ID	RSU ID and location	8 or 16	Lookup table or city coords	Read/Write	Up/Down
Priority	Priority flag set at emergency station or by operator via keypad, resolves conflicts of priority or off-duty bus	8	ex: 0 =none/return to garage 1 = high 2 = med 3 = low	Read/Write	Up/Down
Passenger Count	Records number of passengers for performance stats	7	1...127	Read/Write	Up
Schedule	Records deviance from schedule	8	Field for ahead or behind, field for minutes	Read/Write	Up/Down
Passenger ID	Passenger's ID from smart card, for transmission to RSU	40	Variable	Read/Write	Up
Area	Geographic area of transit system currently occupied by vehicle	8	Lookup table	Read/Write	Up/Down
Distress	Call for help, triggered by operator	1	0 = nominal 1 = distress	Read/Write	Up/Down

¹Down = Data flow from Reader to Transponder. Up = Data flow from Transponder to Reader. Up/Down = Data flow both ways

Messages

Using the data elements, messages were developed by the author for each operation of the tasks identified above. Some messages may be used multiple times by different tasks depending on the design of the transit management system, however the messages can generally be grouped by task.

Signal Prioritization and Preemption Messages

- **Set Priority**
 - Definition: Sets priority number
 - Fields: Priority
 - Generated By: ITS application or on-board equipment
 - Stored In: Transponder read/write memory
 - Received By: Any reader
 - Comments: Sets priority level for use in signal priority and preemption decision making.
For transit, ITS application decides priority based on route, passenger count, schedule variance, etc. For emergency vehicles, could be set by ITS application in conjunction with radio call, or set manually by operator (connected to lights or siren)
- **Transit Signal Priority**
 - Definition: Transfers information to trigger signal priority for transit vehicle
 - Fields: Transponder ID
Vehicle Characteristics
Priority
Passenger Count
Schedule
 - Generated By: Transponder read/only and read/write memory, on-board equipment
 - Stored In: Transponder read/only and read/write memory
 - Received By: Reader on approach to signal
 - Comments: Could be a basic priority using vehicle identification, or use levels of priority set earlier. Priority could also be decided with passenger count and schedule variance, weighing advantages of giving priority versus other approaches to signal. RSU would generally forward command to signal, while notifying local Traffic Management Center.
- **Emergency Signal Preemption**
 - Definition: Transfers information to trigger signal priority for transit vehicle
 - Fields: Transponder ID
Vehicle Characteristics
Priority
 - Generated By: Transponder read/only and read/write memory, on-board equipment
 - Stored In: Transponder read/only and read/write memory
 - Received By: Reader on approach to signal
 - Comments: Signals RSU to start signal preemption if characteristics and priority check out as emergency vehicle on emergency call.

Fare Collection Messages

- **Set Area**
 - Definition: Writes to transponder the geographic area that the vehicle occupies
 - Fields: Area
 - Generated By: ITS Application
 - Stored In: Transponder read/write memory
 - Received By: Any reader
 - Comments: Area could be used when dividing transit coverage into sections or cordons for more advanced fare structures. Could be superfluous if ITS application correlated Reader ID with transit system area.
- **Passenger Entry**
 - Definition: Records passenger entry in to vehicle
 - Fields: Passenger ID
Time
Area
Transponder ID
 - Generated By: On-board equipment, transponder read/only and read/write memory
 - Stored In: Transponder read/only and read/write memory
 - Received By: Any reader
 - Comments: As passenger enters, farebox (on-board equipment) records smart card info and stores in transponder. At next reader, smart card and transponder information is transferred to RSU and ITS application for proper billing. Passenger ID value will contain billing agency.
- **Passenger Exit**
 - Definition: Records passenger leaving vehicle
 - Fields: Passenger ID
Time
Transponder ID
 - Generated By: On-board equipment, transponder read/only and read/write memory
 - Stored In: Transponder read/only and read/write memory
 - Received By: Any reader
 - Comments: Identical to Passenger Entry message, only activated on passenger leaving vehicle. Used to mark end of trip for billing purposes.

Passenger and Agency Information Transfer Messages

- **Transponder Identifier**
 - Definition: Contains information to uniquely identify the transponder and describe its features
 - Fields: Transponder ID
Transponder Features
 - Generated By: Transponder (programmed by agency at time of issue)
 - Stored In: Transponder read-only memory
 - Received By: All readers
 - Comments: Transponder ID contains agency ID data, etc Can be used as part of an automatic vehicle location (AVL) system.

- **Display Location**
 - Definition: Displays current bus location on information screen within vehicle
 - Fields: Reader ID
 - Generated By: RSU
 - Stored In: Transponder read/write memory
 - Received By: On-board equipment
 - Comments: Transponder receives reader ID which is decoded and displayed as geographic location by passenger information screen.
- **Schedule Variance**
 - Definition: Writes time difference from schedule
 - Fields: Schedule
 - Generated By: ITS application
 - Stored In: Transponder read/write memory
 - Received By: Any reader
 - Comments: Transponder Identifier message triggers check of vehicle against the schedule. Variance can be displayed for driver information to speed up or slow down, or used as information for displaying arrival information at transit vehicle stops.
- **Passenger Count**
 - Definition: Contains number of passengers on board vehicle
 - Fields: Passenger Count
 - Generated By: On-board equipment
 - Stored In: Read/write memory
 - Received By: Any reader
 - Comments: Information originates from farebox or door sensor. Can be used with Reader ID and known distance between readers to generate accurate passenger-kilometer statistics for transit system operations.
- **On Board Emergency**
 - Definition: Emergency, covert call for help from vehicle operator
 - Fields: Transponder ID
Vehicle Characteristics
Passenger Count
Distress
 - Generated By: On-board equipment, transponder read/only and read/write memory
 - Stored In: Transponder read/only and read/write memory
 - Received By: Any reader
 - Comments: Alerts transit management center that something abnormal is occurring. Signals from on-board equipment could include driver panic button or vehicle diagnostics. Could also include fields for type of emergency if desired.

CONCLUSIONS AND RECOMMENDATIONS

The DSRC standardization effort is progressing quickly and should yield a very workable set of standards for future development. The open architecture and flexible configurations will allow private developers to market products that best meet the needs of the customers. The standardization should also increase the availability of ITS around North America, because proposed projects would no longer have to determine the basic technologies to deploy.

Almost all stakeholders are working in concert with the standardization project, and there are no significant technical barriers apparent at this time.

Message sets for accommodating transit management systems can be designed using the DSRC standard. The transit management data elements and message set developed in this report should be included in the DSRC Layer 7 standard being developed by IEEE.

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THE EMERGENCE OF ROUNDABOUTS AS AN EFFECTIVE FORM OF TRAFFIC CONTROL IN THE UNITED STATES

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SUMMARY

While roundabout use is relatively new in the United States, they have been used as a form of traffic control in other countries around the world for several decades. It has only been in the last eight years that roundabouts have been considered as a traffic control alternative in the United States. In addition, until the mid-1990s, they were used only by select few cities and states across the country.

However, roundabouts are now becoming more and more prevalent across the United States. States such as California, Colorado, Florida, Maryland, Mississippi, Nevada, South Carolina, Vermont, and Washington have introduced roundabouts to their residents, and in many cases with resounding success. Roundabouts are often a viable alternative to signal installation and other forms of traffic control. Though the initial costs may be higher, savings are seen in the long run in the form of reduced delay, increased safety, and reduced emissions.

Many citizens are understandably concerned, however, upon hearing that a roundabout may be introduced to their community. To most mainstream Americans, the roundabout is a foreign concept, often confused with a traffic circle. Those who do understand what roundabouts are may be confused about who has the right-of-way or may be concerned that others will not yield upon entering. Others may be confused about how they will traverse the area as bicyclists or pedestrians, or in residential areas, parents may be worried about the safety of their children. Consequently, when a progressive state Department of Transportation or other transportation authority wants to install a roundabout instead of a signal, they are often met with opposition.

The objectives of this research were to:

- Document the reasons for using roundabouts;
- Examine the short- and long-term costs associated with signal installation and roundabout installation;
- Document the use of roundabouts in the United States;
- Identify community concerns with respect to installation of a roundabout;
- Survey states which have installed roundabouts to gain insight into their experiences; and
- Develop an informational pamphlet for state and local transportation authorities to distribute to prospective roundabout communities.

In order to accomplish these objectives, the author conducted background research into the history of roundabouts as well as current roundabout installations in the United States. Current literature on safety, capacity, and delay of roundabouts was also reviewed. In addition, the author spoke with over forty members of the roundabout community, including recognized experts on roundabouts, representatives of many state and local agencies, and several roundabout consultants. The purpose of these interviews was to gather information on community concerns regarding roundabout installation as well as any publicity campaigns which may have been implemented to educate the public.

Local communities have expressed a variety of concerns with respect to roundabout installation. The most commonly cited concerns deal with driver expectation and behavior and pedestrian and bicycle issues. Other concerns include the ability of the roundabout to accommodate emergency vehicles and other large vehicles, safety during inclement weather, and the perception of unnecessary monetary expenditures.

In order to alleviate the public's concerns about the operation and safety of roundabouts, state and local transportation authorities must make the effort to educate and inform the public about this new and different form of traffic control and instruct them as to the proper behavior for drivers, pedestrians, and bicyclists. There are many ways in which this can be accomplished, various states have used newspapers, television, and radio to disseminate information. Other states have produced videos or published their own flyers and pamphlets for local distribution. The state drivers manual is also an excellent place to include roundabout information. Ideally, a state could employ all of these approaches in educating the public about roundabouts.

However, if a single method must be chosen, a pamphlet or newsletter is a versatile and effective way of providing educational roundabout material. Still, regardless of the medium selected, what is important is that the public be informed.

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INTRODUCTION

While roundabout use is relatively new in the United States, they have been used as a form of traffic control in other countries around the world. In 1966, Great Britain adopted a yield-at-entry rule for all traffic circles, marking the beginning of the development of modern roundabouts (1). Other European countries followed suit in the coming years, and the 1980s showed an explosion of roundabout construction across Europe as people began to realize the operational and safety benefits afforded by roundabouts. Most notably, in 1991, France was installing roundabouts at a rate of 1,000 per year (1).

Roundabouts are now becoming more and more prevalent across the United States. States such as California, Colorado, Florida, Maryland, Mississippi, Nevada, South Carolina, Vermont, and Washington have introduced roundabouts to their residents, in many cases with resounding success. Roundabouts are often a viable alternative to signal installation and other forms of traffic control. Though the initial costs may be higher, savings are seen in the long run in the form of reduced delay, increased safety, and reduced emissions. However, upon hearing that a roundabout may be introduced to their community, many citizens are understandably concerned. To most Americans, the roundabout is a foreign concept, often confused with a traffic circle. Consequently, when a progressive state Department of Transportation or other transportation authority wants to install a roundabout instead of a signal, they are often met with opposition.

Problem Statement

State Departments of Transportation and local transportation authorities often experience opposition when trying to implement new traffic control strategies. This problem is particularly evident in the case of roundabouts, as they are a form of traffic control foreign to most Americans. When an improvement is necessary at an unsignalized intersection due to volume or safety concerns, most people automatically think of traffic signals, a device with which they are more familiar. However, roundabouts realize many advantages over signals when used in appropriate sites. Preliminary findings show improvements in delay and safety at roundabout intersections. Therefore, the problem at hand is to convince the skeptical public of the worthiness of roundabouts. The end product of this research is an informational document for transportation authorities looking to implement roundabouts which will provide basic information on these intersections for distribution to the public.

Research Objectives

The specific objectives of this research were to:

1. Document the reasons for using roundabouts;
2. Examine the short- and long-term costs associated with signal installation and roundabout installation;
3. Document the use of roundabouts in the United States;
4. Identify community concerns with respect to installation of a roundabout;
5. Survey states which have installed roundabouts to gain insight into their experiences; and
6. Develop an informational pamphlet for state and local transportation authorities to distribute to prospective roundabout communities.

Scope

In order to accomplish the research objectives previously stated, the author interviewed representatives from ten state and local departments of transportation as well as six consulting firms to gain insight into their experiences with local communities with respect to roundabout implementation. In addition, the author contacted four recognized experts in the field of roundabouts.

Organization of Report

In order to clarify some of the terminology used in the report, the author will begin with an overview of roundabouts and their basic geometric elements. This section will also include a comparison of roundabouts to traffic circles and other traffic control devices with respect to design and operational features. In addition, advantages and disadvantages of roundabouts will be discussed. Appropriate and inappropriate sites for roundabouts will be covered in the second section. The third section will outline the types of costs associated with roundabout installation and maintenance and compare these costs to those of a traffic signal. The fourth section will document current roundabout installations across the country. The results of the study will be addressed in the fifth section. This section will include a discussion of community concerns with regard to roundabout installation as well as an examination of the roundabout experiences of several states and local municipalities and how each one dealt with the concerns of the local communities. The report will conclude with a discussion of how to best introduce the roundabout concept to a community as well as the outline of an informational document for transportation authorities looking to implement roundabouts which will provide basic information on roundabouts for distribution to the public.

ROUNDAOBOUTS - WHAT ARE THEY?

One of the first things to be established is what exactly constitutes a roundabout. The term modern roundabout has been coined in the United States to differentiate this form of traffic control from less effective traffic circles or rotaries. According to the National Cooperative Highway Research Program (NCHRP) Synthesis of Highway Practice 264, *Modern Roundabout Practice in the United States*, a modern roundabout is defined by two basic operational and design principles (shown in Figures 1 and 2 (1)) (2):

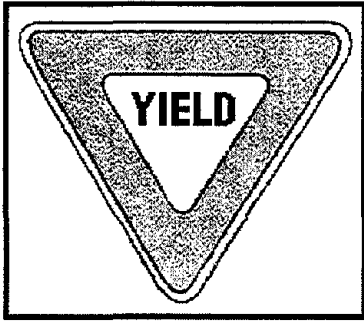


Figure 1 Yield-at-Entry

- *Yield-at-entry*: Also known as off-side priority or yield-to-left rule, yield-at-entry requires that vehicles in the circulatory roadway have the right-of-way, and all entering vehicles on the approaches must wait for a gap in the circulating flow. A YIELD sign is used for entry control to maintain fluidity and high capacity. Modern roundabouts are also not designed for weaving movements, forcing entering traffic to wait for a gap at the entry point; and

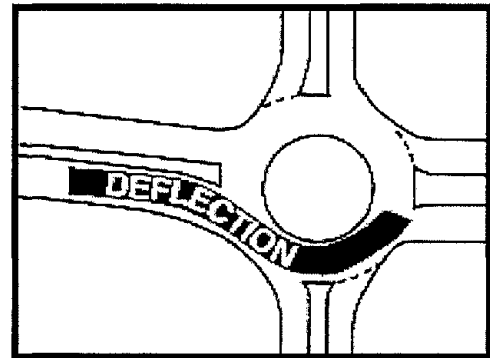


Figure 2 Deflection of Entering Traffic

- *Deflection of Entering Traffic*: No tangential entries are permitted, and no traffic stream gets a straight movement through the intersection. Entering traffic faces the central island, which deflects vehicles to the right, thus causing low entry speeds.

The Maryland Roundabout Design Guidelines list another key feature (shown in Figure 3 (1)) (3):

- *Flare*: The approach widens at the entry point to increase capacity.

The Florida Roundabout Guide lists several other identifying characteristics of roundabouts (4):

- *Parking*: No parking is allowed in the circulating roadway. Parking maneuvers prevent the roundabout from operating in a manner consistent with its design;
- *Pedestrians*: Pedestrians are not intended to cross the circulating roadway. Pedestrian crossings are found in advance of the YIELD sign on each approach;
- *Direction of Travel*: All vehicles travel counter-clockwise, passing to the right of central island;
- *Design Vehicles*: Roundabouts are designed to accommodate specific design vehicles (passenger cars, busses, or a specific size truck); and

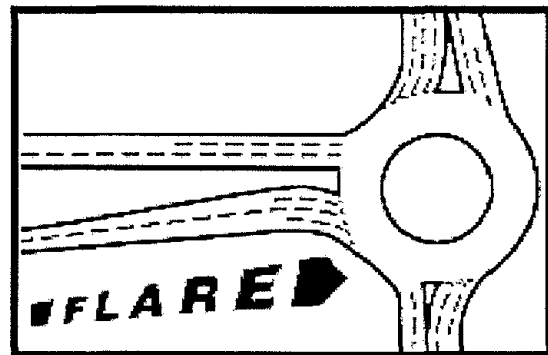
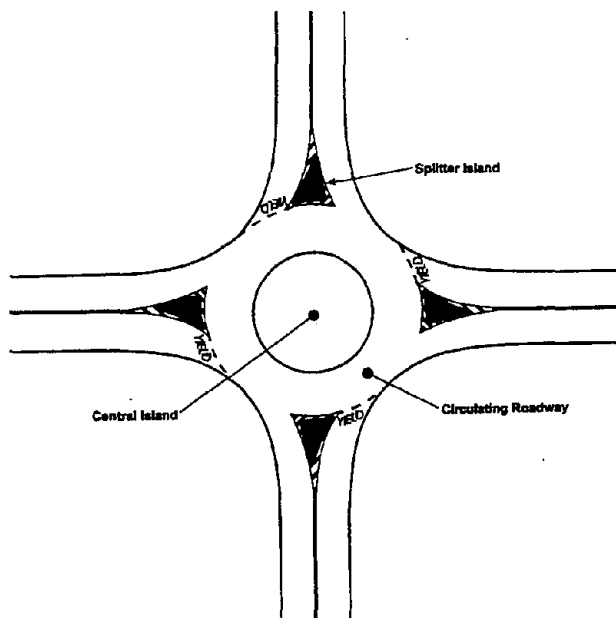


Figure 3 Flare



- *Splitter Islands* (see Figure 4 (4)): Roundabouts have raised splitter islands on all approaches. The splitter islands support the forced deflection, reducing the entry speed. They are also an essential safety feature, providing refuge for pedestrians and separating traffic moving in opposite directions.

Figure 4 Basic Roundabout Characteristics

Basic Geometric Elements of Modern Roundabouts

Figure 5 shows the following geometric elements considered in the design of a roundabout (4). It does not include accommodations for pedestrians or bicyclists.

Each geometric feature is defined as follows (2):

- *Approach Width*: The one-way width the roadway approaching the roundabout. British engineers define this element as the approach half-width;
- *Departure Width*: The one-way width of the roadway departing from the roundabout;
- *Central Island*: The circular central island around which traffic circulates, this island can be raised or flush (for mini-roundabouts), or it can have a raised central island with a mountable or drivable apron surrounding it, often used by off-tracking trucks. The truck apron is generally included in the central island diameter;
- *Circulatory Roadway*: The roadway around the central island on which circulating vehicles travel in a counter-clockwise direction;
- *Entry Width*: The actual width of the road at the entry point, measured perpendicularly from the right curb line of the entry to the intersection of the left edge line and the yield line;
- *Exit Width*: The actual width of the road at the exit point, measured perpendicularly from the right curb line of the exit to the intersection of the left edge line and the inscribed circle;
- *Entry Radius*: Measured as the minimum radius of curvature of the right-side curb at entry;
- *Exit Radius*: The minimum radius of curvature at the right-side curb exit;
- *Inscribed Circle Diameter*: The circle that can be inscribed within the outer curb line of the circulatory roadway;
- *Splitter Island*: The raised island, sometimes called a separator island, placed within the leg of a roundabout, separating entering and exiting traffic, it is designed to deflect entering traffic and to act as a safety zone for pedestrian crossings. As the approach speeds increase, the splitter islands become longer;
- *Truck Apron*: The portion of the central island that is drivable and is specifically provided to accommodate the path of the rear left wheels of larger vehicles, the truck apron is generally constructed with a different material to discourage passenger cars from driving over it; and

- **Yield Line:** A broken line marked across the entry roadway where it meets the outer edge of the circulatory roadway and where entering vehicles wait, if necessary, for an acceptable gap to enter the circulating flow.

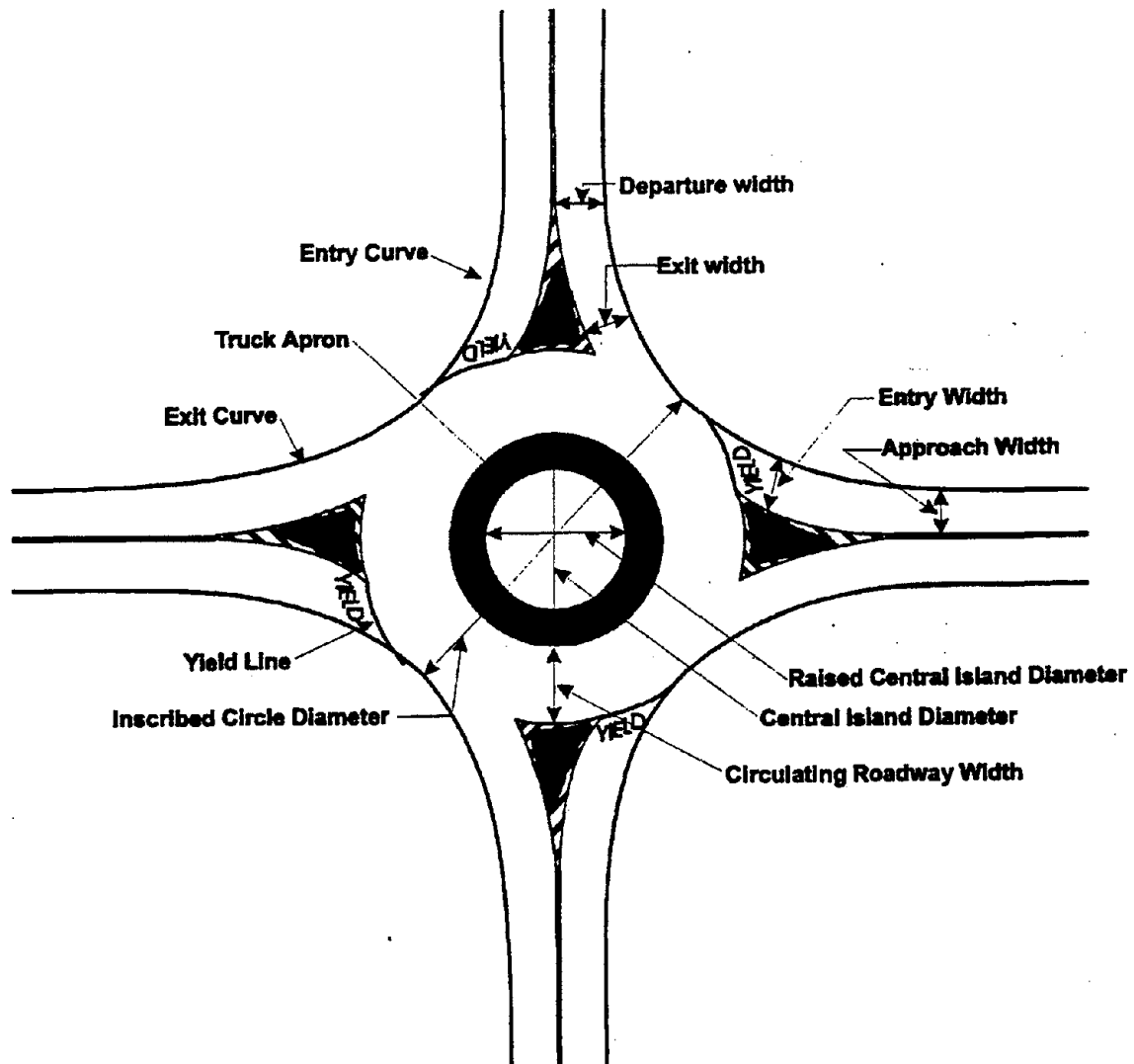


Figure 5 Basic Geometric Elements of a Roundabout

Roundabouts vs. Other Types of Traffic Control

Traffic Circles

From a pure design perspective, roundabouts differ from rotaries and traffic circles in several important respects. These differences include:

- Size;
- Speed;
- Angle of Entry;
- Weaving; and
- Right-of-Way.

First of all, the central or inscribed diameter of modern roundabouts ranges from 10 feet (for a small, single lane, residential roundabout) to 180 feet (for a three-lane arterial roundabout) whereas the inscribed diameter of a traditional traffic circle is 300 feet or larger (5). In addition, the tangential entries to a traffic circle afford much greater travel speeds within the circle, ranging from 25 mph to 40 mph for approach speeds of 30 mph to 60 mph (6). Roundabouts, however, force deflection upon entry and therefore have a lower average design speed of 12 mph to 22 mph (5). Traffic circles also allow for weaving maneuvers, and the combination of high speeds and weaving vehicles degraded the safety of the traffic circle, propagating high accident rates and intimidating drivers. Finally, early traffic circles had no consistent rules regarding right-of-way. In various examples, entering and/or circulating traffic may have had priority, though in most cases, entering traffic was subject to stop or signal control, reducing the capacity and fluidity of the circle. Also, in many instances, pedestrians were permitted to cross the circulating traffic. Figure 6 shows the geometric design features of a traffic circle (6).

However, the differences between roundabouts and traffic circles are often not so clear in practice. There are many examples around the world where traffic circles were converted to roundabouts by simply changing the entry control. The conversions did not necessarily include geometric retrofitting. These circular intersections are now called roundabouts and do observe the yield-on-entry principle, yet many exhibit the design characteristics of traffic circles. In order to see the differences outlined above, the traditional traffic circle must be compared to an intersection where the original functional design is a true roundabout.

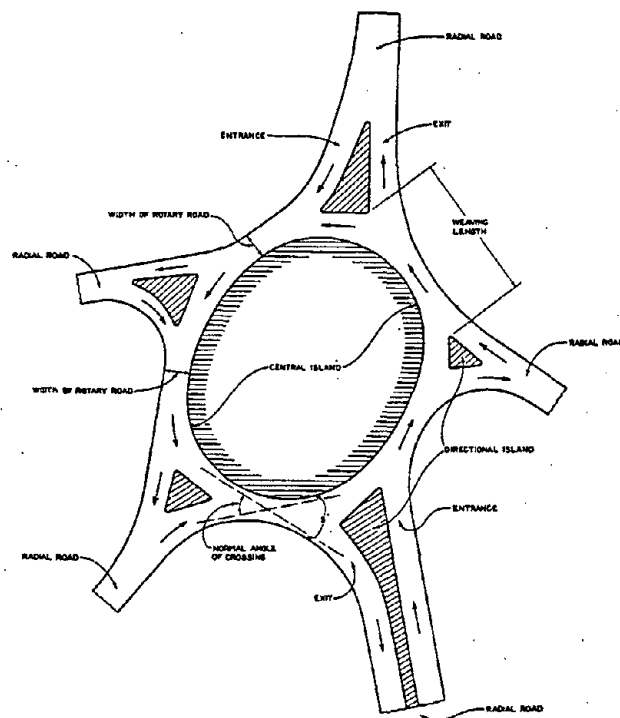


Figure 6 Basic Traffic Circle Characteristics

The NCHRP Synthesis lists several of the more notable traffic circles (2):

- *Dupont Circle in Washington, D.C.*: Entries are regulated by a mixture of traffic signals, stop signs, and yield signs, the circle includes a weaving section, and pedestrians walk onto the central island;
- *Columbus Circle in New York City*: Traffic signals control the entries, the circle is cut by through traffic, and pedestrians walk onto the central island; and
- *Place Charles de Gaulle in Paris, formerly known as Place de l'Etoile*: Entering traffic has priority, and police officers regulate traffic in the circle.

Examples of typical three- and four-leg traffic circles are found in Figure 7 (6).

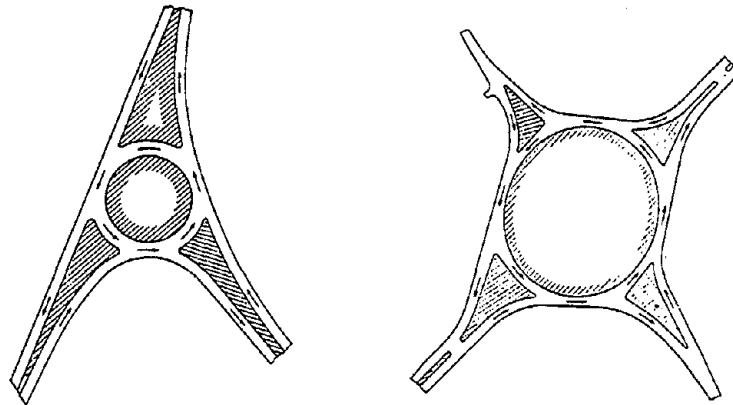


Figure 7 Common Three- and Four-Leg Traffic Circles

Traffic Signals

Aside from the obvious difference that roundabouts have no form of signal control, roundabouts and traffic signals have several major differences. From a safety standpoint, as shown in Figure 8, a four-leg roundabout has four conflict points as compared to 24 for a four-leg intersection. Fewer conflict points means fewer opportunities for collision, and consequently, a reduction in accident rates. Accidents still do occur at roundabouts, but usually they are low speed, low impact rear-end or merge collisions. These types of accidents are typically less severe and have fewer injuries. In contrast, the accidents which occur at signalized intersections are generally the more serious right-angle accidents and occur at higher speeds than do roundabout accidents (5).

Roundabouts also have higher capacities and lower delays than most signalized intersections as there is no "lost time" (unused green, yellow, and all red time) in roundabout control (5). Drivers need only wait for an acceptable gap in the circulating flow. Finally, there are notable cost differences between the two types of traffic control. A small roundabout may have a lower initial cost than a traffic signal, but larger roundabouts with more extensive grading, drainage, and curbing work (i.e., the roundabout interchanges on I-70 in Vail, Colorado) may equal or exceed the cost of installing a signal. However, over time, roundabouts have a lower maintenance cost and often show significant savings in terms of the cost of accidents and delay, making roundabouts a wise long-term decision (5). In short, roundabouts provide all the advantages (except for pedestrian control) of a traffic signal with none of the disadvantages (7).

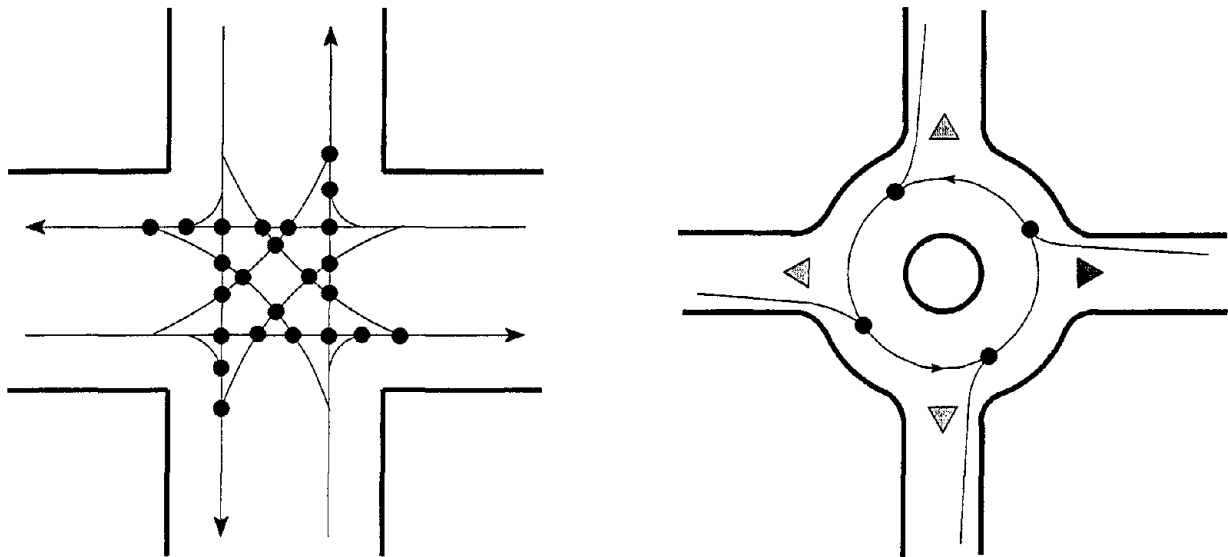


Figure 8 Common Three- and Four-Leg Traffic Circles

Two-Way Stop Control

Two-way stop-controlled intersections are a viable alternative for intersections with low minor street volumes. However, as volumes increase, operation favors the major street at the expense of the minor street. When there is heavy traffic on the major street, there are few opportunities for minor street through and left-turn movements (4). At high major street volumes, minor street movements are often forced to accept shorter gaps at a greater risk of accident in order to enter or cross the traffic stream. Roundabouts eliminate this dilemma by providing equal access for all approaching vehicles, resulting in a safer and more efficient flow of traffic. A before-and-after study of several Florida and Maryland roundabouts showed drastic reductions in the number of accidents after two-way stop control was converted to roundabout control (8).

All-Way Stop Control

All-way stop-controlled intersections treat the minor street more equitably and at low volumes without the delay found at traffic signals. However, the saturation headway is relatively high as all vehicles must stop before proceeding through the intersection. This translates to a lower overall capacity for the intersection (4).

Advantages and Disadvantages

Advantages of Roundabouts

When used at appropriate locations (appropriate locations for roundabout will be discussed in the next section), roundabouts offer the following advantages (9),(10),(11):

- **Safety:** Modern roundabouts have been proven to be the safest form of intersection control. Worldwide research has shown 30- to 80-percent reductions in injury accidents upon conversion of a conventional intersection to roundabout control;
- **Operating and Maintenance Costs:** Roundabouts require only periodic landscape and sign maintenance whereas signals require electricity and continual maintenance of loops, controllers and signal heads. In addition, a lapse in signal hardware maintenance has far greater consequences than a lapse in roundabout maintenance;

- *Capacity:* A roundabout can handle greater capacities at higher levels-of service because the flow is continual. Drivers can enter the roundabout as soon as a gap is available, in many instances without ever stopping on the approach. A single-lane roundabout can easily handle 2,500 to 2,800 vehicles per hour, corresponding to an average daily traffic volume of approximately 30,000;
- *Delay:* When compared to both previously signalized and unsignalized intersections, roundabouts show reductions in delay. At signalized intersections, motorists incur delay as they wait for their allotted green time. At unsignalized intersections, at least two of the four movements are required to stop whether or not there is an opposing vehicle. At roundabouts, however, motorists need only wait for a gap in the opposing flow, and all approaches have equal opportunity to enter the circulating traffic;
- *Traffic Calming:* The geometric configuration of a roundabout, particularly the forced deflection upon entry, fosters low travel speeds and can provide effective speed control in residential areas as well as areas in which there is a change from a higher to a lower speed such as the entrance to a downtown area;
- *Liability:* Traffic signals can be a substantial liability for the operating authority in times of malfunction. In roundabouts, however, liability rests with the entering driver as it is his/her responsibility to yield;
- *Equal Access:* Roundabouts do not favor any approach unlike traffic signals and two-way stop control. Gaps are equally available to all drivers, and no priority is given to any movement from an approach; and
- *Trip Time Perception:* Though the total trip time may not change, the perceived travel time is often shorter due to the reduction in stopped time.

Disadvantages of Roundabouts

Despite their many advantages, roundabouts do have some notable disadvantages (9):

- *Initial Construction Cost:* The development and construction of the first roundabouts tended to be costly as engineers tended to be more cautious in their designs; however, there is work being done to bring the costs down to more reasonable level (such efforts will be discussed in a subsequent section);
- *Driver Expectancy:* As roundabouts are not a common form of traffic control, driver expectancy is an issue. Despite signing, first-time drivers may be unsure of the rule of priority. Fortunately, this tends to be a short term problem; and
- *Public Acceptance:* As should be expected, the public is often skeptical of this new form of traffic control. Especially in the first roundabout installation in an area, there may be the perception among the public of being “guinea pigs.” In 1988, in Ojai, California, this fear of the unknown spawned outcry against a roundabout proposal, and Caltrans was forced to withdraw the proposal (12).

WHEN SHOULD ROUNDABOUT CONTROL BE CONSIDERED?

Roundabouts are very versatile and are appropriate in many different situations. Across the country, they have been used in several new construction projects and have replaced both signalized and unsignalized intersections. Roundabouts have even been used in freeway interchanges. In all of these examples, roundabout control has proven to be safer and more efficient than traditional forms of traffic control.

However, though the use of roundabouts for traffic control has many benefits, it is important to remember that they are not the solution in all cases. Roundabouts should be considered an alternative and used only when the situation warrants.

Appropriate Sites for Roundabouts

Both the Florida and Maryland design guides (4),(3) as well as much of the prominent roundabout literature (9),(11)(13),(14),(15) discuss when and where roundabouts should be considered. The recently published NCHRP Synthesis, *Modern Roundabout Practice in the United States*, summarizes them well (2):

- High accident locations, especially locations with a high proportion of accidents involving cross movements or left-turn or right-turn movements;
- Locations with unacceptably high delays;
- Locations which require improvement but do not meet sufficient warrants for signalization;
- Locations where traffic signals are warranted but have not installed and where a roundabout would provide safer and more efficient operation;
- Locations which are currently signalized but where a roundabout would provide safer and more efficient operation;
- Four-way stop-controlled intersections;
- Two-way stop-controlled intersections where traffic volumes on the approaches are such that there is unacceptable delay for the minor movement;
- Intersections with more than four legs;
- Intersections with unusual geometry (Y-intersections or acute-angle cross intersections);
- Intersections with high left-turn volumes;
- Intersections with changing traffic patterns due to projected changes in land use;
- Intersections where U-turns are frequent or desirable, i.e. in conjunction with access management strategies, particularly raised medians, along commercial corridors;
- Locations where there is insufficient queue storage for a signalized intersections, or where the queues caused by signalized intersections cause operational or safety problems, i.e. diamond interchanges, intersections near rail underpasses, bridges, and tunnels;
- To replace a pair of closely spaced intersections, particularly offset intersections;
- Along congested arterials where operations are degraded by intersection delay, in lieu of full-length widening;
- Intersections where the character or speed of the road changes, i.e. at entry points to a residential community or downtown area or at junctions where a bypass road connects to an arterial; and
- Intersections that are important from an urban design or visual point of view (provided that basic engineering and safety criteria can be satisfied) such as the gateway to a downtown area or the entrance to a residential or commercial development.

However, it is important to remember that the presence of these factors alone does not mandate the use of a roundabout. These guidelines should be used in conjunction with appropriate traffic analyses, benefit/cost analyses, and sound engineering judgement (9).

Inappropriate Sites for Roundabouts

Though roundabouts have the potential to significantly improve the traffic operation of many intersections, they are not appropriate for all sites. NCHRP Synthesis 264 describes the following sites as inappropriate for roundabout installation (2):

- Locations that cannot accommodate an acceptable outside diameter. A single-lane roundabout generally occupies more space than an equivalent signalized intersection at the same junction, but due to the absence of exclusive turn lanes, the approaches are often narrower. However, multi-lane roundabouts are more comparable to signalized intersections in terms of space consumption;
- Locations where it would be difficult or cost-prohibitive to provide a flat plateau for roundabout construction. Constructing a roundabout on a grade introduces visibility conflicts. Most guides recommend a maximum grade of three- to five-percent depending on design speed;
- Isolated intersections within a coordinated signal network where the roundabout would disrupt the platoon structure;
- Locations where vehicles queued at an adjacent intersection would obstruct vehicles exiting the roundabout;
- Locations with unbalanced flows on the cross streets where the equal opportunity treatment of the approaches would cause undue delays to the major road; and
- Locations where reversible lanes are used to accommodate peak period flows.

Other conditions may pose potential problems with respect to efficient operation, but they do not necessarily eliminate the roundabout as an improvement alternative. As for any other type of intersection traffic control, these conditions need special attention in the design and implementation stages, and a detailed analysis of alternatives is required. Such conditions include (2):

- Presence of numerous bicycles or pedestrians. Safe passage for pedestrians can be provided through special design features such as special bicycle lanes, zebra striping, pedestrian underpasses, or pedestrian-activated signals farther away from the roundabout;
- Presence of numerous disabled or blind users. Provision of special surface treatments should be considered to mark the pedestrian paths;
- Large proportion of heavy vehicles. Trucks can be accommodated by allowing for more generous dimensions within the roundabout or by providing a drivable truck apron around the central island;
- Presence of a fire station. Engineers can take similar design precautions as with signalized intersections;
- Rail crossings. Precautions can be taken similar to other intersections; and
- Junctions at the top or bottom of a grade. If sufficient sight distances cannot be provided, special advance signs or flashing signals can be installed.

The NCHRP Synthesis also mentions the use of pedestrian-activated signals with audible messages to accommodate disabled or blind users and special signals to provide immediate access for fire trucks from an adjacent station. However, this contradicts the basic roundabout principle that the only traffic control is the yield on entry. Special signals on an approach for blind or disabled pedestrians or fire stations would disrupt the safe and orderly flow of traffic. Entering vehicles queued on the approach would not pose a huge operational problem, but obstruction of exiting vehicles would result in vehicles queuing within the roundabout itself bringing operations to a standstill. Special signals for these conditions should only be used if they are located a distance away from the intersection eliminating the problem of exiting vehicles queuing into the roundabout.

COST COMPARISON - ROUNDABOUTS VS. TRAFFIC SIGNALS

Roundabouts

The initial construction cost for a roundabout varies greatly depending on the extent of the work completed. Total costs, including engineering, design, construction and maintenance of traffic, range from \$10,000 to \$500,000 due to great variations in design. The lower end of the bracket represents minimal construction work; usually a roundabout installed within existing right-of-way, involving only the construction of the central island and splitter islands. State-constructed facilities (state agencies building on state highways) generally fall in the middle to upper end of the bracket and usually include more extensive grading and drainage (2). At the extreme, \$500,000 represents the cost of building a roundabout interchange, complete with ramps and extensive structural work.

However, operating and maintenance costs for roundabouts are minimal, as there is no expensive signal hardware to maintain. These costs include landscape maintenance, paving, and periodic sign replacement. In addition, the service life of a roundabout is approximately 25 years (9).

Traffic Signals

Traffic signals, on the other hand, cost \$100,000 to \$125,000 for initial installation. This includes signal heads, wiring, and other hardware as well as mounting poles. The maintenance costs, however, are higher than for a roundabout and include electricity and hardware and loop maintenance. The life span for a signal installation is also shorter, averaging ten years (9).

In the long run, however, roundabouts prove to be a cost-effective traffic control strategy. A report by Niederhauser, Collins, and Myers entitled "The Use of Roundabouts: Comparison with Alternate Design Solution" cited an Australian case study which showed a benefit-cost ratio of 15.8 for a roundabout as compared to 12.0 for a traffic signal. The study included construction cost, annual maintenance, projected life span, and the annual personal injury accident reduction (9). This analysis did not include savings due to reductions in delay.

In addition, several states, particularly Maryland, are looking for ways to reduce the initial construction cost to a level comparable with a signal. As roundabouts are a relatively new form of intersection design in the United States, there has been a tendency to be more cautious in design and implementation, often spending more on additional signing, lighting, and landscaping. Maryland has targeted the following areas for cost reduction: maintenance of traffic, paving, landscaping, signing and lighting, and curbing. They are also looking into volume contracting of projects (2).

ROUNDAABOUTS IN THE UNITED STATES

Roundabouts are nothing new in many countries around the world. However, they did not begin to appear in the United States until the 1990s. In 1988, a modern roundabout was proposed in Ojai, California, but the proposal was defeated by some bad publicity and a skeptical public (12). The roundabout concept reappeared in 1990 in Summerlin, Nevada with the construction of two roundabouts in the town center (12). In 1992, the first roundabout built to replace a traffic signal was constructed in Gainesville, Florida (2). Maryland built its first roundabout in Lisbon in 1993. The roundabout idea seemed to take off shortly thereafter, with roundabouts under construction in Colorado, Florida, Maryland, Nevada, and Vermont.

Table 1 lists the roundabouts in operation in the United States as of October 1997.

This trend of roundabout construction shows no signs of slowing down. Many states are following the lead of the roundabout pioneers and have projects in the planning, design, and construction stages.

Table 1 Modern Roundabouts in Operation in the United States as of October 1997 (2)

State	City/Town	Intersection	No. Of Legs	Inscribed Diameter	Previous Traffic Control	Peak Hour Total Approach Volume	Date of Completion
California	Long Beach	Route 1 / Los Coyotes	4	143	Free	4,700 (1994)	June 1993
	Santa	Five Points / Route 144 / Alameda	5	26	AWSC	1,500 (1994)	November 1992
Colorado	Vail	I-70 Ramp / Vail Road North	5	37	1WSC	1,900 (1995)	October 1995
		I-70 Ramp / Vail Road South	6	61	1WSC	3,400 (1995)	October 1995
		I-70 Ramp / Chamonix North	6	46	TWSC	2,300 (1996)	1997
		I-70 Ramp / Chamonix South	6	46	TWSC	2,000 (1996)	1997
		I-70 Ramp / Avon Road North	4	46	TWSC	1,400 (1996)	1997
		I-70 Ramp / Avon Road South	4	46	TWSC	2,100 (1996)	1997
		Avon Road / Beaver Creek	4	46	Signal	3,000 (1996)	1997
		Avon Road / Benchmark Road	4	44	Signal	2,200 (1996)	1997
		Avon Road / US Route 6	4	44	Signal	2,500 (1996)	1997
	Nederland	Highway 72 / Route 119	5	30	TWSC	1,100 (1996)	June 1995
Florida	Ft Walton	Hollywood / Doolittle	3	31	1WSC	1,200 (1993)	May 1994
	Bradenton	SR 789 / Bridge Street	4	20	TWSC	850 (1995)	August 1994
	Tallahassee	Killarney / Shamrock	3	42/28	1WSC	1,800 (1994)	August 1994
	Palm Beach	Boca Raton / Cain Boulevard	4	31	TWSC	650 (1995)	November 1994
	Gainesville	SE 7th Street / SE 4th Avenue	4	23	Signal	550 (1994)	April 1992
	Naples	7th Avenue N / 7th Street	4	21	TWSC	600 (1996)	April 1992
		7th Avenue N / 3rd Street	4	18	TWSC	600 (1996)	April 1995
	Tampa	North Boulevard / Country Club	4	21	Signal	1,500 (1996)	June 1996

State	City/Town	Intersection	No. Of Legs	Inscribed Diameter	Previous Traffic Control	Peak Hour Total Approach Volume	Date of Completion
Maryland	Gaithersburg	Longdraft / Kentlands	4	41			November 1993
	Lisbon	MD-144 / MD-94	4	31	TWSC	630 (1995)	April 1993
	Cearfoss	MD-63 / MD-58 / MD-494	4	37	TWSC	800 (1995)	December 1995
	Leeds	MD-213 / Elk Mills	4	34	TWSC	800 (1994)	August 1995
	Lothian	MD-422 / MD-2 / MD-408	4	37	TWSC	1,400 (1995)	October 1995
	Taneytown	MD-140 / MD-832	4	46	TWSC	1,300 (1996)	August 1996
Mississippi	Jackson	MS475 / Airport / Old Brandon	4	37	AWSC	2,300	October 1997
Nevada	Summerlin	South Roundabout	4	91	New	1,000	March 1990
		North Roundabout	4	61	New	1,000	March 1990
		Banbury Cross / Town Center Drive	4	61			December 1994
		Hualapai / Town Center Drive	4	82			March 1995
	Las Vegas	Lake South / Crystal Way	4	25	TWSC	400	August 1994
		Michael / Harmony Way	3		1WSC	300	August 1993
South	Hilton Head	Main / Whooping Crane	4	34	Signal	1,800	February 1996
Texas	Addison	Addison Circle	4	61			1997
	Olmos Park	Olmos / El Prado	5	32	Signal	1,700	July 1996
Vermont	Montpelier	Main / Spring	3	34	1WSC	1,000	August 1995
	Manchester	Route 7A / Grand Union	4	34	TWSC		October 1997

STUDY RESULTS

In order to gain insight into the experiences of individual states and local municipalities, the author interviewed representative from over ten state and local government agencies and six consulting firms as well as four recognized experts in the field. The roundabout experts provided invaluable information on the locations of roundabouts across the country as well as the names of many potential contacts. The representatives of the government agencies and consulting firms were asked about community perceptions of the roundabout before and after installation. Several were able to provide summary documents of community comments. Interviewees were also asked about publicity efforts made to educate and inform the public about the roundabout projects. The author asked for samples of such materials whenever they were available.

The results of these interviews are discussed in the following pages, beginning with community concerns with respect to roundabout installation and continuing with a outline of the more notable instances in which various publicity tactics were used educate the public.

Community Concerns with Respect to Roundabout Installation

When a roundabout is first proposed in a community, local citizens are often justifiably concerned. To an educated transportation engineer, a roundabout is simply another alternative for intersection traffic control. To the public, however, a roundabout is often a completely foreign concept. Accustomed to stop signs and traffic signals, many people simply cannot picture how a roundabout would work, and when faced with such an unfamiliar form of control, they voice objection. People prefer what is familiar, and not knowing about the operational and safety benefits of roundabouts, they express preference for stop control or a signal.

One specific concern deals with driver behavior, both a person's individual behavior and that of other drivers. People are concerned with how and when to enter the circulating roadway and who has the right-of-way. Even those who understand what action they should take and when they should yield fear that other drivers may not know. Worried that other drivers may fail to yield, they are concerned for their own safety and the safety of their passengers.

Another major issue deals with pedestrians and bicyclists. Perhaps not having seen a modern roundabout and its clearly marked pedestrian crosswalks, people are worried about having to dodge cars to cross the circulating roadway. Others who understand that pedestrians are intended to circle around the roundabout, crossing each approach in advance of the splitter island, dislike the idea of having to walk around rather than cross directly. Bicyclists voice similar concerns, unsure of how to progress through the roundabout.

Other citizens want to know how school busses, emergency vehicles, delivery trucks, and other large vehicles will fit around the roundabout. Despite being reassured that the truck apron would accommodate such vehicles, people still express concern that truck drivers inexperienced in traversing roundabouts would endanger other drivers.

In colder climates, inclement weather was cited as a major concern. Residents were concerned about the ability of snowplows to navigate and effectively clear the roundabout as well as their personal safety in attempting to drive through the roundabout in icy conditions.

Finally, in a concern unrelated to safety, many people feel that a roundabout is an unnecessary expenditure and would prefer to see officials spend the money on other transportation improvement projects.

If roundabouts are to succeed as a new form of traffic control in a given area, traffic engineers, city and state planners, and local elected officials must work together to develop a plan to educate and inform the public about the operation of roundabouts. Across the country, many state and local transportation agencies

resoundingly report that once people become accustomed to roundabouts, they love them. However, much can be done to ease the transition.

Roundabout Publicity Across the Country

Loveland, Colorado (16)

Loveland, Colorado is scheduled to open their first two roundabouts on August 14, 1998. At the current time, 55-percent of residents are opposed to the project, 30- to 35-percent are for it, and the rest are reserving judgement until it opens and they have the opportunity to actually drive through it. The local newspaper has printed numerous letters-to-the-editor, most of which were negative. However, in preparation for the opening of the roundabouts, the town has held several neighborhood meetings in which videos of currently operating roundabouts are shown, and residents are given the opportunity to voice their opinions. On particular concern of residents is the safety of pedestrians. In order to alleviate their fears, local officials have obtained video footage from Michael Wallwork of Alternate Street Design showing pedestrian operations at a roundabout in Melbourne, Australia. The town has also published information about the pros and cons of roundabouts as well as driving instructions in the local newspaper. They also produced a half-hour television show broadcast on local cable access television which featured the city engineer, the mayor, and the police and fire chiefs discussing both sides of the roundabout issue. If these first two roundabouts are successful, several more will follow in the coming years.

Vail, Colorado (17)

When Vail, Colorado installed their first roundabout, the public was decidedly against the idea. However, people didn't want a signal either, and the roundabout concept was given a chance. Vail officials used the Maryland State Highway Administration video to show the public what roundabouts were and how they operated. Residents, however, were still concerned about how well the roundabout would function in inclement weather. In response, Vail officials asked the consulting firm who was doing the design work, Ourston and Doctors of California, to produce a video about operation of roundabouts during severe weather. Using footage of roundabouts in Norway filmed two weeks before the 1994 Winter Olympics they showed that roundabouts could operate efficiently even in deep snow. These videos were shown at public meetings and on local cable access television. Vail officials also used a variety of other methods to educate the public about roundabouts. They printed a educational brochure which was distributed at municipal government and law enforcement offices, local hotels and rental car companies, and at visitor information centers downtown and at the regional airport. In addition, one morning two months after the roundabout opened, local officials and police pulled vehicles to the side of the road as they were exiting the roundabout and distributed free coffee and doughnuts along with a roundabout brochure. Since the installation of the first roundabout, public opinion has been overwhelmingly in support of roundabouts, and several more have been installed, both in Vail and in the neighboring town of Avon.

Lisbon, Maryland (18)

When the Lisbon roundabout was first proposed, it did not receive a warm welcome from local citizens. Rather, they were very much against the idea. Most residents did not want to be a part of an "experiment" in traffic engineering. Faced with this problem, the Maryland State Highway Administration took a rather innovative approach. They offered to put a temporary roundabout in place so residents would have the opportunity to actually drive through it and decide whether they liked it. State officials also put together a short brochure to explain the roundabout concept and highlight the key features (see Appendix A-1). The temporary roundabout turned out to be a resounding success, and the local task force voted to make the installation permanent.

Towson, Maryland (19)

After the success of the Lisbon roundabout, Maryland embarked on several more roundabout projects, in Leeds, Lothian, and Cearfoss. Another roundabout was then planned in conjunction with the Towson Enhancement Project, a broad-scale project to revitalize downtown Towson and relieve increasing traffic congestion. The project includes construction of a modern roundabout, streetscaping, and landscaping. For this roundabout, state officials produced a brochure for the entire enhancement project as well as a door hanger for distribution in the local community with instructions for walking and driving through the roundabout. The Towson informational door hanger can be found in Appendix A-2.

Jackson, Mississippi (20),(21)

When Jackson, Mississippi installed their first roundabout at the entrance to the Jackson International airport, not everyone was enthused about the project. According to the Mississippi Department of Transportation, one of the biggest obstacles encountered was teaching people to yield upon entry and not in the roundabout itself. As part of their educational effort, they provided local newspapers with instructions and graphics depicting how to drive through the roundabout (see Appendix A-3). They also sent press releases and footage of a Maryland roundabout to television stations to help instruct the driving public. One local radio station went so far as to stage a live broadcast from the roundabout site, dubbing it the “fruit loop.”

Hilton Head Island, South Carolina (22),(23)

The Hilton Head Island roundabout is located at the entrance to Hilton Head Plantation, a planned unit development. At first, the town did not support the idea at all, and the issue actually went to referendum. Supporters of the roundabout used the Maryland State Highway Administration video extensively to educate the public about the roundabout concept. The referendum did pass, and the roundabout was installed, but not everyone was convinced it would work, in particular the current fire and police chief. Consequently, on opening day, town officials planned a demonstration with the local fire truck which was covered by the local television stations. In the end, the fire and police chief, who had originally been against the project, became one of its staunchest supporters. In order to educate the driving public about how to drive in a roundabout, the Property Owners Association of Hilton Head Plantation distributed roundabout information flyer in their monthly newsletter, and a similar publication is now included in their new homeowner’s package.

Montpelier, Vermont (24),(25),(26)

Montpelier, Vermont installed their first roundabout as part of a traffic calming effort in a residential area which serves as a gateway to the downtown. Their educational efforts included a brochure prepared by the Montpelier City Roundabout Committee entitled “How to Move in the Right Circles.” This brochure can be found in Appendix A-4. It included an explanation of the roundabout concept, instructions for drivers on how to approach, enter, and exit the roundabout, and a section emphasizing the importance of using directional signals. The brochure also showed examples of the traffic signs which are used in and approaching the roundabout. Guidelines for bicyclists and pedestrians were also discussed.

University Park, Washington (27)

Like many other roundabout sites, controversy reigned in University Place when the idea of a roundabout was first proposed. Roundabouts were a difficult concept for the public to grasp; they often confused them with older traffic circles and could not understand why the local government would want to install such an ineffective form of traffic control. Local officials, however, offered the option of trying the configuration for one year, and the local community agreed. During the planning and construction stages, the city held ten public meetings, published information in the local newspaper, and broadcast several short television spots informing the public about the project. When the roundabout opened, they also published a short newsletter outlining the project history, the benefits of roundabouts, and specific details regarding the University Place

roundabout. In the newsletter, they also provided a contact number and email address for those desiring further information. In another publication, entitled "Roundabouts: Driving in the Right Circles," (found in Appendix A-5) they provided examples of the advance signing used as well as driving instructions and graphic representations of how to make left turn, right turn, and through movements. Instructions for bicycles and pedestrians were also included. The roundabout opened in August of 1997 and now enjoys a 75- to 80-percent approval rating.

Summary of Study Results

In summary, local communities have expressed a variety of concerns with respect to roundabout installation. These include:

- Driver behavior;
- Pedestrian and bicycle issues;
- Accommodation of large vehicles;
- Safety during inclement weather; and
- Monetary expenditures.

State and local governments have addressed these concerns rather well as evidenced by the high approval ratings of currently operating roundabouts. They have used the following media to educate and inform the public about roundabouts:

- Community meetings;
- Newspaper advertisements and articles;
- Television broadcasts;
- Radio broadcasts; and
- Printed materials.

RECOMMENDATIONS FOR STATE AND LOCAL AGENCIES

Whether in the proposal, planning, design, or implementation stage, it seems that good publicity is key to roundabout success. It is important to keep the public well-informed and to educate them as to what exactly a roundabout is, as many people tend to confuse them with traffic circles. When in the proposal, planning, and design stages, publicity should focus on what exactly roundabouts are and how they operate. Information on safety benefits and delay reduction should be emphasized as well. As the implementation stage draws near, the focus should shift more toward driver behavior with specific instructions on how to safely maneuver the intersection. These instructions should be geared toward drivers, pedestrians, and bicyclists individually. Several publicity strategies are outlined below:

Community Meetings

It is important to be open with the public from the start. To that end, it is wise to hold community meetings, and where appropriate, visit local neighborhood associations and civic groups. Show the benefits of a roundabout as compared to other traffic control installations. Several states have prepared videos which have proved very useful in educating the public about what roundabouts are and how they operate.

Newspaper

Provide the local newspapers with graphics and detailed instructions for drivers, pedestrians, and bicyclists on how to navigate the roundabout. It also may be useful to provide them with the latest safety and delay data in order to emphasize the benefits of roundabout installation.

Television

Similarly, provide local television stations with footage of other roundabouts in operation. The Maryland State Highway Administration has produced an excellent introductory roundabout video. If possible, have a news crew film operation of the completed roundabout to show locals exactly what to expect when they encounter it themselves. Also, footage of a fire truck and ambulance circling the roundabout may alleviate public fear that it will impede emergency service vehicles. Again, stress appropriate behavior for drivers, pedestrians, and bicyclists. Local access cable stations are also a broadcast option.

Radio

Though the use of radio for publicity may not be appropriate for all situations, it still should not be discounted. A live broadcast from the Jackson, Mississippi roundabout brought people out to see what it was and how it worked.

Printed Materials

Several states have printed brochures or leaflets explaining what a roundabout is and how it operates. This is a simple and effective way to inform drivers, pedestrians, and bicyclists how to traverse the roundabout. In addition, as signing varies from roundabout to roundabout across the country, it may be useful to include graphics of the roundabout signing which is used locally. Brochures or flyers of this sort could be included as an insert in the local newspapers, distributed through local mailings, circulated through local neighborhood associations and civic groups, made available at public meetings, and displayed at driver licensing stations. This type of brochure would also be ideal for targeting out-of-state drivers at rental car counters. Similarly, the information could be printed on door hangers and distributed in local neighborhoods.

Driver Manual

As roundabouts become more popular across a given state, driving instructions should be included in the driver's manual. This will help to ensure that drivers from all around the state will be familiar with the roundabout as a form of traffic control.

APPLICATION

The most versatile of the methods used by state and local agencies to inform the public about roundabouts is the use of printed materials, whether they be newsletters or brochures. Using this medium, local officials or consulting firms can include a great deal of information in a single sheet. Ideally, such a pamphlet or newsletter would include examples of locally posted roundabout signing and instructions for drivers, pedestrians and bicyclists. A design drawing or graphic will also help the driver know what to expect upon approaching the roundabout for the first time. Space permitting, information and statistics on the safety and efficient operation of roundabout could be provided. Finally, a contact name and phone number should be provided for those wish to learn more.

Such a publication could be distributed in a variety of ways, including, but not limited to:

- Direct mailing to local residents;
- Inclusion in local newspapers;
- As an attachment to local civic or neighborhood newsletters;
- At visitor information centers;
- At rental car counters;
- In municipal government offices;
- At local police and fire stations;
- At public and community meetings; and
- At driver licensing offices.

Some states have had their brochures professionally published, but with the advent of desktop publishing, this type of document could be easily produced in-house, keeping the associated costs down. For an in-house pamphlet, the only costs involved would be the time of the person creating the document and the cost of reproduction. With the exception of direct mailing, distribution would add no additional incremental cost.

A pamphlet or newsletter is a simple and effective way of reaching a large audience with important educational information about roundabouts. A prototype brochure is provided on the following pages.

ROUNDAABOUTS

What is a Modern Roundabout?

A modern roundabout is a circular intersection in which traffic circles counter-clockwise around a central island. All entering traffic yields the right-of-way to circulating traffic. Roundabouts can reduce injury accidents, traffic delays, fuel consumption, air pollution, and operating costs.

DRIVING THE ROUNDAABOUT

Approaching the Roundabout:

Slow down to 10-15 mph when approaching the roundabout. Be prepared to stop for pedestrians.

Yield at the Roundabout:

Always yield to vehicles already in the roundabout. Enter the roundabout only when there is an adequate and safe gap in the traffic.

Driving the Roundabout:

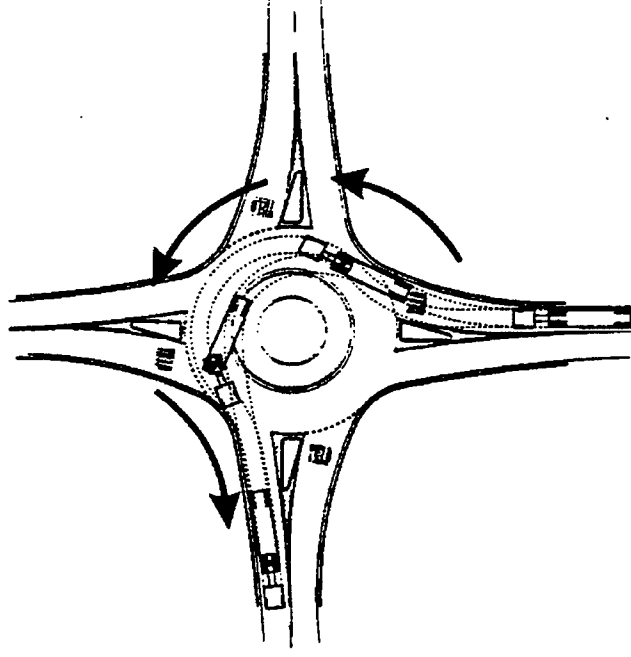
Continue through the roundabout following the path of the circular roadway.

Exiting the Roundabout:

Move to the right to exit the roundabout. Be prepared to stop for pedestrians as you exit.

Signaling at Roundabouts:

Always use your turn signals to signal your intentions to other drivers.



WALKING THE ROUNDAABOUT

Always cross the roundabout at the designated crosswalks. First, look for oncoming traffic to ensure the way is clear. Cross to the median island, then look again for traffic and cross the remainder of the street.

Do not attempt to cross the circulating roadway.

CYCLING THE ROUNDAABOUT

Experienced bicyclists should enter the traffic stream just like a motor vehicle. Inexperienced bicyclists should walk their bicycles through the pedestrian crosswalks watching carefully for approaching vehicles.

How to Drive the Roundabout

BENEFITS OF ROUNDABOUTS

Safety:

Roundabout research shows a 30- to 80-percent reduction in injury accidents at roundabouts as compared to signalized or signed intersections. Accidents that do occur at roundabouts are generally sideswipe or rear-end types. They are low-speed, low-impact collisions that result in few, if any injuries.

Time Savings:

Motorists at roundabouts experience only a fraction of the delay found at signalized or signed intersections. In some cases, delay dropped from 2 to 3 minutes per vehicles to less than 30 seconds. Roundabouts process vehicles on an equal basis as they approach. No movement is given priority over another. At a signal, a driver may have to wait to receive a green light, but at a roundabout, a driver may accept the next available gap.

Additional reference materials are available on loan from the city.

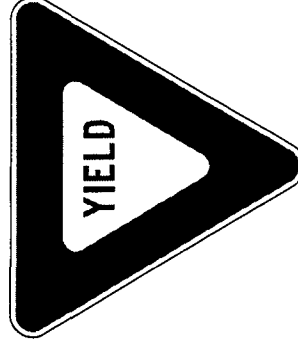
For further information, contact the City Engineer at (999) 555-5555.

Prepared by:
The Roundabout City
Public Works Department

ROUNDABOUTS



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Moving in the Right Circles

CONCLUSIONS

In locations across the country, roundabouts have proven to be a safe and effective form of traffic control. As the data available on American roundabouts grows, there is conclusive evidence that when used in appropriate sites, roundabouts are safer and more cost-effective than many traditional forms of intersection control. Various studies have shown dramatic reductions in the number and severity of accidents. Other studies have demonstrated equally impressive decreases in delay per vehicle. Though the initial costs of a roundabout installation may be higher than signalization in some cases, the savings in yearly maintenance and the longer life span favor a roundabout in the long term.

To some traffic engineering practitioners, these benefits are obvious, but to the public, the idea of a roundabout is usually a strange and foreign concept. Many people confuse roundabouts with the traffic circles of yesteryear. Those who do understand what roundabouts are may still be confused about who has the right-of-way or may be concerned that others will not yield upon entering. Others may be confused about how they will traverse the circle as bicyclists or pedestrians, or in residential areas, parents may be worried about the safety of their children.

Therefore, it is important to keep the public informed about current roundabout projects. In doing so, public officials and engineers can alleviate their fears about this new and different form of traffic control and instruct them as to the proper behavior for drivers, pedestrians, and bicyclists. There are many ways in which this can be accomplished. For example, various states have used newspapers, television, and radio to disseminate information. Other states have produced videos or published their own flyers and pamphlets for local distribution. The state driver's manual is also an excellent place to include roundabout information. Ideally, a state could employ all of these approaches in educating the public about roundabouts. However, if a single method must be chosen, a pamphlet or newsletter is a versatile and effective way of providing educational roundabout material. Still, regardless of the medium selected, what is important is that the public be informed.

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Michael Thomas of the California Department of Transportation
Michael J. Wallwork of Alternate Street Design, P.A.
Bette Weseman of the Hilton Head Plantation Property Owners Association
Ben Yazici of the City of University Place, Washington

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APPENDIX A

EXAMPLES OF PUBLICITY MATERIALS

A-1: Lisbon, Maryland

KEEPING YOU MOVING

At the Maryland State Highway Administration (SHA), keeping our roadways safe and efficient are top priorities. But as communities grow, it becomes more difficult to keep up with the increasing traffic demands placed on our roads. SHA traffic engineers are aware of the problems heavy traffic can create, especially at signalized intersections. Heavy traffic prevents cars from clearing intersections, thereby wasting time and money. There is also the potential for serious injury accidents at intersections.

SHA is always looking for new ways to meet the needs of motorists. One solution to relieve traffic problems at intersections is the modern traffic roundabout. This brochure will familiarize you with the modern roundabout.

WHAT ARE THEY?

A modern roundabout is an intersection having one-way circulation around a central island in which entering traffic yields the right-of-way to circulating traffic. Roundabouts can reduce injury accidents, traffic delays, fuel consumption, air pollution, and operating costs. A well landscaped roundabout can also enhance the beauty of your neighborhood.

WHERE ARE THEY NOW?

Roundabouts have been used successfully in Britain, France, Switzerland, Denmark, the Netherlands, Norway and Australia as well as other countries as an alternative to traffic signals in controlling speed, managing traffic and reducing accidents.

HOW DO I USE ONE?

You'll be surprised how easy it is to travel through a roundabout, but don't confuse roundabouts with the traffic circles you may have driven around in Washington, D.C. or New Jersey. Roundabouts are smaller and vehicle speed is slower, usually about 15 to 25 mph. You enter the roundabout by selecting a gap in the circulating traffic. The only decision is whether or not the approaching gap is large enough for you to safely enter. You can adjust your speed and enter without stopping. The small diameter, low entry speeds and low circulating speeds provide easy access for motorists.

Modern roundabouts, though more compact than traffic circles, have a larger traffic capacity due to their wider entries which allow more vehicles to safely enter.

SAFETY

A key difference between roundabouts and customary intersections is safety. Roundabouts have a lower potential for accidents compared to intersections. No one can run a red light and cause a right angle collision. The driver who enters the roundabout has to yield to only one traffic movement. By contrast, at a stop sign, the driver has to deal with two or three different movements.

(Cont. on back)

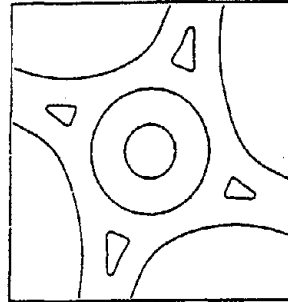
Research shows a 30 to 90 percent reduction in injury accidents at roundabouts compared with signalized or signed intersections. Accidents that do occur at roundabouts are generally side-swipe or rear-end types. They are low speed, low impact collisions that result in few if any injuries. Additionally, SHA is paying special attention to the needs of pedestrians and bicyclists in the roundabout design.

SAVING MONEY

Roundabouts can also save taxpayers money. They need little maintenance, such as resurfacing, landscaping and sign replacement. Traffic signals, on the other hand, cost about \$3000 per year for maintenance, electricity, controllers, lamps and other upkeep.

In spite of these advantages, roundabouts are not the only solution to traffic problems. Rather, they are an option to be considered. Roundabouts are not needed at locations where traffic from a minor road can enter the intersection safely and without delay. They also should not be used where a nearby signal could back-up traffic into the roundabout.

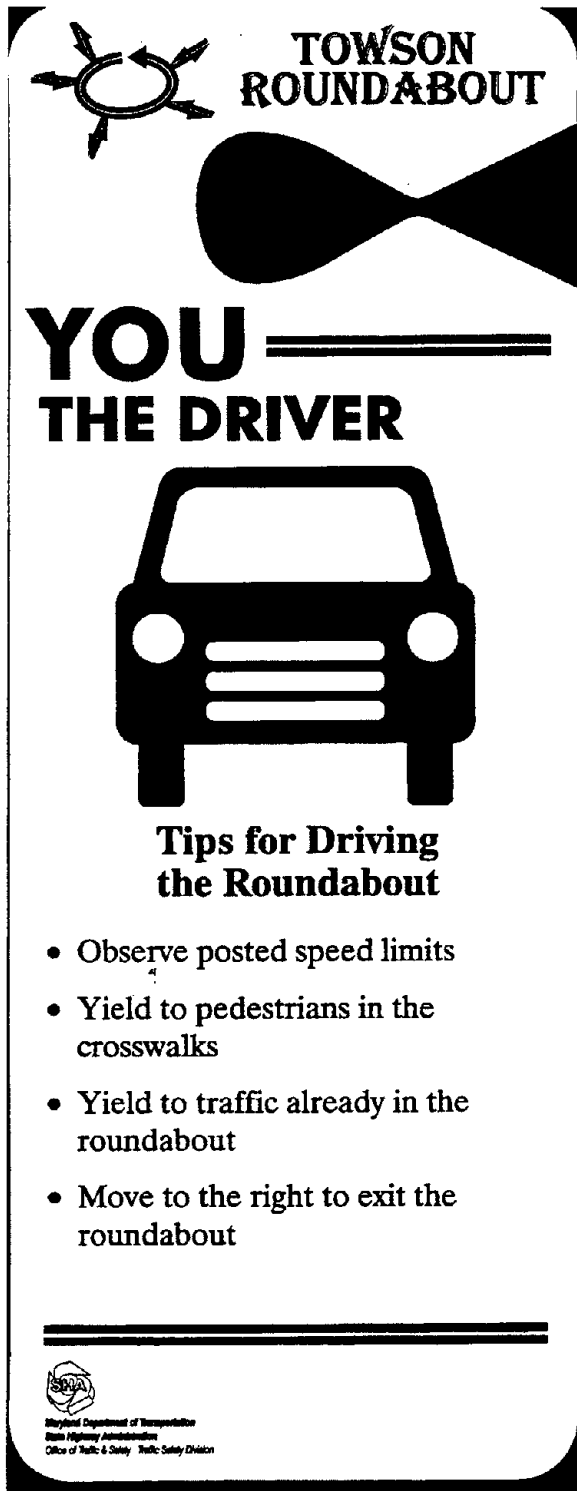
MARYLAND STATE HIGHWAY ADMINISTRATION




THE MODERN TRAFFIC ROUNDAABOUT




A-2: Towson, Maryland




**TOWSON
ROUNDABOUT**

YOU 
THE DRIVER

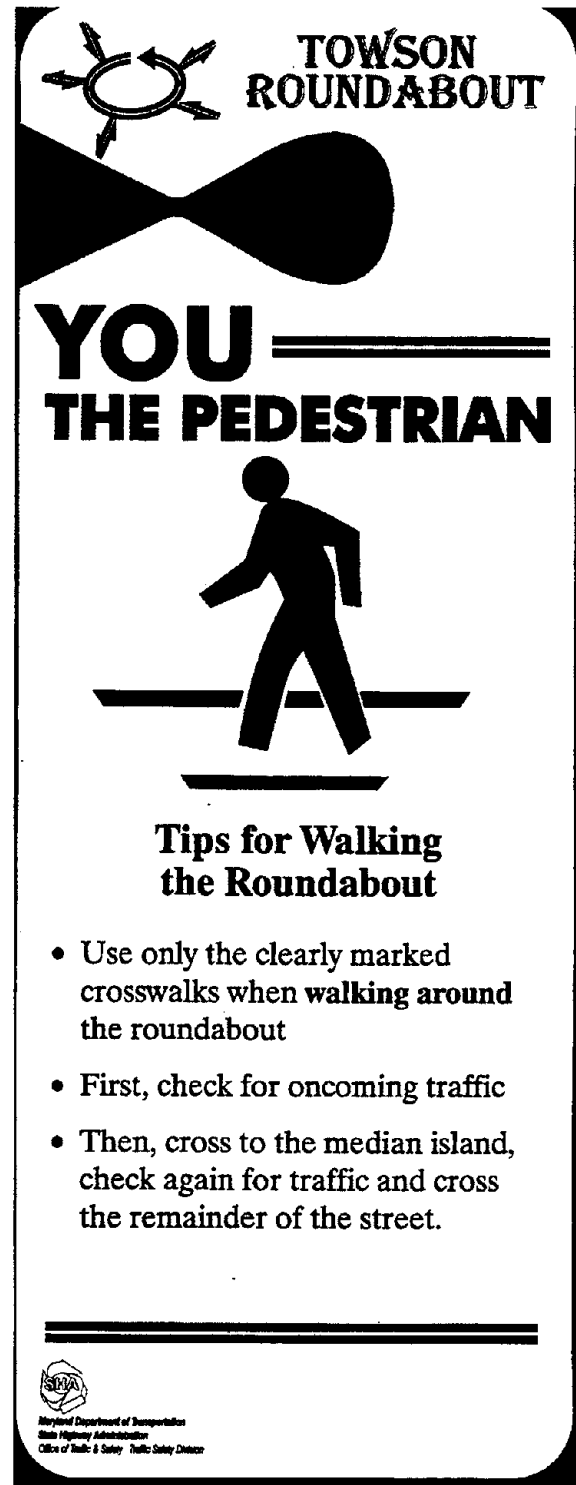


**Tips for Driving
the Roundabout**


- Observe posted speed limits
- Yield to pedestrians in the crosswalks
- Yield to traffic already in the roundabout
- Move to the right to exit the roundabout




Maryland Department of Transportation
State Highway Administration
Office of Traffic & Safety Traffic Safety Division




**TOWSON
ROUNDABOUT**

YOU 
THE PEDESTRIAN



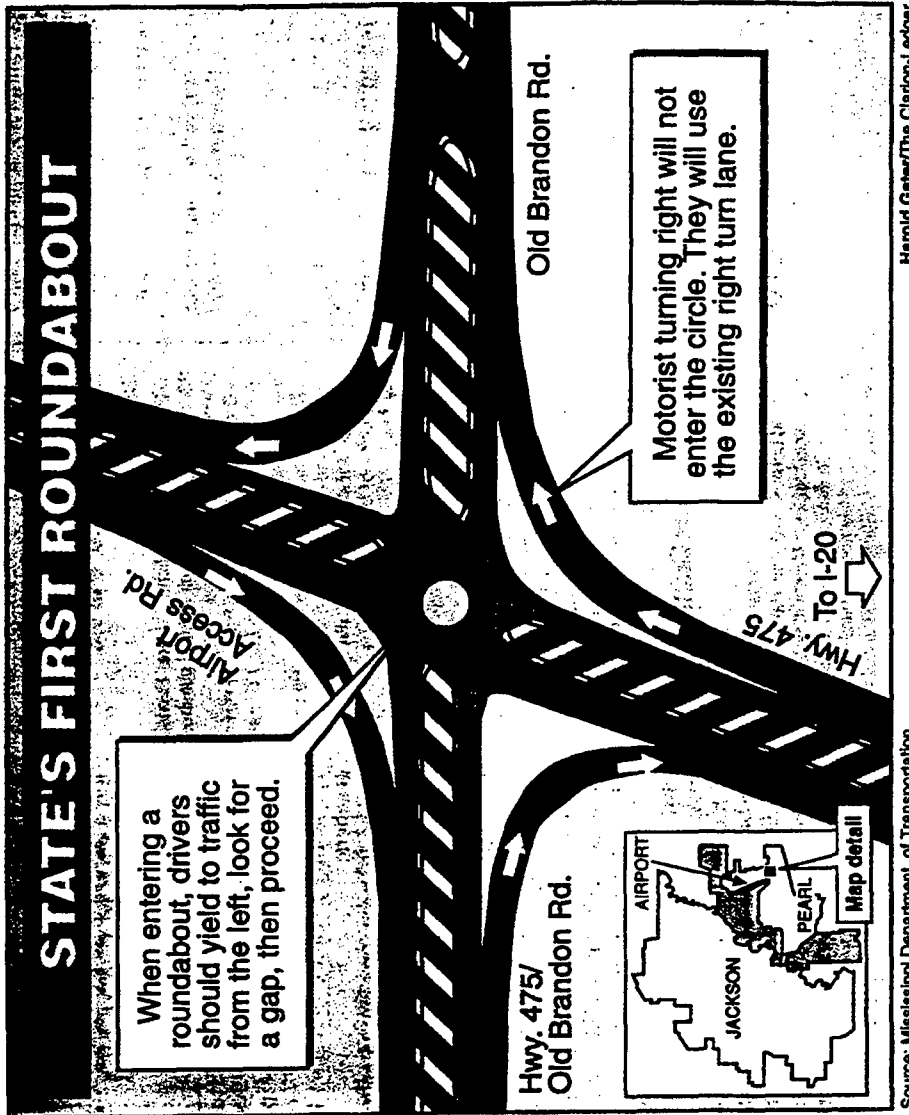
**Tips for Walking
the Roundabout**

- Use only the clearly marked crosswalks when **walking** around the roundabout
- First, check for oncoming traffic
- Then, cross to the median island, check again for traffic and cross the remainder of the street.



Maryland Department of Transportation
State Highway Administration
Office of Traffic & Safety Traffic Safety Division

A-3: Jackson, Mississippi



Harold Gater/The Clarion-Ledger

Source: Mississippi Department of Transportation

Circular island will speed trip to airport

■ Round intersection will end time-consuming wait at 4-way stop

By Clay Harden
Clarion-Ledger Staff Writer

A roundabout way will soon provide a faster route to and from Jackson International Airport.

Mississippi Department of Transportation officials say construction will begin Monday on the state's first roundabout intersection at Mississippi 475 and Old Brandon Road at the airport entrance.

The new intersection, designed around a circular island, will have traffic moving counterclockwise on a continual basis by Nov. 1.

MDOT officials said the intersection will be especially effective during rush hour when 20-30 cars may back up at the four-way stop, causing motorists delays up to three minutes.

"Roundabouts are ideal for high-traffic areas and will move traffic more efficiently than the four-way stop now in place," said Bob Mabry, MDOT traffic signal engi-

neer. "Currently, there are about 35 modern roundabouts in the country, and they have proven to be very successful."

Dirk Vanderleest, executive director of Jackson International Airport, is optimistic the intersection will alleviate the need for airport police to direct traffic from 7:30-8 a.m. on weekdays.

"We get to be the guinea pig for the rest of the state," Vanderleest said. "We are very excited about the project and hope it will provide our customers with a faster way to enter and leave the airport."

MDOT spokeswoman Sarah Crowell is concerned that Mississippians become informed about roundabouts, popular in Europe

and other foreign countries, before the intersection is complete in 3-4 weeks.

"We want people to know what we are doing and how to drive when they approach the roundabout," Crowell said.

The main rule in negotiating a roundabout is that drivers enter

See **ROUNDABOUT, 3B**

A-4: Montpelier, Vermont

ROUNDABOUTS

What is a Modern Roundabout?

A modern roundabout is a new circular intersection design able to slow traffic while lowering delays and handling higher traffic volumes. Modern roundabouts have proved to more safely accommodate vehicles, pedestrians and bicyclists than alternatives, like stop signs or traffic

signals. U-turns are permitted! Compared to other types of intersections, roundabouts save energy, reduce pollution, and require less land and maintenance. No intersections are perfect, but roundabouts generally provide the best conditions for movement of pedestrians, bicyclists, and all types of motor vehicles.

For Drivers...

Signs at Roundabouts


A "Roundabout Ahead" and a "Reduced Speed Ahead" signs tell you that you are approaching a roundabout

**ROUNDABOUT
AHEAD**

**REDUCED
SPEED
AHEAD**

The "Advisory Speed Limit 15" sign tells the driver the maximum safe operating speed approaching the roundabout and operating through the roundabout

**ADVISORY
SPEED
LIMIT
15**

 Roundabout Yield Signs mean yield, that is, slow or stop at the entry line to the circular roadway when there are vehicles there—vehicles in the circulating roadway have the right-of-way over vehicles entering the roadway.

Remember: Vehicles must give way to pedestrians.

Pedestrians, bicycle riders and motorcyclists are often very hard to see. They are particularly at risk, so always keep an eye out for them.

Approaching the Roundabout

Slow down to about 10-15 mph when approaching the roundabout (the advisory speed limit for motor vehicles at the Montpelier roundabout is 15 mph). Also, be prepared to stop for pedestrians because pedestrian crossings are located one car length before the

entry line and one car length after the exit points.

Yield at the Roundabout

Always yield at the entry line to vehicles already in the roundabout.

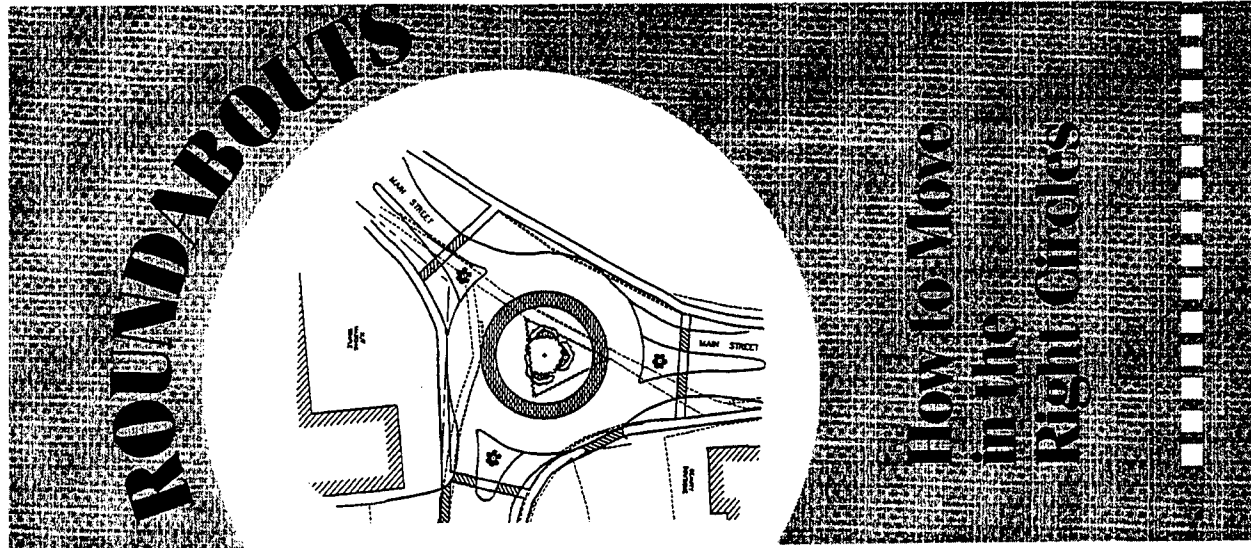
Enter the roundabout only when there is an adequate and safe gap in the traffic.

Remember: bicyclists and motorcyclists are the most difficult to see when entering a roundabout.—be on the lookout for them when entering the circulating roadway.

Signaling at Roundabouts

It is important and courteous to let others know your intentions, and it is the Vermont law. When approaching, show a right signal for right hand turns, no signal for through travel, and left signal for left hand turns. When nearing your exit point, use a right turn signal just past the exit before your exit.

One Lane Roundabouts – It's Quite Simple



For pedestrians...

Roundabouts present a pedestrian friendly environment because of the slow speeds of vehicles—normally 5 to 15 mph. The Montpelier Spring and Main Streets roundabout features three crosswalks, each with an eight-foot wide pedestrian refuge within each entry or “splitter” island. Pedestrians thereby cross one lane at a time. After a glance at the “wrong way” direction, the pedestrian looks in the direction of the oncoming traffic and when there is no vehicle present or a vehicle has stopped to yield, the pedestrian moves across a lane. Each lane is about five or six average steps wide—from median to curbside or curbside to median.

Remember:

At any unsignalized crosswalk the pedestrian must exercise care.

Do not try to cross the circulating roadway or the central island.

Do not run across crosswalks.

Prepared by :

Montpelier City
Roundabout Committee
City Hall
Montpelier, Vermont 05602

Driving and Exiting the Roundabout

Operate at the slow speed around and exiting the roundabout. If a vehicle is stopped in the circulating roadway because of pedestrians at crosswalks just outside the exit points, slow down and stop until the way is clear. Pedestrian crossings are just one car-length beyond each exit point, so you will need to be prepared to yield to pedestrians just past the exit line.

For bicyclists...

Experienced bicyclists enter the traffic stream just past roundabout warning signs. Bicyclists, like vehicles, yield at the entry line to traffic in the circular roadway. Bicyclists enter the circular roadway when there is an adequate and safe gap in traffic. Again, bicyclist signal right for a right turn, no signal for a left through movement, and left for a left turn. Just past the last exit before the exit the bicycle will use, the bicyclist signals a right turn. Less experienced bicyclists should stop at the roundabout warning sign, and use the sidewalk and crosswalk to pass through the intersection before resuming bicycle operation.

Remember...yield to pedestrians when approaching or exiting the roundabout. Be extremely careful when traveling the circular roadway that entering cars are aware of your presence.

A-5: University Place, Washington

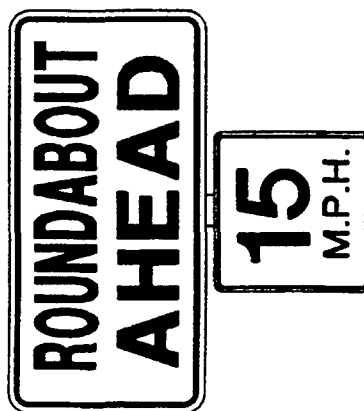
What is a Modern Roundabout?

A modern roundabout is an intersection having a one-way circulation around a central island where entering traffic must yield the right-of-way to circulating traffic.

For Drivers...

Signs at a Roundabout

The following signs will be posted at the approach to the roundabout, signaling a roundabout is ahead.



The advised speed approaching and driving through the roundabout is 15 mph.

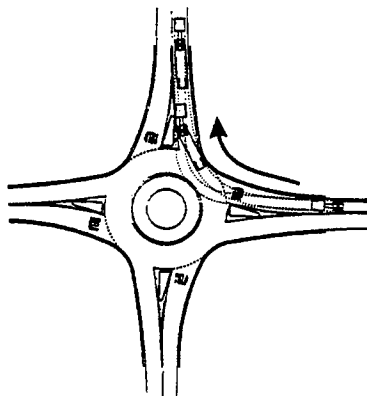
Approaching a Roundabout

A driver should use the same caution as approaching any yield sign. Drivers must be prepared to stop and wait for a sufficient gap in the circulating traffic before entering the roundabout. *Vehicles already inside the circulating roadway have the right-of-way over vehicles entering the roadway.* Crosswalks are located approximately one car length in advance of the yield line. Therefore, drivers should approach cautiously and be prepared to stop for all pedestrians.

Signaling at a Roundabout

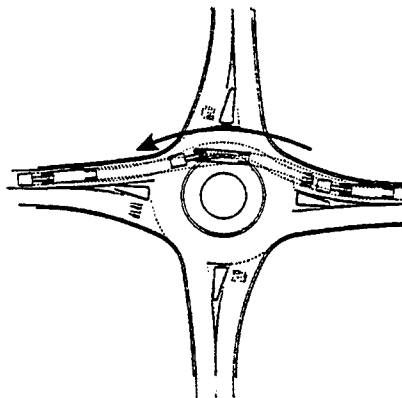
All the normal rules of the road apply. It is very important to be courteous and signal your intentions as you approach and drive through the roundabout.

Right Turn Movement



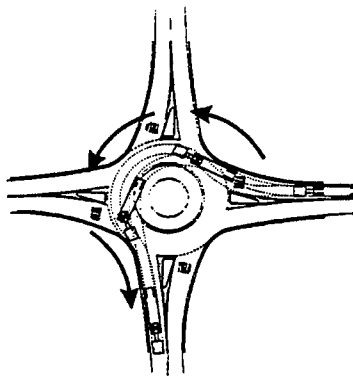
Signal a right turn on the approach and while in the roundabout.

Through Movement



No Signal is required for through travel.

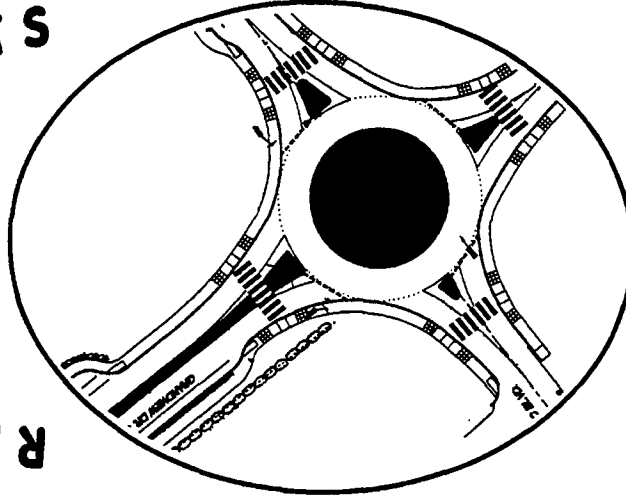
Left Turn Movement



Signal a left turn on the approach and while in the roundabout.



ROUNDABOUTS



Driving in the Right Circles

Truck Apron

This is an outer mountable portion of the Central Island of the roundabout. It is designed to allow large and emergency vehicles to maneuver around the circulating roadway. No other vehicles should drive in this area.



Additional materials available on loan from the City

The following reference materials on Roundabouts are available on loan.

Videos
Articles

Please call (253) 460-2526 to reserve reference materials.

Prepared by:
The City of University Place
Public Works Department
Please call (253) 566-5656,
if you have questions.

For Bicyclists

Bicyclists can use either the pedestrian crossing or ride through roundabout. A less experienced bicyclist can use the pedestrian crossing by stopping at the roundabout, dismounting, and using the sidewalk and the designated crosswalk to pass through the intersection. Experienced riders may choose to cycle through the roundabout. However, as with motorists they must wait at the yield line for a sufficient gap in the circulating traffic before entering the roundabout.



For Pedestrians

At each approach to the roundabout there is a clearly marked pedestrian crossing. Pedestrians should cross only at these designated crosswalks. Although vehicles are required to yield for all pedestrians, caution should be exercised at all pedestrian crossings.



**DEBORAH C. KREIS**

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VARIABLE PRICING FOR TOLL FACILITIES

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SUMMARY

Traditional transportation pricing strategies of toll facilities does not effectively influence travel demand to reduce traffic congestion during peak periods. The use of variable pricing offers the potential of increasing the efficiency of the toll facility by enticing users to travel during less congested periods and thus improving operations during the peak period. Variable pricing also offers the potential of making the toll road more competitive when compared to other routes during off-peak periods.

Included in this report is an evaluation of the background of toll facilities and variable pricing, a state of the practice review of toll facility operations, and a review of barriers associated with the conversion of a fixed rate toll structure to a facility that is variably priced. The variable pricing strategy has been implemented in two communities in the United States and plans for additional tests are described in this report. An implementation strategy for this type of policy is suggested and a hypothetical application is demonstrated to further explain the theoretical strategy.

A survey of toll agencies was conducted to develop a database of information about operating procedures and toll structures currently being applied in both rural and urban settings. This survey showed the growing acceptance of variable pricing and the increased use of electronic toll collection at toll agencies. The interviews and surveys were completed through a series of phone calls to toll agencies and other transportation officials.

The goal of this research was to increase the awareness of variable pricing for toll facilities and identify the theoretical benefits of using variable pricing for transportation system management. Based on the results of this research, recommendations were made to aid the transportation professional overcome barriers that are unique to toll agencies. The implementation of a variable pricing strategy should consider including the following steps for project development:

- Develop mission statement;
- Evaluate policy considerations;
- Develop an understanding of the barriers and constraints;
- Identify problems and set goals;
- Identify political allies;
- Establish contact with federal level;
- Design scheme to meet goals;
- Complete initial feasibility analysis;
- Provide incentive to motorists combined with initiation of new toll structure; and
- Prepare evaluation program.

By following the steps outlined in this report, agencies will be able to convert fixed toll rate pricing to more equitable variable pricing programs. The importance of these schemes are twofold. First, the toll facility operators will be in position to effectively influence travel demand by incremental changes in the price structure. Second, the use of variable pricing should make more motorists aware of the effects of driving during the congested peak periods.

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INTRODUCTION

Toll facilities (also frequently referred to as turnpikes or toll roads) provide a way to build and use roads without requiring an increase in state or local taxes. These “pay as you go” roads operate to complement the surface transportation system, which are local or state-maintained roads that local, state, and federal taxes pay for. Prior to the development of the Interstate system, toll facilities were developed in many states as a way to supplement the existing transportation system, providing a safe, high-speed facility to encourage economic growth and vitality throughout a region.

As transportation demand has continued to grow over the past 30 years, views of the role of the transportation system has changed. The completion of the Interstate highway system has shown that there is a limited ability to expand highway capacity (1). The fact that vehicle travel volumes are much higher than the roadway capacities in many metropolitan areas stands as testimony to the inability or unwillingness to provide enough capacity to avoid congestion. The congestion levels on state highways and the Interstate system are among the driving forces today behind a State Department of Transportation (DOT) considering transportation system management (TSM) and transportation demand management (TDM) measures (2). For example, TDM and TSM measures considered by the Maryland DOT include (3): reducing the need for trips, modifying destination and time of trips, encouraging shifts from single occupant vehicles, improving the efficiency of the system, improving connectivity, etc.

Turnpike Authorities operating toll facilities have separate goals from those of a State DOT. Because of the nature of the organization and the financing used to develop the facility, toll facilities must operate in a profitable manner. For many of these facilities, no state tax money is used to fund these toll roads. Prices on the facilities are set to insure the facility is well traveled and return on the initial investment of the bond holders can be provided. Price is usually insensitive to the levels of congestion experienced by the facility (a flat rate of 3-4 cents per mile is typical). Toll facilities are not immune to high levels of congestion and in some cases the congestion can be severe.

The use of more appropriate pricing schemes by toll authorities, such as congestion pricing (also referred to in the literature as value pricing or variable pricing) may assist state DOTs in managing their transportation systems more effectively. Fair pricing for transportation is one of the key elements identified by Public Technology Inc. in their report, “Roads Less Traveled: Intelligent Transportation Systems for Sustainable Communities” (4). Pricing is one of several transportation system management measures that will serve to meet the needs of the present without compromising the future.

With the authorization of ISTEA in 1991 and the TEA-21 legislation recently signed by President Clinton, these programs will continue to be investigated in metropolitan areas as a means to provide a sustainable transportation system. Thus, it is important to understand the benefits and issues surrounding pricing.

Problem Statement

Traditionally, toll authorities have operated toll facilities using a fixed price to generate revenue which would be used to maintain existing facilities and in some case, procure new routes. The price of the toll is fixed throughout the day, and thus the facilities may be operated without due of consideration of the quality of service provided to facility users. Furthermore, the operation of these facilities using a fixed price throughout the day tends to work contrary to a DOT's efforts of encouraging more efficient use of the transportation system.

In order to complement the efforts of state DOTs and further the efficiency of the transportation system, some sort of variable pricing may allow toll facilities to operate in a more optimal fashion. An evaluation of the operation of toll facilities will be undertaken to identify barriers that exist for implementation of such variable

pricing schemes. This evaluation will identify when and if alternatives to fixed price schemes may improve the operation of toll facilities.

Research Objectives

The objectives of this study were as follows:

1. Identify the use of toll facilities throughout the United States.
2. Identify the pricing schemes currently in place and the policy issues with respect to transportation demand and management.
3. Review the jurisdictions implementing variable road pricing and pilot studies that are currently ongoing and identify issues being evaluated.
4. Identify potential barriers to implementation of a variable pricing scheme on a toll facility.
5. Describe the impetus for alternative pricing with respect to equitable transportation pricing.

Study Scope

The scope of this research is limited to the identification of barriers which restrict toll authorities from using variable pricing structures. As indicated in the problem statement, a review of agency goals will also be undertaken to understand the conflict which is apparent between the fixed price structure for toll facilities and variable pricing. The study will focus on existing toll facilities that could implement a variable pricing strategy. In addition, the congestion pricing projects in California and Florida will be reviewed.

Organization of the Report

Following the introduction, this report is divided into seven sections. An overview of the history of toll facilities and other background information is provided in the first section. The following section includes a summary outlining a state of the practice and provides an impetus for variable pricing and potential benefits on the transportation system. The various implementation barriers to a variable pricing scheme are discussed in the third section of the report with issues ranging from social and technical issues. The fourth section includes the study design and the provides summary information collected by the author. A review of variable pricing projects is then presented in the fifth section. Finally, an implementation strategy is developed and a hypothetical application is reviewed to expand the concept and provide specific examples to gather support for the proposed structure. A conclusion summarizes the results of the research and offers suggestions for further research.

BACKGROUND - HISTORY OF TOLL FACILITIES AND VARIABLE PRICING

A variety of toll facilities are operated throughout the United States. These toll facilities are both rural and urban in character. These facilities serve customers largely in a competitive fashion with other state financed roads. The nature of the toll/non-toll relationship is complex, similar in many ways to a consumer's choice at a grocery store. The relationship depends greatly on competition and personal choice. Similar to a shopper selecting a certain type of bread, a traveler must choose among the alternative paths, selecting a route which is agreeable based on price and other qualities. If the store only has one type of bread, the consumer is limited in their choice. This analogy is identical for motorists in cases where toll facilities are the "only" way to get to a particular destination. In "choice" markets, the consumer can agree to pay a premium for a different bread, or if you will, a faster or more convenient path. The toll facilities that are "choice" facilities must provide a benefit to the user to entice the users to pay a toll. These benefits can be in the form of travel time savings, safety, convenience, and/or improved reliability. In the engineering design of these early highways, utmost attention was given to the drivers' safety and comfort largely because planners felt that was of key concern to users of the facilities.

History of Toll Facilities

The first toll facility built in America was the Philadelphia and Lancaster Turnpike Road which was completed in 1795. This private road was built to improve the horse and carriage corridors in and out of Philadelphia. Several other facilities in the 1800s followed this concept, and most of these were built exclusively with private funds. Throughout the 1800s, funding for transportation projects was left to local and state governments. Federal government involvement in transportation facility construction was introduced in 1893 by the Office of Roads Inquiry in the U.S. Department of Agriculture, forerunner of the Bureau of Public Roads.

Early Development of Toll Facilities

The first modern toll facility for automobiles developed in the United States was in Pennsylvania in 1940. The 160-mile roadway provided a link throughout the state and improved commodity flow throughout the entire corridor. The idea was used in several other states and additional facilities similar to the Pennsylvania Turnpike were developed. In retrospect, the Pennsylvania Turnpike was an excellent example of public-private partnerships. Fares collected from the turnpike allowed the construction bonds to be retired early and reissued for capital improvements to the road (5). Among the states following the trend of the Pennsylvania Turnpike were Massachusetts, Oklahoma, Florida, Maine, Ohio, Indiana, Illinois, New York, and New Jersey. Similar organizational structures were used in the development of facilities in these states throughout the 1940s and 50s. During this period, the organization of toll authorities allowed smaller states to raise highway funds by charging out of state motorists driving through their state. States like Connecticut, Delaware, and Maryland received funds in this manner (6).

The Interstate Era: Increased Government Involvement in Transportation

During this era of toll road construction, federal government funding of our nation's transportation system was limited. In the 1940s, a number of highways were set aside as military transportation corridors, but funding issued to these facilities were modest. The construction of toll facilities continued to increase until the onset of the Federal-Aid Highway Act of 1956 which reduced the need for more toll facilities in the short-term. The Federal-Aid Highway Act increased transportation funding drastically and is regarded as one of the most important laws ever passed regarding transportation. The act provided nearly \$25 billion for the construction of the National System of Interstate and Defense Highways, the system envisioned during World War II (7).

After 1956, federal involvement became a mainstay in the transportation industry and the highway construction. Because of this influx in funding from the federal level, and the focus on state-to-state travel, the majority of new toll facilities after 1956 were built within urban areas to serve demand that had not been met. The Interstate system was sufficient during this time for state-to-state travel, and increasing congestion in the inner city could be offset by new facilities. The Interstate system developed in this period of rapid highway construction was a toll free system built for the people of the United States. Initially for defense, the system grew to accommodate an increasingly mobile population of motorists. Response to congestion on the Interstate system was to increase capacity. In certain regions, increasing capacity lead to increased suburbanization of American cities and an increased reliance on the automobile for mobility within the new urban form created by the Interstate system (8).

Legislation of the 1980s

The United States began to emerge from the Interstate era in the late 1980s, as the Interstate system was nearly complete. Part of the evolution and development of the transportation system has included increased involvement of the public in making choices for community development. Several pieces of federal legislation have lead to an intensive public involvement process resulting in an increased importance of facilitating all travel modes and investigating environmental concerns. Largely due to the planning process, community involvement and public criticism of continued highway development became louder in the late 1980s. Alternative funding of facilities to enhance the transportation system was proposed during this time as a way to improve the flexibility to the long held policy of "free"-ways.

The Federal Highway Act of 1987 was the first government encouragement of toll-financed facilities at the federal level. This Act allowed eight demonstration projects across the country to mix toll revenues with state and federal funds on new projects (9). This was followed by the National Transportation Policy released in 1990, which emphasized "an increased reliance of user fees" (10) and provided the initial impetus for the evaluation of collecting tolls on the Interstate system.

ISTEA: Federal Interest in Tolling and Congestion Pricing:

Congestion within urban areas has been recognized as a problem long before automobiles were prevalent. One of the reasons automobiles flourished as they have is because they were seen as a symbol of freedom and mobility. Early toll facilities supported this notion of freedom and increased the mobility of the public. Throughout the past forty years, however, our transportation system has begun to change because of the continued demand on these facilities. The demand has reached a point where many cities have realized that they can not build their way out of congestion. Furthermore, the Clean Air Act Amendments of 1990 and the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) contain strict prohibitions on the addition of new highway capacity in areas failing to meet federal air quality standards. One author summarizes the plight of the transportation system well in this passage: "*we cannot build our way out of this (transportation and air quality) crisis, although more construction is needed. We must look at transportation on a more systemic basis, integrating it with land-use decisions, with air quality improvement, and with economic planning...*" (11) Spurred by concerns of air quality and increasing congestion in urban areas, ISTEA legislation liberalized the federal toll provisions, authorizing pricing on federal facilities for the first time under pilot projects.

ISTEA provided the impetus for these improvements through its mandate for congestion pricing pre-implementation projects. The stated objective of ISTEA is "the improved performance of statewide and metropolitan transportation systems through preservation, operational, and capacity improvements." It is the initial premise of these projects asserting that alternative pricing will encourage more efficient use of the transportation system.

Value Pricing in TEA-21

The current status of pricing projects is clearly stated in the initial TEA-21 summary developed by the U.S. Department of Transportation (12). The focus of the revised program is to continue the initial progress of ISTEA and increase the number of demonstration projects using variable tolls. The overall goal of the program is “to promote economic efficiency in the use of highways and support congestion reduction, air quality, energy conservation, and transit productivity goals”(12).

The Act provides further authorizations for the Value Pricing Pilot program, which was originally dubbed the Congestion Pricing Pilot program in the ISTEA legislation. The program will encourage planning by funding up to fifteen additional pre-implementation studies. One key element of this legislation is that any value pricing project under this program may involve the use of tolls on the Interstate System. Further development of the program is expected, but significant opportunities exist as a result of this legislation.

Further support for the use of tolls on the Interstate system was provided when, for the first time, reconstruction or rehabilitation of a free Interstate highway segment and its conversion to a toll highway is allowed on a pilot project basis. Up to three pilot projects have been authorized although at this time it is uncertain as to whether these funds will be used. The purpose is to provide for the reconstruction or rehabilitation of Interstate highway corridors where improvement costs exceed available funding sources, and work cannot be advanced without the collection of tolls.

STATE OF THE PRACTICE REVIEW

Toll Facilities

There are currently about 7,500 kilometers of toll roads in the United States (13). Twenty-four of the fifty states in the U.S. have tolled facilities. These toll roads, bridges, and tunnels are, to a great extent, financed by tolls through turnpike commissions and authorities, city and county operating authorities, and State Departments of Transportation. The various organizations that operate these facilities make for a complex set of relationships. The turnpike authorities are essential for financing constructing, and maintaining the Nation's toll facilities around the country. Figure 1 is a map showing which states currently have toll facilities.

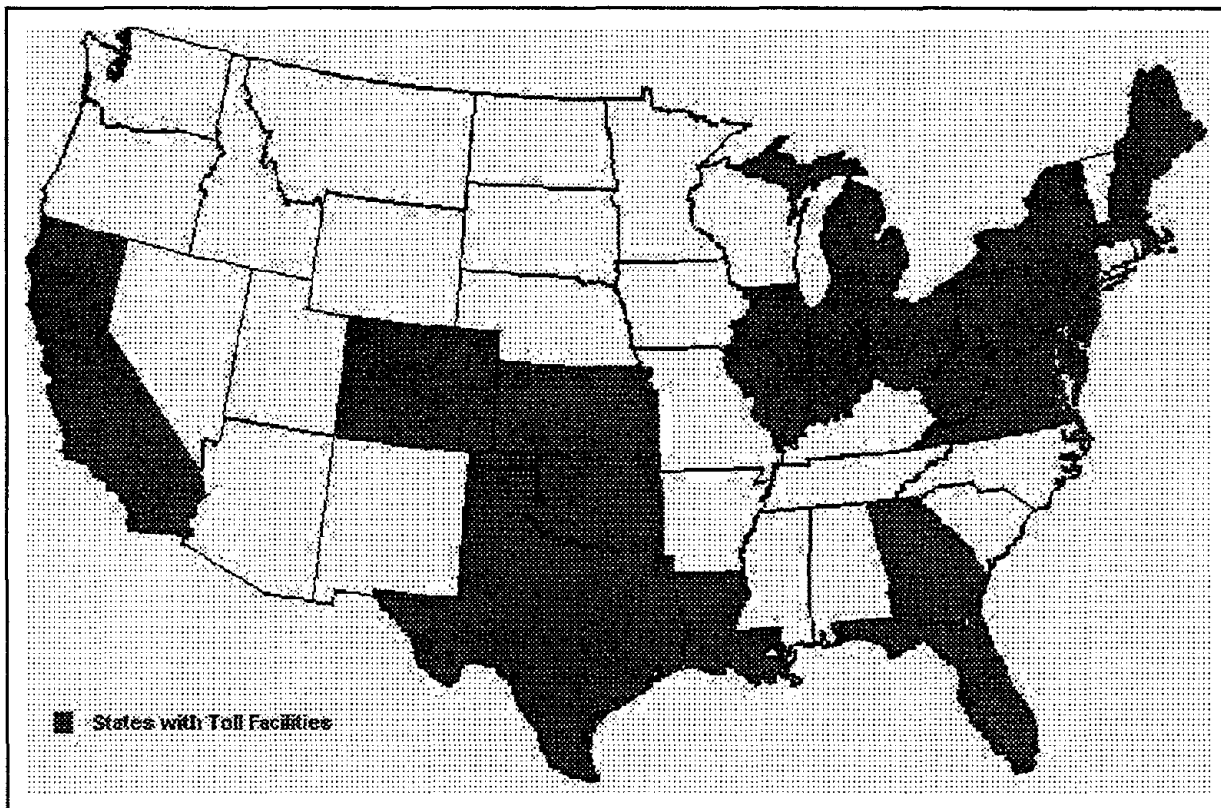


Figure 1. States with Toll Roads in the United States

Turnpike Authorities are active today in many states. Toll facilities are being looked to for providing an alternative to more traditional facility development. Toll facilities are unique because they can be developed with limited government involvement. This excerpt from the Oklahoma Turnpike Authority best describes how turnpikes operate as compared to state operated facilities.

Turnpikes provide a way to build and use roads now and pay for them as we use them. Turnpikes operate separately from the state financed roads. The facilities are built to supplement the limited money appropriated for highway construction and maintenance. The Authority receives no tax money to operate its turnpikes. Turnpike revenues pay all operating and maintenance costs for the turnpikes and pay off the bonds issued to finance their construction. Also, turnpikes do not receive motor fuel tax money generated by those driving on turnpikes, that is returned to the state-maintained roads. (14)

Toll Collection

Toll collection is performed in a variety of different ways. On the majority of toll facilities in the U.S., toll booths are used to collect tolls. These booths are configured in a variety of ways either for manual collection, automated collection techniques such as token or change baskets, and electronic toll collection. Automation at toll booths can be in the form of a change bucket or by using electronic toll collection. With the advent of Electronic Toll Collection (ETC), toll booths are becoming less attractive. The number of toll facilities with electronic toll collection technology has increased from 49 in 1995 to 77 in 1997 (15). This increase shows the growing acceptance of this Intelligent Transportation System (ITS) application as motorists are recognizing the benefits as they grow more comfortable with the idea. The transition to electronic toll collection has been a conservative one mainly because of the following factors (15):

- Public willingness to use the electronic toll tags have been mixed depending on the location. Some communities seem wary of the government via the “Big Brother” syndrome;
- The installation costs of electronic toll collection are not trivial. These systems require a significant amount of infrastructure depending on the facility type and current collection system; and
- Installation of these types of systems requires significant manpower at the supervising agency. Marketing of these systems, once implemented, is of critical importance and requires a significant amount of labor.

Toll System Structure

Toll structures are established to capture all users of the road in a way which maximizes the efficiency of operation. This structure largely depends on the type of facility and the available locations for toll collection. On bridges, toll booths are normally located on either side to capture the traffic using the facility. A bridge is a form of a barrier system which establishes a barrier that users must cross to use the tolled facility. Where the system is much larger, a ticket system is used. Prior to entrance to a ticket system, the motorist is issued a tag which establishes the time and location for the origin of the trip. The tag is collected at the destination toll booth and a set toll for the traveled distance is collected at the end of the trip. A brief overview of the two structures is discussed in the next section because of the challenges of the different systems impose on variable pricing.

Development of Toll Rates

Toll rates are typically set at a “optimum rate” which reflects maximization of revenue with the least impact on diverting traffic away from that facility. Toll roads that initially opened in the United States operated for years under the philosophy that they were providing the maximum service possible at the lowest possible cost in order to make the facilities politically palatable and acceptable to motorists. The acceptability of the toll to motorists is of key concern to the bondholders that are expecting a return on their initial investment. Most toll authorities must answer to these investors when changes are made to the operation of the facilities.

Toll facilities in many cases, were established to provide a facility that would eventually be turned over to the state once the debt on facilities were paid off. Trust agreements were initially set up with the statement that the facilities would operate until the deficiency of all debt and then would revert to the control of the state in which the facility was located free of charge. Over the years this has been resisted on many facilities and political pressures have been brought to bear in a few isolated cases to insure that the facilities became toll free once their debt was required. The Dallas-Fort Worth Turnpike in Dallas, Texas was an example of this type of relationship. In this case, the ability of the Authority to continue operating the facilities with a maintenance toll was overruled due to political pressure to adhere to the originally intended mandate of the trust agreement to turn the facility over to the auspices of state government when the debt was paid (6). In many states, the

expansion of facilities and the continued capital improvements program on the toll facility is organized under the original debt to continue the operation of the facility by the turnpike authority. In many cases, these capital improvements are planned based on the expected excess funds that are generated by the normal operating tolls.

The toll road industry has developed and continued its moderate growth by providing a higher level of service than parallel facilities. Tolls have been revised based on the need for additional income to satisfy debt service requirements, system maintenance, operating cost requirements for the facilities, and expansion of the agency's facilities. Consideration in setting toll rates is given by comparing service with the cost in terms of travel time and analysis of the sensitivity between alternative routes. In other words, travelers are more likely to react negatively to toll increases on short facilities with many competing routes than longer inter-city routes that offer a service with less competition (8).

Why Variable Pricing?

The traffic congestion on America's highways clearly shows that highways are a valued commodity. This is especially true where bumper-to-bumper traffic is typical during the peak hours of the day. As a valued commodity, the economic theory of supply and demand is applicable. As with almost every other industry where a supply and demand relationship exists, whenever the price of using some valued good does not increase when demand increases, that good will be in short supply (16). Supply will be exhausted if it can not be readily enhanced. Variable pricing is a way to introduce pricing which might improve the way in which motorists choose to use toll facilities. An increase in the price for a good normally reduces the demand for that good.

In a variable pricing scheme on a toll facility, the utilization of the road is improved by spreading the travel demand over the course of the day and reducing the peaking characteristics of traffic. This spreading of the peak period is accomplished by providing an incentive for motorists in the form of a reduced toll. Variable pricing would use at least one price change throughout the day to encourage this spreading. Variable pricing could take on many forms, the most dynamic and thorough of which has been dubbed congestion pricing.

Congestion pricing is a way of rationing space on roads, just like pricing is used in other sectors of the economy to ration scarce capacity. Congestion pricing would use the identified level of congestion on the facility to set the toll based on a predetermined rate. The premise is that congestion pricing will lead to cost-based decisions that will give travelers incentives to eliminate lower-valued trips, or combine them with other trips, to take trips at different times or by different routes, or to choose an alternative mode of transportation. Pricing also provides incentives for more efficient use of existing capacity and prices would provide more effective signals of the need for future capacity expansion, thus laying the groundwork for a more efficient and demand-responsive urban transportation system. Direct, variable pricing of roadways provide a much more efficient mechanism to allocate road space during the peak-period when the demand is much greater than the supply (4).

Throughout the course of this research, three guiding principles for the implementation of variable pricing have been used to focus the research and justify the conversion from fixed tolls on toll facilities. These principles are listed below followed by some discussion regarding each of the statements.

1. Current transportation pricing is not equitable and users are not charged the total costs.

How users pay for mobility is a key factor sustaining the continued growth of our dependence on private automobiles. Unpriced or free roads and inexpensive fuel prices mean it costs almost nothing to drive once a person has a car. This type of transportation pricing encourages use of roads, as motorists drive more, the cost per mile decreases, spurring higher demand. Similar to an "all you can eat buffet", once one pays the set price for sitting at the table, you may consume all you desire, the more you eat the higher the value.

According to the Congressional Office of Technology Assessment study, "Saving Energy In US Transportation" (1994), motorists pay only a fraction of the true costs of driving through user taxes. A third of the cost of building and operating roads is paid for out of property taxes or other local and state general revenues. User taxes cover only a portion of the (from 44-80 percent of total depending on the source and the indirect social costs that are included) direct roadway costs at the federal level and even less at the state and local levels (4,17,18,19). Most studies include socialized costs such as police, fire, emergency services, accidents, air and noise pollution, congestion delay, security of fuel supplies, and other "external costs" due to motor vehicle use. In summary, the pricing system encourages consumers to maximize vehicle use and inhibits the emergence of new services that might compete with private motor vehicle travel in niche markets. Effective management of transportation systems and their growing external costs requires reform of these price structures.

2. Operating agencies require a paradigm shift of maximizing the public benefit while improving efficiency of operations.

At this stage of growth in automobile travel demand, existing toll roads offer an ideal testing ground for alternative pricing. Many toll roads currently operate under congested conditions through many hours of the day. Reduction in throughput as a result of congestion, reduces the efficiency and attractiveness of a facility which slows revenue growth for the toll authority. Slow revenue growth makes it difficult to guarantee return on the original investment. This is particularly true of facilities that serve a commuter market and those that serve major metropolitan areas. Many agencies face increasing expansion costs to provide sufficient peak-period capacity which is prohibitive due to Clean Air Act Amendments and environmental constraints. Organizing the toll rate structure in a variable or time of day fashion will help alleviate existing capacity deficiencies and prepare a Turnpike Authority for future traffic growth directing traffic demand to the periods where excess capacity is available.

3. Toll road pricing could be manipulated to further State DOT TSM goals

One of the issues that underlies the way a toll authority operates and attracts customers is the necessity to succeed and provide transportation that motorists are willing to pay for. The nature of the operation and the competition by mode and route is complex. Improvements in transportation should be a primary goal of any change in toll price structure. In other words, a necessary condition for making any transportation investment or adopting any transportation policy is that the performance of the transportation system should be better able to service the transportation needs of the public. If this takes the form of improving efficiency by reducing demand during particular hours of interest, then the policy has been effective. Providing users an incentive to reduce peak hour congestion will help State DOTs by improving the balance of travel demand over the day.

Transportation agencies utilize demand as an indicator of transportation needs. A goal of many State DOTs is to meet the needs of the public in a safe and efficient manner. The process which is currently used to match the needs is somewhat flawed. Transportation planners determine the size of a road by what is needed to meet the peak-hour demand. If that demand can be reduced by spreading the demand by using variable tolls, fewer roads and smaller roads could be used to provide the same public service. Under this scenario, environmental goals may be more attainable by reducing the periods and length of congestion.

BARRIERS TO IMPLEMENTATION

The array of potential barriers to implementation of a variable pricing scheme on a toll facility are numerous, but tend to fall into a number of general categories. There are three congestion pricing projects operating in the United States as a result of the initial round of ISTEA legislation which will provide a significant amount of background information for identification of problems faced in the onset of variable pricing on a facility. Additional discussion regarding the implementation of a time of day or variable pricing scheme on a specific toll facility will be undertaken.

Technical

ITS is fostering a revolution in surface transportation by allowing information to be enhanced in virtually every part of our transportation system. Toll facilities are implementing ITS to continue providing optimum service to users. One ITS application of particular importance is electronic toll collection. A few years ago this was not economically feasible because of the cost of such devices. The magnitude of this barrier has been reduced due to the production of lower cost electronic devices that are commercially available. These devices permit high speed automated collection of tolls, parking fees, and transit fares.

Electronic Toll Collection (ETC)

Electronic Toll Collection (ETC) is the use of various technologies to allow automatic in-lane toll collection. This automated process is completed by reading electronic transponders installed on the vehicle. This has been done with relative simplicity in many communities for speed data collection. The tags are read by overhead antenna that can access the transponders and deduct toll costs from a prepaid account. In many applications, this type of toll collection has been installed in lanes adjacent to the existing manual toll collection lanes to handle this type of toll collection. A configuration used in Houston, Texas is shown in Figure 2.



Figure 2. ETC Lanes Separate From Manual Toll Booth Lanes

The arrangement shown provides a premium service to those with AVI transponders. The public support for the AVI only lanes have been strong where AVI transponders have been accepted. The overhead sign structure shown in the figure holds the antenna and supporting apparatus for communication with the transponder. Creating "ETC only" lanes provides an opportunity to serve customers such that they do not have to stop and pay cash at a toll booth. With ETC, a manned toll plaza is not even a requirement to collect tolls. The overhead hardware for the ETC system on the Hardy Toll Road in Houston is shown in Figure 3.

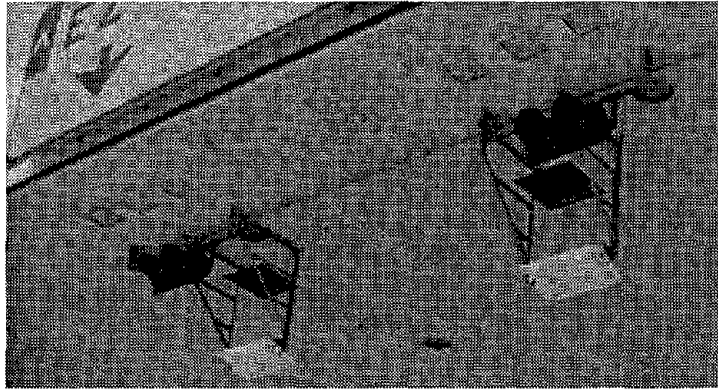


Figure 3. ETC Overhead Apparatus

Electronic toll collection can also be combined with existing lanes to improve toll booth operations. This has been done a number of different locations where expansion of the toll booth facilities were unnecessary or prohibitive. An example of a combined lanes setup in Houston is shown in Figure 4.

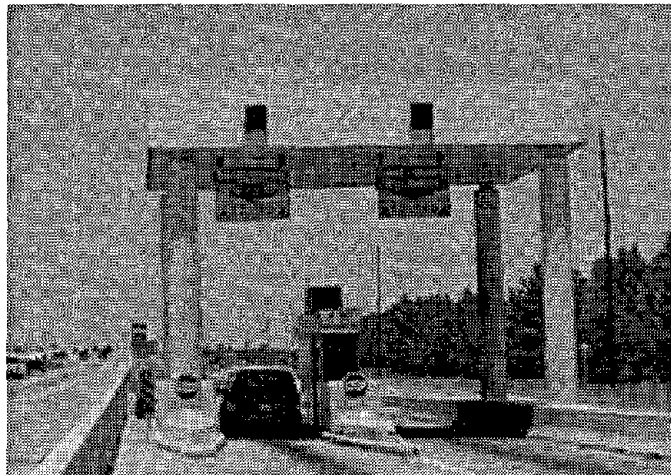
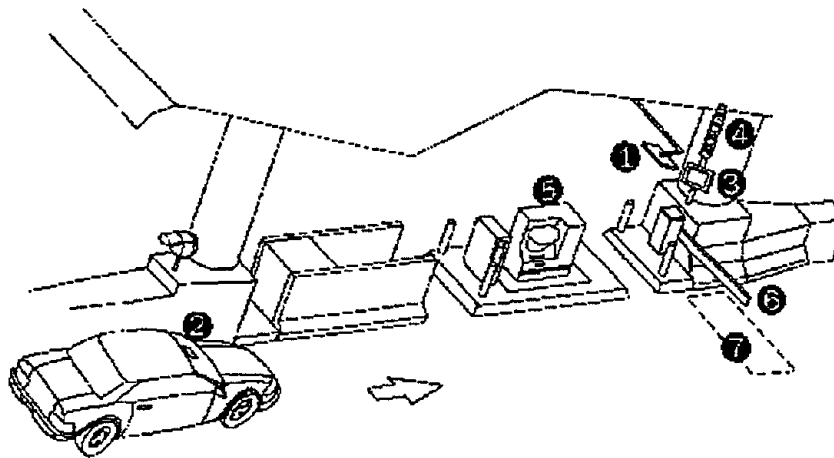


Figure 4. ETC Lanes Combined with Manual Toll Booth Lanes

Toll collection using the ETC is completed in both lanes in this instance. A more detailed schematic from the Lee County, Florida electronic toll collection program is shown in Figure 5 on the next page.



- | | | | |
|---------------------------|----------------|------------------------------|----------------|
| 1. Overhead antenna | 2. Transponder | 3. Toll display | 4. Lane signal |
| 5. Automated coin machine | 6. Toll Gate | 7. Inductive loop classifier | |

Figure 5. ETC Lanes Combined with Manual Toll Booth Lanes (schematic) (20)

For an ETC implementation to be effective, reliable, and achieve maximum throughput and customer acceptance, three major components are required:

- Automatic Vehicle Identification
- Automatic Vehicle Classification
- Video Enforcement Systems

Automatic Vehicle Identification (AVI) uses a radio Frequency (RF) device located in the vehicle to uniquely identify the vehicle to the toll equipment. Various systems are being used in toll facilities for this purpose. Figure 6 shows the AVI tag used by the Lee County, Florida (LeeWay) system. This small transponder contains information about the monetary balance of a “blind” account which is communicated to

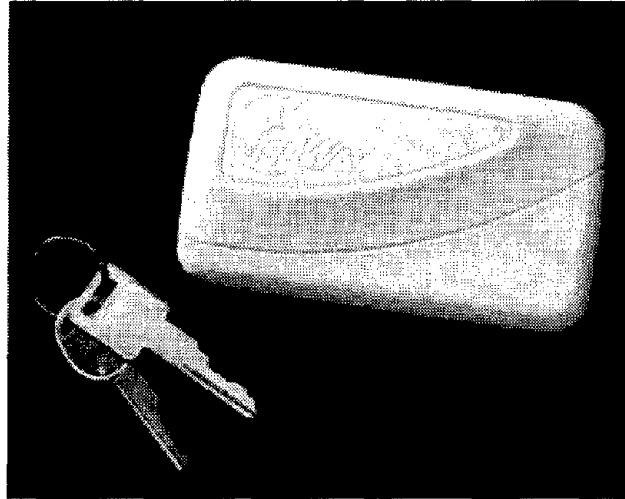


Figure 6. LeeWay AVI Transponder for ETC

the AVI reader. Once a vehicle passes the AVI reader, a fee is reduced from the balance. Automatic Vehicle Classification (AVC) uses various sensors in and around the lane to determine the type of vehicle so that the proper toll can be charged. Video Enforcement Systems (VES) capture images of the license plates of vehicles that use the facility without a valid tag so that the owners can be identified and notified that a toll is due. All of these systems are tied together by what is commonly referred to as a "lane controller".

The lane controller is a computer that receives its inputs from the AVI, AVC, and VES equipment. Usually, there is one lane controller per lane which coordinates the activities of all other lane equipment and creates the actual transactions which will be used to charge the customer's toll. The lane controller is also the device that maintains a list of valid tags which it uses to validate the information provided by AVI. In addition to all this in-lane equipment, each toll plaza usually has a host computer which collects the transaction information from the lane controllers and is in communication with a central host computer which collects data from all plazas so that the data exists in one consolidated location. The plaza host computer is also used to transmit to each lane controller the list of valid tags which is used for AVI validation.

Putting all this technology together can be a daunting task. A "one size fits all" philosophy can not be applied to integrate this technology into the existing toll environment. The ETC system must be carefully designed for the jurisdiction. It is also important for coordination to occur with nearby agencies to insure interoperability of the systems with one another. This is critical especially where motorists can encounter different jurisdictional facilities in a short distance, perhaps during a commute. The Inter Agency Group is a Delaware-New York-New Jersey consortium that is leveraging resources to insure a seamless ETC system is in place for their region. This consortium is proving to be a good model for other agencies that are working toward an efficient application of an integrated system. The State of Florida and Lee County, Florida have also done a good job of coordinating development of these systems for the benefit of the motorist. The organization of the Florida tags are especially unique because the tags maintain account cells for each of the jurisdictions on one tag, allowing users to establish two or more accounts on one tag. This will also improve the distribution of the tags throughout the state (21).

Barrier Tolls System

Electronic toll collection is nearly a prerequisite for implementation of a variable pricing scheme on a barrier toll facility. There are a host of issues surrounding adequate toll collection and toll booth performance that necessitate a simple price for users. One particular issue of importance is the number of times which a motorist may have to pay on their trip. Varying tolls by time of day will confuse some motorists and dwell times at the toll booth will be affected. Labor issues are also important considerations in setting the price because of the opportunity for theft that variable pricing presents. Token systems for commuter discounts and automated toll collection would have to be revisited to maintain the price structure which allows these types of arrangements. Non-electronic automation of toll collection will have to be modified significantly to meet the needs of the customers.

The barrier system may be easily implementable by targeting one section of the facility that is significantly congested. This type of arrangement may be spread over several entrances to the facility to increase the equity involved, affecting all users throughout a particular section of roadway by time of day.

Ticket Tolls System

The ticket toll system has an advantage over the barrier tolls system because the payment is handled in one location for a trip. The magnitude of an increased service time at the toll booths is not as significant because of the location of the toll booths, i.e. only exiting traffic has to stop at a toll booth, mainline traffic does not have to stop. The ticket system would have to recognize the periods of travel and length to identify off-peak vehicles that may be allowed to receive discounts for traveling during a specified period. The variable pricing could be burdened by unfamiliarity with the system and complexity of the price structures required.

Political/Public

Resistance to taxes, distrust of government, and obsolete infrastructure financing strategies dependent on state gasoline taxes—in many states constitutionally restricted to highway spending—make it likely that public highway and transportation agencies will increasingly yield to privately financed, user fee oriented systems (22). Toll authorities are set up as public agencies that are financed by offering bonds to the public. The toll authority is managed or reviewed by a Commission appointed by the state's Governor that normally includes persons with a keen interest in transportation issues. In most cases, the agencies are directed with public oversight and involvement in mind because of the nature of the service that is provided. The agencies are committed to serving motorists with a high quality service, but also committed to maintaining a prosperous system for the bondholders. The political issues involved include the relationship between the Governor and the public. The Governor has a responsibility to the users of the facility to insure that the toll facilities serve the public interest and the toll is politically palatable. There is also a necessity to follow policies established by the government to improve the community and the State. Political interest and government policy must be harmonized to insure the public is agreeable to any changes made in a toll facility.

Many toll authorities operate independently from the State Department of Transportation (DOT). Although largely independent from the State DOT, the policy considerations of the Toll Authority mirror that of the state financed and operated roads up to a point. The main difference is the toll facility must offer a return on the original investment. Thus, the Toll Authority works within the organization of the agreement with the bondholders to operate a financially successful system. This is the key paradigm in the operation of toll facilities. The basic philosophy of many toll facility operators in the United States is to place an emphasis on customers, providing a premium service for a price. For political reasons, and to encourage use of the toll road, facility operators endeavor to keep toll rates at minimum levels to cover debt service and operating costs. Even

in congested conditions, the public may be unwilling to accept higher fees for an improved service, largely because in many cases the entire transportation system is not established to handle motorists that choose not to accept the price increase (23).

Privacy

Privacy is more of an issue of electronic toll collection than of variable toll pricing, but it is of concern in communities where ETC is being introduced. One way to handle the privacy issue is to use a “blind” ETC system. A “blind” ETC system would allow users to set up accounts that are pre-paid, allowing tags to be used interchangeably. Special consideration during the design of an AVI system should consider the invasion of privacy as an issue of concern for the citizens involved in the program. Any design for an ETC system should effectively reduce the potential for invasion of privacy concerns. It seems that no matter what assurances are made that a certain portion of the public will be naturally skeptical and will not believe that the safeguards are adequate.

Equity

Any time you try to take away personal freedoms in this country, people get emotional because freedom is one of the cornerstones of this great country of ours. Pricing a road would place an additional requirement on citizens for using a freeway that was created with federal taxes. The concept of paying for a facility that has been paid for previously has been continually argued against. Equity issues are of primary consideration as pricing of facilities raises questions regarding social and economic boundaries. Additional comparison of other groups can also be made to identify impacts.

These groups include:

- Single occupant vehicles and carpool vehicles,
- Automobile drivers and other travelers (transit, other non-auto)
- Rural citizens and city dwellers, and
- other distinguishable groups based on geographic or political boundaries.

In the case of the San Francisco Bay Bridge variable pricing project, tolls were proposed to increase in the peak direction to inhibit demand and improve operations. Political boundaries were the main focus of these toll increases and public outcry was intense once the proposal was released. The tolls were never increased because the increase would only affect users from the east side of the bay, in essence discriminating across political and geographic boundaries.

Public and market acceptance of a shift to fuller marginal cost pricing of transportation will follow only if users who experience higher user costs gain improved system performance. The increased cost must be sufficiently warranted. To deal with equity issues for the lower income groups, the array of alternatives and transportation choices must be expanded. Public information and marketing emphasizing positive attributes and a customer service orientation will insure that all market groups are adequately represented in the program.

One common argument with respect to equity is the concern that lower income workers will be “priced off” the facility. This argument is backed by the reasoning that there is a greater propensity for this group’s employers to be less flexible with respect to work start time. This would “target” the lower income group, making this type of pricing a regressive tax. The concern for this group is disputed by the data collected on the SR 91 project, which has shown that it is “incorrect to conclude that higher priced lanes will only benefit high income travelers” (24).

Agency Restrictions

The financial backing of toll authorities is organized by bonds that establish a certain amount of capital for the purpose of building and operating the roadway. Most toll authorities do not receive appropriates of tax money from the government to support the operations. Although bonds are sometimes met with credit from the State. To insure the toll authority meets its expected return on the investment for the bondholders, an agreement between the agency and the bondholders is made. One of the agreements that is made in the contract agreement is the nature of the coverage ratio of a bond which requires the toll authority to meet certain goals throughout the schedule of the payback. Thus, innovative approaches are required to maintain operating revenues during these projects. In many cases, strategic partnerships must be formed among state DOT and toll authority officials.

Bondholders are naturally conservative. In some cases, additional restrictions are placed on the agency to maintain a more steady investment return. The New Jersey Turnpike Authority has an agreement that they cannot make any specific operating changes that will result in a one percent or more change in revenue without consulting the bondholders (25). The bondholder uses a transportation consultant when changes are suggested. The review process for any change expected to result in the one percent increase or reduction in net revenue must be agreed to in principle by the bondholders. This arrangement is very restrictive and precludes widespread changes in tolls.

SURVEY DESIGN AND RESULTS

In order to provide current information and to develop an understanding of the current state of the practice, a survey of some of the state and private agencies operating toll facilities was conducted. The survey included a series of phone calls and an oral survey administered over the course of the research. Prior to each survey, additional research was conducted to outline the State DOT goals and the toll facility agency's operating standards. The link within this evaluation was to identify any conflicts which might be overlooked and to possibly identify variable pricing as a transportation system management tool. The survey used for this evaluation of current practices is included in Appendix A.

Additional anecdotal information was extremely helpful in gaining an understanding about the operating agencies' perspectives on toll rates and their operations. There was a great deal of interest with respect to the prospective projects organized among the country, although a lack of information of ongoing variable pricing events was somewhat common throughout the individuals surveyed. This is probably due to the fact that the federal program only chose one toll authority for the first round of pilot projects, and toll authorities were the focus of this survey. The federal program involvement for congestion pricing symposiums only included agencies which were involved in the initial pre-implementation studies, of which Lee County, FL was involved the only one.

Follow-up discussions were conducted with several of the participants once additional contact was established. These follow-up conversations allowed further exploration into the type of barriers which preclude the use of variable pricing strategies and other pricing techniques to accomplish transportation system management objectives and meet the goals of the State DOT.

Profile of Survey Respondents

A total of twelve agencies were contacted, and ten accepted requests for interviews. Obtaining a high response rate required a great deal of persistence. Of the nine agencies that responded, five were from the northeast and two were from the midwest. These agencies serve a diverse mix of traffic. Most serve urban areas, although four agencies also have rural sections of toll as well. Some of the respondents noted that they also serve a large proportion of commercial vehicles with some serving as a primary route for truck traffic.

Summary of Responses

Figure 7 provides a summary of the multiple choice survey questions for comparison purposes. The only qualitative question amongst the four shown was the prevalence of congestion question. The survey was concerned with perceptions rather than actual data, and therefore, should be taken as such. The single variable price structure currently in use was the SR 91 project, which is also the only solely electronic system. The SR 91 project could be considered a barrier type of toll structure because the users have only one choice of entrance and exit.

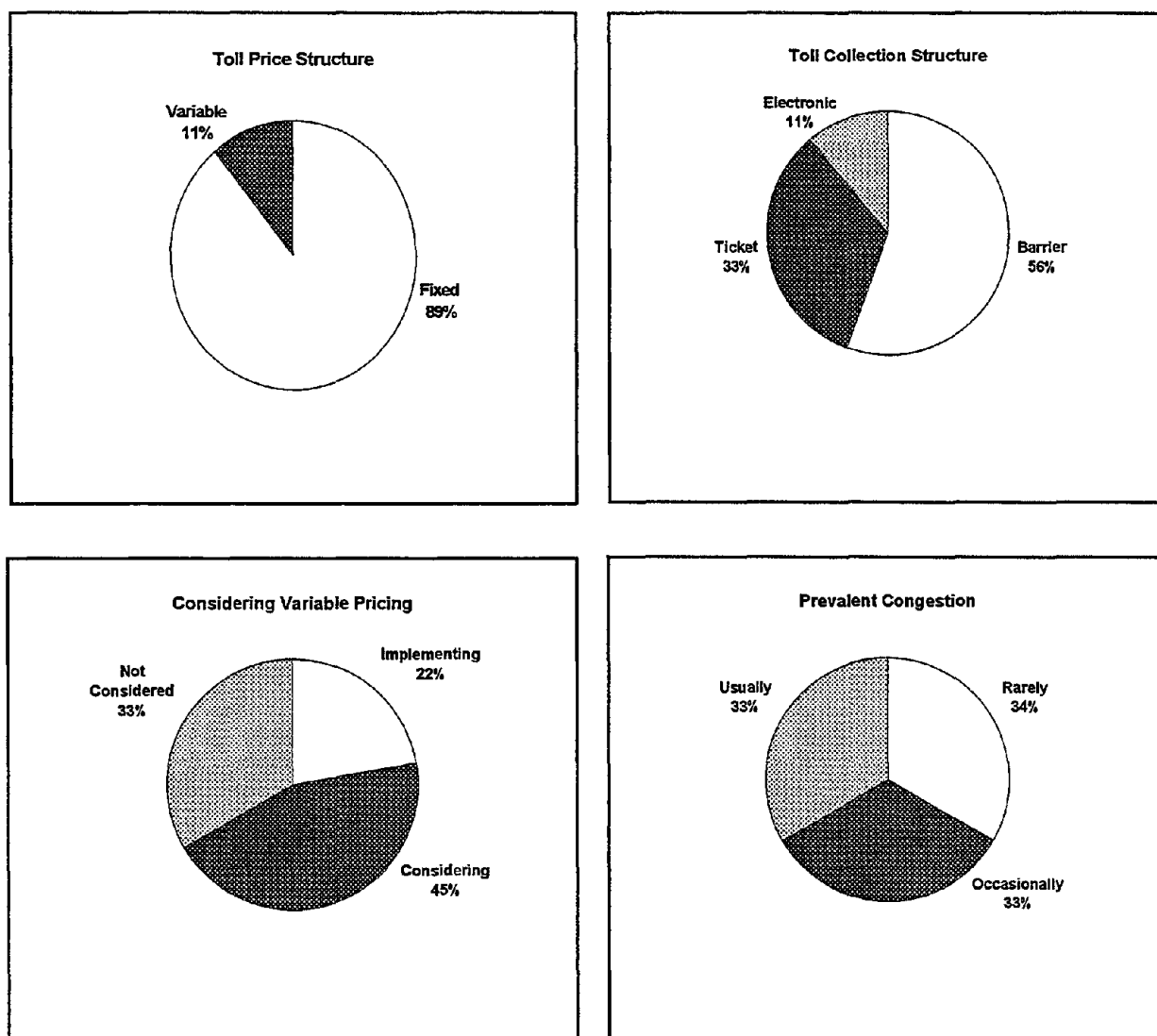


Figure 7. Responses to Multiple Choice Survey Questions (n=9)

Consideration of Variable Pricing

The participants were queried as to whether their respective agencies had considered any form of variable toll or congestion pricing strategy. The responses were surprisingly high for the group, with two-thirds responding that they were either implementing a variable toll structure or had considered it at one time. The various alternative pricing schemes considered by the different agencies contained a lot of interesting ideas. For the most part, these variable pricing schemes were designed to reduce congestion on the facilities.

Discounts for Toll Users

Figure 8 provides some insight on the number of agencies that currently have some sort of discount for specific users of the facility. The most prevalent discount is provided for commuters. This discount is a marketing tool designed to maintain a certain level of frequent users on the facility. The commuter discount is sometimes designed as an integral component to the AVI system (Lee County, FL and California SR 91) as the AVI is conducive to a complex pricing strategy which allows more levels of toll charges between users. The commercial trucking discount is a proposed discount program which will be discussed in detail in the next section of this report. At the time of this publication, the implementation of this program is imminent pending authorization by the Governor of the State.

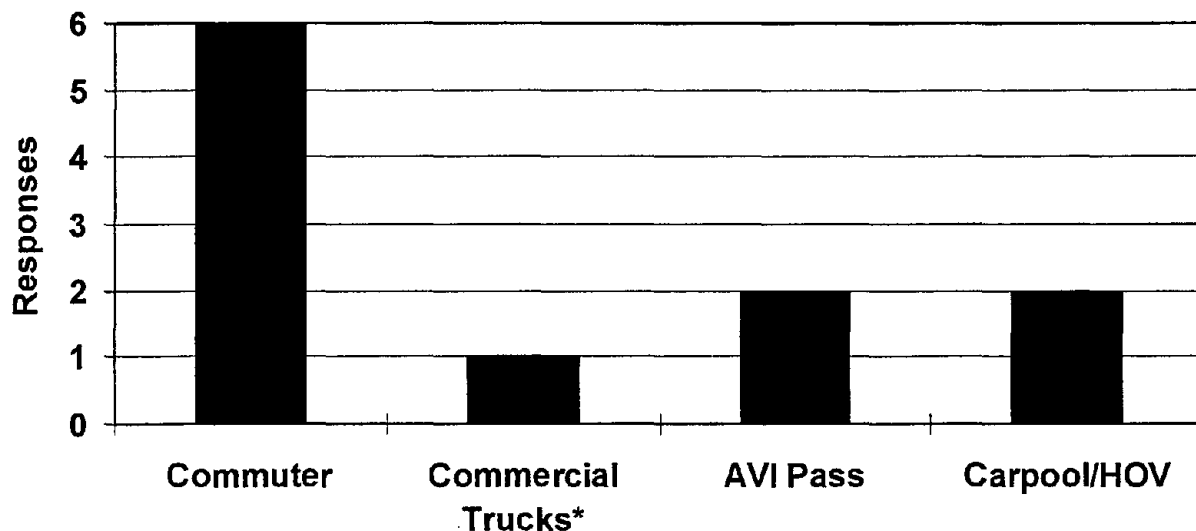


Figure 8. Discounts Available for Toll Users (n=9)

Perceived Barriers to Implementation

The perception of implementation barriers of variable price tolling is key to this research. The survey question detailing these issues provided several choices for responses. The surveyed individual was asked to identify as many barriers as they could think of. Figure 9 shows the responses that were recorded. The most popular concerns amongst the choices were public and political concerns and revenue restrictions. One of the respondents considered the political/public response a non-issue because of the relationship that exists between the toll facility and the local political officials.

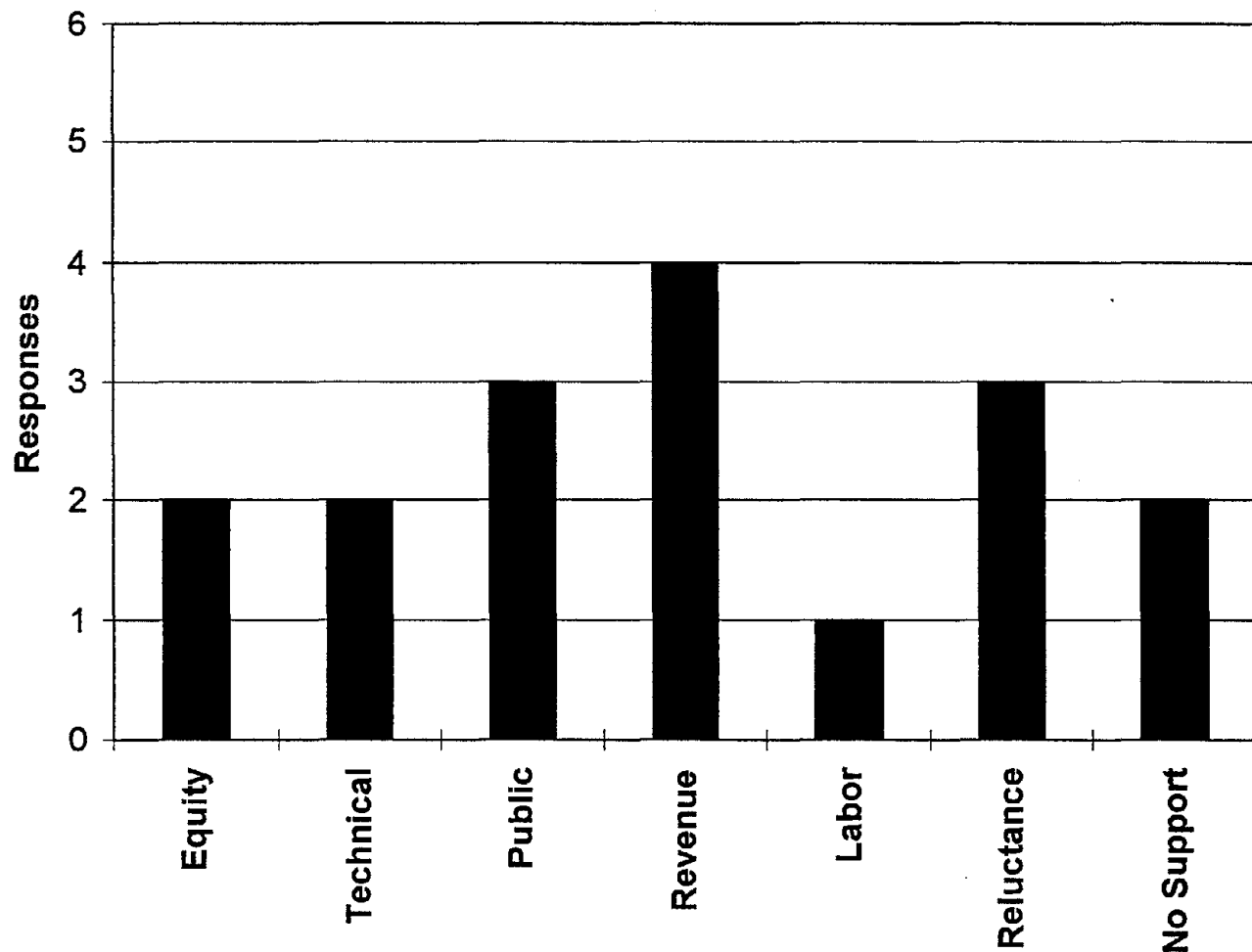


Figure 9. Perceived Barriers to Toll Changes (n=9)

Revenue restrictions are key in many locations where bond indebtedness is a priority issue. Many toll authorities are severely restricted by their bond service agreements. Many toll authorities use toll rates for ten to twenty years before requesting an increase. The process for changing tolls is extremely complex, and it seems that the complexity increases as the number of users and the increased governmental involvement in the project increases. Politics is a key issue with respect to toll rates in many locations.

Reluctance to change is a significant response, because it shows a lack of perceived importance to reach transportation system management goals. In areas without congestion, variable pricing may not be necessary at this time to improve traffic operations throughout the day. In these cases, it is important to identify longer term concerns which may be not be as clear, but are still important. Organizing a price structure when it is less controversial may be an advantage for the toll authority. The complexity of such a system could be limited to certain periods of the day, but should be considered for the future.

Equity issues are of importance not only for the toll authority, but at the national level. The federal outline for pre-implementation projects maintains that equity must be a key criteria evaluated during the course of an analysis.

Technical consideration was only a minor obstacle identified by the group of agencies surveyed. The respondents pointed to an increased reliance on electronic toll collection and even public support of such programs to reduce congestion at toll booths. One respondent said *"the technology that currently exists is moving more people towards (variable pricing)"*.

Labor is of concern because of the number of employees that might be replaced as a part of ETC. When asked about this issue, one respondent noted their agency's reduction in hiring new employees for toll collection: *"we are reducing our toll collection workforce naturally through retirement"*.

APPLICATIONS OF VARIABLE PRICING PROJECTS

This section of the report contains a review of variable pricing projects. Two of the projects, (Lee County, Florida and Harris County, Texas) discussed included toll facility price fluctuation, the third (State Route 91 in California) was a newly constructed facility that was introduced as a variable toll facility.

California State Route 91 - Orange County, California

The final evaluation study for the SR 91 Variable Toll Express Lane Facility was completed in January 1998 (24) with the collection of traffic volume, occupancy counts, and speed data assimilated along with information on transit and ridesharing. The researchers evaluated many different issues associated with the development of the toll facility. The new four-lane toll facility was built in the median of an existing ten-lane segment of SR 91. The ten-mile section provides users with an alternative to the main lanes for a fee.

This project is unique because of the public-private arrangement between the developer of the SR 91 project and the State of California who leased the right-of-way for the facility. The lease gives the developer of the road, the California Private Transportation Company (CPTC), thirty-five years to return a profit to its investors, after which the facility is turned over to the State. The CPTC recently released its annual report, which cited travel time savings by Express Lane users in the range of 20 minutes per 10-mile trip, as well as responses from the most recent public opinion surveys. Results indicate that the project is viewed favorably by 65 percent of Express Lane users, 62 percent of the free HOV-lane users, and 53 percent of the main-lane drivers.

The California State Polytechnic University (24) study reported that since the opening of the Express Lanes, average weekday traffic in the lanes has increased from about 8,000 to just under 30,000 vehicles, with small corresponding increases in traffic on the main lanes. Additionally, daily HOV-3+ traffic on the Express Lanes has steadily increased to over 5,000 vehicles (or 20 percent of total Express Lanes traffic), which, according to CPTC, is a new record in Southern California. Initial concerns that the Express Lanes would only be used by those in the highest income bracket have not materialized, as researchers have found only a weak relationship between income levels and Express Lane use. "Although toll revenues do not yet cover total annualized facility costs, prospects of becoming profitable in the long run seem promising" (24).

LeeWay Variable Pricing Project - Lee County, Florida

Lee County, in cooperation with the Florida Department of Transportation and the Federal Highway Administration has undertaken an implementation project making use of the revenue reserve fund provisions of the Congestion Pricing Pilot Program. The revenue reserve fund provides the Lee County Toll Authority (LeeWay) with the opportunity to maintain debt service coverage for three years through the use of federal funds while implementing the variable toll scheme is used. The project was initiated at the local level by a Lee County Commissioner that believed in the concept and championed the issue through the political and bureaucratic processes.

The purpose of the project is to study ways of using existing roads more efficiently, thus reducing the demand to build new roadways (26). The study will also evaluate the effectiveness of variable tolls for use as a model for other communities. Tolls will be reduced on the shoulders of the morning and evening rush hour peaks to flatten the peaking of traffic. Electronic toll collection facilities have been installed to assist the toll collection and discounts (50 percent discount) are only given to those with transponders. Rush-hour motorists will be offered a 50 percent discount if they traverse the bridges during the shoulder of the peak period. At all other times, bridge tolls will remain at the \$1.00 level established in 1995.

The Lee County project has pledged to maintain the coverage ratio on the bondholders investment by receiving help from the federal, state and local governments to establish a revenue reserve fund. The revenue reserve fund will supplement lost returns that insures existing revenue streams would not be jeopardized by the adoption of these pricing differentials. The start date of July 28, 1998, has been set by the project manager in Lee County, and the pilot program will operate for three years.

New Jersey Turnpike Commercial Pricing, New Jersey

The New Jersey Turnpike Authority (NJTA) is preparing a plan to implement variable pricing on commercial truck traffic based on the time of day. The plan is to entice commercial vehicle operators to the off-peak by offering discounts that are likely to change scheduling of trucking companies. *"The Turnpike Authority plans to offer toll discounts ranging from 7.5 to 15 percent to trucking firms with Turnpike charge accounts that travel outside the height of the morning and afternoon rush."* (27) The Turnpike Authority planning department expects that this will encourage both a shift of traffic from the peak to the off-peak as well as additional traffic on the facility that was using other routes because of the existing tolls (25). The NJTA is structuring the discounts to encourage a specific amount of use and the discount is regressive as the use of the facility increases. The companies who pay \$50 to \$200 a month in tolls will receive a 15% discount for off-peak travel. Those with a \$200 to \$500 a month bill will receive a 12.5% break, and those with more than \$500 a month in tolls will receive a 7.5% discount. This discount structure is sensitive to the constraints of the Revenue coverage agreement between the bondholders and the Turnpike Authority and was structured to limit the potential for a large decrease in revenue.

Hardy Toll Road Reduced Rate Program - Harris County, Texas

The Hardy Toll Road is a radial route that extends 21 miles from serving north Houston parallel to Interstate 45 from the Houston Intercontinental Airport to Interstate 610. Actual traffic and revenue experience on the Hardy Toll Road fell short of initial forecasts. In January 1990, the Harris County Commissioners Court approved a 90-day test program designed to encourage higher midday travel on the Hardy Toll Road. The plan was to improve the usage of the facility by reducing the tolls during the midday. The peaking characteristics on this facility are significantly large, with up to 25% of the traffic during the entire day using the facility during the peak hour (28). The toll authority attempted to attract additional midday traffic to the toll road by offering a 50 percent discount to all two-axle passenger cars from 10:00 a.m. to 2:00 p.m.. Discounts were only allowed at the two mainline toll plazas during the weekdays only. During this period of reduced tolls, the automated tolls were replaced by manual collection to avoid overpayment.

The results of the study were significant. The Hardy County Toll Road Authority reported that total traffic during the four-hour "reduced toll" period increased by 20 to 40 percent during the test, most often hovering just above 22 percent. The peak period impacts were not available from the study analysis that was published by the Harris County Toll Road Authority. Additional contact with the HCTRA was initiated to gain further insight on this variable toll application, but the information was not received in time for inclusion into this report.

Summary of Applications

Based on the findings of this research, the use of variable pricing on toll facilities is still in its infancy. The existing and planned applications are each unique in its implementation scheme. The goals of these projects are largely the same, to improve the peak period of operation on transportation facilities that are (or will be) burdened by traffic congestion. This is accomplished either by providing an incentive to motorists (and or

commercial truckers) who are flexible and can choose a time of day or a penalty for travel during the peak periods. All of these pricing schemes are independent of the type of congestion that is on the adjacent facilities, although the SR91 sets its price by considering the level of demand on the alternative facility by time of day and day of the week. A summary table of the surveyed agencies is included in Appendix B.

Conclusions

The following conclusions are made from the applications reviewed for this research:

- **In the presence of careful planning, variable toll pricing can be a market success.** SR 91 was the first evidence that variable toll pricing is a worthwhile endeavor. The facility provides motorists with a choice for increasing their relative mobility which has been a key selling point for the project.
- **Public relations and marketing are important to the success of the projects.** Public involvement in the project development stage of an undertaking such as this is a good way to begin to create acceptance with the community. Marketing design should focus on clearly communicating the benefits of the variable toll pricing.
- **Community leaders should be involved to spearhead eliminating financial and political barriers.** It is important to get political leaders within the community involved to initiate contact on the local and state levels. Securing funding to match the federal monies is a crucial step in project development.
- **Congestion is not absolutely necessary for variable pricing to be politically palatable.** Lee County, Florida's variable toll system is scheduled for implementation where new capacity has been provided to serve peak hour demand. The initialization of the pricing structure establishes a status quo which can be maintained and updated with future toll increases.
- **Alternative schemes for commercial trucks are being pursued for variable toll pricing and these schemes can be organized to fit under the existing bond provisions.** Variable pricing for commercial traffic should improve traffic flow during the peak periods by enticing trucking companies to schedule truck usage during off-peak periods. This unique approach to improving the transportation system is receiving a vote of support from the local press for being a win-win for commuters and the trucking companies alike.
- **Electronic toll collection is not a prerequisite for implementing a variable toll pricing scheme.** The Harris County Toll Road Authority used manual toll collection during the off-peak. This strategy allowed the collection to operate without introducing an excessive amount of delays at the toll booths.

IMPLEMENTATION STRATEGY

A strategy to assist jurisdictions in the conversion from fixed price toll facilities to variable pricing is presented in this section. As discussed in Section four, there are many barriers surrounding the implementation of variable pricing and additional barriers related to the conversion of fixed price facilities because of the existing status quo and reluctance for change. A listing of the steps for converting a fixed price toll facility is provided below.

1. Develop Mission Statement - What are you trying to accomplish, and why are you doing this? - A mission statement is important in any new endeavor to define the goals to be achieved. It is important to be focused on the positive aspects and the motive behind the policy. Variable toll pricing can accomplish many different approaches depending on the scope and the magnitude of the program. This could be as simple as developing a price structure that will (either in the future or present) allow the managed facilities to operate more efficiently. An example of a mission statement and some general justification is included in the next section.

One special policy consideration to contemplate when developing the goals is whether or not the current operating philosophy of the toll authority is really being satisfied if the authority allows congestion to occur on the fixed priced facility. An evaluation of the State DOT goals can also be used to compare with the toll authority operations. Specifically, TSM and TDM measures should be considered.

2. Evaluate policy considerations that exist which will prohibit variable pricing. One of the critical issues of a variable pricing program is the ability to implement a system based on legal or legislative constraints. The desired pricing structure must be agreeable to the public officials (via legislation) and legal within the laws of the land. In certain cases, legislators have placed restrictions on the collection of tolls that may discriminate against a certain type of user. Variable pricing could be considered discriminatory towards travelers who are unable to shift their travel times. Similarly, where toll facilities serve as boundaries between the communities (San Francisco Bay Area Toll experience) political issues and fairness can be the stumbling block of the entire plan.

Due to the original agreements of the tolling agency with the bondholders, restrictions may be placed on the type of tolls that are allowed. Bond provisions were found to be similar among the agencies that were surveyed as a part of this research. The constraints imposed by existing agreements might be circumvented by developing new agreements in periods of system rehabilitation or when new bonds are let. The toll authority agreements are crucial because flexibility in the price structure is crucial for the feasibility of the program. Commuter discounts are frequently used by tolling agencies to encourage use of the facility by reducing the price. This policy is counterproductive from a demand management standpoint but is effective from a marketing standpoint for the toll facility. This type of relationship is consistent with the paradigm shift that is necessary to improve the operational efficiency of toll facilities.

3. Develop an understanding of the barriers and constraints of changing toll rates. The growth of electronic toll collection will reduce the magnitude of the technical barriers that a tolling agency faces in implementing variable pricing. Five years ago, ETC was untested and transportation officials were uncertain of the reliability of these systems in this type of environment (high speed recording, various environmental conditions, etc.). Today, these systems are used in many locales across the United States. Penetration of the commuter market is greater than 70% on some facilities (29) and this has greatly improved toll booth operations.

Another barrier to conversion is dealing with the occasional user, or the non-ETC motorist. Conversion of the

existing equipment may be difficult for some agencies. In Lee County, Florida, the toll booths will continue to be utilized even for the electronic toll collection. Vehicles will slow to 5 m.p.h. through the toll booth, the transponder tag will be read and the gate will open if sufficient funds exist on the toll tag account. The variable pricing discount offered by the Lee County project during the off-peak will not be awarded to non-ETC vehicles. This plan of operations is being considered by other agencies as a way to improve penetration of the transponders and to restrict discount programs overall. This overall effect of this type of policy is still unknown at this time, but it is the hope that it will provide the user with an additional incentive to acquire a transponder which can be used to improve service and reduce user costs at the toll booths.

The use of other technological advances will improve the ability of turnpike authorities to implement variable charging. In Toronto, Canada, a system is being implemented to recognize cars whether they are equipped with ETC or not. Non-ETC vehicles will be identified by a video imaging system which will post-process license plate information. The images captured at entry and exit prints will be matched electronically and the vehicle's owner will be billed through the mail. Registration information will be used to identify users from their license plates.

In many areas, the existing labor force is a key issue for the reluctance to change to an ETC system. In New Jersey at the New Jersey Turnpike Authority (NJTA), the hiring of new toll collectors has been frozen, and through retirement and reassignment, no layoffs are expected. This is a key issue for some agencies and this type of approach could be used by other agencies to reach desired staffing levels.

4. Identify problems and set goals for project. The set of problems which toll authorities face are numerous and diverse. There are several different areas where variable pricing must be evaluated and organized in order to establish accord between the individuals and agencies involved. Once this accord is established, a public information, or marketing campaign should be undertaken. Preparing the public is of key importance because of the feedback they provide. This feedback can be critical throughout the project, specifically during implementation.

One other major area (quite possibly the goal for the project) that toll facilities must address is unacceptably high levels of congestion at certain places at certain times. This is the essence of congestion problems: at certain times of day on certain stretches of road, more vehicles are trying to use the road than its capacity permits to flow freely. While some congestion is desirable (it indicates an efficient investment in transportation capacity), a lot of congestion is not. Excessive traffic congestion can significantly reduce the attractiveness of the toll road. The congestion also costs users in terms of delay, additional pollution, wasted natural resources. Under variable toll pricing, people who benefit from the use of highways during the peak periods, and who impose congestion costs on others when they do so, would contribute more to the upkeep, and especially, expansion of the system (since it is to accommodate peak period use that the system is typically expanded). A result of this financing program is that people should find it in their interest to use peak capacity more frugally. This reduction of congestion will allow the toll authority to continue providing a premium service. An additional benefit for reduction of congestion would occur if motorists decided to change their times of travel to less congested periods, thus contributing to a more effective use of the existing facility. Goals for the projects include evaluating the potential impacts (both positive and negative) of a variable price toll in a congested area of the toll facility and making recommendations for implementation of variable price tolls.

5. Identify political allies in the DOT and jurisdictional agencies who will support this position. A review of State DOT goals is an initial indication of whether support on a statewide basis for increased transportation system management and improved transportation efficiency is mandated. City and county policy is also important and should be reviewed to identify potential conflicts with neighboring agencies. City and county politics can play a major role in the end result of the program. Solidarity across jurisdictional boundaries is vital

to the success of the program, as dissenting views can result in lack of support. Elected officials are key with respect to the support of the project because of the politics that be and the number of constituents that can be affected by a change in toll prices. Support for increases in the price on highly congested corridors or projects that are tangible are the most palatable for politicians to back.

Engaging a range of stakeholders during initial organization of the study provides an opportunity to build arguments and to identify proponents. Building consensus within leadership of the community and various transportation agencies will improve the public relations support of the concept. Representatives of business interests also can play a role in the transition from fixed toll prices by providing insight on the transportation needs of the private sector. The business leaders are also able to identify the needs of their employees. Meeting with business officials can also lead to improvements in transportation demand management at the workplace which would improve the ability of the pricing structures to work for their employees. Transit agencies should also play a key role in the organizational structure, especially where revenue-neutral formats (funding transit) are involved. Finally, a key ally for the initiative should be environmental groups that have long supported congestion pricing as a way to reduce energy use, improve air quality, and reduce transportation demand.

6. Establish contact with the federal level when describing, proposing, and attempting to secure funding for a pilot study. The pre-implementation project is supported at the federal level with funding approved for an additional 15 projects in TEA-21. This financial support is important because it builds a critical mass for the process. The critical mass takes the form of additional scoping meetings and points toward the evaluation of the potential portions of a toll facility to target for a variable pricing project. One critical issue with respect to the funding is the structure of the tolls and the policy chosen. The FHWA modified the original Congestion Pricing Pilot Program to allow federal funds to be used for loss protection associated with a variable toll pricing strategy. This type of arrangement is important to reduce any resistance based on the financial considerations of the project.

7. Design a scheme to meet goals that is acceptable within the constraints that have been established. The barriers that toll authorities face in setting the price for traveling on the facilities were presented in detail in section 4. As discussed, the revenue impacts are of key concern in the decision to establish a variable toll rate structure. The alternative analysis conducted in the previous step will be used to tailor a rate schedule for a facility. The motivational factor used in setting rates for the Hardy Toll Road Off-Peak Reduced Rate Project in Houston was to entice users to use the facility during the underutilized off-peak periods. This focus was geared to improve the financial performance of the toll facility during the off-peak and throughout the day. Because of this underutilization and the competition with the alternative parallel facility, (Interstate 45) prices were reduced on the Hardy Toll Road to enhance the attractiveness of the facility during the afternoon midday periods. In many cases, toll authorities are restricted from this type of activity because of the covenants within their agreement with their bondholders. Several agencies have language in their agreements that allow reduced toll rates only on frequency or volume of use, mainly to encourage repeat usage by commuters. This type of arrangement assures a steady demand for such facilities which makes the investment more secure for the bondholders. Certain other agreements do not allow the toll authority to take any action that may act to reduce revenue by a predetermined percentage. This type of constraint heavily restricts the ability of the toll authority to consider various operational and policy changes that may align the agency with the State DOT.

Marketing, education, and public involvement should be priorities throughout the design of the scheme. The successful projects to date (SR 91, LeeWay) have experienced strong initial response largely because of their work with the political and public issues that are of key concern.

8. Complete initial feasibility analysis using transportation modeling and various toll structures. A traffic impact analysis is conducted once toll rate changes are proposed. These impact analyses formally evaluate the effects of a toll rate change on the use of a toll road. In many instances, the use of a transportation modeling

package such as EMME/2 or TRANPLAN is utilized for estimating the sensitivity of the demand on the facility. Trip tables within the transportation model are updated to represent the new cost of the facility. Several toll rate schedules are analyzed to identify the impact of the various toll rates on traffic. In addition to the base year analysis that is completed, additional future year analyses are used to compare the future impacts a certain policy or amount will effect the transportation system, and most importantly to a toll authority, the toll facility. Traffic assignments are made for both peak and off-peak conditions, at both the base toll levels and the various alternative toll rate schedules.

Additional analysis can be completed by performing a stated preference survey of existing users of the toll facility. A stated preference survey is used in some cases to identify appropriate ranges of value of time for use in determining potential toll rates for a facility. The surveys ask current users of the freeway to determine the implied values of time based on tradeoffs within specific questions. These time-cost, tradeoff questions offer the respondents choices based on travel alternatives. In the evaluation of equity considerations it is important that demographics and other "lifestyle" questions are considered to complete the cross sectional sample.

In transportation planning, individual motorists are assumed to have perfect information. Their ability to evaluate options within the transportation system are based on "multiple" experiences that have allowed them to make a decision which optimizes their ability to navigate the network. The quality of these experiences are based on travel time and speed, cost, and other factors. Utility models are used to combine these factors into a single measure of "cost" to the user. Congestion is a key component of this as increasing congestion increases the time required to travel a given distance. Time is a highly weighted portion of the equations used to identify these relationships. This relationship varies by person depending on household size, household income, and other factors. It is this relationship or willingness to "pay" for service that should be critical in setting the price of a facility.

9. Provide incentive to motorists combined with initiation of new toll structure. Tolls are set and revised based on the need for additional revenue to satisfy debt service requirements, operating costs, and system maintenance and expansion. Additional considerations for the setting of the lowest possible toll rates are the need to compete with other non-toll facilities in the same corridor and to maintain market share of the traffic in that corridor. System expansion has been a primary opportunity for increasing tolls. In the implementation of a variable toll structure, system improvement or expansion also could provide an opportunity to offer an incentive to use the facility during the uncongested periods. Furthermore, initiating a toll increase without justification is politically difficult. Providing additional service whether this be in the form of enhanced toll booth operation or roadway facilities should spur interest in the facility to supplement the traffic on the system and reduce the loss of motorists that resist the toll increase. Currently, the introduction of electronic toll collection seems to be a concern for many officials. Public acceptance is difficult to judge with privacy concerns and public distrust being sufficient barriers to offering ETC as the justification for increased tolls. Many infrequent drivers may resort to nearby alternatives to avoid the higher toll because they have not benefitted (travel time decreases may not be noticeable to driver) from the increase in price. Thus, it is important to provide a benefit the driver can recognize easily.

Communication and public outreach of the program should be a primary consideration of this step in the implementation. The public involvement process should be used to test strategies and develop public support for the project. Contacts with the media should be made in an attempt to explain the goals and justification for the project.

10. Prepare an evaluation program to quantify and estimate potential benefits. The evaluation program for any project should be completed up front prior to implementation. Data should be collected a significant period before the implementation to establish a baseline, identify trends, and analyze performance. The criteria one chooses to evaluate a pricing alternative depends on one's view of the proper way to handle many issues

about theory, measurement, and methods that inevitably arise during such evaluations. An evaluation program should focus on the following:

- *Performance of the transportation system.*

The key issue with respect to the performance of the price structure is whether or not the pricing alternative works efficiently toward congestion relief and maintaining overall user support. Improvements in the transportation system should be a primary goal of any transportation improvement. In other words, a necessary condition for making any transportation investment or choosing a transportation policy is that the performance of the transportation system be “better” than it would have been without the improvement. Identifying “better” requires an evaluation of both performance benefits and the costs of achieving those benefits. Personal preference and politics should play a limited role in this evaluation. Cost reductions to all travelers (in terms of travel time and vehicle operation) are the most important direct benefits of a transportation improvement.

- *Indirect effects of the variable pricing scheme on the transportation system.*

The key issue with respect to indirect effects is the surrounding transportation system. Hypothetically, one could argue that pricing a toll facility will lead to subsequent diversion to other corridors and an increased reliance on a lower class of facilities. This burden on the local facilities could also impact the air quality of the surrounding communities and make neighborhood groups raise concerns about the effect on their streets. Additional effects on transit ridership should be evaluated to identify the impacts of the toll pricing on the efficiency of the total transportation system. Diversion of automobile traffic to transit is of key concern and could be credited to the toll authority. In summary, the evaluation of the price structure should consider additional aspects of the transportation system rather than just the toll facility.

- *Effects on land use and urban form.*

Land use and urban form are transportation issues that have a rich history in theory. In the congestion pricing debate two arguments have been made regarding the impact of pricing on urban form. One stance is that underpriced transportation has led to lower intensity land use patterns and a larger metropolitan area largely due to the fact that it is easy to move about in the urban areas. The other side of the argument is that additional costs on the transportation system lead to a further decentralization and that people and businesses would move away. Both arguments have a certain amount of validity, and it is important for policy considerations in communities to identify the impacts if possible. Traveler responses will provide some insight into the changes variable pricing imposes on the transportation system, but additional evaluation of the land use implications should be considered because of the demand implications land use has on our transportation system.

- *Effects on distribution and equity.*

Of particular concern to the federal government in the evaluation of these projects is whether or not they are fair for the lower income users. The benefits that are calculated and estimated by the transportation models do not identify the distribution of these benefits. The pricing scheme may not benefit everyone equally, and more importantly, may cause some groups to be worse off. The spatial benefits must also be addressed, i.e. does one group get better transportation performance than another group pays for but does not receive (e.g., a central city alternative costs central city residents but primarily benefits suburban commuters). A variable pricing strategy needs to be compared to regional transportation policy and financial impacts should be investigated completely prior to implementation. Once a policy is in place, the effects on the transportation system should be closely monitored to measure the impact of the pricing strategy.

HYPOTHETICAL APPLICATION

The following is a discussion of the research findings applied to a hypothetical situation. The hypothetical situation is presented as follows.

The goal of AnyState DOT is to reduce the number of days the air quality in the northwest region of AnyState reaches nonattainment status. The transportation corridors within this region are plagued by poor traffic flow during peak periods. AnyState DOT would like to improve traffic flow by reducing the number of choice users traveling the Route 33 corridor during the congested periods. The AnyState Toll Agency operates Route 33 using a barrier toll system and is configured as shown in Figure 10. The five mile section south of Avenue A is heavily congested in the inbound during the a.m. rush hour as is the opposite direction during the p.m. peak hour. The existing toll for this five-mile section is \$2.00. Truck traffic is on the order of 5% of the traffic during the peak hours of demand.

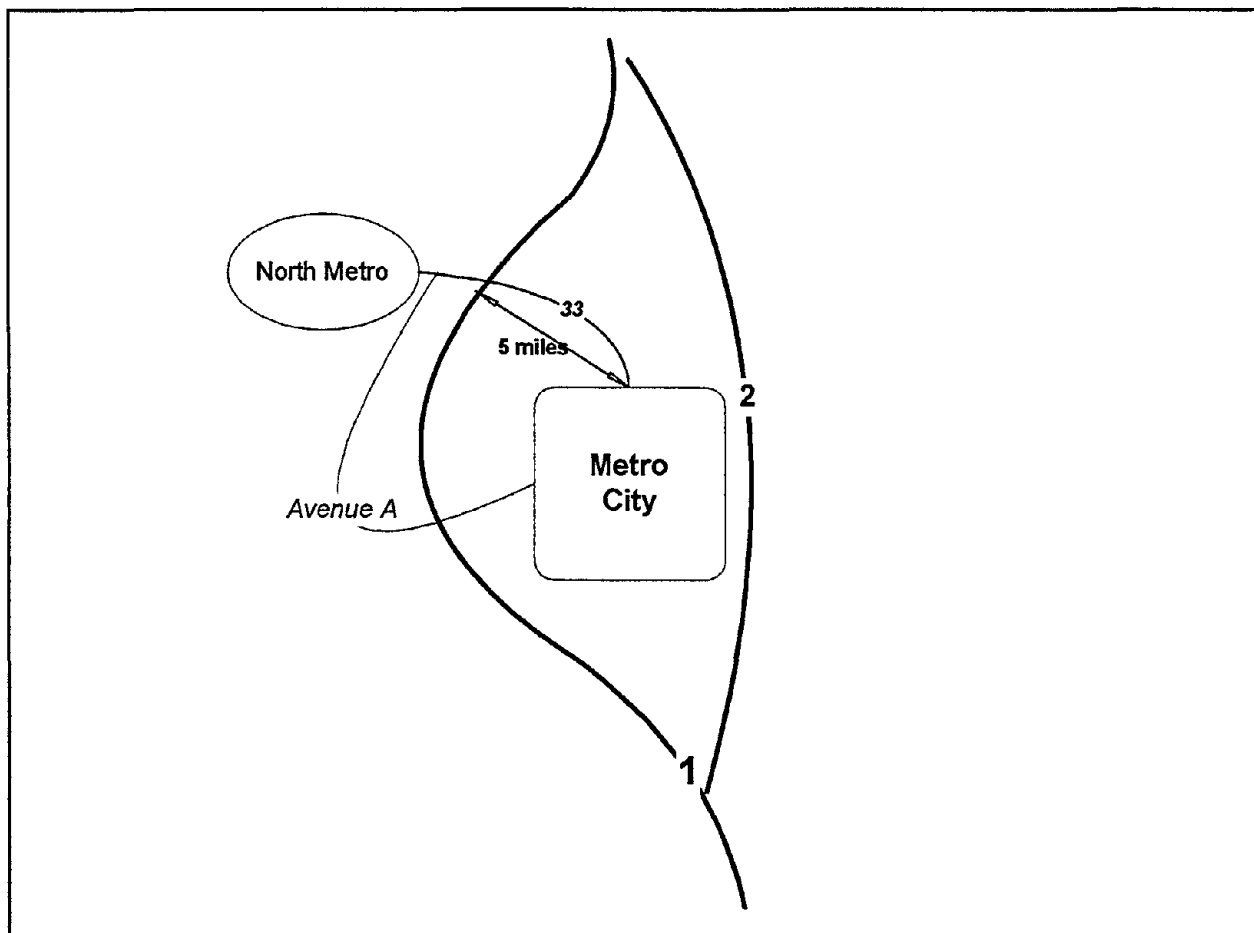


Figure 10. System Map for Route 33 in Metro City

1. Develop Mission Statement - What are you trying to accomplish, and why are you doing this?

The goal of the AnyState Toll Agency (ASTA) is to improve the operations of Route 33 during the peak period of travel. ASTA is hopeful that variable pricing may encourage more efficient use of the facility which is critical for the continued success of the facility, because further widening is not possible due to of an

environmentally sensitive area along a section of Route 33. A reduction of demand in the range of 8-10 percent would serve Route 33 well.

The implementation of variable pricing will improve the operation of our toll facilities by increasing the throughput during peak periods and the utilization throughout the day. This will be accomplished by enticing motorists to the shoulders of the peak period by providing discounted tolls for those motorists who travel during the less congested periods. Urban congestion is not something (our city) can build enough roads to solve. The pattern followed by many cities in the United States has been to attempt to keep pace with the growth in roadway traffic by constructing new highways. This strategy has not been effective in the past and will not solve long-term mobility concerns. As supported by the Governor, (Our city) will make strides to explore various opportunities to manage travel demand and reduce the growth of traffic congestion along critical transportation corridors. Variable pricing is a promising traffic management tool that links road prices to actual costs and spreads the load of travelers over a longer period. The variable pricing program must further the AnyState DOT's goals of improving the mobility of the citizens, revitalizing the State's urban centers, and promoting sustainable growth.

2. Evaluate policy considerations that exist which will prohibit variable pricing.

After careful consideration of all of the operating procedures of AnyState Toll Agency (ASTA), it was determined that the bondholder agreement is probably the most critical barrier for toll changes. ASTA has an agreement with the bondholders that they will not make changes to the toll structure that will reduce income from tolls by 2% or more.

Reluctance to change based on investor concerns is a realistic problem for ASTA. Political resistance to this change can be met with a public education campaign that should target elected officials initially with carryover to the public.

3. Develop an understanding of the barriers and constraints of changing toll rates.

The AnyState Toll Agency has instituted an electronic toll collection system, but it has not penetrated the market exceptionally well (30 percent during the peak hour). One of the reasons for the poor ETC acceptance has been the lack of a benefit for using the electronic tags. Toll booth lanes are not strictly established for ETC only lanes and thus users have not "gone out of their way" to pick up a tag. Therefore, the technical barrier is of low importance in this system, while the market acceptance of the electronic toll collection is critical.

Commuter traffic is a significant amount of the traffic on the Route 33 corridor during the peak hours, typically 70 percent. Thus, direct increases to the peak hour tolls will affect regular users of the facility. The residents within the Route 33 corridor have been somewhat vocal over previous toll increases, but the last increase was some time ago. Political justification for the toll increase will be difficult, but it is not a significant constraint. One other political issue is that the neighboring suburb North Metro has some concerns about the costs to its citizens. The City Council in North Metro is resistant to toll increases and the impact they will have on their city.

4. Identify problems and set goals for project.

The problems that face this project include the following:

- Poor acceptance of the current ETC system;
- Frequent congestion at the toll booths and on Route 33;

- Moderate public and political resistance to an increase in tolls;
- Equity issues with respect to geographic and political boundaries; and
- Revenue constraints imposed by the bond agreement.

The goals for the project include the following:

- Improve traffic flow and operations to improve air quality throughout the Route 33 corridor;
- Meet public expectations for providing an adequate and efficient transportation system;
- Enhance the urban areas of the state; and
- Meet the revenue expectations of the facility's bondholders.

5. Identify political allies in the DOT and jurisdictional agencies that will support this position.

To improve agency relationships and initiate the necessary partnerships to organize the project, an interagency meeting was held. The meeting allowed every agency involved to identify concerns with variable tolling. It was decided that an Advisory Committee be formed to assist ASTA planners in developing the formal plan. Two officials each from Metro County, the Metro City, City of North Metro, and AnyState DOT would form the Advisory Committee.

6. Establish contact with the federal level when describing, proposing, and attempting to secure funding for a pilot study.

At the initial meeting, it was decided that the AnyState DOT officials and the ASTA project manager would represent Metro City and the Route 33 corridor in front of the Federal Highway Administration (FHWA) Value Pricing Program's Director. The proposal would include a request for funding to complete the pre-implementation study for initiating a variable pricing program on Route 33.

7. Design a scheme to meet goals that is acceptable within the constraints that have been established.

The main goal of smoothing traffic will be realized by increasing tolls on all traffic during the peak two hour periods during the a.m. and p.m. rush hour by 10-20%. The cost of commuter tokens will be increased as well to encourage the use of electronic toll collection whose tolls will be held constant for an introductory period. In order to reduce the incentive for trucks to use the facility during the peak period tolls will be increased by the same amount 10-20%. To address the concerns of Metro City that this will negatively affect the central business district, the AnyState DOT will direct more transit funding to the Route 33 corridor and conduct a signal timing improvement along the Avenue A corridor to improve travel time into Metro City via this facility. Additional considerations will be made in special cases to users that may be unduly affected by the toll increases. One potential transportation demand management measure is to reward those users that reduce the number of trips they make during the peak throughout a week on the system.

Travel during the uncongested shoulders of the peak will be encouraged by reducing the toll on a scale based on time during the hour before or after the peak hour. This discount will only be offered to ETC users because of the complexity of this operating structure and the difficulty of implementing the variable pricing for users throughout certain periods of the day. The graduated toll structure is shown in Figure 11.

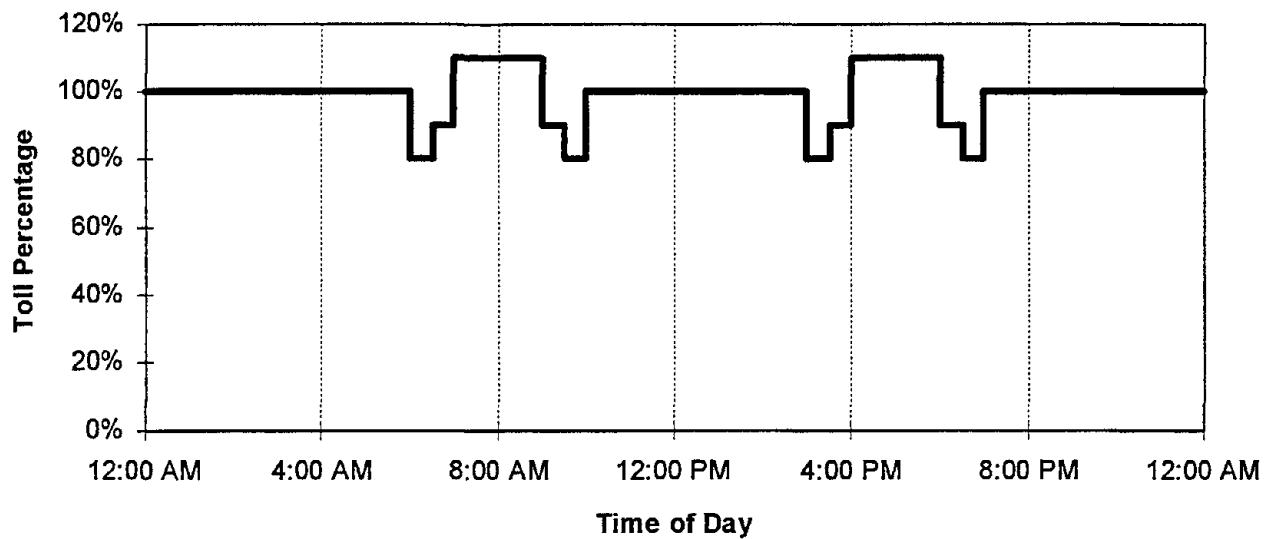


Figure 11. Variable Toll Schedule for Route 33

The bond agreement ASTA operates under is of concern because of the restriction with respect to revenue changes. There are a number of scenarios that can occur in this hypothetical evaluation which are of interest. The federal government involvement allows toll agencies the opportunity to establish a revenue reserve fund that guarantees return on the investment for the bondholders. Another alternative to government funding is to issue new bonds in response to a marked improvement, toll booth expansion and facility improvement in an insensitive environmental area. Excess funds could be acquired through this process and used to establish this initial investment return. Finally, the new toll structure could be revenue neutral or changed to respect the two percent restriction placed on ASTA.

A final issue of concern is the impact on the communities and the central business districts of Metro City and City of North Metro. The initial research concerning livability issues and urban form changes due to time-of-day pricing were inconclusive at best, and it is recommended that some resources be devoted to this topic to insure that the pricing policy supports the regional transportation policies.

8. Complete initial feasibility analysis using transportation modeling and various toll structures.

The regional transportation model developed by the AnyState DOT is used to identify the impacts of several different tolls on travel demand. The detailed analysis reviewed several alternatives for improving traffic flow on the toll facility and the alternative routes. Staff at AnyState DOT updated the transportation model to accommodate the transportation improvements scheduled that affect the Route 33 corridor. The model runs were reviewed for reasonableness and where necessary slight modifications were made. The elasticity of this facility is low because of the poor competition with alternative routes, thus a reduction in traffic on the toll facility will be minimal.

Additional analysis of the plan is tested using stated preference surveys with existing commuters on the facility. The surveys show that users are receptive to the discounts, but have some hesitation to use the electronic toll collection. In retrospect, the marketing plan could have been more proactive and focused on users explaining

the benefits of the technology. The surveys also show that many motorists are unable to vary departure times and are resistant to toll increases of any kind. It is recommended that the Downtown Metro City Association introduce the use of flex time and staggered start times to employers within the central business district.

The traffic analysis showed that travel speeds increase nearly 25 percent during the p.m. peak hour. This results in a time savings for motorists of four minutes. The cost of this improvement (the increase in toll) is \$0.40 with the twenty percent increase in the toll during the peak. Thus, it is determined that the value of time for an individual to choose to accept the higher toll is \$6.00 per hour ($\$0.40/4 \text{ minutes} = \$0.10 \text{ per minute or } \6.00 per hour). This value seems reasonable, and it is determined despite the desire to avoid the toll rate increase that users will not be adversely affected by the toll increase.

Due to the increased traffic forecasted for the off-peak period, traffic conditions are more congested, although not above capacity. The off-peak resulted in a lower average speed, but no noticeable difference in traffic conditions.

9. Provide incentive to motorists combined with initiation of new toll structure.

The incentive provided to justify the increased toll facilities will be a new fully directional interchange at the south end of Route 33 with Route 1 the Metro City Loop Freeway. This fully directional interchange will be funded jointly by ASTA and the AnyState DOT because the interchange benefits both parties. Additional improvements will be made on Route 33 through the five-mile section northwest of the new interchange. The environmental constraints will restrict adding additional lanes, but weaving lengths will be lengthened and interchanges along that section will be improved to enhance the flow on the main lanes. It is expected that these improvements will improve the capacity of the toll facility by five percent resulting in a capacity that under current traffic demands should operate just under capacity.

10. Prepare an evaluation program to quantify and estimate potential benefits.

Following a trend that has been established by the other implemented pricing projects, the local University, AnyState A&M University will be retained for evaluation of the program. The analysis will focus on the following five areas:

- Highway traffic operations and travel conditions;
- Observations about travelers and travel behavior;
- Impacts on public transit ridership and ridesharing;
- Assessing public opinion and acceptance; and
- Analysis of effects on urban form (this will be a longer term study which will begin with an extensive, existing conditions data collection effort).

The analysis should will on the willingness of commuters and travelers to pay a premium for more efficient service. Impacts on the transportation system will be measured throughout the Route 33 corridor and on parallel facilities. Equity concerns for lower income motorists will also be evaluated with the study program identifying user impacts based on various socioeconomic characteristics.

CONCLUSIONS AND RECOMMENDATIONS

The development of transportation pricing reforms should proceed cautiously and deliberately, beginning with pilot projects and innovation on local levels. There are many barriers to be overcome to reach equitable transportation financing. Reform of tax structure, privatization laws, and development of more flexible funding agreements are all necessary components. Variable pricing is just one step in this process. System reform will require longer term institutional restructuring and changes in marketing, advertising, and public education.

The implementation projects online are showing that the public is receptive to choices when it comes to transportation. The choice of paying for a premium service, i.e. an opportunity to drive on an uncongested toll road is being accepted in California in two separate communities. Congestion may be a necessary evil for acceptance of this type of project, however, without it a fare increase or change might not be easily justified.

Variable tolls have not enjoyed a great deal of success in other communities, however. The resistance to this type of policy is not trivial. Political interests and public response are at the heart of the matter, which makes effective marketing and careful public relations a necessary priority. Additional attention should be given to media exposure that can negatively affect a project of this nature. Marketing and public relations should emphasize the benefits to motorists where possible. A conversion of a fixed toll rate structure should proceed with system improvements so that the toll rate change can be associated as positive by the public.

The planning of these systems requires a certain amount of reliance on basic transportation modeling techniques and in most cases computer-based transportation models. These models are mathematical constructs of the transportation system and are poor evaluators of transportation patterns in many aspects. Careful evaluation of utility model constructs and value of time estimates must be tempered against reasonableness and local understanding of the transportation system. Local knowledge is invaluable in the design of a toll facility price structure and should consider public response carefully. Additional focus groups may be needed to address public sentiment and provide realism in the planning of a system.

Further research into the conversion of fixed toll pricing is necessary in many areas. The most intriguing issues include the effects of variable pricing on travel demand, urban form, and transit use. The topic of travel demand is well studied, but this issue of pricing facilities is difficult to quantify. The application of variable pricing will likely cause some motorists to change their behavior, but quantifying the travel demand changes is critical to furthering the understanding of motorist behavior. The reduction of travel demand is important in the creation of a sustainable transportation system. Beyond the travel demand, a thorough analysis of the effects of variable pricing on the urban form are needed to identify impacts on the community and to avoid undesired consequences. It is also important to address the size of the impacts to examine their importance for justification of a variable pricing program.

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APPENDIX A - SURVEY

As a part of the Advanced Institute Program, at Texas A&M University I am surveying Turnpike Authority officials for state of the practice in tolling users. This research will analyze different pricing schemes for toll collection. As part of this study, we would like to get some information regarding your agency's tollway operations.

Name:

Agency:

Date:

1. On your tollways, which type of fare structure are currently being used (check all that apply)?
☐ Fixed Price (entire day)
☐ Preferential Treatment ☐ Commuter Discounts ☐ Carpool
☐ EZ Pass Discounts ☐ Commuter Discounts
☐ Variable Pricing
☐ Other
2. Do your tollways currently experience congestion? Ask about severity (duration, diversion).
☐ Rarely ☐ Occasionally ☐ Usually

Other Insight:
3. Has your Turnpike Authority considered the use of Alternative Pricing for your facilities?
☐ Yes ☐ No ☐ Other
4. Do you have any perception regarding the barriers of implementation of Alternative Pricing for your facilities?
☐ Equipment ☐ Public/Political ☐ Revenue
☐ Lack of Alternative ☐ Reluctance to change ☐ Other
5. Are you aware of the goals of the DOT and if so has any conflict between fixed pricing schemes and TSM been brought to your attention?
☐ Yes ☐ No

For the remainder of the questions, discuss one tollway for the following questions.

Tollway: _____

6. What type of congestion occurs?
☐ Toll Booth ☐ Roadway ☐ Other
7. Are there alternative routes, modes serving this tollway corridor (check all that apply)?
☐ Arterial ☐ Freeway
☐ Rail or Express bus service ☐ Local bus service
☐ Other: _____

Thank you for taking the time to respond to these questions.

APPENDIX B - SURVEY RESPONSES

Agency	Price Structure	Congestion?	Considered Alternative Pricing	Barriers	Other
NJ Turnpike	Fixed, ticket system. Emphasis on Commercial	Usually	Yes, for commercial traffic	Equipment, Revenue Admin, labor	bondholders are key obstacle
Garden State	Fixed, barrier system, small commuter discounts	Usually in the northern, more urban section	Yes, once a commuter/ frequent user discount proposed	Public, Equity,	Implementing some of DOT issues - ramp metering to improve ops, but no pricing
Maryland	Fixed - summer traffic reductions	Occasionally on Roadways	Yes, Tourist credits	Public regressive tax Revenue	Tollways priced to keep drivers driving. Resistance from business traffic travel specific times of day.
Lee County	Fixed, commuter-50% discount moving to variable	Rarely, w/ new bridge. Used to usually	YES, Implement July 27 th ! Maintain commuter disc	Public - attacked by county commis-sioner	lowering tolls was key to political success, reserve fund -also added capacity at same time.
Delaware River and Bay	Fixed - 50% reduction for commuters	Rarely - NJ is the bottleneck	No - not a commuter route, no congestion	Lack of alternative, Reluctance to change	<i>No reason to implement without congestion.</i>
CA SR91	Variable	Rarely, Occasionally on adjacent lanes	Yes, implemented 1995.		Still striving to meet annualized facility costs, still gaining public acceptance
Kansas	Fixed Price, EZ Tag -10% discount Closed ticket system	Occasional	No, Rural focus	Lack of congestion, <i>traffic growth?</i> Reluctant to change	
New York	Fixed Price, Congestion Pricing Pilot	Occasional	Yes, Commuter	CP Pilot Project	
Illinois	Fixed Price - no discounts	Usually	No official evaluation	Public/ political Reluctance to change but moving	

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CLEARANCE OF FREEWAY INCIDENTS INVOLVING HAZARDOUS VS. NON-HAZARDOUS MATERIALS

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SUMMARY

The consequences of incidents involving the transport of hazardous materials (hazmats) on our nation's freeways are significant, particularly in terms of the potential threat posed to the health and safety of emergency responders, passing motorists, and the general public. Additional threats to the environment and personal property also demand attention at a hazardous materials incident. As a result of the overriding life safety concerns relating to a hazmat incident, the effects of such an incident on freeway traffic operations tend to become a secondary concern. However, given the intensive nature of the response and clean-up required for such an incident, it is reasonable to assume that a hazmat incident would have a more detrimental impact on traffic operations than would an incident involving non-hazardous materials.

The primary objectives of this research effort were to obtain data regarding the clearance times of hazardous and non-hazardous materials incidents, use the results of this data analysis to develop guidelines for the routing of hazmat cargos, and to apply those guidelines to make recommendations for improvements to the existing policy for the State of Maryland.

The acquisition of data from the states proved to be the greatest challenge, and further research and literature review shows that the lack of available data regarding incident histories is a widespread problem. As a result, recommendations are based on a limited statistical sample. Also, because states have adopted the federal statutes and, due to conflicting on court rulings, have little flexibility to create more stringent regulations, few changes to existing policies have been recommended in this paper.

The primary recommendation of this research effort is that all states establish a centralized database to facilitate incident tracking. This would allow all of the data that are presently collected to be stored together, permitting the complete picture of an incident, at least to the extent that it is known to investigators, to be available to other investigators and researchers. The proposed system, as described in this report, does not further complicate the jobs of on-scene emergency responders or impair any agencies current operating procedures, but does coordinate data storage and retrieval after the fact.

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INTRODUCTION

The consequences of incidents involving the transport of hazardous materials on our nation's freeways are significant, particularly in terms of the potential threat posed to the health and safety of emergency responders, passing motorists, and the general public. Additional threats to the environment and personal property also demand attention at a hazardous materials (hazmat) incident. As a result of the overriding life safety concerns relating to a hazmat incident, the effects of such an incident on freeway traffic operations tend to become a secondary concern. However, given the intensive nature of the response and clean-up required for such an incident, it is reasonable to assume that a hazmat incident would have a more detrimental impact on traffic operations than would an incident involving non-hazardous materials.

The closure of a part or all of a major transportation facility, even for a portion of a single day, can have a tremendous economic impact on a community. In addition to the frustration experienced by motorists, large amounts of time are wasted by users of the closed facility and all other diversion facilities due to delay on congested detour routes. Furthermore, delayed shipments impact business and manufacturing operations across a wide area, and, given society's dependence on the modern interstate system, can impact businesses at a considerable distance from the actual incident site.

The transportation of hazardous materials is of particular concern to the highway community because approximately 25 percent of major chemical incidents in the United States occur during the transportation of hazmat substances. It is important to note, however, that vehicle accidents account for a relatively small percentage (approximately 4.5 percent) of hazmat-related highway incidents. A much greater proportion of hazmat-related highway incidents (21.1 percent) are due to operator error, such as leaving a valve open, failing to correctly secure a hatch, or improper loading of cargo. Vehicle accidents, although not the primary cause of a hazmat release, are far more dangerous to the persons involved, resulting in about 90 percent of the deaths and 25 percent of the injuries in hazmat highway incidents. (1)

Problem Statement

Hazardous materials transport policies are generally developed based on safety and environmental concerns, rather than from a traffic operations perspective. Given this prioritization, there appears to be little research or study based on traffic operations experience to support such transport policies. This assumption is further supported by discussions with transportation professionals with working experience in this area. Although federal regulations exist for the packaging and labeling of hazmat items, the determination and enforcement of specific routing restrictions are the domain of the states. As a result, there is variation from state to state in the policies and regulations governing the transportation and routing of hazmat goods.

Clearly, a need exists for further documentation of the impact of hazmat incidents on freeway traffic operations. The goal of this research was to provide a basis for the development of a set of standard guidelines that can be applied to a state's existing hazmat transport regulations. These guidelines, based on traffic operations experience, serve as a minimum threshold for state policies, with those safety and environmental concerns requiring more stringent regulation still taking precedence. Properly supported recommendations for improvements to state policies were also to be proposed based on the results of the research.

Research Objectives

The primary objective of this research was to provide recommendations to improve the way in which the various state regulatory agencies set policies for the transport of hazardous materials. In order to accomplish this, guidelines were to be developed based on the impact of hazmat incidents on freeway traffic operations.

In order to produce such guidelines and subsequently apply them, it would first be necessary to identify the relationships, if any, controlling the time required to clear a freeway incident as a function of the following parameters:

- The presence of hazardous vs. non-hazardous materials;
- The type, class, or nature of the hazardous material, when present;
- The environment surrounding the incident (urban, suburban, rural);
- Weather, time of day, etc.; and
- Other factors (which were to be determined by data availability).

BACKGROUND

This section includes the commonly used definition of a hazardous material, which is used throughout the industry, as well as the general incident history trends and governmental regulatory structure of hazardous materials transportation in the United States. Further discussion of federally-mandated routing practices, packaging, and marking requirements are also included.

Definitions

The term "hazardous" is a broad and highly subjective descriptor that can vary in meaning depending on its context. Within the field of transportation, hazardous materials are commonly defined as follows:

Chemicals that are capable of posing an unreasonable risk to health, property or the environment when stored, used or transported in commerce. Some examples are gases, chlorine, fertilizers, fuels, acids, solvents, and cleaning compounds. Hazardous materials are commonly defined by agencies as substances in a quantity or form posing an unreasonable risk to health, safety and/or property when stored, used or transported in commerce. (2)

Hazardous materials are categorized according to a system developed and adopted by the U.S. Department of Transportation and the United Nations. The DOT/United Nations hazard classes are defined in Table 1. Exact definitions and further details for each category, including numerous sub-classes, can be found in Title 49 of the United States Code of Federal Regulations (49 CFR) (3).

Table 1. DOT/United Nations Standard Hazard Classes (2)

Class	Material
1	Explosives
2	Gases - flammable, non-flammable, and poisonous
3	Flammable and Combustible Liquids
4	Flammable Solids - spontaneously combustible and dangerous when wet materials
5	Oxidizers and Organic Peroxides
6	Poisonous and Harmful
7	Radioactive Substances
8	Corrosive Materials
9	Miscellaneous Dangerous Materials

Incident Statistics

Although there is a perception of a problem among many members of the transportation community, it is desirable to establish the trends, if any exist, in the occurrence of hazmat incidents.

Federal accident statistics, illustrated in Figure 1, show an alarming increase in the number of hazmat-involved incidents on our nation's highways beginning in the late 1980s. However, this likely reflects an increase in publicity regarding fines for failing to report incidents, rather than an actual increase in the occurrence of incidents. Since most hazmat-related incidents are quite small, and frequently went unreported in the past, it is difficult to accurately determine the trend, if any, in the occurrence of hazmat incidents. This fundamental problem with the accuracy and reliability of hazmat statistics is just one illustration of the lack of dependable data plaguing research in this field. (1)

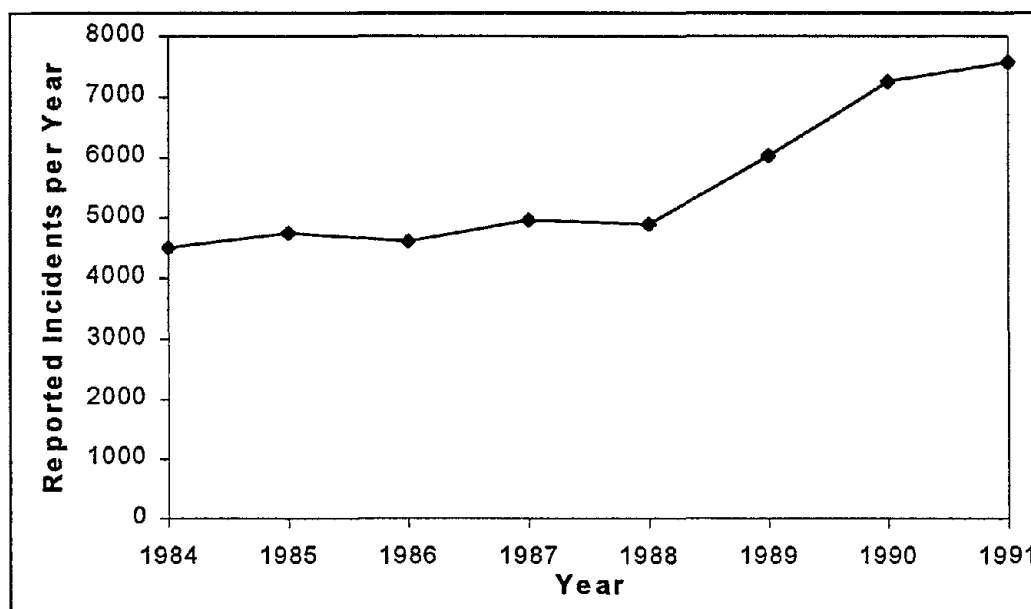


Figure 1. Reported Hazmat Highway Incidents 1984-1991 (1)

Figure 2 shows the location of hazmat-involved highway incidents reported to the U.S. Department of Transportation (USDOT) for 1991. As anticipated, the greatest concentrations of incidents occur in regions with large industrial centers or transportation terminal facilities (1). It is important to note that these data represent just one year's worth of available data, and portray only the raw number of incidents reported, with no accounting for severity, resulting casualties, or fatalities.

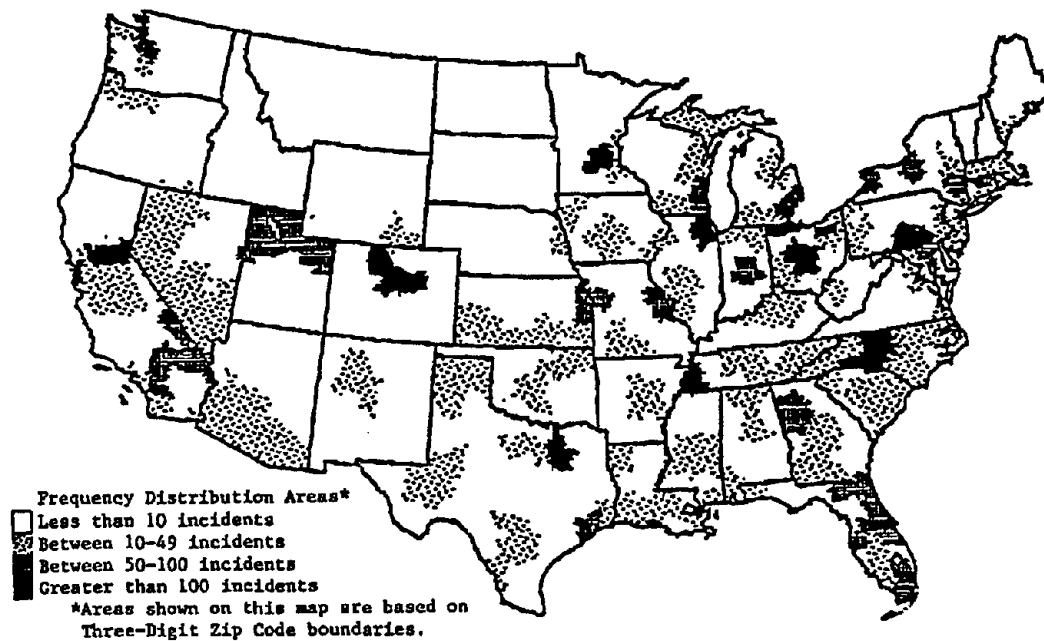


Figure 2. Reported Transportation Incidents Involving Hazmats, 1991 (1)

Regulations

In the past, the regulation of hazardous materials transportation was controlled by a patchwork of various governmental agencies, each with different standards and rules for different modes of transport. The 1966 Department of Transportation Act brought most federal responsibility for hazmat transport under the single umbrella of the USDOT. The Hazardous Materials Transportation Act of 1975 further consolidated responsibility under the direction of the newly created Materials Transportation Board (MTB). This legislation clearly stated the role of the federal government in hazmat transport, assigning the USDOT authority to:

- Determine hazardous materials subject to regulation;
- Regulate any traffic "affecting" interstate commerce, thereby including some intrastate traffic;
- Regulate shipper handling, labeling, and packaging of hazardous materials;
- Regulate manufacturers, reconditioners, and testers of shipping containers for hazardous materials;
- Conduct inspections and penalize violators; and
- Preempt state, local, and Indian tribal rules and restrictions that were found to be inconsistent with federal regulations. (4)

The MTB was later renamed the Office of Hazardous Materials Safety and incorporated into the Research and Special Programs Administration (RSPA) of USDOT, which remains the lead federal agency overseeing hazmat transportation today (4).

Despite this repeated consolidation of responsibilities for hazardous materials transportation, there are still many federal agencies that have a hand in the regulation and enforcement of this business. Table 2 outlines the major regulatory players at the national and international levels.

There are also additional responsibilities delegated to state, local, or Indian tribal governments. Although the federal government, through the USDOT, has developed guidelines for the routing of hazardous materials over public highways, the decision of which specific facilities are to be designated or restricted is delegated to the state or Indian tribal government. Some states have chosen to use the federal guidelines to designate specific primary and alternate routes, particularly around large metropolitan areas. The majority of states contacted,

however, simply rely on the guidelines established in the federal legislation without further specification, or further delegate the routing responsibilities downward to the local or city government. The details of these routing guidelines are discussed below.

Table 2. Regulatory Framework for the Transportation of Hazardous Materials (5)

	Highway	Air	Rail	Water
Department of Transportation:				
Research & Special Programs Administration	✓	✓	✓	✓
Federal Highway Administration	✓			
Federal Railroad Administration			✓	
Federal Aviation Administration		✓		
U.S. Coast Guard				✓
Other Federal Agencies:				
Environmental Protection Agency	✓	✓	✓	✓
Nuclear Regulatory Commission	✓	✓	✓	✓
Occupation Safety & Health Administration	✓	✓	✓	✓
International Organizations:				
United Nations	✓	✓	✓	✓
International Civil Aviation Organization	✓	✓	✓	✓

Hazardous Materials Routing

The federal legislation (49 CFR §397.71(b)(9)) establishes 13 categories of factors to be considered in the establishment of routes for Non-Radioactive Hazardous Materials (NRHM). These are as follows:

1. Population Density - This refers to the population which would potentially be exposed to a NRHM release, and includes residents, employees, motorists, and other persons in the area.
2. Type of Highway - The physical characteristics of the facility must be deemed adequate for the safe transport of hazardous cargo. Consideration includes vehicle weight and size limits, underpass and bridge clearances, roadway geometrics, number of lanes, degree of access control, and presence and location of median and shoulder structures.
3. Types and Quantities of NRHM - Relative impact zones and risks for each type and/or quantity of NRHM normally transported along the route is to be considered in the event of a release.
4. Emergency Response Capabilities - In consultation with the relevant fire, law enforcement, and highway safety agencies, consideration must be given to the proximity of emergency response facilities to the proposed route, as well as their capability to contain and suppress NRHM releases.

5. Consultation with Affected Persons - Due consideration shall be given to the comments and concerns of those persons and businesses affected by the NRHM routing. Specific details regarding the requirements for public hearings and posting of public notices are also specified.
6. Exposure and Other Risk Factors - The distance to sensitive areas is also a consideration. These areas may include, but are not strictly limited to, homes and commercial buildings; special populations in schools, hospitals, handicapped facilities, prisons and stadiums; water sources such as streams, lakes and reservoirs; and natural areas such as parks, wetlands, and wildlife reserves.
7. Terrain - Consideration shall be given to the topography along and adjacent to the proposed NRHM route. Terrain may affect the severity of an accident, the dispersion of the NRHM upon release, and the effectiveness of subsequent control and clean up measures.
8. Continuity of Routes - In consultation with adjacent jurisdictions, NRHM routes must be designated in order to minimize deviation from the most direct route. This reduces adverse impacts on commerce and delays to transportation, as required below.
9. Alternative Routes - Alternative routes to any proposed NRHM route shall be designated and analyzed according to the same factors to the extent necessary to determine if the alternative is safer than the current routing. Alternative route evaluation is also useful in the event that the primary designated hazmat route is closed or unusable.
10. Effects on Commerce - The NRHM routing shall not have an unreasonable burden upon interstate or intrastate commerce.
11. Delays in Transportation - The NRHM route designated may not create unnecessary delays in the transportation of the NRHM. (This guideline has been particularly frequent point of contention in the courts, and a common basis for the overturning of state or local regulatory measures.)
12. Climatic Conditions - Weather conditions which are unique to a proposed route, such as snow, wind, ice, or fog, which could affect the safety of the route, the dispersion of the NRHM upon release, or the difficulty of subsequent control and clean up measures shall be considered.
13. Congestion and Accident History - Traffic conditions which are unique to a proposed route, such as traffic congestion, accident experience, traffic conditions which could affect the potential for an accident, exposure of the public to a NRHM release, ability to perform emergency response operations, or the temporary closing of a highway for cleaning up any release shall be considered. (2)

Radioactive hazardous materials routes are based on similar evaluation criteria, but include additional restrictions and regulatory hurdles.

State and local government agencies are permitted to designate hazardous materials routes provided they are consistent with the regulations stated above. In court, however, a number of routing restrictions imposed by state or local agencies have been overturned and ruled to be inconsistent with the federal regulations. The primary causes for overturning, or preempting, routing restrictions are increased transit times, an absence of adequate safety justification, and regulation without proper coordination with adjoining jurisdictions. (2)

Further routing restrictions with regard to the time of day hazardous materials may be shipped have also been highly debated issues in the judiciary. A Rhode Island statewide ban on hazmat transportation between the hours of 7-9 a.m. and 4-6 p.m. on weekdays was preempted in National Tank Truck Carriers, Inc. v. Burke. On the contrary, a citywide curfew on hazmat transportation was found to be consistent with the federal

regulations in National Tank Truck Carriers, Inc. v. City of New York. The rush hour curfew concept was also found to be consistent in Boston for in-town deliveries and pick-ups between 6 a.m. and 8 a.m. (5)

Such conflicting judicial interpretations of the federal legislation, as well as the omnipresent threat of costly future litigation, are likely reasons for the reticence of state and local agencies to require any additional permitting or routing restrictions for hazardous materials transport through their jurisdictions.

Emergency Response

In addition to establishing the regulations for the routing of hazardous materials, the USDOT also has the responsibility for the specification of the containers, markings, labels, and associated documents to be used in the transportation process. These regulations cannot be made more stringent by state or local agencies for several reasons. First, containers need to be uniform to promote reasonable and efficient interstate commerce. Also, the addition of more markings, placards, or shipping documents would serve only to delay transport and possibly cause confusion in the event of an incident. The notion of additional documentation requirements causing unnecessary delays in transportation has been supported in numerous court rulings. (5)

Placards are required for vehicles transporting certain types and bulk quantities of hazardous materials. A placard is a diamond-shaped sign of specified size and color, including standardized, color-coded symbols, which alert emergency responders to the material being transported without closely approaching the vehicle. Placards are required on both sides and both ends of the cargo vehicles, and also contain or are immediately adjacent to the United Nations (UN) designated material code number for bulk shipments. Example placards are shown in Figure 3. A system of standardized container markings and labels supplements the placards and is also used for shipments of smaller quantities. (4)



Figure 3. Examples of USDOT Hazmat Placards (4)

The USDOT also specifies the information which must be included on the shipping papers on an item-by-item basis. This includes a listing of emergency contact persons, possible threats posed by the materials, and the appropriate emergency response methods to be used, among numerous other items. (4)

An important, non-governmental resource available for emergency response to hazardous materials incidents is the Chemical Transportation Emergency Center (CHEMTREC). This organization, accessible by a toll-free telephone call 24 hours per day, 365 days per year, is sponsored by the Chemical Manufacturers Association (CMA). The service is available to anyone involved with chemical transportation, and can provide emergency responders with vital safety information and appropriate response plans for the chemicals involved, as well as contact the shipper's or carrier's office directly for further assistance or additional on-scene technical support. (5)

STUDY ISSUES AND FINDINGS

As stated in the background of this report, the objective of this research was to quantify the impact of hazardous materials incidents, relative to non-hazardous incidents, on freeway traffic operations, with the ultimate goal of developing and applying a set of guidelines for the routing of hazardous cargoes. This section explains the data collection issues which impacted this process, as well as some findings of the data collection process.

As explained previously, the former patchwork of federal regulatory bodies overseeing hazmat transportation have been, more or less, consolidated into several of the larger federal agencies. Responsibilities at the state and local levels, however, vary significantly from state to state. This issue is primarily the domain of the state department of transportation in some states, while police or public safety agencies carry primary responsibility in other states. Also, since a hazmat incident requires the contributions of a wide variety of agencies and emergency responders, it is not uncommon for many overlapping and conflicting responsibilities are taken on by a number of independent agencies.

A hypothetical case study typifies some of the scenarios encountered during this research project. A cellular telephone call to the state police 911 emergency center alerts authorities to an overturned tanker truck. The first police unit on the scene notes the hazmat placard and radios for assistance. The fire department hazardous materials unit arrives to contain the spill. The state department of transportation is notified and begins traffic control measures and diversion of traffic to alternate routes. The shipping company sends a private carrier with another tanker to off-load the hazardous contents, while a another private wrecker service clears wreckage. The state department of the environment sends a response team to evaluate the environmental impact, and orders a private clean-up contractor be hired to remove, treat, and properly dispose of contaminated soil.

Although many of these same players are also present in a non-hazardous incident scenario, the presence of hazmat cargo serves to further exacerbate the situation. Since no single agency is, or can be, responsible for all aspects of the incident, record keeping quickly becomes jumbled and disconnected. The department of the environment may maintain an incident report documenting their actions in-scene, as will the police and fire departments. However, no coordinated records are kept to document the incident as a whole, as so correlation of the various components of the incidents becomes impossible.

In an effort to determine the agency within each state that would have the most complete database of incidents and their related impacts on traffic operations, most notably through data regarding the closure of lanes, the lead agency for motor carrier safety was contacted. This often lead to a long string of referrals to other agencies, and a process of tracking incident reports through various state bureaucracies quickly ensued. Table 3 lists the lead motor carrier safety agency for each state and selected territories of the United States.

It was commonly found when interviewing representatives of state agencies that each agency believed that some other was probably keeping track of the type of data that was being requested. It was also found that the information regarding incidents that is collected is frequently stored at the local office, district or regional level in hard copy format, and that computerized databases or central statewide incident tracking systems do not exist in a useful and practical form.

The USDOT, which maintains a nationwide database called the Hazardous Materials Incident Reporting System (HMIS), was also contacted for assistance. The USDOT has established a list of clearly-defined criteria, and a hazmat incident must be reported for inclusion in the HMIS when any one of these criteria are met. One of the criteria for inclusion in the HMIS is that "as a direct result of the presence of hazardous materials, one or more major transportation arteries or facilities are closed or shut down for one hour or more" (7). Despite this criterion, the USDOT does not include such facility closure information in the database.

Table 3. Motor Carrier Safety Lead Agencies (6)

State	Lead Agency	State	Lead Agency
Alabama	Dept. of Public Safety	Missouri	Division of Highway Safety
Alaska	Dept. of Public Safety	Montana	Highway Patrol
American Samoa	Dept. of Public Safety	Nebraska	State Patrol
Arizona	Dept. of Public Safety	Nevada	Dept. of Motor Vehicles & Public Safety
Arkansas	State Highway & Transportation Dept.	New Hampshire	Division of State Police
California	Highway Patrol	New Jersey	Dept. of Transportation
Colorado	State Patrol	New Mexico	Taxation & Revenue Dept.
Connecticut	Dept. of Motor Vehicles	New York	Dept. of Transportation
Delaware	State Police	North Carolina	Dept. of Transportation
District of Columbia	Metropolitan Police	North Dakota	Highway Patrol
Florida	Dept. of Transportation	Oklahoma	Dept. of Public Safety
Georgia	Public Service Commission	Ohio	Public Utilities Commission
Guam	Dept. of Revenue & Taxation	Oregon	Dept. of Transportation
Hawaii	Dept. of Transportation	Pennsylvania	Dept. of Transportation
Idaho	Dept. of Law Enforcement	Puerto Rico	Public Service Commission
Illinois	Dept. of Transportation	Rhode Island	State Police
Indiana	State Police	South Carolina	Dept. of Public Safety
Iowa	Dept. of Transportation	South Dakota	Highway Patrol
Kansas	Highway Patrol	Tennessee	Department of Safety
Kentucky	Motor Vehicle Enforcement	Texas	Dept. of Public Safety
Louisiana	Dept. Of Public Safety & Corrections	Utah	Dept. of Transportation
Maine	State Police	Vermont	Dept. of Motor Vehicles
Maryland	Dept. of Transportation	Virginia	State Police
Massachusetts	Dept. of State Police	Washington	State Patrol
Michigan	State Police	West Virginia	Public Service Commission
Minnesota	State Patrol	Wisconsin	Dept. of Transportation
Mississippi	Public Service Commission	Wyoming	Highway Patrol

Within the time frame of this research effort, and despite extensive telephone contacts, it was only possible to trace hazardous materials incident reports successfully through the governmental bureaucracies, from agency to agency, for nine states. These states were as follows: Maryland, Massachusetts, Michigan, New York, North Carolina, Ohio, Pennsylvania, Texas, and Virginia. In order to maximize the likelihood of locating the necessary databases, those states which were known to have, or could be expected to be more likely to have, more developed record-keeping systems were contacted first. Consequently, not all U.S. states were contacted, but it is reasonable to conclude from the responses received during telephone interviews with numerous representatives of the above states, that the data regarding incident type and facility closure is not available in a compiled format. Manual sorting of data and cross-referencing of incident reports at local governmental offices was deemed to be beyond the scope of this research project.

Consequently, the only data available for this study were obtained from the Maryland Department of Transportation, State Highway Administration. These data were obtained in two primary formats, described below.

The first consisted of a spreadsheet with estimated incident occurrence times and estimated times of facility reopening for a number of primarily non-hazardous incidents. Information regarding responding agencies and a brief description of the incident type was also included. Using these data, an average non-hazardous incident clearance time was calculated and several suspected hazardous materials incidents were identified and isolated using the descriptive information available.

The second type of data received from the State of Maryland consisted of field incident reports documenting the activities of the Maryland Department of the Environment, Emergency Response Division (MDE ERD). Since the MDE ERD is not responsible for traffic control measures at incident sites, and responds only to large incidents where the need for their specialized expertise justifies the commitment of limited resources, only sporadic information could be gained from these reports with regard to transportation facility closure.

The problem of lack of data availability was further echoed by a Transportation Research Board (TRB) report which intended to analyze the performance of information systems for emergency response at hazardous materials incidents. After exhaustive exploration of potential data sources for detailed incident reports, the TRB research committee altered the project to simply perform a review of only selected case studies, about which detailed information was known to be available (4). Given the summary nature of this research, however, such case study analysis is not a feasible research tool in this case.

STUDY RESULTS

Given the limited data available for analysis, the quantitative results obtained are admittedly subject to some question. However, the results do show the relationship anticipated prior to the data analysis based on interviews with transportation professionals familiar with the issues involved. Also, telephone interviews with authorities at various state agencies, primarily state police agencies in the states listed above, provided additional anecdotal support for the results described in this report.

Hazmat vs. Non-Hazmat Incidents

Based on review of the Maryland data, average incident clearance times for incidents with and without the involvement of hazardous materials were calculated and are shown below. This was based on the reported length of time that freeway lanes were closed, and includes a combination of data from both the Maryland Department of the Environment and the Maryland State Highway Administration.

- Non-Hazardous Materials Incident: 2 hours, 11 minutes
- Hazardous Materials Incident: 4 hours, 23 minutes

Careful review of the incident reports did illuminate a further point which was previously unknown. The overwhelming majority of incidents involving materials classified as hazmats for the purposes of emergency response are not true hazmats in the sense of the definition given earlier in this report. This is because the materials are not being stored, used, or transported for the purpose of commerce. This is generally the case with diesel fuel, which, when carried in saddle tanks on a tractor-trailer, may leak or spill from a vehicle. This can occur as the result of a mechanical failure or motor vehicle accident, and often requires on-scene treatment as a hazardous material. However, diesel fuel in these small amounts is not regulated as a hazardous material and is not subject to possible routing restrictions.

Due to the significant limitations in the data available for this project, it was not possible to stratify the incident clearance times according to factors such as the specific type of hazardous material involved, weather conditions, traffic conditions, or surrounding area type. It is also important to note that, particularly when minor diesel spills are eliminated from consideration, there are relatively few hazmat incidents on our freeways each year. Consequently, even with perfect information, it may not be possible to reliably categorize incidents into narrow classes based on cause or conditions and still have enough samples for reliable statistical analysis.

Hazmat Routing

Throughout the telephone data location process, inquiries were also made regarding the nature of each state's regulation of hazmat routing. Specifically, this focused on whether or not the state simply accepted the federal guidelines, or if attempts had been made to further strengthen the regulations. Also of interest was whether or not the states exercise their authority to designate specific routes for non-radioactive hazardous materials.

Those states agencies contacted that were knowledgeable regarding the routing regulations confirmed that all use the federal guidelines as written. Two states noted that more stringent regulations had been adopted with regard to government vehicles and personnel and the transportation of hazardous materials. As written, the Code of Federal Regulations establishes guidelines only for private carriers, and federal, state, and local governmental agencies are exempted. Maryland and Virginia both require that governmental vehicles and personnel under their jurisdiction also conform to the same regulations as private carriers, since they pose no less danger to the public health and safety in the event of a hazmat release. Emergency vehicles and vehicles transporting hazardous materials under emergency conditions are exempted across the board.

An additional effort was also made during the course of this research to determine the perception, on the part of the relevant state agencies, of each state's hazmat routing regulations. However, since most states contacted do not specify routing, and simply rely on the guidelines provided in the federal legislation, the agencies had little to offer in terms of comments or criticisms. The relative infrequency of hazmat incidents as compared to standard incidents and recurring congestion also translated into a reduced level of concern about the traffic operations impacts expressed by the representatives interviewed. The overriding concerns expressed, as expected, were for the safety of emergency responders and the public.

RECOMMENDATIONS

Hazmat Routing

Given the limited data available for this research effort, and the fact that state and local governments have little flexibility in the creation of hazardous material regulations under the uniform federal regulations, there are few specific guidelines that can be recommended.

At a minimum, all states should follow the examples set by Virginia and Maryland with regard to requiring that government agencies adhere to the same regulations for safe transportation as private carriers. This is logical given that the threats posed by hazardous materials are no less significant in the public sector.

Also, given that, on average, an incident involving hazardous materials can be expected to close a freeway or other major transportation facility for approximately twice as long as a more common non-hazmat incident, it seems reasonable to prohibit the routing of hazardous cargos through congested areas during the morning and afternoon peak hours. Judicial review has shown this to be consistent with the federal regulations in congested metropolitan areas, although a statewide ban incorporating less congested areas is unwarranted.

Example Application of Routing Guidelines

A final goal of this research project, as described in the introduction, was to apply the recommended guidelines which were to be developed based on the issues revealed through analysis of the data. For the purposes of providing a sample application of the guidelines developed, the hazmat routing regulations for the State of Maryland were to be studied, and changes recommended where appropriate.

Given the limited data availability, and the fact that the federal regulations are generally used as written, there are few changes that can be made. The history of this issue in the courts has shown that any regulation that goes much beyond the existing national statutes is considered to unnecessarily delay transportation or negatively affect interstate commerce, and, as such, is not permitted. The minor changes recommended in the previous section are likely the most stringent that can be found consistent with the CFR, based on the outcomes of previous attempts at enacting further restrictions.

With the exception of the removal of the exemption for state and local government agencies, as discussed previously, Maryland has adopted the federal regulations governing the transportation of hazardous materials. No additional recommendations, beyond those discussed above, can be made without the benefit of additional, more detailed, incident data.

Incident Tracking

The primary recommendation of this research effort is that all states establish and maintain better incident tracking systems. Such a system would take incident reports from all federal, state, and local governmental agencies responding to an incident or providing some form of related emergency response services, and compile these data for inclusion into a single, centralized database. The development of this type of incident tracking database, maintained on a statewide basis, would pose numerous challenges and provide many benefits, as described below.

Challenges

There are many obstacles which interfere with the establishment of a centralized incident tracking system. The most obvious and daunting obstacle is that which promotes the establishment of a database in the first place.

Each agency within a state typically uses unique data collection forms and has individualized record-keeping systems, which are not, and are not designed to be, compatible with those of other state agencies.

Another challenge facing the possible development and implementation of a centralized incident database is cost. State governments have limited financial resources available, and have a wide variety of urgent needs requiring state attention. There are too few resources and personnel to address the competing demands placed on state governments, and this is particularly true in today's era of downsizing and public support for reduced taxes and government spending.

Benefits

Such a system, recording all known incident conditions, causes, and results in a central location, has a wide variety of potential uses that go far beyond hazardous materials research. Such a unified system can greatly ease data collection for a number of highway safety projects, and would allow government agencies to evaluate past actions and improve both emergency response methods and the allocation of resources.

First, the existence of a centralized incident database would allow for research efforts, such as the one described in this report, to be undertaken successfully. Having all traffic, road, and environmental conditions recorded together would allow for classification of incidents into categories and more detailed analysis of incident causes. This would permit states to determine and more cost-effectively address potential safety issues, either due to cargo, road or traffic conditions.

The information needed to go into such a system is generally collected for each incident, and with the reduced cost and increased power of modern computer systems, the barriers to implementing such a system are somewhat less overwhelming today than they have been in the past.

Recommended Procedure

The fundamental steps necessary to collect and compile the incident data for such a database can be reduced to those described in the list below.

- Collect necessary traffic, roadway, and environmental conditions information;
- Collect necessary accounts from involved persons and eyewitnesses;
- Convey all data from various agencies to central processing agency; and
- Input data into computerized database for ease of search and retrieval.

It would initially appear that the most efficient method of collecting the variety of data that must be obtained at an incident would be to develop a single form which could be used during the data collection process. There are several positive and negative aspects associated with the single form concept.

A single form would significantly ease the entry of data into the database by the compiling agency, as only one form would represent each incident. It would also help ensure accuracy by attempting to rectify conflicting data at the time of data collection, which typically occurs at the incident scene. If conflicting data, such as the time of incident occurrence, is recorded on multiple forms and does not agree, and this is not discovered until the data forms are processed some time later, then it will be difficult to determine the most accurate entry for inclusion in the database. The use of a single form brings such inconsistencies to light much earlier in the process, and at a point when the individuals directly involved are still readily accessible for clarification or correction.

The single form, however, places a significant additional burden on just one agency responding to an incident. One agency must be given the full responsibility for completing the form, even though some of the data items

to be collected may be of little or no interest to that particular agency. If no one agency is required to complete the master incident report, and all major responding agencies have copies of the master form to complete, then the problems associated with multiple forms quickly surface again. There is little difference in the accuracy of data collected on several master forms as compared to the agencies' original department-specific forms, and so this should be avoided.

This issue is further complicated by the fact that all agencies do not respond to all incidents. Although some agencies, such as the state police or department of transportation, may frequently respond to incidents, most agencies have local counterparts or substitutes. No single agency has the resources to respond to every reportable incident in a state, nor are its services required at every incident. It is also common for several agencies of the same type (i.e. - police, fire, highway safety) to respond to larger incidents and to share jurisdictions under mutual aid agreements.

Given the above considerations, and the desire to eliminate the need for additional workload to be imposed on on-scene emergency responders, the development of yet another form to be completed is not recommended. Since the incident documentation for each agency tends to remain consistent over time, it should not be unreasonably difficult for a central processing agency for a single state to reliably gather the desired information from each agency's individual report, provided such a processor has access to the incident reports for all responding agencies, and that those reports are fully and properly completed.

A vital further consideration is the amount of time it takes to complete this processing. Guidelines need to be established in order to ensure that the database remains current, and that incidents are logged in a timely manner so that discrepancies can be more easily resolved, if necessary. Example guidelines are described below.

- All governmental agencies and contracted private service providers responding to an incident shall provide a copy of their standard incident reporting form, as well as any supplementary notes or documentation, to the designated central processing agency. Reporting agencies include, but are not limited to, the following: police, fire departments, ambulance/emergency medical services, highway departments, environmental management departments, wrecker services, and public/private environmental remediation firms.
- The accepted standard incident reporting form for the agency must be properly completed, including all requested data which are applicable to the incident. Requested data fields which are not applicable to an incident should be marked as such, with a filler line or "N/A" in the appropriate field. Blank fields do not indicate to those persons not knowledgeable about the incident details whether the data were unavailable, failed to be noted, or did not pertain. Blank data fields are a potential source of the introduction of errors or uncertainty into an incident record.
- In addition to processing the incident report form through the individual agencies in the standard manner, a copy shall be transmitted to the state's processing agency. The most likely choice for a processing agency would be the state police or public safety department, as such agencies likely already maintain large incident databases which could be expanded to include the additional types of data collected by others.
- Preferably, agencies with some form of electronic record-keeping could work with the processing agency to establish a means of electronically transmitting and compiling the data, to reduce the need for manual data entry and the costs, delays, and potential for error associated with it. If this is not possible, as would be likely in most states and with most agencies facing limited resources, fax is the second most preferred method of transmission. Fax machines are very common in field and district offices of all types throughout the country, and do not require additional hard copies of reports to be generated. Also, faxes received at

the central processing agency can be stored electronically, further reducing the potential for additional paperwork generation. Stored faxes can be viewed on computer and transcribed into the electronic database without the need for the production of additional hard copies, voluminous paper handling or storage.

- Incident forms shall be conveyed in a timely manner, as determined in advance by the processing needs of each agency. Most incident reports, based on those studied for this report, are completed by field personnel while on-scene, or immediately thereafter. Consequently, it is reasonable to expect that data could be relayed within 24 hours without undue burden. This aids in the process of resolving conflicting reports, as described previously.

CONCLUSIONS

The primary finding of this research was that the primary objectives could not be successfully and reliably completed due to the lack of cohesive data management systems in the United States. It was determined, based on a limited statistical sample, that incidents involving hazardous materials require, on average, twice as long to be cleared as non-hazardous materials incidents. This was found to be further supported by the experience of professionals in the transportation and emergency response communities.

Overall, there was a clear need for better management of the data that are currently collected but underutilized. Unfortunately, no one agency within a state bureaucracy has a strong incentive to undertake such a large task, as the benefits of such a system are spread across a wide variety of potential recipients from both the public and private sectors. It is the conclusion of this report, however, that such a system can be implemented as described with a minimum of expense and effort, and that this would greatly facilitate research on hazardous materials-related and other types of incidents.

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IN-VEHICLE INFORMATION SYSTEMS FOR COMMERCIAL VEHICLE OPERATIONS (CVO)

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SUMMARY

The purpose of commercial vehicle operations (CVO) is to transport goods and people using trucks and buses on the North American highway system. However, as the highways become more congested, the cost to commercial carriers and regulatory agencies to meet the demands of the consumer will rise. Therefore, constant attentiveness is required by government agencies, motor carriers, and drivers to keep commercial vehicle operations safe and efficient.

Technology must be applied to improve the efficiency and safety of existing commercial vehicle operations. Intelligent Transportation Systems (ITS) offer many possible benefits by utilizing information, communication, sensor, and control technologies to achieve improved levels of performance. In the last ten years a wide range of in-vehicle information systems has been developed to serve the motor carrier industry. However, the actual use of these systems and their ITS components by the commercial vehicle companies is unknown. Also, the needs of commercial vehicle companies must be identified and assessed to determine if the current ITS components included in the in-vehicle information systems meet commercial vehicle companies' needs.

To determine the in-vehicle information (ITS technologies) used and needed by commercial vehicle companies, a survey of four categories of commercial vehicle companies was conducted: truckload, household goods, tank, and package. The two ITS technologies that are the most widely used are the truck tracking systems and the vehicle condition systems. However, within each commercial vehicle category, the larger companies currently use and are testing more ITS technologies than the smaller companies.

From the survey, several needs were identified by the commercial vehicle companies. First, in-vehicle information systems and their ITS components need to be cost-effective and reliable. Second, the continuity of the use of these systems needs to be seamless from state to state and across international borders. Third, the drivers need to be educated about the systems, so the systems can be used to their full potential.

Based on the data collected from the survey, existing in-vehicle information systems that fulfill the needs of commercial vehicle companies were recommended for each commercial vehicle category. The recommendations were then used to design an in-vehicle information system for the truckload commercial vehicle community. The results of this design may be used as a future basis for the actual application of these technologies within the commercial vehicle industry; therefore, improving the efficiency and safety of commercial vehicle operations.

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INTRODUCTION

A commercial motor vehicle is either a vehicle: 1) with a gross vehicle weight of 26,001 or more pounds; 2) designed to transport 16 or more passengers, including the driver; 3) designed to transport 11 or more passengers, including the driver, and used to transport students under the age of twenty-one to and from school; or 4) used to transport hazardous materials which is required to be placarded (1). The purpose of commercial vehicle operations (CVO) is to transport goods and people using trucks and buses on the North American highway system. CVO provides a service to its customers, shippers and travelers (2).

In 1995, trucks and buses in America traveled over 100 billion miles. As the highways become more congested, the cost to commercial carriers and regulatory agencies to meet the demands of the consumer will rise. At the same time, the commercial vehicle industry will face increasing pressure to ensure that they remain competitive and technologically efficient. Revenues for the commercial vehicle industry are approximately \$300 billion annually and represent approximately five percent of the United States' gross domestic product; however, the costs to the commercial vehicle industry are continuing to rise while profit margins shrink (3). Therefore, constant attentiveness is required by government agencies, motor carriers, and drivers to keep commercial vehicle operations safe and efficient.

Technology must be applied to improve the efficiency and safety of existing commercial vehicle operations. Intelligent Transportation Systems (ITS) offers many possible benefits. ITS consists of transportation systems which utilize information, communication, sensor, and control technologies to achieve improved levels of performance (2).

The National ITS Program Plan developed by the U.S. Department of Transportation (DOT) contains a provision called Intelligent Transportation Systems Program for Commercial Vehicle Operations, or ITS/CVO. The ITS/CVO provision includes the operations associated with moving goods and passengers via commercial vehicles and the activities necessary to regulate these operations. The scope of the program includes activities related to safety, credentials and tax administration, roadside operations, freight and fleet management, and vehicle operation (2).

The vision for ITS/CVO is that safe and legal commercial vehicles would travel freely from state to state and across North American international borders. They would not be stopped or slowed down for credential, weight, and size checks. Also, commercial vehicles would not be burdened with excessive paperwork related to safety, taxes, and credentials (2).

Research Objectives

The specific objectives of this research were to:

- Determine the in-vehicle information systems (ITS technologies) that are currently available for CVO;
- Determine the in-vehicle information used and needed by commercial vehicle companies;
- Identify and recommend existing ITS technologies for in-vehicle information systems that fulfill the needs of commercial vehicle companies;
- Identify additional information and technologies for in-vehicle information systems that fulfills the current unmet needs of commercial vehicle companies; and
- Design an in-vehicle information system for a specific segment of the commercial vehicle community.

Study Approach and Scope

The initial objective of this research was to determine the in-vehicle information systems (ITS technologies) currently available for CVO. The data were obtained from the Federal Highway Administration's (FHWA)

Demonstration Project 111 Technology Truck, a survey of on-board technologies applicable to CVO produced by The Johns Hopkins University for the FHWA Office of Motor Carriers (OMC), and a research report concerning CVO and ITS produced by the California PATH Program. The data included information on current and future ITS technologies that are applicable to CVO. The reports also provided specific information about the manufacturers of in-vehicle information systems.

The second objective, to determine the in-vehicle information used and needed by commercial vehicle companies, defined a need to conduct a survey of commercial vehicle companies. The survey focused on collecting information about the use of existing in-vehicle information systems from four categories of commercial vehicle companies: truckload, household goods, tank, and package. The needs of the chosen commercial vehicle companies were also surveyed. Information about the companies chosen was provided through on-line references such as Transport Topics News (TT News) and company web sites.

The data collected from the surveys were then used to identify the in-vehicle information systems currently used and the needs of commercial vehicle companies that are not being met by the current technology. Existing in-vehicle information systems that fulfill the needs of commercial vehicle companies were recommended. The recommendations were then used by the author to design an in-vehicle information system for the truckload commercial vehicle community. The results of this design may be used as a future basis for the actual application of these technologies within the commercial vehicle industry; thereby, improving the efficiency and safety of commercial vehicle operations.

Organization of Report

The report begins with background information about commercial vehicle operations. Following the background information is a presentation of current ITS technologies that can be included in the in-vehicle information systems for commercial vehicle operations. Following the technology section is a summary of the surveys completed by commercial vehicle companies. This section includes information about each company interviewed, information on the current use of ITS technologies for CVO, and the needs of commercial vehicle companies that are not being met by the current technology. Recommendations for the use of existing in-vehicle information technologies are then suggested for each commercial vehicle category surveyed. Based on the recommendations, an in-vehicle information system for the truckload of the commercial vehicle community is presented.

COMMERCIAL VEHICLE OPERATIONS

CVO encompasses a range of industries, including trucks, private buses and taxis, and service and repair vehicles. The most prominent segment of CVO, motor carriers (i.e., trucking companies) is the focus of this research (4).

In 1992, motor carriers had total revenues of \$295 billion. Interstate trucking accounted for \$82 billion in revenue, intrastate/intercity accounted for \$96 billion and intrastate/local accounted for \$117 billion. The largest carrier, United Parcel Service (UPS) had revenues of \$12.7 billion, just 4.3% of the total. Therefore, even though the trucking industry is large, the vast majority of trucking companies are small (4).

There are three general classifications of motor carriers: common, contract, and private. A common carrier hauls goods for-hire, serving the general public or other businesses at established rates. A contract carrier also carries goods for-hire, but on a contract basis, for specific customers. A private carrier is a unit that serves the internal transportation needs of an organization (4).

The motor carrier industry can be further segmented by shipment size. Less-than-truckload (LTL) carriers serve small and medium size shipments (100-5000 pounds) through networks of consolidation terminals (4). Thus, LTL carriers consolidate LTL cargo from multiple origins for multiple destinations on one vehicle (5). LTL can be further segmented by longhaul and regional. The major longhaul, nationwide, carriers are Consolidated Freightways (CF), Roadway Express (operating independently of Roadway Package System), and Yellow Freight System. Truckload (TL) carriers serve full truckload segments, which are not consolidated in terminals (4). Thus, TL carriers dedicate one vehicle to a single shipper's cargo (5). The largest TL carriers are J.B. Hunt and Schneider National (4).

The motor carrier industry can also be segmented by commodity. For example, a trucking company can carry household goods, automobiles, hazardous materials, refrigerated goods, general freight, or packages. The most prominent companies carry boxed, palletized, or otherwise packaged shipments. Bulk cargo such as fuels, agricultural products, and gravel, as well as some hazardous materials, are carried by specialized carriers or private fleets (4).

ITS TECHNOLOGIES FOR CVO

ITS is a program designed to identify, analyze, test, and implement new and existing technologies. These technologies are aimed at improving safety, increasing efficiency, and cutting transportation costs in the movement of people and goods throughout the U.S. (6). CVO is a significant part of the ITS program. The effort called ITS/CVO is a cooperative public and private sector partnership that has formed the common goals of safe, simple, and cost-effective commercial vehicle operations. The Federal Highway Administration (FHWA) is the lead Federal agency for the program, and the ITS/CVO Division is directly responsible for oversight of the program (7).

There are several aspects of the ITS/CVO program including Commercial Vehicle Information Systems and Networks (CVISN), Mainstreaming, International Border Crossing, and Emergency Response. The role of the ITS/CVO Program is to foster the development and implementation of technology designed to assist trucks and buses in moving safely and freely throughout North America (6). To accomplish this goal, intelligent transportation systems must be brought to the motor carrier industry, enhancing safety and making commerce more efficient.

In the last ten years a wide range of ITS technologies has been developed to serve the motor carrier industry. These ITS technologies can be grouped into seven general categories: collision avoidance, collision information, driver condition, vehicle condition, navigation and routing, automated processing, and driver assistance. This report discusses each of the general ITS technologies categories.

Collision Avoidance

Collision avoidance systems advise the driver, through appropriate driver-vehicle interface, of imminent crashes. However, these systems can be segmented based on the information the system monitors to determine if a collision is pending. The following six types of collision avoidance systems are discussed in this paper:

- Rear end;
- Road and lane departure;
- Lane change and merge;
- Obstacle and pedestrian detection;
- Intersection; and
- Railroad crossing.

Rear End

Rear end collision avoidance systems sense the presence and speed of vehicles and objects in front of the equipped commercial vehicle. Warnings and limited control of the commercial vehicle speed are provided to minimize the risk of collisions with vehicles and objects in the commercial vehicle's lane of travel. In the future, these systems may include adaptive cruise control (8).

Road and Lane Departure

Road and lane departure collision avoidance systems monitor the lane position, motion relative to the road edge, and commercial vehicle speed relative to road geometry and conditions. These systems provide warning and control assistance to the driver when an unintentional road departure is imminent. In the future, these systems may include cooperative communication with the highway infrastructure to automatically provide safe speeds for upcoming road geometry and conditions (8).

Lane Change and Merge

Lane change and merge collision avoidance systems monitor the lane position, relative speed, and position of vehicles beside and to the rear of the equipped commercial vehicle. These systems warn the driver of the potential for a collision during the decision-phase of a lane change maneuver. Future systems may provide additional advice about an imminent crash to the driver during the actual lane change or entry-exit maneuver (8).

Obstacle and Pedestrian Detection

Obstacle and pedestrian detection systems monitor the location of pedestrians, vehicles, or obstacles that are in close proximity to the driver's intended path through on-board sensors or infrastructure-based sensors. A warning is provided to the driver when an object is detected (8).

Intersection

Intersection collision avoidance systems provide a warning to the driver when the potential exists for a collision at an intersection. These systems monitor such complexities as sensing vehicles on the intersecting roadways and determining the intent of these vehicles. The intent of the vehicles on the intersecting roadway includes slowing, turning, or potential for violation of traffic control devices (8).

Railroad Crossing

Railroad crossing collision avoidance systems monitor trains and provide warnings to drivers as they approach a railroad crossing if it is unsafe to enter due to approaching or present rail traffic. These systems share many onboard vehicle components with intersection collision avoidance systems (8).

Collision Information

Collision information systems include two types of systems: automatic collision notification systems and safety event recorders. Automatic collision notification systems monitor the position of a commercial vehicle and the severity of the crash. This information is transmitted automatically to the appropriate Public Safety Answering Point (PSAP). Safety event recorders document selected driver and commercial vehicle parameters to support the reconstruction of conditions leading to a crash (8).

Driver Condition

Driver condition systems monitor drowsiness and/or alcohol substances to detect degraded performance. Drowsiness can be detected through algorithms, lane tracking, eyelid movement, and arm movement. Alcohol substances can be detected through hand held breath-alcohol analyzers that are connected to the ignition system of a commercial vehicle. These systems provide warnings or other countermeasures to alert the driver to problems and prevent the problems continuance (8).

Vehicle Condition

Vehicle condition systems monitor different aspects of the commercial vehicle to determine if a problem will arise in the future. The following three types of vehicle condition systems are discussed in this paper:

- Stability;
- Low friction; and
- Diagnostics.

Stability

Vehicle stability warning and assistance systems aid drivers in maintaining safe speeds on curves by measuring the rollover stability properties of commercial vehicles. The driver is provided with a graphical depiction of the commercial vehicle's loading condition relative to its rollover propensity. Future systems could employ an active stability system, electronic brake system technology, and infrastructure information to selectively apply brakes to stabilize the commercial vehicle (8).

Low Friction

Low friction warning systems have on-board sensors that detect when the tire-to-road surface coefficient of friction is reduced due to water, ice, or road surface condition. These systems alert the driver of reduced traction. In the future, more advanced systems would provide control assistance capabilities to assist the driver in regaining control of the commercial vehicle (8).

Diagnostics

Vehicle diagnostic systems monitor commercial vehicle safety-related functions and are intended to be useful to the driver. The vehicle diagnostic information used is an extension of vehicle monitoring and self-diagnostic capabilities, such as oil pressure and coolant temperature gauges. Some examples of conditions monitored include braking system integrity, tire pressure, sensor and actuator performance, and communication system (8).

Navigation and Routing

Navigation and routing systems provide location and route guidance information to the driver using Global Positioning Systems (GPS) and direction finding (4). These systems also provide the capability to receive travel-related information from the roadside. The information received includes vehicle location, route guidance instructions, motorist and traveler services information, safety and advisory information, and other real-time updates on congestion and work zones (8). However, navigation and routing systems usually do not relay vehicle locations back to a base station. Truck tracking systems also provide location and direction to the driver. These systems use GPS, cellular, and pager based technologies to transmit information from the vehicle to a base station. However, truck tracking systems usually do not provide road directions (4).

Automated Processing

Automated processing is the electronic transmission of information or an electronic data interchange (EDI). Automated processing includes weigh-in-motion (WIM), credentials and permit verification, and cargo information systems.

Weigh-In-Motion

WIM systems in conjunction with credentials and permit verification allow a commercial vehicle to be electronically weighed and the identity of the commercial vehicle to be verified as the commercial vehicle approaches a weigh station. As the commercial vehicle passes over the WIM sensors, the distance between axles is measured and the weight of each axle or combination of axles is recorded and used to calculate the truck's total gross weight. An in-cab transponder identifies the commercial vehicle to the weigh station. After the commercial vehicle is weighed and credentials verified, the status (bypass weigh station or pull into weigh station) is transmitted to the driver via the in-cab transponder (9).

Cargo Information

Cargo information systems utilize EDI to transmit and receive data on cargo. Hand-held devices, including keyboard and bar-code scanner, allow drivers to electronically record information about their cargo. This process reduces paper-work and provides immediate entry of shipment information into tracking systems (4).

Driver Assistance

Driver assistance systems provide aid to drivers. The following three types of driver assistance systems are discussed in this paper:

- Longitudinal and lateral control;
- Vision enhancement; and
- Location specific alert and warning.

Longitudinal and Lateral Control

Longitudinal control systems range from normal cruise control to advanced cooperative cruise control and applications which permit full automatic braking. These systems sense the presence and relative velocity of moving vehicles ahead of the equipped commercial vehicle, and adjusts the speed of travel of the equipped vehicle to maintain a safe separation between vehicles. Vehicle speed is adjusted by allowing the vehicle to coast or by transmission downshifting. Lateral control systems sense the center of the lane and continually actuate the steering to keep the commercial vehicle in the center of the lane (8).

Vision Enhancement

Vision enhancement systems provide the driver with an enhanced view of the road-ahead using infrared radiation from pedestrians and roadside features. Future versions of these systems may include additional information from improvements in the highway infrastructure (8).

Location Specific Alert and Warning

Location specific alert and warning systems provide information to the driver by integrating commercial vehicle speed and pertinent commercial vehicle dynamics with the knowledge of roadway geometry. Future systems could include information about the environment and road surface conditions (8).

COMMERCIAL VEHICLE COMPANY SURVEY

To determine the in-vehicle information (ITS technologies) used and needed by commercial vehicle companies, a survey of four categories of commercial vehicle companies was conducted: truckload, household goods, tank, and package. The categories of commercial vehicle companies were chosen randomly from a list of the 100 largest trucking companies in 1996 produced by Transport Topics. The 100 largest companies were determined based on 1996 revenues. The individual commercial vehicle companies surveyed from each category were also selected from the Transport Topics list. Within each category, the individual companies were chosen to represent different revenue levels.

The survey (Appendix A) focused on collecting information about the current use of existing in-vehicle information systems by the companies. The needs of the selected commercial vehicle companies were also surveyed. Information about the companies chosen was provided through on-line references such as Transport Topics News (TT News) and company websites.

Truckload

Truckload carriers dedicate one vehicle to a single shipper's cargo (5). The following four truckload companies were surveyed: Schneider National, Swift Transportation, Roehl Transport, and Elder Lite Express.

Schneider National

Schneider National has been in business for more than 60 years. Schneider National's van equipment consists of 12,000 tractors and 35,000 trailers which operate in all 48 contiguous states, Canada, and Mexico. Every day Schneider National transports over 5,000 truckloads of products and raw materials. Schneider National is a general freight carrier, that mainly carries consumer goods, metal, and glass (10, 11).

Schneider National currently uses vehicle performance, vehicle position reporting, and two-way data satellite communications in their van equipment. The driver-interface is a hand-held computer. Schneider National is in the process of testing collision avoidance, lane position, and fatigue or drowsiness systems. Overall, Schneider National would like the component prognostic systems to become more reliable at predicting the failure of components, such as the battery, engine, and transmission (11).

Swift Transportation

Swift Transportation's fleet consists of 6,000 vehicles and operates in all 48 contiguous states and Canada. Swift Transportation mainly carries dry goods. Currently, Swift Transportation uses the QUALCOMM® system to track their vehicles. This system also allows the drivers and dispatch to communicate. To introduce the QUALCOMM® system to the drivers, the drivers must attend a day course. However, Swift Transportation indicated that not all of their drivers are technically inclined, so some of the drivers cannot correctly use the current system. Therefore, Swift Transportation is not testing any additional ITS technologies (12).

Roehl Transport

Roehl Transport started in 1961 with one truck. Today, Roehl Transport has a fleet of over 1,000 tractors and 2,300 trailers that provide curtainside, flatbed, specialized, and van trailer services throughout the all 48 contiguous states and Canada (13, 14). Roehl Transport currently uses OmniTRACS® by QUALCOMM® (14). OmniTRACS® is an interactive information management system that includes two-way mobile communications, satellite tracking, and fleet management software. The OmniTRACS® system vehicle hardware includes a driver display unit (DU) and a continuous-tracking antenna communications unit (ACU) housed in a sealed dome (15).

Within the OmniTRACS® system, Roehl Transport uses the JTRACS® and SensorTRACS® systems. JTRACS® is a vehicle diagnostics system that monitors engine oil pressure, engine coolant temperature, transmission oil pressure, injector cylinders, alternator current, gas supply pressure, refrigerant pressure, and glow plug relay. SensorTRACS® is a comprehensive performance reporting system that addresses driver behavior. SensorTRACS monitors speed, revolutions per minute (RPM) of the engine, and idle time. Drivers are provided with real-time feedback so they can immediately correct their own performance (15). Currently, Roehl Transport is in the process of testing collision avoidance and E-mail systems (14).

Elder Lite Express

Elder Lite Express operates approximately 35 trucks in all 48 contiguous states. Elder Lite Express mainly carries caskets, but also transports retail store fixtures and general commodities. Elder Lite Express uses TMW Trucking System and QUALCOMM® tracking to follow the progress of their trucks (16). The TMW Trucking System (TTS) is a personal computer, network-based dispatch operations and administrative management system (17).

All four of the truckload companies that were surveyed currently use a two-way mobile satellite communication system that allows the driver and dispatcher to communicate and a truck tracking system that provides location and direction information to the driver and dispatcher. Two of the four truckload companies surveyed also currently use a vehicle condition system that includes a vehicle diagnostics system and monitors such aspects of the vehicle as speed, RPMs, and idle time. Driver condition systems, collision avoidance systems, and E-mail systems are being tested by two of the four truckload companies surveyed to evaluate their potential for future use. Two needs identified by the truckload companies were that ITS technologies provide reliable information and that drivers need to be educated about the ITS technologies.

Household Goods

Commercial vehicle companies that carry household goods are mainly less-than-truckload. LTL carriers consolidate LTL cargo from multiple origins for multiple destinations on one vehicle (5). The following four household goods companies were surveyed: North American Van Lines, Mayflower Transit, United Van Lines, and Graebel Forwarders, Inc.

North American Van Lines

North American Van Lines operates 5,470 units in all 48 contiguous states and Alaska. The company mainly carries household goods, but also transports high value products and new furniture. North American Van Lines currently uses the OmniTRACS® system by QUALCOMM® to track their trucks (18).

Mayflower Transit

Mayflower Transit operates 3,550 trucks in all 48 contiguous states. Mayflower Transit mainly carries household goods, but also transports electronics, trade shows, and general commodities. Currently, Mayflower Transit uses a vehicle tracking system, two-way electronic messaging, and on-line order updating. Mayflower Transit is testing vehicle condition and navigation/routing systems (19).

United Van Lines

United Van Lines operates 1,671 trucks in all 48 contiguous states. United Van Lines mainly carries household goods, but also transports electronics, trade shows, and general commodities. Currently, United Van Lines uses the QUALCOMM® system to track their trucks, for on-line order updating, and for two-way E-mail

correspondence. United Van Lines is testing vehicle condition and navigation/routing systems that may be added to the QUALCOMM® system in the future (20).

Graebel Forwarders, Inc.

Graebel Forwarders, Inc. was started in the early 1950s in Wausau, Wisconsin with one truck. Currently, Graebel Forwarders, Inc. operates 500 long haul and 200 short haul commercial vehicles in all 48 contiguous states. Graebel Forwarders, Inc. uses driver condition and vehicle condition systems. The driver condition system monitors drowsiness, performance, and alcohol and drug substances. The vehicle condition system monitors stability, low friction, and diagnostics. Graebel Forwarders, Inc. also uses a nationwide paging system for communication between drivers and dispatch. Currently, Graebel Forwarders, Inc.'s needs are being met through the use of the in-vehicle information and paging system mentioned above. However, Graebel Forwarders, Inc. would use more in-vehicle information systems if the systems' cost, availability, and reliability warranted their use (21).

All four of the household goods companies that were surveyed currently use a two-way communication system that allows the driver and dispatcher to communicate. Three of the four household goods companies surveyed currently use a truck tracking system that provides location and direction information to the driver and dispatcher. One of the four household goods companies surveyed currently uses a vehicle condition system that monitors such aspects of the vehicle as stability, low friction, and diagnostics. Vehicle condition systems are also being tested by two of the four household goods companies surveyed. One of the four household goods companies surveyed currently uses a driver condition system that monitors drowsiness, performance, and alcohol and drug substances. Navigation and routing systems are being tested by two of the four household goods companies surveyed. One need identified by the household goods companies was that the ITS technologies be cost-effective.

Tank

Commercial vehicle companies that carry such commodities as petroleum products, starch, and sugar are considered tank companies. Tank trucks also carry hazardous materials. The following three tank companies were surveyed: Chemical Leaman Tank Line, DSI Transports, Inc., and Groendyke Transport.

Chemical Leaman Tank Line

Chemical Leaman Tank Line was founded in 1913 by B.F. Leaman and originally called B.F. Leaman and Son (22). Today, Chemical Leaman Tank Line operates 1,500 tank trucks in all 48 contiguous states and Canada. Chemical Leaman Tank Line mainly carries liquid bulk chemicals and petroleum (23). Chemical Leaman Tank Line currently uses the QUALCOMM® system to track their vehicles and for messaging. The company also uses longitudinal and lateral control of the vehicle to assist the drivers.

DSI Transports, Inc.

DSI Transports, Inc. was started in 1942 as the Robertson Transport company hauling products that included gasoline, cement, molasses, and asphalt (24). Currently, DSI Transports, Inc. operates 951 tractors and 1,368 trailers in all 48 contiguous states and Canada. The main commodities carried by DSI Transports, Inc. are petroleum and chemical products, plastic pellets, starch, and sugar. Approximately 30% of the products that DSI Transports, Inc. carries are considered hazardous materials (25).

In 1989, DSI Transports, Inc. purchased a satellite tracking system. Currently, the company utilizes the QUALCOMM® satellite tracking system in 236 long distance tractors. DSI Transports, Inc. plans to expand the satellite system to an additional 150 tractors in 1998, and to 100 more tractors in 1999 (25).

In 1992, DSI Transports, Inc. expanded the function of the satellite system by installing product temperature and pressure sensors in specific tank trailers. These sensors allow dispatch to set a temperature and pressure range through the satellite system for a product. If the product's temperature or pressure exceeds the established range, the computer system will automatically increase or decrease the temperature or pressure while the vehicle is traveling on the roadway. Messages and alarms are transmitted via satellite communications to DSI Transports, Inc.'s main computer (25).

In 1997, DSI Transports, Inc. modified the satellite system to include data macros. These data macros provide information from the driver about the load status and available driver hours. The data macros aid in matching drivers, equipment, and available loads in the dispatching system. The macros also provide information for driver pay, customer billing, improved equipment utilization, and load optimization (25).

Also in 1997, DSI Transport, Inc. installed the Lockheed Martin PrePass system into all of their tractor fleet. The PrePass system allows for the weighing-in-motion of commercial vehicles on some of the nation's highways. However, since DSI Transport, Inc. carries hazardous materials their vehicles can only bypass state regulated weigh stations 50% of the time in some states. In other states, WIM systems are not accepted for bulk carrier movements. DSI Transport, Inc. also currently uses longitudinal and lateral control systems (25).

DSI Transport, Inc. has not implemented satellite systems in their short haul business because the systems are not cost-effective. Thus, DSI Transport, Inc. is testing the Motorola two way pager for communication. Motorola is currently working with the company to program the satellite system macros into the pagers; thus, providing the valuable load and driver information at a lower cost (25).

Currently, DSI Transport, Inc. is evaluating a fuel optimization/routing system to improve fuel utilization efficiencies. The routing system will provide information on in-transit fuel stops and purchase volumes. The plan is to have the fuel optimization system in production in 1999. Other systems such as collision avoidance, driver condition, and vehicle condition are not currently planned for evaluation (25).

Groendyke Transport

Groendyke Transport has been in business for 65 years (26). Currently Groendyke Transport operates 774 tank trucks in all 48 contiguous states, Canada, and Mexico. Groendyke Transport mainly carries hazardous materials and dry bulk. Groendyke Transport currently uses the QUALCOMM® system to track their vehicles and to provide driver assistance (27).

All of three of the tank companies that were surveyed currently use a two-way mobile satellite communication system that allows the driver and dispatcher to communicate, a truck tracking system that provides location and direction information to the driver and dispatcher, and a driver assistance system that provides for longitudinal and lateral control of the vehicle. One of the three tank companies surveyed currently also uses a weigh-in-motion system. Navigation and routing systems are being tested by one of the three tank companies surveyed. One need identified by the tank companies was the need for continuity of the use of ITS systems from state to state and across international borders.

Package

Package distribution companies use commercial vehicles to transport parcels and documents. The following two package companies were surveyed: UPS and RPS, Inc.

UPS

UPS was founded in Seattle, Washington in 1907 (28). Currently, UPS uses a system called II Morrow. This system records the driver's DOT hours of operation, speed, RPM of the motor, miles driven, trailer numbers, and origin and destination locations. However, this information is not transmitted via a communication system. Instead the information is downloaded when the driver finishes a shift (29).

RPS, Inc.

RPS, Inc. opened for business in 1985, with just 36 terminals east of the Mississippi River that served 33 % of the United States. Eleven years later, RPS, Inc. delivers packages to businesses throughout the United States, Canada, and Mexico (30). Currently, the only in-vehicle communication system used by RPS, Inc. is the STAR SYSTEM®. RPS, Inc. contractors scan each package at pickup and delivery with hand-held scanners. This information is then uploaded into the RPS, Inc. computer system via an in-vehicle communications system (31).

One of the package companies that was surveyed currently uses a system that records the driver's DOT hours of operation, speed, RPM of the motor, miles driven, trailer numbers, and origin and destination locations. The other package company that was surveyed currently uses a cargo information system that allows the driver to scan packages at pickup and delivery and a communication system that allows the package information to be transmitted to a main computer.

Summary

Overall, each commercial vehicle company surveyed used at least one of ITS technologies that was discussed previously in this paper. Table 1 is a summary of the ITS technologies currently used and being tested by each company.

Two needs identified by the commercial vehicle companies were that ITS technologies be cost-effective and reliable. Several of the companies surveyed mentioned that the current ITS technologies were too expensive to implement in a whole fleet. Other companies stated that the current ITS technologies do not provide reliable information; thus, making the implementation of the technologies not cost effective.

A third need identified by commercial vehicle companies addressed the issue of implementation barriers. The particular barrier that was discussed concerned the use of weigh-in-motion systems. Hazardous material carriers can only bypass state regulated weigh stations approximately half of the time in some states. In other states, WIM systems are not accepted for bulk carriers. Thus, the continuity of the use of ITS systems from state to state and across international borders needs to be considered, especially since the amount of time a company uses a technology directly affects the technologies' cost-effectiveness.

A fourth need identified by commercial vehicle companies was that some drivers are not technically inclined. This leads to the incorrect use or no use at all of the in-vehicle information systems currently used by the commercial vehicle companies. This issue also hinders the addition of new technologies. Therefore, educating the drivers about the systems is an issue that needs to be addressed, especially for the use of the systems to be cost-effective.

Table 1. Summary of ITS Technologies

Type	Company	Operating Tractors	Collision Avoidance	Collision Information	Driver Condition	Vehicle Condition	Navigation/ Routing	Automated Processing	Driver Assistance
Truckload	Schneider	12,000	T		T	✓	✓*		
	Swift	6,000					✓*		
	Roehl	1,000	T			✓	✓*		
	Elder	35					✓*		
Household Goods	N. American	5,470					✓*		
	Mayflower	3,550				T	✓*/T		
	United	1,671				T	✓*/T		
	Graebel	700			✓	✓			
Tank	Chemical Leaman	1,500					✓*		✓
	DSI	951					✓*/T	✓	✓
	Groendyke	774					✓*		✓
Package	UPS				✓	✓			
	RPS							✓	

✓ Currently using; * Truck tracking systems; T-Testing

RECOMMENDED ITS TECHNOLOGIES

As a result of the research on the current use of ITS technologies for CVO and the needs of commercial vehicle companies, the following recommendations have been made by the author for the development of in-vehicle information systems for CVO. The actual application of these recommendations could result in a more efficient and safer commercial vehicle environment. Separate recommendations have been made for the four categories of commercial vehicle companies: truckload, household goods, tank, and package. Truckload companies refer to companies that dedicate one vehicle to a single shipper's cargo (5). On the other hand, household goods companies mostly refer to less-than-load carriers. LTL companies consolidate LTL cargo from multiple origins for multiple destinations on one vehicle (5). Tank companies are companies that mainly operate tractors with tank trailers. Package companies use commercial vehicles to carry parcels and documents. Listed below are the recommendations for the ITS technologies that should be included in the four in-vehicle information systems. All four of the recommended systems need to be cost-effective and provide reliable information.

Truckload

Based on the current use and testing of ITS technologies by the four truckload companies surveyed, the truckload in-vehicle information system should include:

- A two-way mobile satellite communication system that allows the driver and dispatcher to communicate;
- A truck tracking system that provides location and direction information to the driver and dispatcher;
- A vehicle condition system that includes a vehicle diagnostics system and monitors such aspects of the vehicle as speed, RPMs, and idle time; and
- A collision avoidance system that includes rear end collision, road and lane departure, and lane change and merge collision components.

Household Goods

Based on the current use and testing of ITS technologies by the four household goods companies surveyed, the household goods in-vehicle information system should include:

- A two-way mobile satellite communication system that allows the driver and dispatcher to communicate;
- A truck tracking system that provides location and direction information to the driver and dispatcher;
- A navigation/routing system that provides additional location and route guidance information to the driver; and
- A vehicle condition system that includes a vehicle diagnostics system and monitors such aspects of the vehicle as speed, RPMs, and idle time.

Tank

Based on the current use and testing of ITS technologies by the three tank companies surveyed, the tank in-vehicle information system should include:

- A two-way mobile satellite communication system that allows the driver and dispatcher to communicate;
- A truck tracking system that provides location and direction information to the driver and dispatcher; and
- A driver assistance system that provides for longitudinal and lateral control of the vehicle.

Package

Based on the current use and testing of ITS technologies by the two package companies surveyed, the package in-vehicle information system should include:

- A two-way mobile satellite communication system that allows the driver and dispatcher to communicate; and
- A cargo information system that allows the driver to scan packages at pickup and delivery and transmits the package information to a central location.

APPLICATION OF RESEARCH FINDINGS

Based on the recommended ITS technologies, an in-vehicle information system for the truckload commercial vehicle category was designed. The design includes the ITS components of the system, the information processed by the ITS components, and how the types of information are transmitted and received.

Design of In-Vehicle Information System

The in-vehicle information system for truckload commercial vehicle companies should be an interactive information management system that includes two-way mobile satellite communications, truck tracking, vehicle condition reporting, and collision avoidance warning. The two-way mobile satellite communication would link every equipped vehicle in a fleet to a dispatch center; thus, enabling the fleets and dispatch to maintain continuous two-way communication.

The truck tracking system should provide location and direction to the driver and dispatcher via the satellite communication system. The truck tracking system permits the driver and dispatcher to be in contact throughout the whole shipment process. Table 2 contains an example of the interaction between the driver and dispatcher during the shipment process.

Table 2. Driver/Dispatcher Interaction (15)

Communication	Information
Dispatcher to Driver	Load Assignment
Driver to Dispatcher	Acknowledgment
Driver to Dispatcher	Arrival at Shipper
Driver to Dispatcher	Loaded and Leaving
Driver to Dispatcher	Arrival at Stop for Pickup/Drop
Driver to Dispatcher	Leaving Stop
Driver to Dispatcher	Check Call/Fuel Purchase
Driver to Dispatcher	Empty

Data macros incorporated into the satellite system provide preformatted "fill-in-the-blank" messaging between the driver and dispatch. These preset messages provide information about the load status, available driver hours, weather, fueling, accidents, and delays. Table 3 contains examples of data macros.

The vehicle condition system should monitor fault codes from engines and other onboard systems. Such aspects as the speed of the vehicle, RPMs of the motor, idle time, and other vehicle diagnostics should be monitored to enable a proactive response to potential problems. The vehicle condition system should alert the driver to any potential problems even while in transit. The dispatch can be continually provided with the vehicle data via the satellite system. Thus, the system helps prevent unnecessary breakdowns and repairs.

Table 3. Data Macros (25)

ACCIDENT REPORT COF# __ - ____ Date __ / __ / __ - Time __ : __ Type of injuries _____ _____ Ambulance required (Y/N) __ Can the vehicle be driven (Y/N) __ Can trailer be moved (Y/N) __ Message _____ _____ _____ _____	WEATHER REPORT COF# __ - ____ New ETA - Date __ / __ / __ - Time __ : __ Current Weather _____ _____ _____ COF# __ - ____ Date __ / __ / __ - Time __ : __ Current Weather _____ _____ Road Condition _____ _____ _____
BEGIN FUEL STOP COF# __ - ____ Date __ / __ / __ - Time __ : __	COMPLETE IN-TRANSIT DELAY COF# __ - ____ Date __ / __ / __ - Time __ : __

The collision avoidance system should monitor the speed and presence of vehicles and objects in the front, back, and to the side of the equipped vehicle to determine if the potential for a collision exists. The system should also monitor the lane position and speed of the equipped vehicle to determine if an unintentional road departure is imminent. Warnings should be provided to the driver to minimize the risk of a collision.

The in-vehicle information system would have to include an antenna for the transmitting of data via the two-way satellite system. The driver-interface would be a hand-held computer similar to the Display Unit produced by QUALCOMM®. The display should feature a large screen, full keyboard, and numeric pad. The interface should be user-friendly, prompting the operator with simple, straightforward commands allowing drivers to easily send and receive messages. Warnings should be provided on the display's screen and verbally.

For the in-vehicle information system to be used properly, the drivers and dispatchers must understand and be able to operate the system. Short courses should be held to introduce and educate the drivers and dispatchers about the system. Manuals should also be accessible to the drivers and dispatchers.

Overall, the in-vehicle information system must be reliable and cost-effective. To be cost-effective, the information provided to the driver and dispatcher concerning the vehicle's location, condition, and safety have to be reliable. The system should include back up systems and checks to reduce the number of false alarms.

CONCLUSIONS

In the last ten years a wide range of ITS technologies has been developed to serve the motor carrier industry. However, only a portion of these technologies are currently being used by the commercial vehicle industry. The two ITS technologies that are the most prominent are the truck tracking systems and the vehicle condition systems. However, within each commercial vehicle category, the larger companies currently use and are testing more ITS technologies than the smaller companies. The following recommendations have been made by the author for the development of in-vehicle information systems for CVO:

- Truckload systems should include a two-way mobile satellite communication system, truck tracking system, vehicle condition system, and collision avoidance system;
- Household goods systems should include a two-way mobile satellite communication system, truck tracking system, navigation/routing system, and vehicle condition system;
- Tank systems should include a two-way mobile satellite communication system, truck tracking system, and driver assistance system; and
- Package systems should include a two-way mobile satellite communication system and cargo information system.

Several needs were identified by the commercial vehicle companies. First, in-vehicle information systems and their ITS components need to be cost-effective and reliable. Second, the use of these systems should be seamless from state to state and across international borders. Third, the drivers need to be educated about the systems, so the systems can be used to their full potential. The consideration of the needs identified by the commercial vehicle companies and actual application of the recommendations could result in a more efficient and safer commercial vehicle environment.

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APPENDIX A

In-Vehicle Information Systems for CVO Survey

Name (optional):

Company Name:

Date:

1. How many units do you operate which are based in the United States? What states do you operate in?
2. What commodities do you carry (i.e., household goods, packages, hazardous materials, etc.)? Are these commodities less than truck load or truck load?
3. Which in-vehicle ITS/CVO technologies do you currently use? Please check the general in-vehicle ITS/CVO technologies that you currently use and then circle all specific in-vehicle ITS/CVO technologies that you currently use.

_____ Collision Avoidance (rear end, road/lane departure, lane change/merge, obstacle/pedestrian, intersection, railroad crossing)

_____ Collision Information (notification, event recorder)

_____ Driver Condition (drowsiness, performance, drugs/alcohol)

_____ Vehicle Condition (stability, low friction, diagnostics (i.e., oil, coolant, tires, brakes))

_____ Navigation/Routing (route guidance, optimal routes, weather information, real time traffic information (i.e., congestion, work zones))

_____ Automated Processing (weigh-in-motion, toll collection, credentials and permit verification, cargo identification)

_____ Driver Assistance (longitudinal control, lateral control, vision enhancement, location specific alert and warning)

_____ None (Please explain why) _____

_____ Other (Please list) _____

4. Are your commercial vehicle operations needs being met through the use of the in-vehicle ITS/CVO technologies you selected above? If not, please explain the unmet needs.

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TRANSIT TRIP PLANNING ON THE INTERNET

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SUMMARY

The Internet is continually proving itself to be a vital tool for developing Intelligent Transportation Systems in a variety of applications. Currently there is a drive to develop interactive, regional transit itinerary planning web pages on the Internet. Transit information provided in this way can eliminate much of the fear and guesswork from the task of creating a point-to-point itinerary using transit. The quality and quantity of useful, up-to-date travel information which can be provided in the form of transit trip planning web pages are just beginning to “knock down” some of the communications-related barriers to transit use.

As the first transit trip planning systems are being implemented on the Web, the need arises for the answers to some important questions. First and foremost are the questions of whether the web sites are successfully making transit trips easier and/or improving the transit systems’ public image (i.e., do the web sites work?). What follows naturally then is the question of whether the web sites are encouraging people to make more transit trips and/or change their mode choice from automobile to transit (i.e., do the web sites have an impact?). The future of transit trip planning on the Internet depends on the answers to such questions. Information such as age, sex, income level, language needs, and other characteristics of those who use web pages for transit trip planning is also important for purposes of web site design and evaluation. Collecting data regarding the impact of the web site on and the characteristics of its users may help transportation agencies design Internet sites which better serve the public’s needs.

The primary research tasks of this paper included investigating the options currently available for transit trip itinerary planning on the Internet and conducting an online survey of the users of the Go Ventura web page created by the Ventura County Transportation Commission (VCTC). The Go Ventura web page is the only Internet site which provides point-to-point transit trip planning on a regional level in the United States.

The survey findings indicated that the users had a very high opinion of the Go Ventura web site, as the majority found the web site to be very helpful in planning transit trips. The transit trip itinerary planner is often being used to plan trips that cross the boundaries of cities, counties, and transit agencies. There is a large demand for integrated transit information across a region, and the Go Ventura web site is successfully responding to that demand. Furthermore, the survey indicated that people who use the web site are making new trips by transit which were directly facilitated by having access to the information provided at VCTC’s web site. Based on the results of the survey and feedback from users of the web page, several recommendations were suggested that might further increase the appeal of the Go Ventura transit trip planner on the Internet.

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INTRODUCTION

The growth of “traffic” on the information superhighway of the World Wide Web has been phenomenal since the Internet society was first established in 1992 (1). By the year 2000, it is predicted that 150 million adults in America will be using the World Wide Web. This is equal to about 75 percent of the 200 million adults aged 16 and older living in America today (2). Proving itself to be much more than just a fad, the Internet is here to stay as an important information resource.

The Internet contains information on virtually all aspects of everyday life, including news, hobbies, travel, entertainment, government and community, health and medicine, product information, sports, music, and games. According to a recent survey of 1000 adult Internet users, travel was the third most popular topic for Internet use, behind news and hobbies (1). The combination of computer monitor output and touch-screen or mouse-based input enables a wide variety of display formats; because the Internet utilizes this powerful interface, it has become the ideal medium for transmitting versatile travel information (3).

Most large metropolitan areas now offer a traveler information home page free of charge to users of the Internet (4). The type of information available on such home pages includes transit schedules and rates, airport information, weather conditions, trip planning, and maps (4). Unfortunately the databases behind most of these sites are not connected to each other, making it difficult to plan trips that cross different transit systems and/or metropolitan areas (2). Currently many agencies are working together to integrate transit information and to create regional automated trip planning capabilities on the Internet (5).

The expected benefits of interactive, multimodal travel planners include improving the public image of transit and facilitating wider user of mass transit, thereby reducing the adverse environmental and safety impacts of congestion on roads and highways (2). One agency currently offering a regional transit planner is the Ventura County Transportation Commission, which sponsors the Go Ventura web site.

Problem Statement

The deployment of regional interactive travel planners on the Internet comes with great expectations for broader user of transit as more people gain the ability to confidently plan complex trips anywhere within a region. The hope is that the entire information barrier to using transit would be eliminated by the power of the Internet trip planner. As the first transit trip planning systems are being implemented on the Web, the need arises for the answers to some important questions. First and foremost are the questions of whether the web sites are successfully making transit trips easier and/or improving the transit systems’ public image (i.e., do the web sites work?). What follows naturally then is the question of whether the web sites are encouraging people to make more transit trips or to change their mode choice from automobile to transit (i.e., do the web sites have an impact?). The evaluation of the benefits of transit trip planning on the Internet depends on the answer to questions such as these. Information such as age, sex, income level, language needs, and other characteristics of those who use web pages for transit trip planning is also of great importance for purposes of web site design and evaluation. Collecting data regarding the impact of a web site on and the characteristics of its users may help transportation agencies design Internet sites which better serve the public’s needs.

Research Objectives

To address the problem stated above, the objectives of this research were to:

1. Conduct a search of Internet web sites which offer some form of transit trip planning and identify helpful features currently in use;
2. Describe the characteristics of users of a web page that offers transit trip planning;
3. Assess the value of the information found on a transit trip planning web page, as reported by Internet users;

4. Determine additional needs of Internet users and features that the users would like to see on the web site, and
5. Re-design a transit routing web site, if necessary, to better serve the needs of the customers that use it and possibly to attract new users to the web site

Scope of Research

The research described herein focused on Internet web pages that provide transit information. The web page studied in detail was <http://sunbox.goventura.org/transit.htm>, found on Ventura County Transportation's Commission's web site, <http://www.goventura.org>. The selected web page offers trip itinerary planning using transit entities located throughout Southern California and can be accessed by Internet browsers anywhere in the world. The findings of the study were used to suggest possible improvements to the Ventura County transit trip planning web page.

Study Methodology

1. Review relevant web sites.

A review of web sites which currently provide traveler information with a special emphasis on those that provide transit routing capabilities was conducted. Special features of these sites were documented.

2. Review e-mail messages sent by users of Ventura County web site.

The users of Ventura County have sent a great deal of comments via e-mail to the transportation commission regarding the Internet web site. This mail was reviewed for any suggestions to improve the web site or concerns which may need to be evaluated in the survey.

3. Develop survey instrument.

A survey was developed to collect data on the following items: name; sex; age; home address; type of location where web site is accessed; county where origin and destination were located; purpose of trip; method of planning routes before Internet site was available; frequency of use of transit trip planning web site; frequency of transit use; whether the transit routing site has made any impact on the choice between private automobile or transit for making trips; and additional information or features that users would like to see on the Internet trip planner.

6. Implement Survey Instrument

After the format and wording of the survey instrument were approved by Ginger Gherardi, Executive Director of Ventura County Transportation Commission (VCTC), the survey was added to the transit routing page by Steve DeGeorge of the VCTC. Notice of the survey was placed on Internet transportation chat rooms in the local area. Responses to the survey were sent to the VCTC and then forwarded to the researcher.

7. Analysis of Survey Responses.

As the survey responses came in, they were categorized for analysis. Microsoft Excel was used to keep track of the survey responses.

8. Identify Characteristics of Users

The survey responses were used to identify characteristics of users such as where the site is being accessed, what destinations the transit router is serving, frequency of transit use, and automobile access.

9. Identify Additional Needs of Users

Based on the responses of survey participants and e-mail, a list of several additional needs and desired features was compiled for the web site.

10. Possible Improvements to Web Site.

Based on the characteristics of users of the web site and the response to possible added features provided by the survey participants, improvements that might benefit the web site were identified.

Organization of Report

Section 1 of this report presented an introduction. Section 2 contains descriptions of the transit trip planning capabilities currently available on Internet web sites. The results based on the survey of users of the Go Ventura trip planning web site and user feedback are discussed in Section 3. A summary of the findings can be found in Section 4. In Section 5 recommendations are offered that might further enhance the regional transit trip planner on the Internet. The major conclusions of the paper are reported in Section 6.

CURRENT OPTIONS FOR PLANNING TRANSIT TRIPS ON THE INTERNET

Ventura County Transportation Commission's Go Ventura Web Site

A report based on the 1990 census showed that southern California's Ventura County had the highest percentage (54 percent) of households with personal computers in the nation, indicating that the Internet might be a worthwhile medium for public outreach in Ventura County (6). The Go Ventura web site, sponsored by the Ventura County Transportation Commission (VCTC), first went online in 1995. Since that time, the VCTC has implemented many features on its web site, including point-to-point transit trip planning, maps of bike routes, rideshare and park-and-ride information, telephone numbers of transportation providers, monthly pass and fare information, and Internet links to other transportation-related sites (7).

Point-to-point transit trip planning is a unique feature to the Go Ventura web site, enabling the Internet user to plan a trip by transit that will go almost anywhere in southern California. To generate trip itineraries, VCTC uses the "Transtar" database and custom routing software, which has information about nearly all transit providers in the five-county region of Southern California (6). Already in use by telephone operators working the phone lines of a regional 1-800 toll free number, the Transtar software was successfully converted to an Internet application. The Internet transit planner accesses the Transtar database through a server operated by the Southern California Association of Governments (SCAG) (8).

When accessing the transit trip planner on the Go Ventura web site, the user indicates the origin and destination of the trip by entering the street address, intersection, or landmarks at the beginning and ending points of the trip. The user can also choose the time of day and day of week for the trip, in addition to whether he/she desires the trip that is the fastest, requires the least amount of walking, or requires the lowest number of transfers. Once the Transtar server has all the information it needs, the user submits his/her request, and a step-by-step set of instructions for the requested travel itinerary appears on the computer screen. The trip itinerary shows the arrival times and names of buses and trains on each leg of the trip and the amount of fare required (7). In its first years of operation, the Go Ventura web page has been well-received by the Internet-connected public and has averaged about 200 requests per week for trip planning information alone (8).

In June 1998 several upgrades were made to the Go Ventura web site. One of the changes was the addition of pull-down lists from which the user could choose the exact names of "landmarks" or transit nodes within Ventura County and around southern California. Other changes included walking maps that show how to get from one leg of a transit trip to the next, a restore button that allows the user to make changes to a request without having to type the form all over again, a return-trip itinerary option, and a Spanish translation of the site (7).

Other Internet Web Sites Offering Transit Trip Planning

Several sites offering transit route planning on the Internet were investigated. The objectives of the Internet search were to gain insight into the types of features currently being offered and to evaluate how well these features seem to work from a user's perspective.

Riderlink: King County, Washington (Seattle)
<http://www.transit.metrokc.gov>

Seattle's Riderlink project has been dedicated to producing a Web site to disseminate information about Metro Transit since December 1994 (5). The Riderlink home page provides general information, including links to other transportation Web sites, and information on van/carpool, bus, bicycle, ferry, and park & ride options. A Regional Automated Trip Planning system (RATP), expected to be implemented in 1999, is being developed for the Puget Sound region. The RATP system would allow users to plan transit itineraries for origins and

destinations chosen anywhere within King, Kitsap, or Pierce Counties. As part of the planned EZRider II program, the RATP software is expected to be used as a basis for online itinerary planning (5). Currently, some of the following features of the Riderlink site may be used to plan transit routes.

Regional Map. The user may click on one of eight sections of the regional map of King County, which brings up a zoomed-in map of the section showing neighborhoods only (no bus routes). Clicking on the name of a neighborhood results of a list of bus routes that serve that neighborhood (9).

Description of Bus Routes. On the list of bus routes that serve a given neighborhood, a listing of the areas served by each bus route is given. This information helps the user decide which route is appropriate for the trip before clicking on the bus route name (9).

Bus Schedule and Map. Once a route is chosen, the user may view a map of the route and the schedule.

CRITIQUE. It is easy to get lost in the large timetables shown at this site; by the time the user finds the desired time, quite likely the bus stop name (or time point) at the top of the page is no longer in view (9).

Pierce Transit: Pierce County, Washington (Tacoma)
<http://www.ptbus.pierce.wa.us/index.htm>

The Pierce Transit web page provides bus routes and schedules for Pierce Transit's bus system and provides links to other transportation services in the Puget Sound Region (including Riderlink). The following are some of the features found at Pierce Transit's web site that would be useful in transit trip planning.

Up-Front Access to Bus Route Information. A visitor to Pierce Transit's web site might access bus route information in one of two ways. A patron who already knows the bus route(s) required to make the desired trip would click on a list of bus route numbers to access the correct information. A new user to Pierce Transit would open a map of the bus system that shows the locations and numbers of the bus routes, the names of towns or neighborhoods, and the geographical layout of the county. To determine the proper bus route, the user would find the location of the desired trip on the map and click on the nearest bus route (10).

Maps of Bus Routes. For over 50 bus routes, simplified, easy-to-read maps of the route can be found at the web site. By clicking on one of the symbols that denote transfer points on the map, the user can access a new map which shows a zoomed-in view, including all routes that run through that transfer point (10).

Time Schedules in Frames. When the user clicks on the desired bus route type (i.e., weekday or weekend, outbound or inbound, etc.), a new window appears which only contains the schedule. The new window allows the user to scroll through the times while keeping in view the names of each time point (i.e., the name and/or location of the bus stop corresponding to the time). Frames also allow the user to transfer back and forth quickly between the map and the time schedule (10).

CRITIQUE. The maps at this web site are exceptional for their simplicity and attractiveness on-screen. The maps are very user-friendly, as they show all streets and major landmarks relevant to the bus routes, without overcrowding the map with excessive detail. However, the text is almost too small to read, and the bright colors used on the maps do not show up well when printed on a black-and-white printer. The timetables and schedules at the Pierce Transit web site are much easier to view than those of other sites because they appear in frames. One drawback to the use of frames is the difficulty getting the time point locations to print out with the time schedule (10).

LTD Lane Transit District: Lane County, Oregon (Eugene)
<http://www.efn.org/~ltd>

The web site for the Lane Transit District provides information on the history of the LTD, transit station locations, park & ride locations and connecting bus routes, bicycles on buses, and how to ride the bus. A visitor to the web site is given three choices for finding the right bus for his/her trip. The first choice is to use the FastTracks system, described below (11). The other two options are to check the LTD system map (not provided at the web site) and to call the 24-hour telephone information system.

FastTracks. On the LTD web site, the FastTracks system allows the user to indicate the origin and destination of the trip. After clicking on two of 18 possible locations (indicating the start and end of the trip), the user receives a listing of several options of buses that can be used to make the trip (11). LTD is currently converting their route maps and schedules to a format that can be viewed on the Internet and is planning to make the new maps available on the web site by September 1998 (12).

CRITIQUE. Although this system is functional and easy to use, it is limited only to origins and destinations in the Lane Transit District corresponding to the 18 locations listed.

Bay Area Transit Information Project: San Francisco Bay Area, California
<http://www.transitinfo.org>

Instant online access to transit information in the nine-county San Francisco Bay Area is provided by the Bay Area Transit Information Project (BATIP). The Metropolitan Transportation Commission (MTC) recently took over responsibility for the web site. To ensure that the data provided at the web site is as up-to-date and accurate as that provided by telephone operators at the Transtar trip planning system, the MTC is developing a method for transferring information from the Transtar database directly to the web (5). However, at present, BATIP makes the disclaimer that any schedules provided therein are subject to change without notice and that any information gained at the web site should be verified first by telephone (13). Some of the options available for trip planning at the BATIP web site are described below.

Regional Transit Diagram. BATIP offers a regional map which shows the service coverage of all Bay Area transit agencies. Clicking on a point in the map either zooms to a certain area or brings up the web page of the transit agency with a route closest to the point that the user chose. Different levels of transit route planning are provided, depending on the transit agency (13).

Interactive BART Schedule. The BART schedule system starts with a color-coded map showing all stations along BART's five transit lines. After the user clicks on the station desired for the origin of the trip, the map pops up again, and the user picks the destination. Next, the user is asked to choose either weekday, Saturday, or Sunday/ holiday scheduling and to choose times of departure and arrival for the trip. The one-way fare is given, in addition to the schedules that meet the criteria specified by the user (13).

Transit Connections to Popular Travel Destinations. For many of the Bay Area's most popular tourist sites, shopping malls, government buildings, transit terminals, theaters, and other destinations, the BATIP web site provides listings of the transit routes from all transit agencies in the Bay Area that serve these locations (13).

CRITIQUE. Although it is helpful to have a synopsis of the transit options accessible from a given point, trip itinerary planning does not appear very user friendly as it requires that Internet users connect all of the routes on their own.

Oahu Transit Services (TheBUS): Honolulu, Oahu
<http://www.thebus.org>

The transit system of Honolulu, TheBUS, maintains a web site which gives directions for how to take transit from Waikiki to more than 50 different popular tourist attractions in Honolulu and on the island of Oahu.

CRITIQUE. The system is very easy to use because the only steps it involves are choosing the category of destination (e.g., beaches, shopping, universities, etc.), finding the desired destination among those listed, and reading the detailed instructions provided. However, all trips must have Waikiki at one end or the other. Thus, the user is limited to finding instructions about trips radiating from Waikiki to any of the tourist attractions listed, and the system cannot be used to plan trips from one of the listed tourist attractions to another (14).

Subway Navigator, Worldwide (based in Paris, France)
<http://metro.ratp.fr:10001/bin/cities/english>

The Subway Navigator helps the user find subway routes between two destinations in about 40 cities worldwide. After choosing the desired city from a list, the user is asked to pick an arrival station and a departure station. These may either be chosen by using a pull-down list of all stations on the system or by clicking on the desired station on a map. The route search results in an estimation of the time to get between the two stations on the subway and a recommended itinerary of subway routes. The path that the route follows may also be observed on the system map (15).

CRITIQUE: Subway schedules are not provided at this site; thus, this site tells the user how and where to go, but not when to go (15).

Metropolitan Atlanta Rapid Transit Authority: Atlanta, Georgia
<http://www.itsmarta.com>

The Metropolitan Atlanta Rapid Transit Authority (MARTA) provides point-to-point transit trip planning with the Passenger Routing and Information System (PARIS) over the telephone; however, this service is not currently available through the Internet (5). MARTA's web site disseminates transit information such as the MARTA system map, parking information and connecting bus routes at light rail stations, bus schedules, and bus route maps (16). The following is an unusual feature of the MARTA bus routes.

Maps Viewable by Adobe Acrobat Reader. The maps of MARTA bus routes were provided in the form of files to be opened using Adobe Acrobat Reader, a software package available free of charge on the Internet (16). If the user has the link set up to launch Acrobat when opening a map file in the Internet browser, it is just as easy to view MARTA's map files as it is to view graphics directly in the browser.

CRITIQUE. One major advantage of the files saved in Adobe Acrobat Reader format is the clarity of the print-outs which are much more legible than the fuzzy-looking images printed directly from the Internet browser. This is especially helpful for reading print-outs of transit routing maps, which often contain very small print.

SURVEY RESULTS AND USER FEEDBACK

Information about use of the Ventura County Transportation Commission (VCTC)'s transit trip planner on the Go Ventura web site was obtained in two ways. The first was to examine data taken from all successful queries made to the transit trip planner. During the survey period (July 3 to August 14, 1998) about 2900 transit trip itinerary requests were successfully submitted. The second method of obtaining data was through the Internet user survey and comments from visitors to the Go Ventura web site (made via direct e-mail and through the survey). Filling out the survey form, which was located at the beginning of the transit trip planning web page, was entirely voluntary. Seventy-four surveys were submitted by sixty-six different individuals. A copy of the survey questions and format may be found in the Appendix.

Potential for Survey Bias

Voluntary Survey

The Go Ventura web page had been in service for more than 2 years prior to the administration of the survey. During that time, the trip planning page was visited an average of 60 times per day (17). From July 3 to August 14, seventy-four survey forms were submitted by sixty-six users of the Go Ventura transit trip planner. Assuming an average of 60 "hits" per day, there was about a 2.9 percent return rate on the surveys. Because filling out the survey was purely voluntary, responses have only been recorded for the subset of web site users that decided to fill out the survey. Thus, the survey results may reflect the characteristics of this subset rather than all users of the web site.

Interruptions to Continuous Service

During the period when the survey was being conducted, there were several interruptions to the service which had previously been provided continuously by the Southern California Association of Governments (SCAG). The service provided by SCAG is a database of schedules for nearly 25 operators in the southern California region. During the times when the trip planner could not access SCAG's database, many complaints were received by the VCTC concerning lack of service. The problems with accessing the SCAG database (and therefore not being able to get a response to transit trip queries) may have negatively affected some of the survey responses, even though the problems were not caused by the design of the transit trip planner itself.

Results Based on All Successful Queries to the Go Ventura Transit Trip Planner (n= 2900)

The sample size (n) for this section consisted of the 2900 successful itinerary requests submitted from July 3 to August 14, 1998.

Inter-county and Inter-city Travel

When a trip itinerary request is made, the web site user must enter the origin and destination of his or her trip. Because this information is submitted to the Transtar server, it was possible to keep track of all the origin-and-destination pairs used for trip itineraries. Figure 1 shows the results for origin and destination by county. Although the Go Ventura web site was originally designed by the VCTC to benefit the residents of Ventura County, the results show the web site has become a truly regional information page. From Figure 1 it can be seen that the web site is being used for trips with origins and destinations throughout southern California.

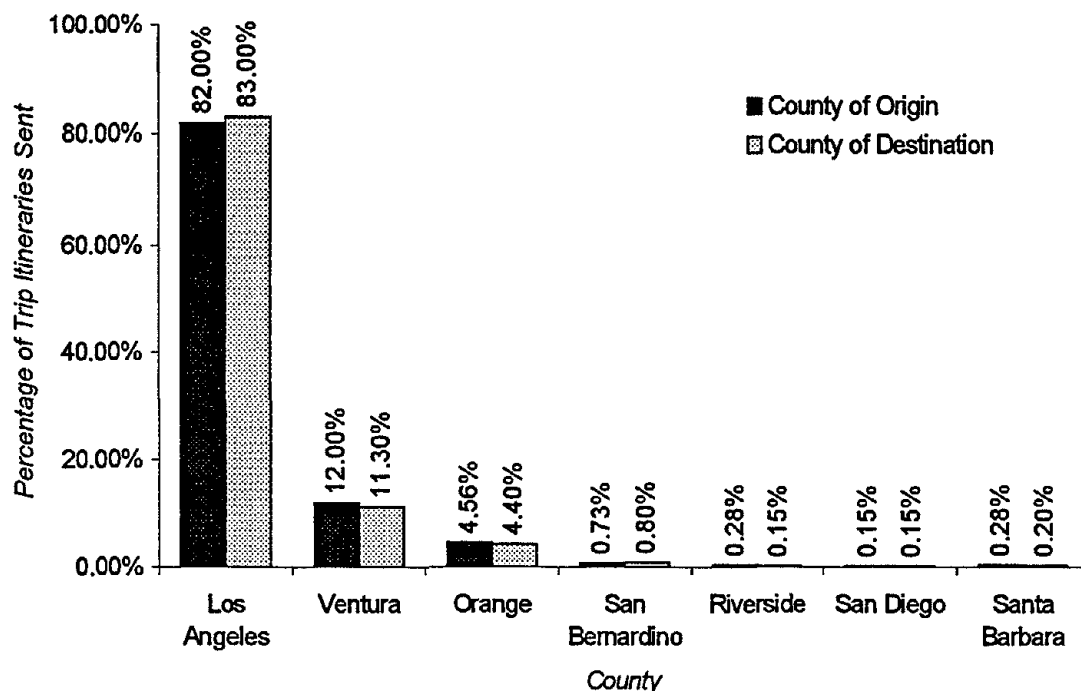


Figure 1. Counties of Origin and Destination for Trip Itineraries (n=2900)

By investigating individual origin-destination pairs, it is clear that many of the trips being planned at the Go Ventura web site are for travel between different cities and/or counties (18). About 20 percent of the voluntary survey results were between different counties. Thus, there is a strong demand for transit travel that goes beyond the boundaries of one's own city or county. A regional information source is needed for planning inter-county and inter-city trips, which often require the use of more than one transit agency. The large quantity of regional trips being planned with the transit planner show that the Go Ventura web site is already being used to fulfill this need in southern California.

Use of Transit Trip Planner by Time of Day

Based on the approximately 2900 successful itinerary requests made to the Transtar server between July 3 and August 14, the web site usage by time of day is shown in Figure 2. According to these results, 56.5 percent of itineraries were requested between 11:00 a.m. and 6:00 p.m. The busiest hour for transit trip planning is from 4:00 p.m. to 5:00 p.m., when 9 percent of all queries are made. Because the web site usage drops sharply after 5:00 p.m., the results seem to indicate that the majority of requests are being made from the workplace. A moderate level of activity is sustained outside office hours, from 6 p.m. until midnight. Thus, there is apparently a lesser, but significant, portion of requests being made from outside the workplace (for example, in a home or college environment).

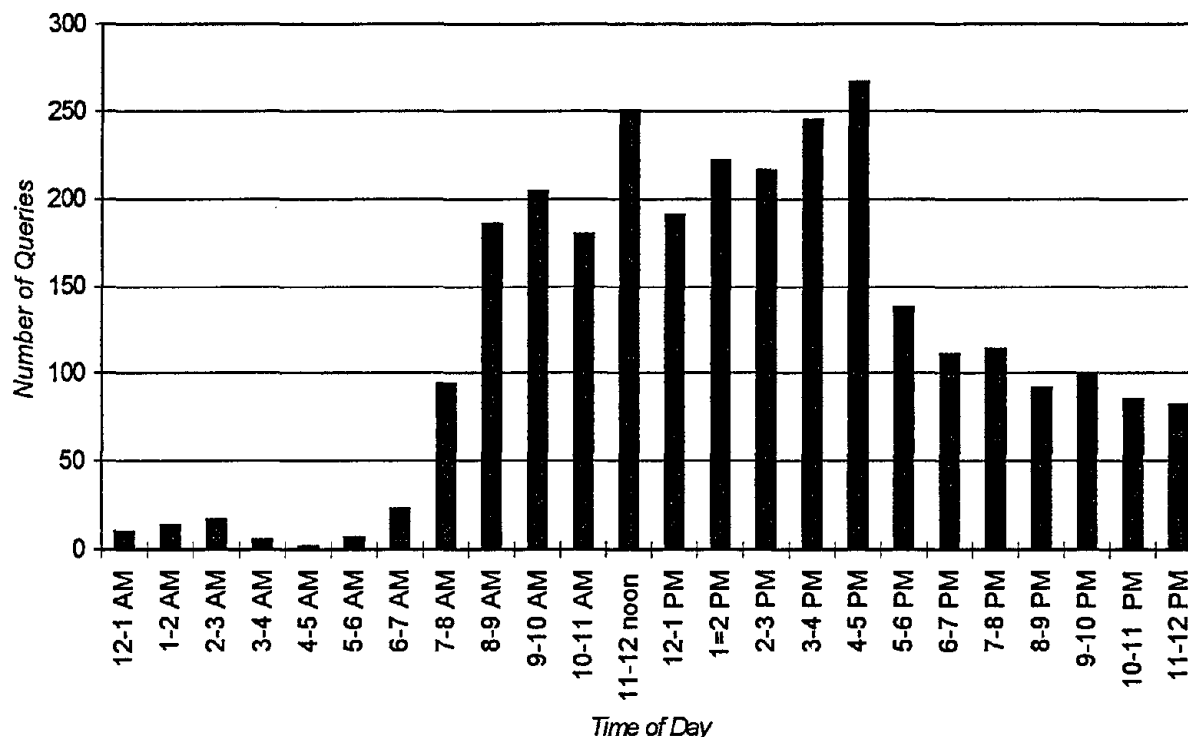


Figure 2. Time of Day When Trip Planning Requests Are Made (n=2900)

Transit Use Characteristics (n = 74)

Users of the Ventura County Transportation Commission's web site were asked to indicate the frequency of their transit use and the sources of information that they used to plan transit trips before finding out about the Go Ventura web page. The results in this section are based on the sample size (n) of 74 surveys received.

Frequency of Transit Use

The results related to the frequency of transit use by the survey participants can be found in Figure 3. The largest group of respondents were those that use transit several times a week (42 percent). Occasional riders, using transit less than once per week, made up 24 percent of survey respondents. Cross-tabulations of transit ridership with other attributes are presented later in this report.

Previous Methods of Getting Information

Before the Internet web page was available to plan transit itineraries, transit riders had to obtain the information they needed from other sources. Survey participants were asked to choose any and all of the information sources

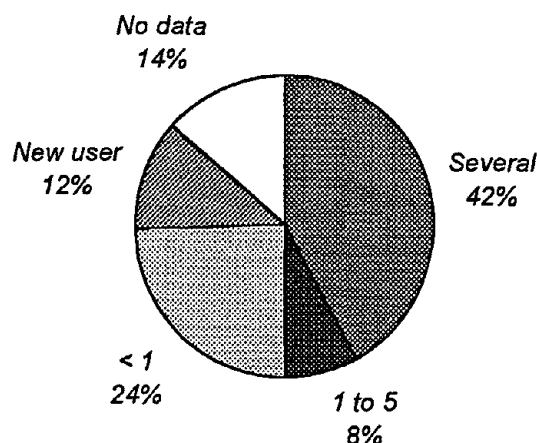


Figure 3. How many times per week do you use transit?

that they used before having access to the Go Ventura web site. By far the most commonly cited response (49 percent) was checking printed schedules, as shown in Figure 4. The other options were calling the 1-800 number to get a trip itinerary plan over the phone (41 percent), asking other transit users (22 percent), calling the bus or train company (18 percent), and "didn't use bus/train before using web site transit router" (22 percent). The survey respondents that did not use transit before Internet trip planning was in place may be a) new transit users who would have started using transit during the past 28 months regardless of whether Internet route planning existed, or b) new transit users that began to ride transit because of the advantages afforded by Internet itinerary planning. Fourteen percent of survey respondents did not answer this question.

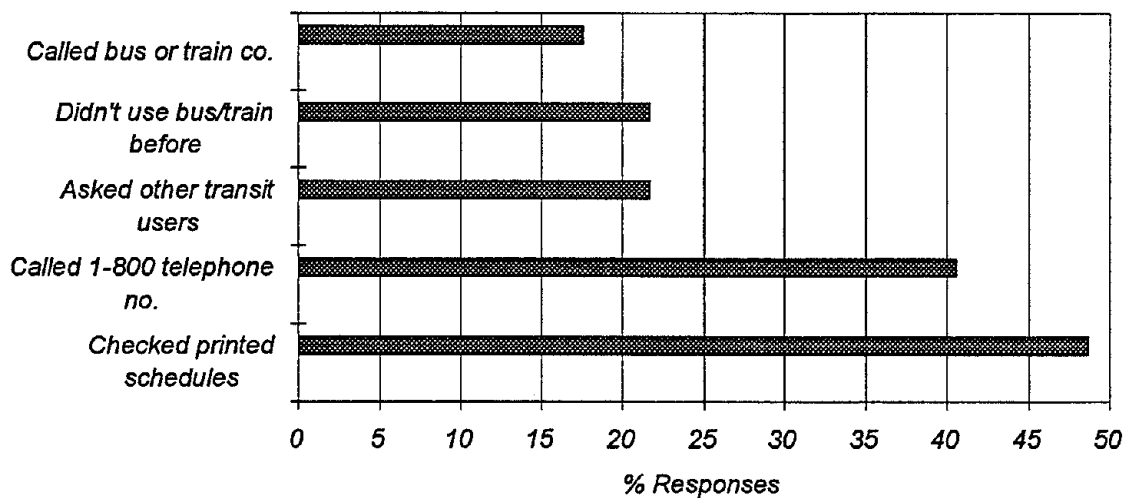


Figure 4. How Did You Plan Transit Trips Before Using the Web Site? (n=74)

Use of the Go Ventura Transit Trip Planner on the Internet (n=74)

Questions asked about the patrons' use of the Go Ventura web site included where the site was being accessed, how frequently the web site was used to plan trips, and whether the ability to plan trips with the web site had enabled the patrons to make new transit trips. The results in this section are based on the sample size (n) of 74 surveys received.

Where the Web Site is Being Accessed

As illustrated in Figure 5, the majority of responses to the survey (64 percent) indicated that the transit trip planning web site was being accessed from home. In light of the data showing that the majority of all queries were made during business hours (as described above), the survey result regarding location of web site access at first does not seem logical. However, the result may be explained by the possibility that users of the web site are more likely to take the time to fill out a survey in the leisure of their own home than at work; such a relationship could greatly affect the number of surveys sent from home or office.

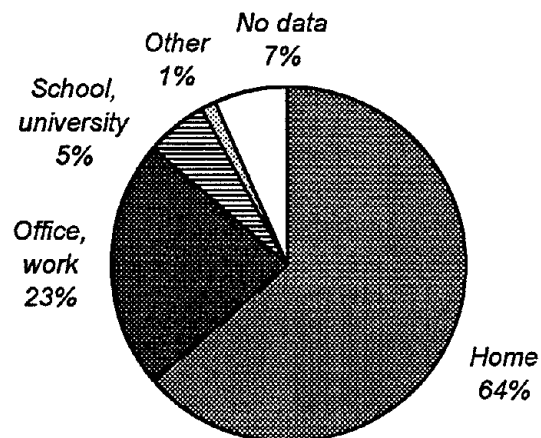


Figure 5. Where are you using this site?

Frequency of Go Ventura Web Site Use

The following were the results to the question regarding how many times per week survey respondents used the Go Ventura web site: 24 percent used the site several times a week; 12 percent used it between one and five times per week; 36 percent reported occasional usage, and 14 percent were first-time users. Fourteen percent of surveys had no answer to the question. The number of responses given for frequency of web site use are cross-tabulated with frequency of transit use in Figure 6. The largest groups were occasional users of transit that were also occasional users of the web page (15 responses) and very frequent transit users that were also very frequent users of the web site (14 responses). As expected, the results indicate that frequent users of the Go Ventura web site are likely to be frequent users of transit.

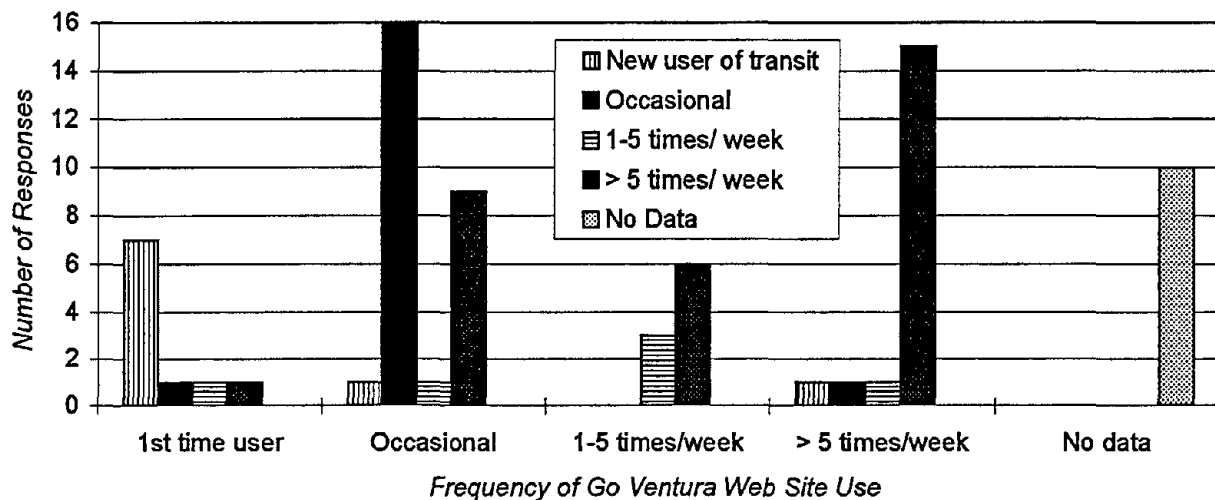


Figure 6. Number of Responses By Frequencies of Transit Use and Web Site Use

Ability to Make New Transit Trips

To find out about the transit trip planner's possible effects on mode choice, the following question was asked: has using this web site allowed you to make a trip by bus or train that you otherwise would have made by automobile? The responses to this question were 70 percent "yes" and 16 percent "no" (with 14 percent not responding). This result is especially interesting when compared with the finding (discussed below) that only 46 percent of the survey participants would have used a car if transit were not available. Although it is not known how many new transit trips are being generated, it is clear that the transit trip planner has allowed people to make trips by transit when they otherwise would have driven a car or stayed home.

Characteristics of the Trips Being Planned with the Go Ventura Web Site (n=74)

To obtain information about the trips being planned with the Go Ventura web site, questions were asked regarding the purpose of the trip being made and the modes other than transit available to the patron for making the trip. The sample size, n, consisted of the 74 surveys successfully submitted.

Purpose of the Trip

The responses received for the question "Is the trip you are planning for ... (choose from list)" are represented in Figure 7. The most common response, commute to work, made up 43 percent of responses. Trips made for social and recreational purposes accounted for 24 percent of responses, followed by trips made for errands or

business at 21 percent. Nine percent of survey participants did not answer this question. The high percentage of social and recreational trips corroborates some of the e-mail sent to VCTC, which indicated that the transit route planner has enabled people to make more discretionary trips using transit.

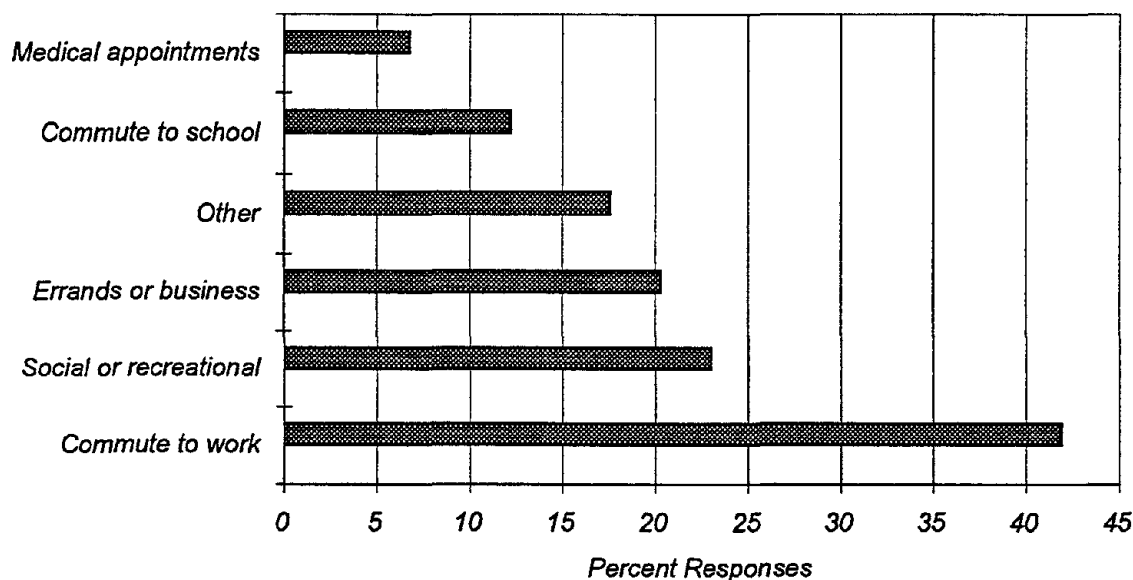


Figure 7. Is the Trip You Are Planning For ...

The number of responses given for different trip purposes and locations of site access are shown in Figure 8. From this graph, it appears that the profiles of trips made for different purposes are fairly similar for survey participants accessing the site at home and at work. The major exception to this was that trips made for a school commute were common for those accessing the Internet at home but not for those accessing it at the workplace.

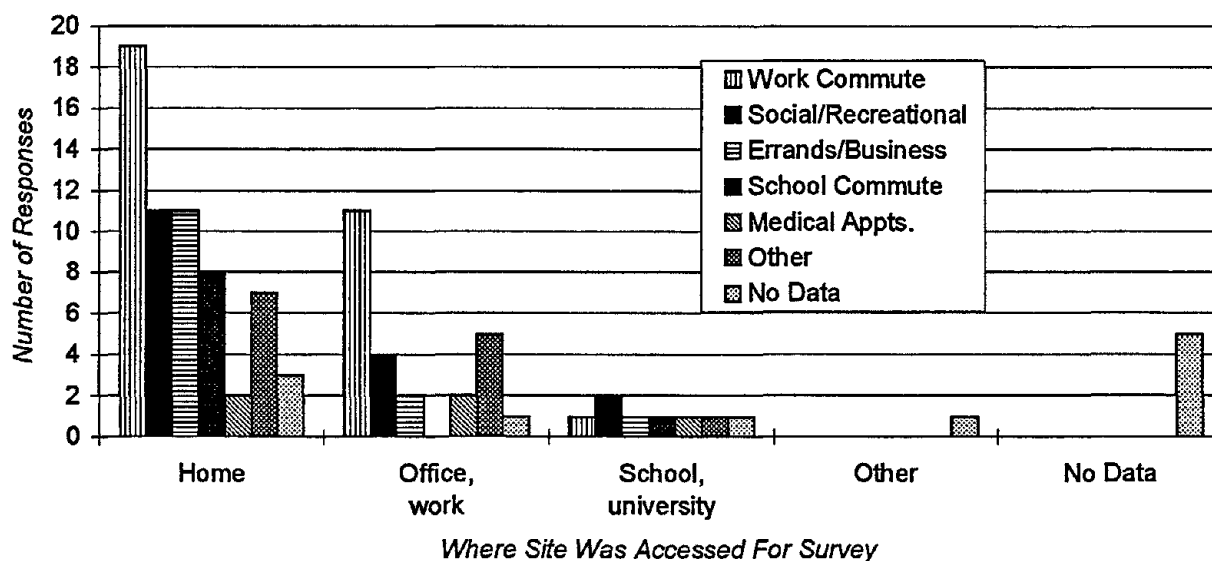


Figure 8. Number of Responses By Location of Internet Access and Trip Purpose

Other Transportation Modes Available to Users

The following are the results showing how survey participants would have made the trip they were planning if transit (bus or train service) had not been available. Forty-six percent would have driven a car, 3 percent would have carpooled or vanpooled, 3 percent would have bicycled, 1 percent would have walked, 34 percent would not have made the trip, 4 percent responded “other,” and 9 percent did not answer the question.

Captive Ridership. The percent responses “wouldn’t make the trip” (35 percent) logically corresponds to the percent of surveys filled out by people with no other transportation mode available (“captive” transit ridership). As shown in Figure 9, those who would not make the trip in the absence of transit were also the most frequent users of transit (and as such, more likely to be frequent users of the web site, as shown in Figure 4). Because frequent users of the web site are under-represented by the voluntary survey format, the percent of trip itinerary requests being made by captive ridership is probably much higher than 35 percent.

Discretionary Ridership. As observed in Figure 9, of those that would otherwise make the trip by car (46 percent of total responses), thirteen were very frequent and eleven were occasional transit riders. Frequent transit users tended to be frequent users of the web site (in this survey); thus, the findings of Figure 6 and Figure 9 suggest that many trips are being planned by non-captive transit riders using the Go Ventura web page. The Internet trip planner appears to be facilitating many transit trips that would otherwise have been made by automobile.

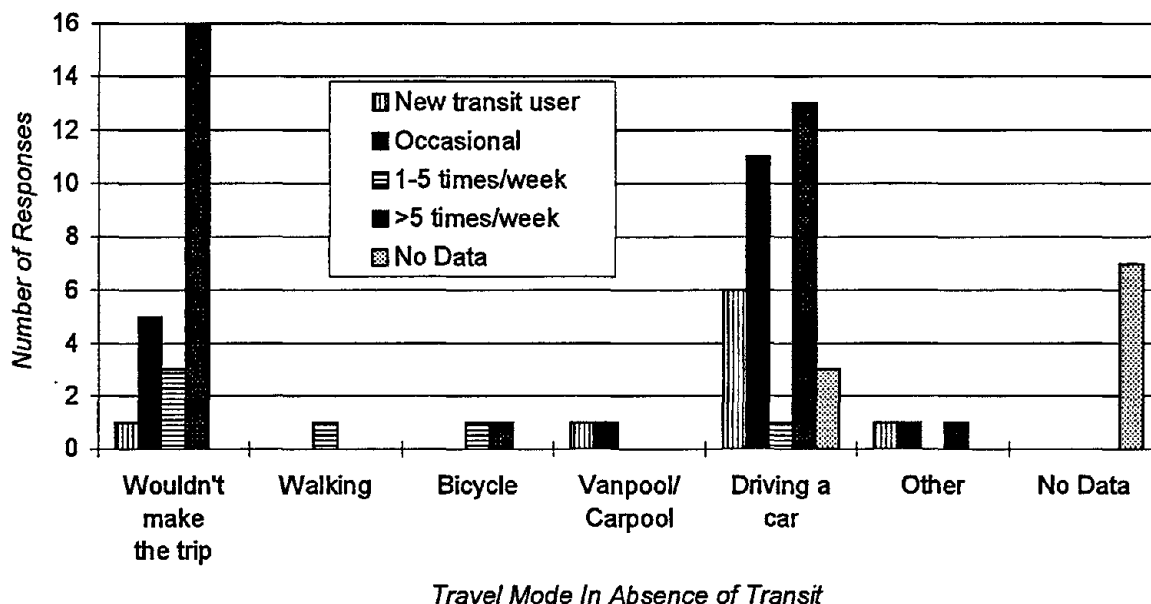


Figure 9. Number of Responses by Transit Use Frequency and Alternative Mode

Basic Demographics (n = 66)

Those who filled out the survey were asked to answer questions regarding their sex, age, working status, and annual income. The survey sample size, *n*, for these questions was equal to the sixty-six different individuals that sent in surveys.

Male/Female Split

The survey sample of 66 individuals consisted of 57 percent male and 26 percent female respondents (17 percent did not answer the question). The high proportion of males is surprising given past research indicating

that women are more likely to use pre-trip planning (3). Also, women generally make up a higher proportion of transit ridership than men. The high proportion of men in the sample may be due to the survey bias (if, for instance, men are more likely than women to fill out such a survey) or it could reflect the higher proportion of men using the Internet. According to a nationwide survey, the gap between the proportion of men and women using the Internet has been decreasing since 1995; however, as of 1997 men still made up 60 percent of adult Internet users in the U.S. (1).

Age

A young age distribution describes the survey sample, as shown in Figure 10. Eighty percent of respondents were of age 44 and younger. The largest age group (22 percent) was 25-34 years, followed by 35-44 years (25 percent). The college-aged adults (19-24 years old) were the third largest age group (14 percent). These results are similar to the results of the Bay Area Transit Information Project (19), which involved a survey of users of the Internet transit information provided by the San Francisco Bay area. The researchers conducting the BATIP survey concluded that the high proportion of users over age 25 reflected the emerging popularity of the Internet as a tool for commercial and personal uses, surpassing research and academic purposes (19).

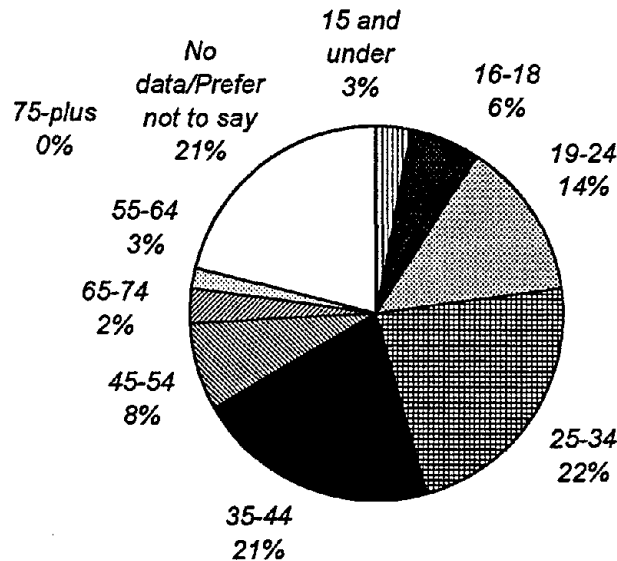


Figure 10. Age Groups

Working Status

Among the survey sample, 20 percent of participants described themselves as students; 55 percent worked outside the home, 5 percent worked at home (summing to 72 percent employed), 2 percent were retired, and 3 percent were "other" (two responses: "actor" and "not working"). Seventeen percent of survey participants did not answer the question. The BATIP results for a similar question showed that 79 percent of BATIP web site users were employed, 18 percent were students, and 1 percent were retired (19). Similar to the BATIP survey, the majority of respondents to the Go Ventura survey were employed, and many may have been work commuters.

Estimated Household Income

A summary of the results for the question of estimated annual household income, cross-tabulated with frequency of transit use, can be found in Figure 11. Summing together some of the income categories, the results for household income alone were: 20 percent of households earning \$0- under \$20,000, 12 percent earning \$20,000- under \$50,000, and 23 percent earning \$50,000- under \$100,000. The data appears skewed away from the middle incomes, toward higher incomes especially and secondarily toward lower incomes. The frequencies of transit use reported by survey respondents with different levels of income are shown in Figure 11. Quite a bit of data is missing due to 45 percent of respondents not answering the question. From the data that was recorded, transit use was highest for the under \$10,000 income group (as expected), and surprisingly second-highest for the \$50,000 to \$75,000 income group. Thus, it appears that level of income and frequency of transit use were not clearly related for the participants in this survey.

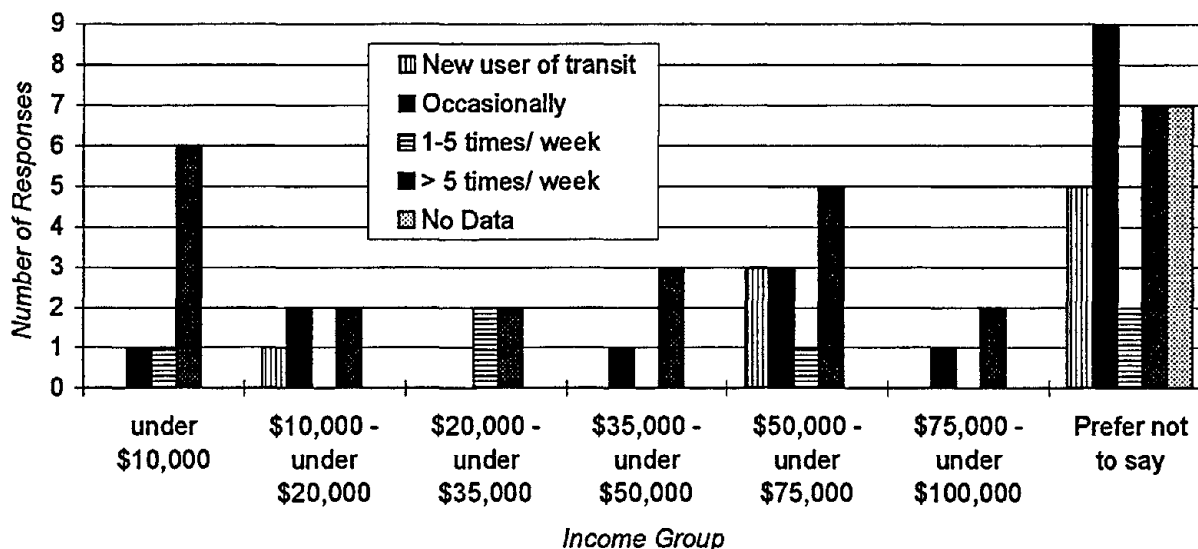


Figure 11. Number of Responses by Frequency of Transit Use and Income Group

Helpfulness of Go Ventura Trip Planner and Recent Upgrades (n=74)

The Web Site in General

For the question of the web site's helpfulness in planning a trip, 55.4 percent found the site very helpful, and 18.9 percent found the site somewhat helpful, as shown in Table 1.

Recent Upgrades

All the upgrades evaluated in the survey were perceived as very helpful according to the majority of responses received (see Table 1). It appears that fewer of the Internet users have tried the restore information button and walking maps, since at least 20 percent of the users had not yet formed an opinion about these features. Excluding those to whom the helpfulness of a Spanish translation did not apply, 76.6 percent of responses indicated that the Spanish translation was very helpful.

Table 1. Helpfulness of Go Ventura Web Site and Recent Upgrades

Rating	Percent Responses					
	Web site in general	Pull-down list of landmarks	Return trip button	Restore information button	Walking maps	Spanish translation
Very helpful	55.4	55.4	64.9	52.7	59.5	31.1
Somewhat helpful	18.9	6.8	4.9	2.7	5.4	0.0
Not helpful at all	8.1	12.2	8.1	5.4	5.4	5.4
Not sure yet	8.1	16.2	13.5	29.7	20.3	4.1
Does not apply						50.0
No answer	9.5	9.5	9.5	9.5	9.5	9.5

User Feedback

E-mail Received by VCTC

Ever since VCTC's web site went online in 1995, user feedback in the form of e-mail to the VCTC has been coming in on a regular basis. Many of the e-mail messages dealt with delight in, frustrations with, or questions about the point-to-point transit itinerary planner on the Go Ventura web site. Table 2 shows a summary of the sentiments expressed in 186 e-mail messages sent by the general public to the Ventura County Transportation Commission from March 1995 to June 1998.

Table 2. Summary Of E-Mail Messages Regarding Go Ventura Web Site

E-mail Received By VCTC From March 1995 Until June 1998	No. of Responses
Comments	
Great job ... I like the site	72
Thanks for a great service	19
Request for more information	14
Information has been a great help	12
Frequent user of web page	5
Web page allows user to make new trips	4
Information is accurate	1
Complaints	
Trouble getting a response or connecting to the server	70
Out-of-date, inaccurate, or incomplete information	16
Difficult to use or general dislike	14
Best route not given by server (or illogical one given)	12
Errors on the web page	7
Trouble getting program to recognize desired origin or destination	7
Transit alternatives not comparable to automobile	3
Suggestions	
Ability to choose routes and modes or to see alternate itineraries	7
Return trip button	4
Restore information button	4
Walking distance/times	3
Text links for non-graphics users	3
Ability to see full schedule information for any route	3
Maps or graphic representation of routes	3
Ability to choose day of week or date to travel, instead of x days from now	2
Plan travel between cities, without having to pick specific destinations	2
Cheapest fare option for determining best itinerary	2
Simpler color schemes and graphics (for faster loading)	2
Pull-down list of landmarks to choose from	1
Name of bus line and type of day to appear at top of bus schedule print-out	1
More publicity for web site	1
More specific error messages to pinpoint problems	1
Ability to chain trips one after another	1
Bus direction so rider knows to wait on correct side of street	1
Mechanism to insure privacy of addresses	1
Sign-ups for traffic school (for traffic violations) on Internet	1

Feedback Given As Part of Upgrade Survey

In the upgrade survey, a blank space was provided so that users could offer any suggestions for improvements that might further enhance their trip itinerary planning. However, most used the space for comments about the service in general, rather than giving specific ideas for improvements.

Comments. Nine of the 56 survey respondents wrote to thank the Ventura County Transportation Commission for doing a wonderful job and providing a great service. One patron wrote that having the pull-down list of landmarks was an “excellent” upgrade because it made trip planning much easier. Another patron enjoyed the service but was unsure of the accuracy and thus felt obligated to check any information received via telephone.

Complaints. There were four complaints that the itineraries provided by Transtar were illogical or incorrect. By far the most common complaint (fourteen responses) was when the server was not working. Any problems which cause interruptions in service should be addressed as soon as possible; the many complaints received when the “server was down” show that many people have grown to depend on the Go Ventura web site to plan their transit trips.

Suggestions. Some of the suggestions which were given on the survey were: to offer the sale of transit tokens and passes, to improve the print-out quality of the walking maps and schedules, and to allow the user to pick the specific day of the week for the trip, rather than having to choose the start of the trip as a certain number of days from today. Other suggestions were to show maps of the bus routes, to include distances, especially walking distances in the itinerary, and to make sure that the web page layout can be viewed fully on a 640 pixel by 480 pixel computer screen.

SUMMARY OF FINDINGS

The following are a summary of the major findings of this report.

Regionwide Travel

- Although the transit trip planner on the Go Ventura web page is sponsored by the Ventura County Transportation Commission (VCTC), the percentages of trips planned at the web site with origins or destinations in Ventura County were only about 12 percent for origins and 11 percent for destinations.
- About 20 percent of trips planned at the Go Ventura web site were between different counties.

Time of Day

- The majority of trip itinerary requests, about 57 percent, were requested between 11:00 a.m. and 6:00 p.m., with the busiest hour being from 4:00 p.m. to 5:00 p.m.

Using the Go Ventura Trip Planner on the Internet

- Before using the Internet trip planner, the most commonly used methods for planning transit trips were checking printed schedules (49 percent) and calling the 1-800 telephone number for information (41 percent).
- Sixty-four percent of survey responses reported accessing the Internet at home, most likely due to the higher likelihood of filling out the survey at home.
- Occasional users of the web site (using the web site less than once per week) were the most likely to be occasional transit users (using transit less than once per week). Very frequent web site users (using the site more than five times a week) were the most likely to be very frequent transit users (using transit more than five times per week).

Characteristics of Trips Being Planned

- Seventy percent of surveys responses indicated that using the Internet transit trip planner had helped the survey participants make a trip by transit that they otherwise would have made by automobile.
- The commute to work was the most common trip purpose (43 percent), followed by social or recreational (24 percent), errands or business (21 percent), "other" (18 percent), commute to school (12 percent), and medical appointments (7 percent).
- The types of trips made when the user was accessing the web site from home or from work were similar, except that planning a school commute was common when accessing the site at home but not when accessing the site at "work or the office."
- When the survey participants were asked how they would make the trip if transit were not available, 47 percent reported they would take a car, while 34 percent reported they would not make the trip. The Internet trip planner is apparently attracting both captive and non-captive transit users.

Characteristics of Survey Participants

- In the survey population, 57 percent of participants were male, 26 percent were female, and 17 percent did not respond.
- The majority of respondents (66 percent) were under the age of 45, with the largest single age group being those aged 25-34 years (22 percent).
- With regard to working status, 55 percent of respondents worked outside the home, 20 percent were students, 5 percent worked at home, 2 percent were retired, and 3 percent were "other."

- In summary of the estimated household incomes reported by the survey participants, 20 percent were from households earning under \$20,000; 12 percent were from households earning from \$20,000 to less than \$50,000, and 23 percent were from households earning greater than \$50,000. Forty-five percent of respondents did not answer this question.
- Estimated household income did not appear to be related to frequency of transit use for the survey sample.

User Feedback Regarding Transit Trip Planner

- The web site in general and new upgrades to the site were considered “very helpful” by the majority of survey participants.
- The most common message sent by e-mail to the VCTC regarded congratulations for making a wonderful site. Many web site users reported that the information was very helpful. Some users specifically mentioned that the web site had allowed them to make new transit trips that they previously would not have even attempted.
- Many people are relying heavily on the service provided by the Internet trip planner, as evidenced by the abundance of negative feedback received via e-mail when the server was down.
- The most commonly requested improvements to the trip itinerary planner (which have not already been implemented) were the ability to choose the transit route or mode desired for travel or to view alternate itineraries, walking distances and/or times between points, text links for non-graphics users, the ability to see full schedule information for any route, and maps of the routes selected by the trip planner.
- The transit trip planner is used heavily by the public, as evidenced by the 2900 successful itineraries sent from July 3 to August 14, at a time when the server was experiencing unusual difficulties and often not providing a successful connection to the Transtar database.

RECOMMENDATIONS

Based on the results of the survey and feedback from users of the Go Ventura web page, the following recommendations are suggested which might further increase the appeal of the transit trip planner on the Internet:

1. Allow the transit rider to choose preferred transit modes.

Some people prefer to take only the bus or only the train. The trip itinerary request form should have a list of possible transit modes (e.g., bus, subway, train, or walking for more than some distance). The patron would check a box next to each of the transit modes that he or she would consider using for making the trip. The route planning software would filter out any trip itineraries that include modes not acceptable to the user so that a more customized trip itinerary will be generated.

2. Give the user the option to specify a maximum walking distance.

When the user specifies a walking distance there should be a choice of entering the distance in feet, miles, meters, kilometers, or city blocks. The maximum walking distance is the total distance that the patron is willing to walk while getting to and from all the transfer points required for the trip. The trip itinerary request form should have a space for entering a "maximum walking distance," with the units of measurement chosen from the above list. The trip planning software would sum the walking distances for each possible itinerary and eliminate any itineraries that exceed the maximum total walking distance.

3. Give the user the option to specify a minimum walking distance.

The "minimum walking distance" is the minimum amount of walking that the patron feels would justify using transit to cover the distance instead. For example, some patrons may prefer to walk a few blocks to get from one bus stop to another instead of waiting half an hour for a transfer that would take them there. Thus, the trip planner would only look for a transfer if the distance between the bus stops at the ends of the two segments of a trip were greater than or equal to the minimum walking distance. This is not the same as the maximum walking distance because the patron may be willing to walk a longer total distance during the course of the entire trip.

4. Show total walking distance and travel time with trip itinerary.

In addition to supplying information on total fare, add up the total distance that the user would be expected to walk and the total amount of time to be spent traveling if the proposed itinerary were followed. The "total travel time" and "total walking distance" would appear just before the "total fare" already given at the end of the completed, step-by-step trip itinerary.

5. Provide alternate routes to get to the destination, allowing the user to choose which one is best.

If several trip itineraries are generated, an "index" to the trips should be given. The index would display a summary for each option, including what types of modes to be used (for example "bus only" or "bus, subway, and walking"), the number of transfers, the initial departure and final arrival times, the total fare required for the trip, and the total walking distance involved. After scanning the summaries, the user would click on the alternative that looks the best and then would view the corresponding step-by-step itinerary in detail. If the user decides not to use that itinerary, there should be a "View Index Again" button which takes the user back to the index so that a different alternative can be chosen.

6. Generate a map of the proposed itinerary.

After providing the step-by-step trip itinerary in words, allow for the option of viewing a map of the route that the proposed itinerary will traverse. The map should be capable of showing the entire region served by the trip planner at a low level of detail. For a more detailed or “close-up” view of the route on a specific portion of the trip, the user should be able to click repeatedly on any region of the map until the desired level of detail is achieved.

7. Construct a web page with links to transit schedules maintained by individual operators.

One of the reasons for point-to-point transit trip planning is the elimination of the need to consult and match up individual bus schedules. However, there are times when some users prefer to see detailed route schedules. Therefore, it is recommended that a web page be constructed which contains links to all transit operators within the region. If this page were constructed by the VCTC, it would be the perfect complement to the existing point-to-point regional trip planning capabilities. At the Go Ventura web site, the page could be accessible from the “Getting There By Bus or Train” web page, which is also where the transit trip planner is accessed. The user would click on an icon for the page, possibly named “Get Transit Schedules,” and would then view a list of the names and phone numbers of all transit operators in the region. The names of operators with Internet web sites would be “clickable” links that would cause the user to exit the Go Ventura web site and to enter the web site of the transit operator in charge of the desired route.

The rest of the work would be up to the individual transit operator. Ideally the “Schedule Information” page of all operators would be similar in appearance. The “Schedule Information” page would list all transit routes managed by the chosen transit operator. Clicking on the name of the desired route would bring up the latest version of the time schedule and possibly even a map of the route. Setting up and maintaining the “Schedule Information” page would be the responsibility of each individual operator, not the sponsor of the regional trip itinerary planner.

8. Review Transtar database for accuracy.

One recommendation which is not connected to the structure of the web page, is that all transit operators that provide information to the Transtar database periodically review the input information for accuracy. In addition, individual operators should notify the Southern California Association of Governments (SCAG) whenever any changes are made to the regular schedules or transit routes that are used by Transtar to generate trip itineraries. An accurate and up-to-date database is vital to generating reliable trip itineraries for the public to use.

9. Investigate Ways to Reach Individuals Without Internet Access.

More applications for the technology should be investigated so that interactive transit trip planning can reach individuals without Internet access. For instance, the interactive trip planner at the Go Ventura web site is already “user friendly” enough to be installed in traveler information kiosks at airports or transit centers. In addition, telephone operators at the regional 1-800 number for transit information could retrieve more detailed itineraries by accessing the Internet trip planner directly. “Hard copies” of the maps and route itineraries generated by the Internet trip planner then could be sent to transit patrons either by fax or regular mail. Disseminating the information found on the web site via telephone, fax, and regular mail is also an option for those with text-only versions of Internet browsers. Measures such as these should be investigated so that the benefits of regional trip planning on the Internet can extend to a greater number of current and potential users of transit.

CONCLUSIONS

The most important conclusions to be drawn from this study are the following:

1. The transit trip itinerary planner at the Go Ventura web site, although initiated by only one county, has become a truly regional system, transcending the boundaries of cities, counties, and transit agencies. There is a large demand for integrated transit information across a region, and the Go Ventura web site is successfully responding to that demand.
2. The pre-trip itinerary planning software allows people to make trips by transit when they would have otherwise driven an automobile or not taken the trip at all. The power to create point-to-point transit itineraries is helping to reduce some of the information barriers to using transit.

The Ventura County Transportation Commission is the first truly regional web page offering point-to-point trip itinerary planning on the Internet. The gratitude of many Southern Californians can be read in the numerous e-mail messages and responses to surveys which have been gathered and reviewed during this study. The Go Ventura web site maintained by VCTC has shown that the technology is available to integrate transportation information from a wide range of municipalities and transit operators, and the technology works. The Internet is playing a vital role in the realization of the dream of a seamless transportation system.

ACKNOWLEDGMENTS

This paper was completed as part of a graduate-level course entitled CVEN 677-Advanced Surface Transportation Systems. Warmest gratitude is felt toward all six of the Advanced Institute mentors who took time out from their busy, productive schedules to coach, inspire, and guide the students of this course. The author would like to especially thank Ginger Gherardi of the Ventura County Transportation Commission, for her enthusiastic support, thoughtfulness, and many helpful suggestions as the survey was administered and the paper was written. Many thanks also go to Steve DeGeorge, also of the VCTC, who was responsible for putting the survey on the web site and for downloading the responses and mailing them each week to the author.

The author would like to thank Dr. Conrad Dudek, the instructor of the course, who has shown his dedication to future transportation professionals by offering his time, talents, and leadership to CVEN 677 and to the Advanced Institute program. Dr. Dudek has given students just starting out in transportation the opportunity to work closely with some inspiring role models in their chosen profession and to push the state of the art in surface transportation by working on projects of special interest chosen by the students.

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APPENDIX**About the transit routing request you just made:**

- * What is the Address you began your routing request from: _____
- * What is the City you began your routing request from: _____
- * What is the Address you ended your routing request at: _____
- * What is the City you ended your routing request at: _____
- * Are you using this site from ...
 - Home
 - Office, work
 - School or university
 - Other: _____

- * Is the trip you are planning for (if more than one, check all that apply) ...

Yes Commute to work	Yes Commute to school	Yes Social or recreational
No	No	No
Yes Errands or business	Yes Medical appointments	Yes Other _____
No	No	No

- * If transit (bus or train service) were not available, how would you make this trip ?

- Driving a car
- Carpooling, vanpooling, or getting a ride with someone else
- Bicycling the entire way
- Walking the entire way
- Wouldn't make the trip

About your general use of transit and this web site:

- * Is this the first time you have used this web site?

- Yes
- No

- * How helpful is the web site in planning your transit trip?

- Very helpful
- Somewhat helpful
- Not helpful at all
- Not sure yet

- * How helpful do you find the recent upgrades?

- Pull-down list of landmarks:*

- Very helpful
- Somewhat helpful
- Not helpful at all
- Not sure yet

Return trip button:

Very helpful
Somewhat helpful
Not helpful at all
Not sure yet

Restore information button:

Very helpful
Somewhat helpful
Not helpful at all
Not sure yet

Walking Maps:

Very helpful
Somewhat helpful
Not helpful at all
Not sure yet

Spanish translation:

Very helpful
Somewhat helpful
Not helpful at all
Not sure yet
Does not apply

* How often do you use this web site?

More than five times per week
Between one and five times per week
Occasionally
First-time user of transit routes web page

* How often do you use transit?

Several times a week
Between one and five times per week
Occasionally
New user to transit

* How did you plan your transit trip before you knew about this web page?
(check all that you used on a regular basis)

Yes Called 1-800 number and received information by telephone
No
Yes Called bus or train company
No
Yes Asked other bus or train riders
No
Yes Checked bus or train maps and schedules
No
Yes Didn't use bus or train before using web site transit routes
No

* Has using this web site allowed you to make a trip by bus or train that you would have otherwise made by private automobile?

Yes

No

* What additional information or features would you like to see on this web site?

Your information:

* Name: First, Last (optional) _____
Your home city: _____
Your home state: _____
Your home zip code: _____
Your home country: _____

* Sex:

Male

Female

* Please enter your age.

15 and under

16-18

19-24

25-34

35-44

45-54

55-64

75-plus

* Are you:

Employed outside the home

Student

Retired

Other: _____

* Estimated annual household income

under \$10,000

\$10,000 - under \$20,000

\$20,000 - under \$40,000

\$40,000 - under \$50,000

\$50,000 - under \$75,000

\$75,000 - under \$100,000

\$100,000 and above

Prefer not to say

Thank you for completing this survey.

RACHEL A. DONOVAN

Rachel A. Donovan received her B.S. in Civil Engineering from Texas A&M University in December 1997. Rachel is currently pursuing her M.S. in Civil Engineering from the Texas A&M University. She has been employed by the Texas Transportation Institute (TTI) as a Graduate Research Assistant since January 1998. While completing her undergraduate studies at Texas A&M, Rachel spent a summer working for a concrete construction firm in the Dominican Republic and then spent two academic semesters studying civil engineering at the Instituto Tecnológico in Monterrey, Nuevo Leon, Mexico. She worked full-time as an undergraduate research fellow with TTI during the summer of 1997.

Some of her activities at Texas A&M University include: American Society of Civil Engineers - newsletter editor, concrete canoe and steel bridge competitions; Society of Women Engineers - SWE Summer Camp; Fish Camp '98 Counselor; Institute of Transportation Engineers; and ITS America. Her areas of interest include: planning, design, and operation of alternative modes of transportation, including public transit, car-pooling, bicycling, and walking.



APPENDIX A - Transportation Professionals Who Served As Mentors

The following transportation professionals gave so much of their valuable time and talent toward the education of many graduate students who participated in the Advanced Institute for Transportation Systems Operations and Management at Texas A&M University. Their participation and willingness to serve as mentors and to share their knowledge provided our students with unforgettable learning “experiences” that have greatly enhanced their educational base. Texas A&M University extends its heartfelt “thank you” to these professionals.



MARSHA D. ANDERSON



DONALD CAPELLE



WALTER DUNN



GINGER GHERARDI



THOMAS HICKS



LES JACOBSON



JACK L. KAY



RANDALL A. KEIR



WALTER H. KRAFT



JOSEPH M. McDERMOTT



COLIN RAYMAN



H. DOUGLAS ROBERTSON



DAVID H. ROPER



EDWIN ROWE



WILLIAM M. SPREITZER



GARY K. TREITSCH



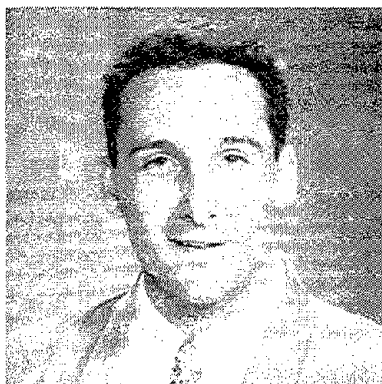
THOMAS C. WERNER



KEVIN N. BALKE

1991

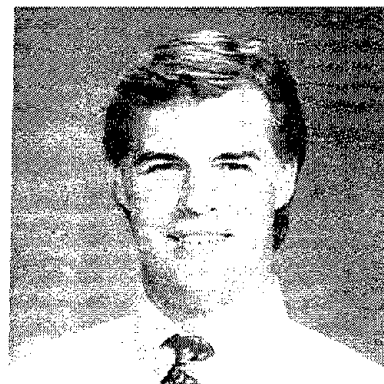
BSCE Texas A&M University
MSCE Texas A&M University



JAMES J. DALE

1991

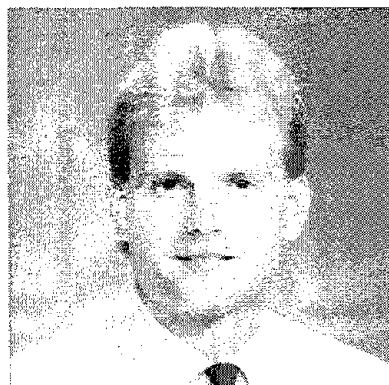
BSCE Texas A&M University
MSCE Texas A&M University



MICHAEL R. RINGROSE

1991

BSCE University of Notre Dame
MSCE Texas A&M University



FAUSTYN E. KNOBLOCH

1991

BSCE Michigan State University
MSCE Texas A&M University



SARAH M. LILLO

1991

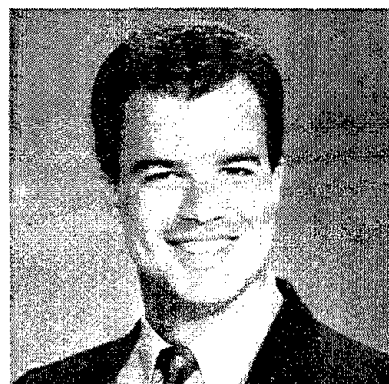
BSCE Purdue University
MSCE Texas A&M University



VICKIE L. TOPMILLER

1991

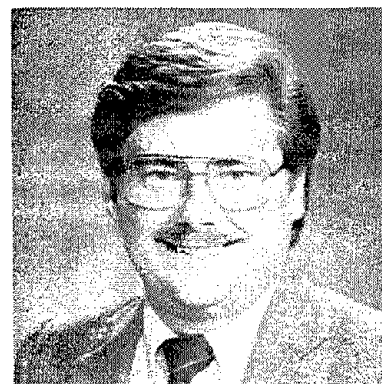
BSCE New Mexico State University
MSCE Texas A&M University



MARC D. WILLIAMS

1991

BSCE Texas A&M University
MSCE Texas A&M University



GEORGE CURTIS HERRICK

1991

BSCE Texas A&M University
MSCE Texas A&M University



ELENA AGUILAR GARZA

1991

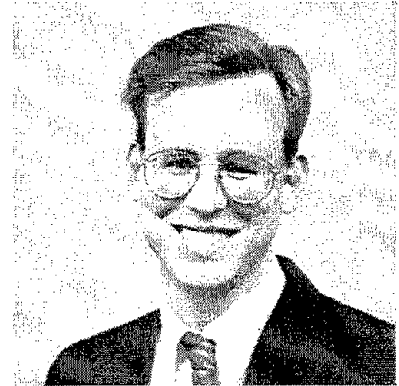
BSCE Iowa State University
MSCE Texas A&M University



CHARLES J. ROBBINS
1991
BECE Manhattan College
MSCE Texas A&M University



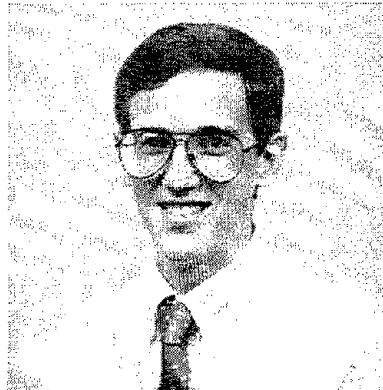
INGRID B. ANDERSON
1992
BS Physics North Park College
MSCE Texas A&M University



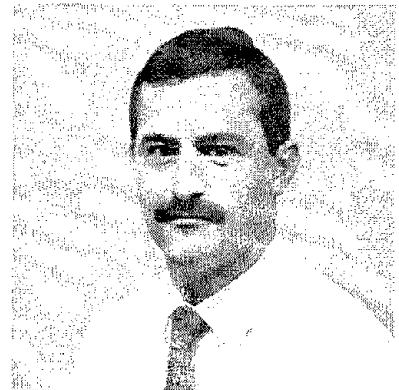
JASON A. CRAWFORD
1992
BSCE Texas A&M University
MSCE Texas A&M University



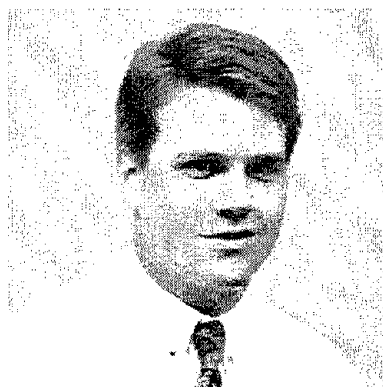
JANICE DANIEL
1992
BSECE Princeton University
Ph.D. Texas A&M University



NEAL A. HUDDERS
1992
BSCE University of Virginia
MSCE Texas A&M University



CHRISTOPHER MOUNTAIN
1992
BSCE Texas Tech University
MSCE Texas A&M University



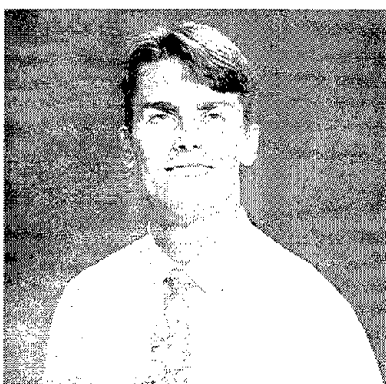
JEFFERY L. OTTESEN
1992
BSCE Brigham Young University
MSCE Texas A&M University



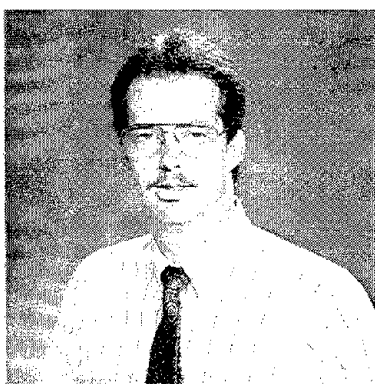
SHAWN M. TURNER
1992
BSCE Pennsylvania State Univ.
MSCE Texas A&M University



KENNETH L. VAUGHN
1992
BSCE Tulane University
MSCE Texas A&M University



P. SCOTT BEASLEY
1993
BSCE Virginia Tech University
MSCE Texas A&M University



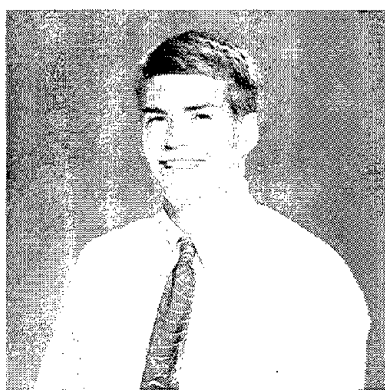
DAVID W. FENNO
1993
BSCE University of Texas S.A.
MSCE Texas A&M University



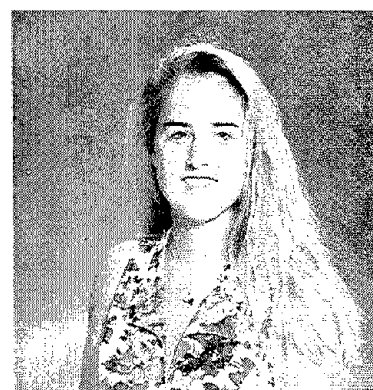
KENNETH L. FINK
1993
BSCE Pennsylvania State Univ.
MSCE Texas A&M University



ROBERT A. HAMM
1993
BSCE Texas A&M University
MSCE Texas A&M University



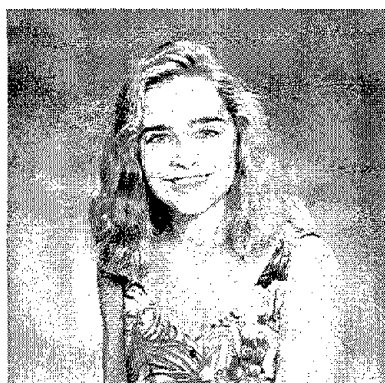
PATRICK E. HAWLEY
1993
BSCE Marquette University
MSCE Texas A&M University



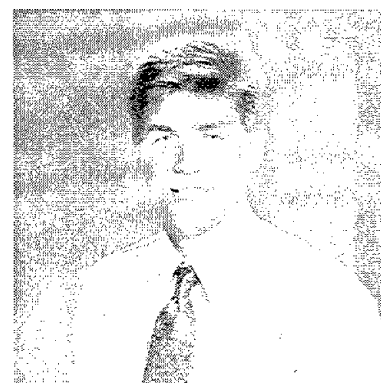
KELLY S. KLAVER
1993
BSCE University of Kansas
MSCE Texas A&M University



KAREN KUENZER
1993
BSCE University of Virginia
MSCE Texas A&M University



MARTY T. LANCE
1993
BS Mathematics Lander College
MSCE Texas A&M University



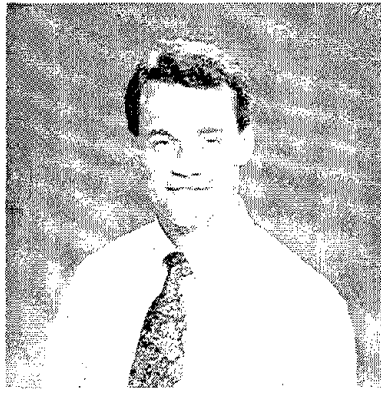
MICHAEL E. OBERMEYER
1993
BSCE Virginia Tech University
MSCE Texas A&M University



MARK A. SHAFER

1993

BSCE Texas A&M University
MSCE Texas A&M University



STEVEN P VENGLAR

1993

BSCE Texas A&M University
MSCE Texas A&M University



KENT M. COLLINS

1994

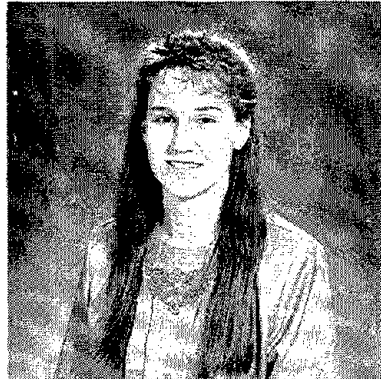
BSCE Texas A&M University
MSCE Texas A&M University



BRIAN P. CRONIN

1994

BSCE Virginia Tech University
MSCE Texas A&M University



TRACY L. HENRY

1994

BSCE Lawrence Technological U.
MSCE Texas A&M University



WILLIAM E. KNOWLES

1994

BS Ocean Engr. Texas A&M Univ.
MSCE Texas A&M University



GREGORY D. KRUEGER

1994

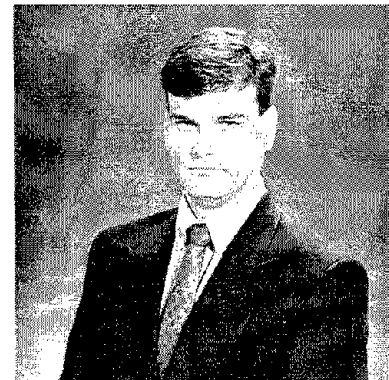
BSCE Colorado State University
MSCE Texas A&M University



KRISTA A. LIENAU

1994

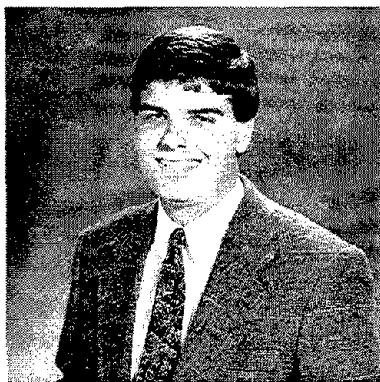
BS Applied Math. Univ or Virginia
MSCE Texas A&M University



MICHAEL LLOYD

1994

BSCE Southern Methodist Univ.
MSCE Texas A&M University



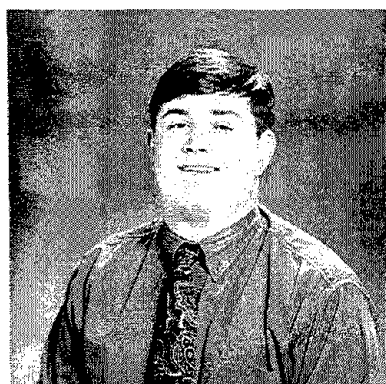
RONALD L. NOWLIN
1994
BSCE Texas A&M University
MSCE Texas A&M University



DALE L. PICHA
1994
BSCE Texas A&M University
MSCE Texas A&M University



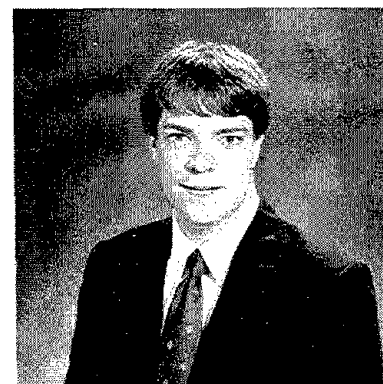
JANET RICCI
1994
BECE Cooper Union
MSCE Texas A&M University



RICHARD A. SOMERS
1994
BECE Vanderbilt University
MSCE Texas A&M University



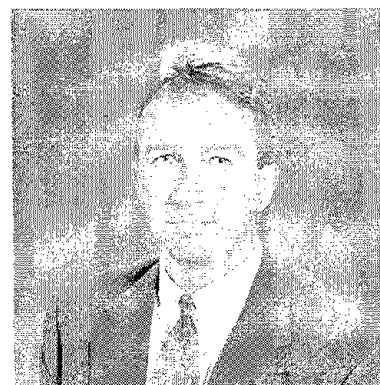
ANGELA M. STODDARD
1994
BSCE Pennsylvania State Univ.
MSCE Texas A&M University



FRED M. TYNER
1994
BSCE Mississippi State University
MSCE Texas A&M University



ANTHONY P. VOIGT
1994
BSCE Texas A&M University
MSCE Texas A&M University



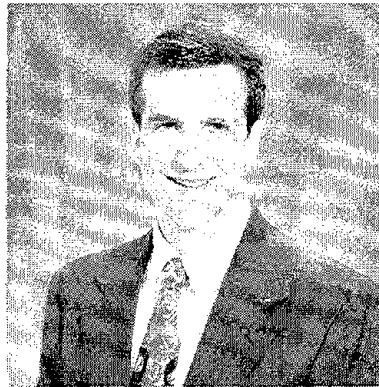
GARY A. CARLIN
1995
BSCE Pennsylvania State Univ.
MSCE Texas A&M University



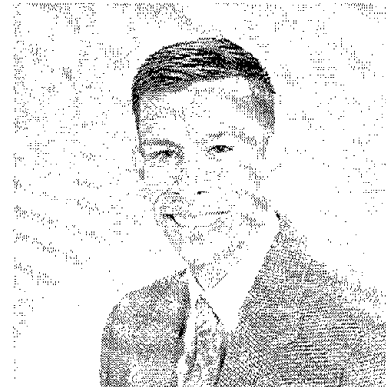
RYAN C. CHRISTENSON
1995
BSCE Brigham Young University
MSCE Texas A&M University



SCOTT A. COONER
1995
BSCE Texas A&M University
MSCE Texas A&M University



STEPHEN M. ENDRES
1995
BSCE Texas A&M University
MSCE Texas A&M University



JESUS GUZMAN, JR.
1995
BSCE Texas A&M University
MSCE Texas A&M University



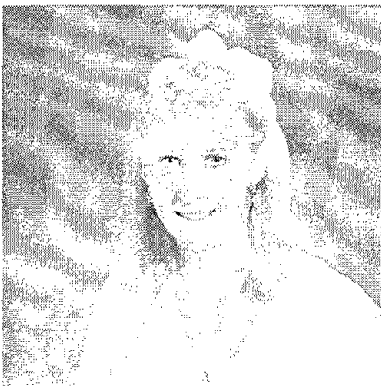
BRIDGETTE D. KELLER
1995
BSCE Clemson University
MSCE Texas A&M University



KEITH K. KNAPP
1995
BSCE Univ. of Wisconsin Madison
Ph.D. Texas A&M University



STEPHANIE L. KOLB
1995
BSCE Virginia Tech University
MSCE Texas A&M University



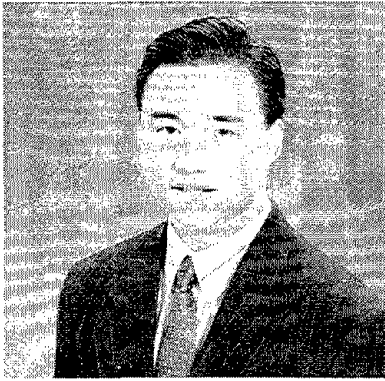
ALLISON C. MEADORS
1995
BSCE Texas A&M University
MSCE Texas A&M University



JENNIFER MESSICK
1995
BSCE University of Delaware
MSCE Texas A&M University



CARL BRIAN SHAMBURGER
1995
BSCE Texas A&M University
MSCE Texas A&M University



BRYANT WOO
1995
BSCE Univ of California Berkeley



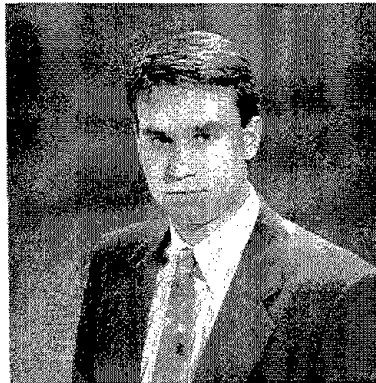
MATTHEW E. BEST
1996
BSCE Pennsylvania State Univ.
MSCE Texas A&M University



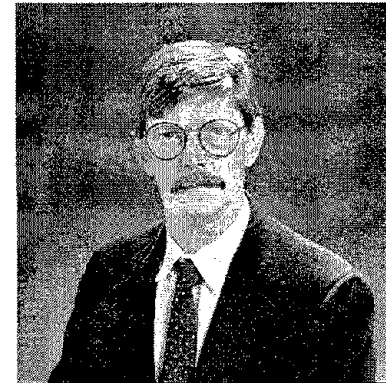
CHRISTOPHER L. BREHMER
1996
BSCE Clarkson University
MSCE Texas A&M University



DAVID M. HALLOIN
1996
BSCE Michigan State University
MSCE Texas A&M University



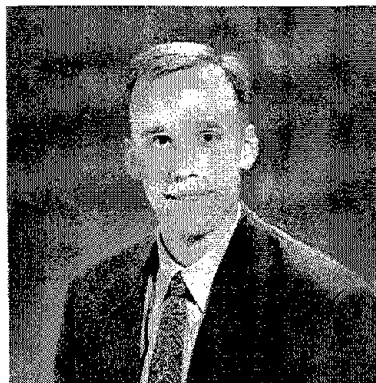
DOUGLAS J. HOLDENER
1996
BSCE Washington Univ St. Louis
MSCE Texas A&M University



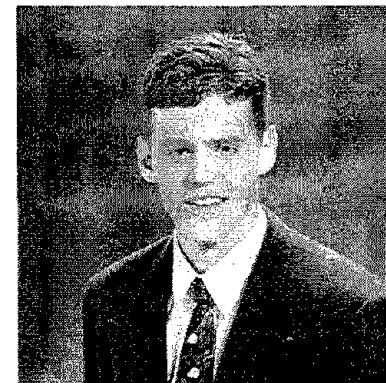
A. BOWMAN KELLY
1996
BSCE U. North Carolina Charlotte
MSCE Texas A&M University



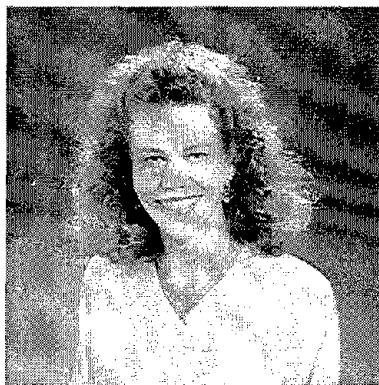
DAVID A. NOYCE
1996
BSCE Univ. of Wisconsin Madison
Ph.D. Texas A&M University



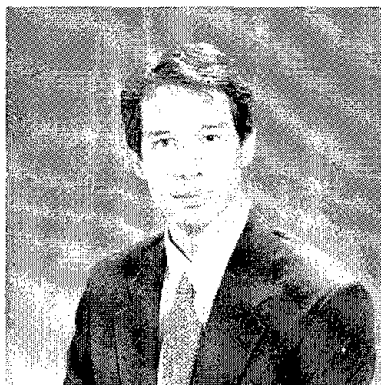
KELLY D. PARMA
1996
BSCE Texas A&M University
MSCE Texas A&M University



CLINT SCHUCKEL
1996
BSCE University of Michigan
MSCE Texas A&M University



LEE ANN SHULL
1996
BSCE Texas A&M University
MSCE Texas A&M University



JOE VAN ARENDONK
1996
BSCE State Univ. Of N.Y. Buffalo
MSCE Texas A&M University



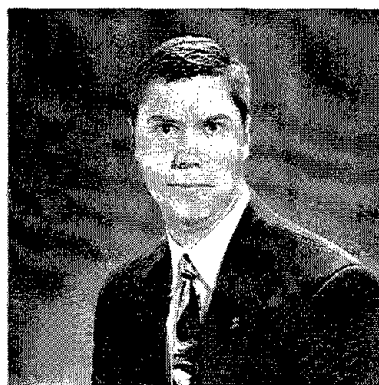
JONATHAN A. BEAN
1997
BSCE Texas A&M University
MSCE Texas A&M University



JULIA KUHN BUTORAC
1997
BSCE University of Idaho
MSCE Texas A&M University



MARC A. BUTORAC
1997
BSCE University of Idaho
MSCE Texas A&M University



JON M. COLLINS
1997
BSCE Texas A&M University
MSCE Texas A&M University



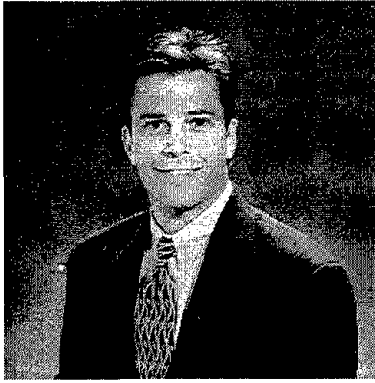
MICHAEL P. DIXON
1997
BSCE Brigham Young University
Ph.D. (In progress) Texas A&M



KENDALL L. FOGLE
1997
BSCE Texas A&M University
MSCE Texas A&M University



AARON M. HOTTENSTEIN
1997
BSCE Pennsylvania State Univ.
MSCE Texas A&M University



MARC W. HUSTAD

1997

BSCE U. Of Wisconsin Milwaukee
MSCE Texas A&M University



MARC S. JACOBSON

1997

BSCE Texas A&M University
MSCE Texas A&M University



KARL A. PASSETTI

1997

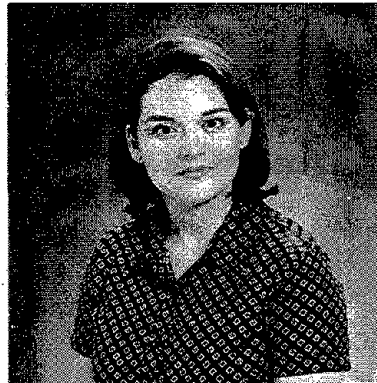
BSCE Pennsylvania State Univ.
MSCE Texas A&M University



KERRY V. PERRILLO

1997

BSCE Pennsylvania State Univ.
MSCE Texas A&M University



CRISTINA BORJA SLABIC

1997

BSCE MIT
MSCE Texas A&M University



JULIA K. WILKIE

1997

BSCE Michigan State University
Ph.D. (In Progress) Texas A&M

APPENDIX C
ADVANCED SURFACE TRANSPORTATION SYSTEMS PAPERS (1991-1998)

Topic	Paper Title	Author
Congestion Management (General)	Congestion Management: Identification Of Issues (1991)	Kevin Balke
	Strategies For Generating Public Cooperation And Support For Freeway Congestion Management (1991)	Marc Williams
Congestion Management & Ramp Metering	An Investigation Of Possible Solutions To The Congestion Cycle (1992)	Ingrid Anderson
	Managing Congestion By Discouraging Short Trips On Freeway Segments Through Ramp Metering And Trip-Length Management (1992)	Jason Crawford
	The Design And Operation Of Ramp Metering For Freeway-To-Freeway Connection (1993)	Michael Obermeyer
	A Guide To Successful Ramp Metering Implementation (1994)	Kent Collins
	Geometric And Operational Guidelines For Multi-Lane Ramp Meters (1997)	Marc Butorac
Incident Management	Synthesis Of Incident Management Teams (1991)	James Dale
	An Analysis Of Incident Management Programs In North America (1993)	Kenneth Fink
	Institutional Concerns Regarding The Implementation Of State-Managed Service Patrols (1994)	Ronald Nowlin
	Evaluation Of Cellular Call-In Programs For Incident Detection And Identification (1995)	Ryan Christenson
	Clearance Of Freeway Incidents Involving Hazardous vs Non-Hazardous Materials (1998)	Michael J. Pacelli
Advanced Traffic Management Systems	Advanced System Implementation With Limited Resources (1991)	Curtis Herrick
	Changes That Advanced Traffic Management Systems Are Expected To Bring To Texas (1992)	Chris Mountain
	The Process Of Solving A Nationwide Transportation Problem: Traffic Control System Operations And Maintenance (1993)	Karen Kuenzer
Advanced Travelers Information Systems	The Use Of The Internet As An Effective Tool For Disseminating Traveler Information (1996)	Lee Ann Shull
	The Development Of An Internet Home Page To Provide Information For Regional Travelers (1997)	Kendall L. Fogle

Topic	Paper Title	Author
Advanced Public Transportation Systems (APTS)	Signal Priority For Public Transit Vehicles Using Advanced Traffic Control Systems: A Comparative Evaluation Of ATSAC, SCATS And SCOOT (1992)	Janice Daniel
	Enhancement Of An Expert System For An Advanced Traffic Control System For Corridor Transit Operations (1994)	Gregory Krueger
	Barriers To The Implementation Of Signal Priority Systems For Transit Operations: Lessons Learned From Advanced Traffic Management Systems (1996)	David Noyce
	The Role Of Advanced Technology In Facilitating Transit Use For Tourists (1997)	Cristina Borja Slabic
	Implementation Of A Dynamic HOV Lane (1998)	Kelly L. Blume
	Advanced Techniques For Influencing The Pre-Trip Planning Process (1991)	Michael Ringrose
Advanced Travelers Information Systems	Use Of Advanced Travelers Information Systems To Minimize Single-Occupant Driving (1992)	Jeffery Ottesen
	Applications Of The Internet In The Transportation Industry (1995)	Jennifer Messick
	Examination Of A Uniform Smart Card For Electronic Toll Collection And Transit Fees (1996)	Clint Schuckel
	Incorporating Commuters' Choice Behavior Into Traveler Information And Route Guidance Systems (1997)	Julia Kuhn Butorac
	Kiosk Deployment Issues and Guidelines for the Dissemination of Traveler Information (1997)	Aaron Hottenstein
	An Evaluation Of Public-Private Partnership Strategies Within The Traveler Information Services Market (1998)	Dena D. Jackson
Advanced Travelers Information Systems: In-Vehicle	A Pilot Study Of The Marketability Of In-Vehicle Systems (1993)	Scott Beasley
	Enhancing Highway Advisory Radio As An Effective Advanced Driver Information System Interface (1994)	Dale Picha
ITS and Privacy & Security	Electronic Toll Collection Information: Is Personal Privacy Protected? (1996)	Douglas Holdener
	Addressing Security Issues In ITS/ATMS (1996)	Christopher Brehmer
Automated Highways	A Discussion Of Liability Issues Associated With Automated Highway Systems (1994)	Kristina Lienau
	A Strategy For The Implementation Of Automated Highway Systems (1995)	Stephen Endres

Topic	Paper Title	Author
Advanced Parking Systems	Integrating Advanced Parking Information Systems With Traffic Management Systems (1995)	Bridgette Keller
	Challenges And Guidelines For Implementing Advanced Parking Information Systems In The United States For Daily Downtown Traffic (1996)	Kelly Parma
ITS and Border Crossings	Criteria For The Selection Of Advanced Border Crossing Systems (ABS) Locations (1997)	Jonathan Bean
	Assessing The Institutional Barriers Associated With Implementing ITS At Border Crossings (1997)	Jon M. Collins
	ITS Technologies For Expediting International Border Crossing Movements (1998)	Pete J. Ferrier
	Alternative Methods For Maintaining Freeflow Conditions On HOV Facilities (1991)	Vickie Topmiller
High-Occupancy Vehicle Treatments (Freeways)	Freeway Signing Needs For HOV Users (1993)	Marty Lance
	An Examination Of Operational Alternatives For Existing And Proposed HOV Facilities (1995)	Brian Shamburger
	Implementation Elements For Conversion Of A General Purpose Freeway Lane Into A High Occupancy Vehicle (HOV) Lane (1996)	Matthew Best
High-Occupancy Vehicle Treatments (Arterials)	High-Occupancy Vehicle Priority Treatments On Suburban Arterial Streets (1992)	Shawn Turner
	Development Of Arterial High-Occupancy Vehicle Enforcement Techniques (1994)	Angela Stoddard
	Safety-Related Characteristics Of Arterial High-Occupancy Vehicle (HOV) Roadway And Lane Treatments (1995)	Keith Knapp
ITS (General)	A Comparison Of International IVHS (1993)	Mark Shafer
	Marketing Intelligent Transportation Systems (1994)	Janet Ricci
	Improving Information For The Private Auto-Transit Trip: An Application Of The National ITS Architecture (1997)	Michael P. Dixon
ITS and Rural Areas	Incident Management And Motorist Aid Systems In Rural Areas (1997)	Marc Hustad

Topic	Paper Title	Author
ITS and Intermodal Operations and Systems	The Use Of ITS To Improve Commercial Vehicle Operations (CVO) - Port Intermodal Freight Operations (1995)	Gary Carlin
	Applying Selected Current Advanced Technologies To Help Alleviate Frequent Truck Accidents (1997)	Kerry V. Perillo
	In-Vehicle Information Systems For Commercial Vehicle Operations (CVO) (1998)	Melisa D. Peoples
ITS and Railroad Operations and Systems	Integration Of Railroads In Advanced Traffic Management Systems (1995)	Scott Cooner
	An Investigation Of Traffic Signal Preemption At Railroad-Highway Grade Crossings (1997)	Marc S. Jacobson
Automatic Vehicle Identification (AVI) & Automatic Vehicle Location (AVL) Systems	Strategies For Implementing Automatic Vehicle Identification For Congestion Pricing (1992)	Neal Hudders
	Electronic Toll Collection Systems (1993)	David Fenno
	Potential Benefits For Paratransit Programs Provided By Implementing Automatic Vehicle Location System (1994)	Tracy Henry
	A Comparison Of Real-Time Freeway Speed Estimation Using Loop Detectors And AVI Technologies (1996)	Joe van Arendonk
	The Use Of Electronic Toll And Traffic Management Systems For Freeway Incident Detection (1996)	A. Bowman Kelly
	Travel Time Estimation On Freeways Using Loop Detectors And AVI Technologies (1998)	Garry L. Ford, Jr.
Variable Message Signs	Using Changeable Message Signs On Arterial Streets For Incident Management (1993)	Steven Venglar
	The Application Of Advanced Traffic Management Systems For Special Events (1994)	Richard Somers
	Assessment Of Integrating Advertising With Variable Message Signs (1995)	Stephanie Kolb
	Impediments To The Effective Use Of Portable Variable Message Signs At Freeway Work Zones (1996)	David Halloin
	The Use Of Dynamic Message Signs For Diverting Traffic During Freeway Incidents (1998)	Brooke R. Durkop

Topic	Paper Title	Author
ITS Miscellaneous	Use Of Automated Enforcement For Red Light Violations (1997)	Karl A. Passetti
	Using Variable Speed Limit Signs To Mitigate Speed Differentials Upstream Of Reduced Flow Locations (1997)	Julia K. Wilkie
	Extension Of The Dedicated Short Range Communications Standard For Application To Transit Management Systems (1998)	Scot A. Johnson
Congestion Pricing/Variable Pricing	Congestion Pricing For HOV Facilities (1991)	Sarah Lillo
	Variable Pricing For Toll Roads (1998)	Peter J.V. Koonce
Emissions & Air Quality	The ability Of Advanced Transportation Technologies To Facilitate The Attainment Of Urban Air (1991)	Faustyn Knobloch
	An Emissions Model For Arterial Streets (1992)	Ken Vaughn
	Investigation Of CMAQ Funding Obligation Improvements (1994)	William Knowles
Inter- and Intra-Agency Cooperation	A Model Framework For Facilitating Cooperation Between Agencies In The Implementation Of ATMS (1994)	Fred Tyner
	Benefits Of Interjurisdictional Cooperation Of Public Agencies In The Operation And Maintenance Of Traffic Signal Systems (1995)	Allison Meadors
Transportation Demand Management	The Use Of Staggered Work Hours To Reduce Congestion (1993)	Kelley Klaver
Access Management	The Use Of Access Management To Promote Arterial Mobility (1993)	Patrick Hawley
Traffic Characteristics	An Investigation On Capacity Reduction Due To Congestion (1992)	Charles Robbins
	An Evaluation Of Travel Time Estimation Methodologies (1993)	Robert Hamm

Topic	Paper Title	Author
Hardware	Traffic Detector Management System (1991)	Elena Garza
	Fiber Optic Communications Design For Freeway Management Centers (1994)	Brian Cronin
	Assessment Of Caltrans 2070 Controller In Meeting Hardware Requirements Of Advanced Traffic Management Systems (1995)	Bryant Woo
Operations	Improving Guidance For International Travelers To And From U.S. Airports (1994)	Michael Lloyd
	Operational, Safety, And Liability Issues Of Converting Freeway Shoulders To Travel Lanes (1994)	Anthony Voigt
	Traffic Management During A Variety Of Annual Special Events In Texas (1995)	Jesse Guzman
	The Emergence Of Roundabouts As An Effective Form Of Traffic Control In The United States (1998)	Deborah Kreis